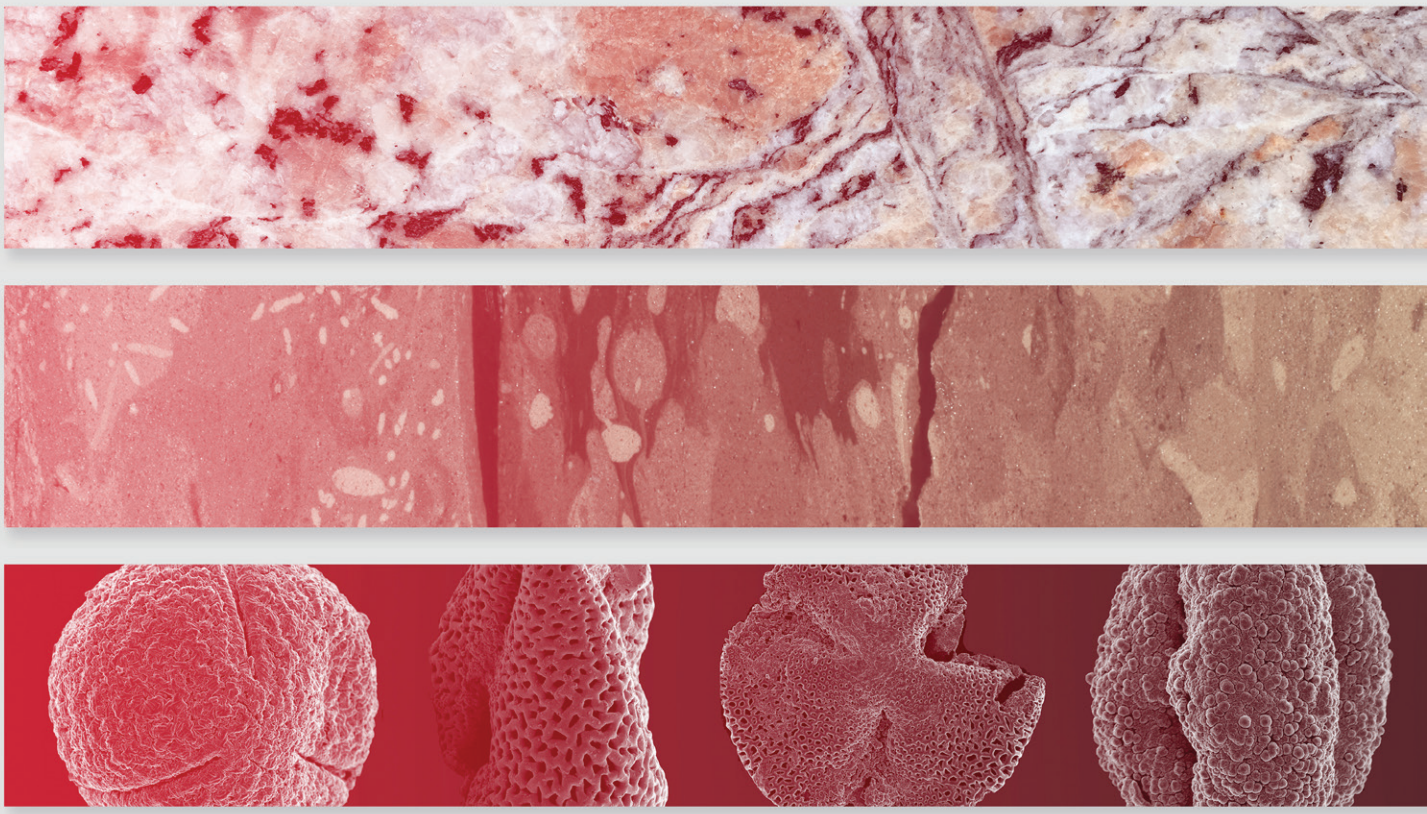
IODP
INTERNATIONAL OCEAN DISCOVERY PROGRAM

icdp

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG



IODP/ICDP Kolloquium

Universität Hamburg
09. - 11. März 2020

Programm und Abstracts

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

DFG Deutsche Forschungsgemeinschaft

Allerich-Stiftung
allerich-umweltstiftung@gmx.de

Liebe Teilnehmerinnen und Teilnehmer des IODP/ICDP-Kolloquiums,

gegenwärtig sind am International Ocean Discovery Program (IODP) und seinem Äquivalent zur Erforschung der kontinentalen Kruste, dem International Continental Scientific Drilling Program (ICDP), Wissenschaftlerinnen und Wissenschaftler aus 26 Nationen beteiligt. Beide Programme zählen ohne Zweifel zu den international erfolgreichsten Verbundprojekten der Geowissenschaften. Die DFG unterstützt Projekte deutscher Wissenschaftlerinnen und Wissenschaftler mit Anbindung an IODP seit 1979 und an ICDP seit 1996 durch die Schwerpunktprogramme IODP 527 und ICDP 1006. Neben seiner konstant hohen wissenschaftlichen Bedeutung hat das jährliche Kolloquium mittlerweile auch eine traditionelle Note in der Förderung durch die DFG. Wir freuen uns, das Kolloquium 2020 im Geomatikum der Universität Hamburg zu veranstalten und heißen alle Konferenzteilnehmerinnen und -teilnehmer herzlich willkommen.

Ihr Ulrich Riller, Ulrich Kotthoff und Christian Betzler

Sponsoren des Kolloquiums

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Deutsche Forschungsgemeinschaft

Allerich-Stiftung
allerich-umweltstiftung@gmx.de

Austragungsort

Die Konferenz wird im Geomatikum und im Geologisch-Paläontologischen Museum (im Haus des Geomatikums), Universität Hamburg, Bundesstraße 55, 20146 Hamburg, stattfinden: Präsentationen werden in Hörsaal 1 des Geomatikums stattfinden. Poster werden im Geologisch-Paläontologischen Museum und im Foyer des Geomatikums aushängen.

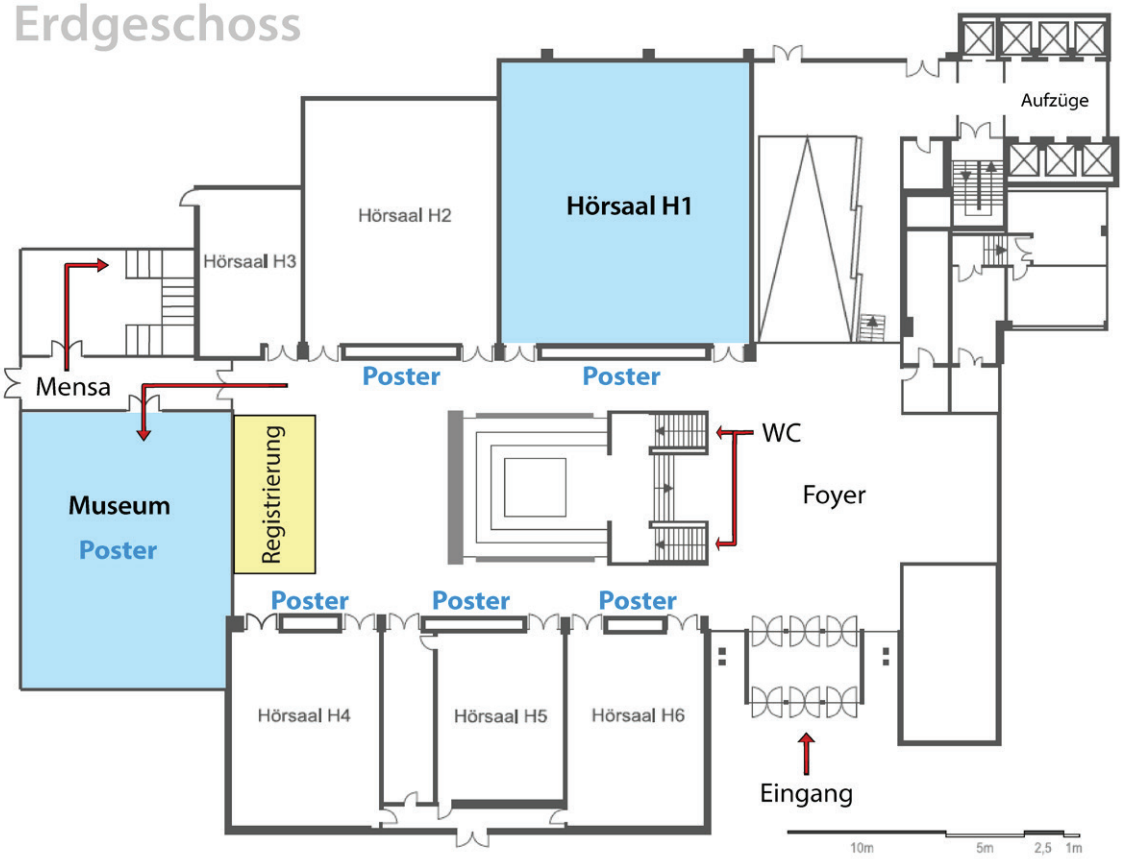
Anfahrt zum Veranstaltungsort
Die Anfahrt kann über die Webseite des Hamburger Verkehrsverbunds HVV geplant werden.

Anfahrt vom Flughafen aus
Nehmen Sie am Flughafen die S-Bahn-Linie S1 bis zur Haltestelle Ohlsdorf. Wechseln Sie zur Linie U1 in Richtung Innenstadt. An der Haltestelle Kellinghusenstraße wechseln Sie auf dem gleichen Bahnsteig in die Linie U3 (Richtung Hauptbahnhof - Wandsbek Gartenstadt). Steigen Sie an der Haltestelle Schlump aus. Von hier aus können Sie das Geomatikum mit seinen 18 Stockwerken bereits sehen. Über die Straße Beim Schlump erreichen Sie es in wenigen Minuten.

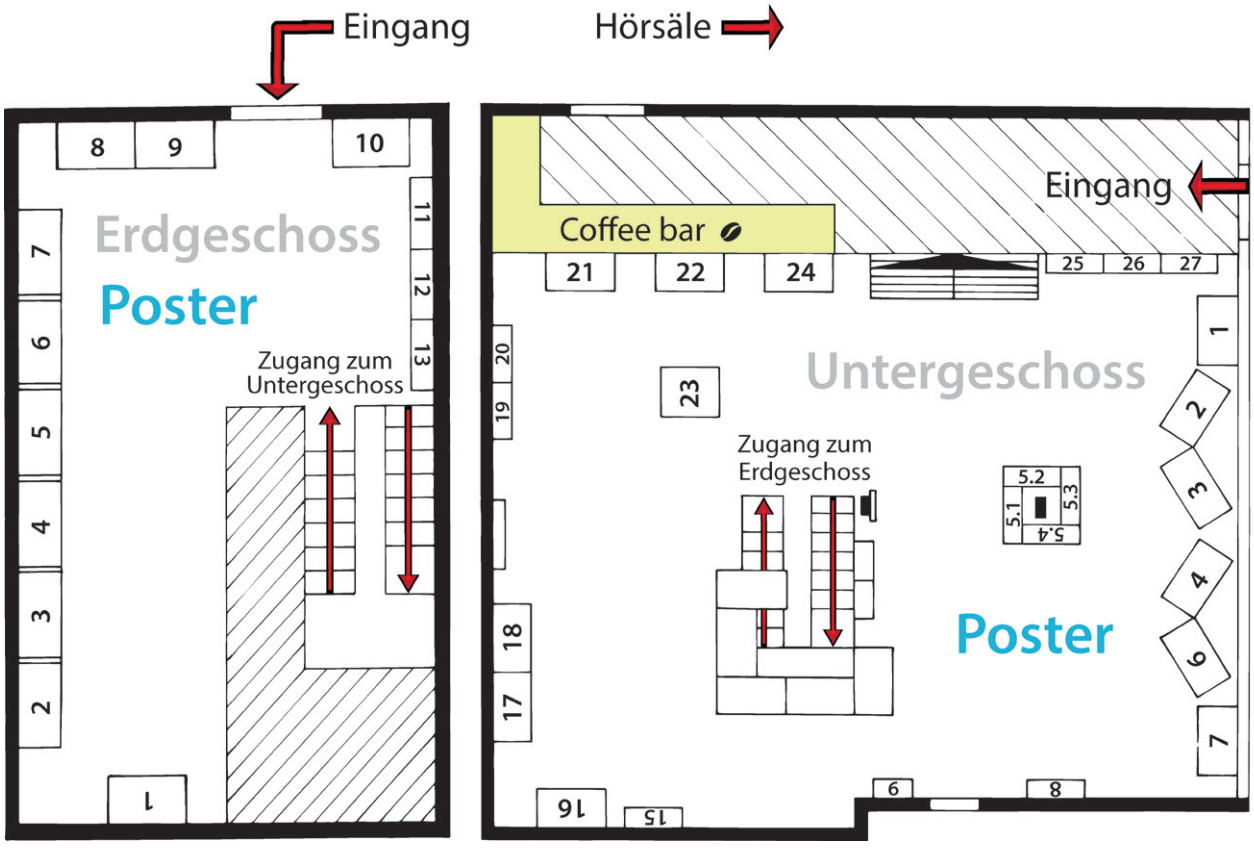
Anfahrt mit dem Zug
Nach Ankunft am Hauptbahnhof können Sie die Linie U2 in Richtung Niendorf Nord oder die Linie U3 in Richtung Barmbek - Wandsbek Gartenstadt nehmen. Beide Linien fahren über die Haltestelle Schlump, an der Sie aussteigen können. Von hier aus können Sie das Geomatikum mit seinen 18 Stockwerken bereits sehen. Über die Straße Beim Schlump erreichen Sie es in wenigen Minuten.

Anfahrt mit dem Auto
Die Anfahrt erfolgt über die A7 aus Richtung Süden kommend mit Abfahrt in Othmarschen oder Bahrenfeld. Dann in Richtung Stadtzentrum in Richtung Universität/Geomatikum. Aus Richtung Norden kommend können Sie die Abfahrt Stellingen oder Bahrenfeld nehmen. Auch von hier aus weiter in Richtung Stadtzentrum bis zur Universität/Geomatikum. Da Parkplätze in der gesamten Umgebung des Geomatikums nur bedingt vorhanden sind, empfiehlt es sich, weiter entfernt zu parken oder mit anderen Verkehrsmitteln anzureisen.

Grundriss des Geomatikums



Grundriss des Museums



Gemeinsames Abendessen

Das gemeinsame Abendessen am 10.03.2020 wird im Restaurant T.R.U.D.E. stattfinden (Maurienstraße 13-15, 22305 Hamburg).

Beginn des Abendessens ist um 19:00 Uhr. Zum Restaurant gelangen Sie von der U-Bahn-Haltestelle „Schlump“ mit Einstieg in die Linie „U3“ (gelb markiert) über Haltestelle „Kellinghusenstraße“ zur Station „Barmbek“ (Fahrtdauer ca. 12 Minuten, Fahrpreis 3,40 Euro).

Hier steigen Sie aus und nehmen den Ausgang in Richtung „Wiesendamm“. Linkerhand gelangen Sie weiter über die „Poppenhusenstraße“ und am „Museum der Arbeit“ entlang zum Restaurant T.R.U.D.E.. Der gleichnamige Tunnelbohrer T.R.U.D.E. (Tief runter unter die Erde) ist dabei schnell gut sichtbar.

Tagungsprogramm

Montag, 09. März 2020		
11:00	13:00	Registrierung - *Registration*
Beginn Kolloquium - *Beginning of the Conference*		
13:30	13:50	Begrüßung - *Reception*
13:50	14:20	*Bornemann, A. / Erbacher, J. / Grunert, P.* - **IODP Rückblick auf 2019**
14:20	14:40	*Krastel, S.* - **ICDP Rückblick auf 2019**
Wissenschaftliche Beiträge zu IODP und ICDP - *Scientific talks related to IODP and ICDP*		
14:40	15:10	*Wagner, B.* - **The Lake Ohrid drilling project SCOPSCO: Scientific results 6 years after the drilling operation**
15:10	16:20	**Posterpräsentation und Kaffeepause - *Presentation of posters and coffee break***
16:20	16:40	*Dahm, T.* - **ICDP project Drilling the Eger Rift - status report**
16:40	17:00	*Mock, D.* - **Drillcore GT1 of the ICDP Oman Drilling Project: Implications on the accretion of lower oceanic crust**
17:00	17:20	*Gutjahr, M.* - **Geochemical constraints on the intensity of early diagenetic processes in sediments drilled during IODP Expedition 382 in the Southern Ocean**
17:20	17:40	*Vasiliev, I.* - **A warmer Mediterranean region at the Miocene to Pliocene transition**
17:40	18:00	*Jurikova, H.* - **Tracking palaeo-hydroclimatic evolution of the Dead Sea using boron geochemistry**
Im Anschluss: Posterpräsentation und Icebreaker - *Presentation of posters and Icebreaker* (Geologisch-Paläontologisches Museum)		

Dienstag, 10. März 2020		
Wissenschaftliche Beiträge zu IODP und ICDP - *Scientific talks related to IODP and ICDP*		
09:00	09:20	*Drinkorn, C.* - **Sensitivity of North Atlantic Contouritic Sedimentation to Climate Variability in a Coupled-Regional Ocean-Sediment Model**
09:20	09:40	*Catunda, M.C.A.* - **A subsurface ocean heat channel that fuelled ice-sheet growth during the Mid-Pleistocene Transition**
09:40	10:00	*Panagiotopoulos, K.* - **New Project: Linking terrestrial and marine ecosystem responses to climate variability since the Last Interglacial in southeast European refugia (Lake Ohrid and Gulf of Corinth)**
10:00	10:20	*Spieß, V.* - **Deformation Styles and Sedimentation Patterns in Lake Issyk–Kul, Tienshan Mountain Range, Kyrgyzstan – Evidence from a Recent Seismoacoustic Survey to Support ICDP Drilling**
10:20	10:40	*Oster, C.* - **Calibration of temperature proxy records from modern Tahiti corals and application to IODP Expedition 310 corals**
10:40	11:10	**Posterpräsentation und Kaffeepause - *Presentation of posters and coffee break***

Wissenschaftliche Beiträge zu IODP und ICDP - *Scientific talks related to IODP and ICDP*		
11:10	11:30	*Pascal, C.* - **Geothermal studies of the COSC-1 scientific drillhole, Sweden**
11:30	11:50	*Tiedemann, R.* - **Metabarcoding of ancient eukaryotic DNA from Chew Bahir, Ethiopia: Reconstruction of past biodiversity responses to drastic environmental change**
11:50	12:10	*Schubotz, F.* - **Response of microbial lipids to increasing temperatures and decreasing microbial populations in the Nankai Trough subduction zone, IODP Exp. 370**
12:10	12:30	*Kallmeyer, J.* - **Methanogenesis and organic matter mineralization in ferruginous sediments**
12:30	14:00	**Mittagspause und Posterpräsentation - *Lunch break & presentation of posters***
Wissenschaftliche Beiträge zu IODP und ICDP - *Scientific talks related to IODP and ICDP*		
14:00	14:20	*Köster, M.* - **Diagenetic overprint of Fe minerals in deep subseafloor sediments from the Nankai Trough offshore Japan: New insights from geochemical and rock magnetic analyses**
14:20	14:40	*Lüdecke, T.* - **Trophic level reconstruction of hominins in the Southern African Early Pleistocene**
14:40	15:00	*Davis, T.* - **Critical fluid volumes and the start of 'self-sustaining' fracture ascent**
15:00	15:20	*Platz, A.* - **3D imaging of the subsurface electrical conductivity structure in West Bohemia covering mofettes and Quaternary volcanic structures by using magnetotellurics**
15:20	16:30	**Posterpräsentation und Kaffeepause - *Presentation of posters and coffee break***
16:30	16:50	*Ulfers, A.* - **Paleoenvironmental indications and cyclostratigraphic studies of sediments from tropical Lake Towuti obtained from downhole logging**
16:50	17:10	*Dietze, E.* - **What we learned so far about low-temperature fires of northeastern Siberia from 420 kyrs old Lake Elglygytgyn sediments?**
17:10	17:30	*Buiven, L.A.* - **Porosity variation in shocked target rock of the Chicxulub impact structure inferred from high-resolution X-ray micro-CT imaging of Expedition 364 drill core**
17:30	17:50	*Henehan, M.* - **New insights into Extinction and Ecological Recovery around the K-Pg boundary**
ab 19:00		**Gemeinsames Abendessen im Restaurant T.R.U.D.E. (Maurienstraße 13-15)**

Mittwoch, 11. März 2020		
Wissenschaftliche Beiträge zu IODP und ICDP - *Scientific talks related to IODP and ICDP*		
09:00	09:20	*Gebhard, C.* - **Dynamics of the Laurentide Ice Sheet during recent glacials: An initiative for an amphibious IODP-ICDP drilling project, shelf-to-inland eastern Canada**
09:20	09:40	*Raschke, U.* - **Hipercorig - a new system for deep lake sediment sampling**
Fahrtberichte IODP - *Cruise Reports IODP*		
09:40	10:00	*Röhl, U.* - **IODP Expedition 378 South Pacific Paleogene Climate: New multiple-hole Paleogene record of the intermediate-depth Subantarctic South Pacific Ocean**
10:00	10:20	*Schubert, F.* - **IODP Expedition 385: Guaymas Basin Tectonics and Biosphere**
10:20	11:10	**Posterpräsentation und Kaffeepause - *Presentation of posters and coffee break***
parallel stattfindend:		
10:30	**12:00**	**Geo-Show „unterirdisch“ (Hörsaal A der Chemie, Martin-Luther-King-Platz 6)**
11:10	11:30	*Gohl, K.* - **IODP Expedition 379: Development and sensitivity of the West Antarctic Ice Sheet tested from drill records of the Amundsen Sea Embayment**
11:30	11:50	*Lamy, F.* - **IODP Expedition 383 - Dynamics of the Pacific Antarctic Circumpolar Current (DYNAPACC)**
11:50	12:10	*Weber, M.E.* - **Report on IODP Expedition 382 at Iceberg Alley**
12:10		**Posterprämierung und Schlussworte - *Poster Awards and Concluding Remarks***
13:00		**GESEP School 2020: “Land-to-Sea Drilling Projects” -** Geomatikum der Universität Hamburg, Raum 740
		The key aspects of this course will comprise: • Key examples present and future of land-to-sea drilling • The Chicxulub Crater drilling: on-site experience and research • Land-to-sea correlation studies such as palynology • The industry perspective of amphibious drilling
Ende: Donnerstag, 12. März 2020, 16 Uhr		

Teilnehmer - Participants

Name	Vorname	Institution und Ort
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Institut für Tierökologie und Systematik, Giessen
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Potsdam
		IOW Warnemünde, Rostock
		Geowissenschaften (FB5 Uni Bremen), Bremen
		Institut für Geowissenschaften, Universität Heidelberg
		ANTARES, Stuhr
		Christian-Albrechts-Universität, Kiel
		Institut für Mineralogie (Uni Hannover), Hannover
		Palynologie und Klimadynamik (Uni Göttingen), Göttingen
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Geowissenschaften (FB5 Uni Bremen), Bremen
		Institut für Geologie, Hamburg
		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover
		RMS, Fulda
		Leibniz Institut für Ostseeforschung (IOW), Warnemünde
		Marine Geochemie, Universität , Greifswald
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover
		Institut für Geologie (Uni Hamburg), Hamburg
		Institut für Geographie und Geologie (Uni Greifswald), Greifswald
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Potsdam
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Universität Bremen, Bremen
		GFZ - German Research Centre for Geosciences, Potsdam
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Geological Institute, RWTH Aachen University, Aachen
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Potsdam
		Institut für Geowissenschaften (Uni Potsdam), Potsdam
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Institut für Geowissenschaften (Uni Frankfurt), Frankfurt am Main
		Zentrum fuer Marine Umweltwissenschaften (MARUM), Bremen
		Institut für Geowissenschaften (Uni Potsdam), Potsdam
		Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover
		Institut für Geologie (Uni Hamburg), Hamburg
		Institut für Chemie und Biologie des Meeres (Uni Oldenburg), Oldenburg
		Institut für Mineralogie (Uni Hannover), Hannover
		Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven
		MARUM - Zentrum für Marine Umweltwissenschaften, Universität Bremen, Bremen
		Institut für Geographiedidaktik (Uni Köln), Köln
		Institut für Geologie (Uni Hamburg), Hamburg
		Institut für Umweltphysik (Uni Heidelberg), Heidelberg
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Universität Bremen, Bremen
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven

Name	Vorname	Institution und Ort
		Institut für Geowissenschaften, Frankfurt am Main
		Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven
		Institut für Geowissenschaften (Uni Kiel), Kiel
		Universität Bremen, Bremen
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven
		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Department of Palynology and Climate Dynamics, Göttingen
		GEOMAR - Helmholtz-Zentrum für Ozeanforschung Kiel
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Institut für Geographie und Geologie, Greifswald
		Institut für Geophysik und Geologie (IGG - Uni Leipzig), Leipzig
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven
		Goethe-Universität Frankfurt, Frankfurt am Main
		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Institut fuer Geowissenschaften (IfG - Uni Kiel), Kiel
		Institut für Mineralogie , Hannover
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Institut für Geowissenschaften (IfG - Uni Kiel), Kiel
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Geowissenschaften (FB5 Uni Bremen), Bremen
		Institut für Geowissenschaften (Uni Potsdam), Potsdam
		Petrology of the Ocean Crust, University of Bremen
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Institut für Biochemie und Biologie (Uni Potsdam), Potsdam
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Bundesanstalt für Geowissenschaften und Rohstoffe, Berlin-Spandau
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven
		Centrum für Naturkunde (Uni Hamburg), Institut für Geologie (Uni Hamburg), Hamburg
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Institut für Geowissenschaften (IfG Geophysik - Uni Kiel), Kiel
		planeterde.de, Köln
		Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover
		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven
		Institut für Geowissenschaften (IfG - Uni Kiel), Kiel
		Institut für Erdwissenschaften, Universität Graz
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven
		Institut für Mineralogie (Uni Hannover), Hannover
		Leibniz-Labor für Altersbestimmung und Isotopenforschung, Christ.-Albr.-Univ. Kiel, Kiel
		Institut für Geowissenschaften, Christian-Albrechts-Universität zu Kiel, Kiel
		GeoZentrum Nordbayern, Friedrich-Alexander Universität Erlangen-Nürnberg,, Erlangen
		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven
		Institut für Geowissenschaften (IfG - Uni Kiel), Kiel
		Institut für Geowissenschaften (IfG Geophysik - Uni Kiel), Kiel
		Institut für Umweltphysik (Uni Heidelberg), Heidelberg
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Institut für Geowissenschaften (Uni Kiel), Kiel
		Senckenberg Biodiversität und Klima Forschunsgzentrum (BiK-F), Frankfurt am Main

Name	Vorname	Institution und Ort
		Institut für Geologie (Uni Hamburg), Hamburg
		Deutsche Forschungsgemeinschaft (DFG), Bonn
		Institut für Geowissenschaften (Uni Potsdam), Potsdam
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Institut für Geographie und Geologie (Uni Greifswald), Greifswald
		Institut für Erdwissenschaften, Universität Graz, Graz, Österreich
		Institut für Mineralogie (Uni Hannover), Hannover
		Mineralogie, Petrologie und Geochemie (Uni München), München
		Deutsches GeoForschungsZentrum GFZ, Potsdam
		Institut für Geowissenschaften (IfG - Uni Kiel), Kiel
		Geowissenschaten, Potsdam
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Helmholtz-Zentrum fuer Ozeanforschung (GEOMAR), Kiel
		MARUM- Zentrum für Marine Umweltwissenschaften, Universität Bremen , Bremen
		MARUM, BremenUniversität Bremen, Bremen
		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Ruhr University, Bochum
		Institut für Geosysteme und Bioindikation (TU Braunschweig), Braunschweig
		Institut für Geowissenschaften (Uni Bonn), Bonn
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum GFZ , Potsdam
		Klima und Umweltphysik (Uni Bern)
		BernInstitut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Institut fuer Geophysik (Uni Hamburg), Hamburg
		Institut für Geowissenschaften, Heidelberg
		Institut für Geosysteme und Bioindikation (TU Braunschweig), Braunschweig
		Institut für Geologie (Uni Hamburg), Hamburg
		Museum für Naturkunde , Berlin
		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Deutschlandfunk, Köln
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven
		Max-Planck-Institut für Chemie (Mainz), Mainz
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Institut f. Geowissenschaften, Universität , Kiel
		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Max-Planck-Institut für Chemie (Mainz), Mainz
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Institut für Geologie (Uni Hamburg), Hamburg
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Institut für Geowissenschaften, Christian-Albrechts-Universität zu Kiel
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Institut für Geologie (Uni Hamburg), Hamburg
		Geowissenschaften (FB5 Uni Bremen), Bremen
		Deutsches GeoForschungsZentrum GFZ, Potsdam
		Institut für Geosysteme und Bioindikation (TU Braunschweig), Braunschweig
		Fachbereich Geowissenschaften, Universität Bremen
		Institut für Chemie und Biologie des Meeres (Uni Oldenburg), Oldenburg
		Deutsche Forschungsgemeinschaft (DFG), Bonn

Name	Vorname	Institution und Ort
		Universität Frankfurt/M
		Geowissenschaften (FB5 Uni Bremen), Bremen
		Steinmann Institut für Geologie, Mineralogie und Paläontologie (Uni Bonn), Bonn
		Geowissenschaften (FB5 Uni Bremen), Bremen
		EPSP Member, Independent Consultant, Ratingen
		Deutsche Forschungsgemeinschaft (DFG), Bonn
		Institut für Geowissenschaften (Uni Heidelberg), Heidelberg
		Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Potsdam
		Institut für Biochemie und Biologie (Uni Potsdam), Potsdam
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam
		Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven
		Leibniz-Institut für Angewandte Geophysik (LIAG), Hannover
		Institut für Geowissenschaften (IfG - Uni Kiel), Kiel
		Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover
		Senckenberg Biodiversity and Climate Research Centre, Frankfurt am Main
		Institut für Geophysik und extraterrestrische Physik (TU Braunschweig), Braunschweig
		Institut für Geowissenschaften (Uni Frankfurt), Frankfurt am Main
		Ludwig-Maximilians-Universitaet Muenchen, Muenchen
		Institut für Geologie und Mineralogie (Uni Köln), Köln
		Steinmann Institut für Geologie, Mineralogie und Paläontologie (Uni Bonn), Bonn
		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Institut für Geowissenschaften (IfG Geophysik - Uni Kiel), Kiel
		Leibniz-Institut für Angewandte Geophysik (LIAG), Hannover
		Leibniz-Institut für Angewandte Geophysik (LIAG), Hannover
		Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
		Universität, Würzburg, Würzburg
		Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ, Potsdam

Abstracts und Fahrtberichte

FAHRTBERICHTE:

ABSTRACTS:

Fahrtberichte - Cruise reports

Ultradeep drilling targeting the subduction zone megathrust: The NanTroSEIZE IODP Expedition 358

M. J. Ikari[1], A. Dielforder[2], A. J. Kopf[1], A. Schleicher[2], K. Stanislowski[1], J. Zhang[1], Expedition 358 Scientists

[1]Marum – Center for Marine Environmental Science, University of Bremen,
[2]Helmholtz Center Potsdam, GFZ German Research Centre for Geoscience, Potsdam

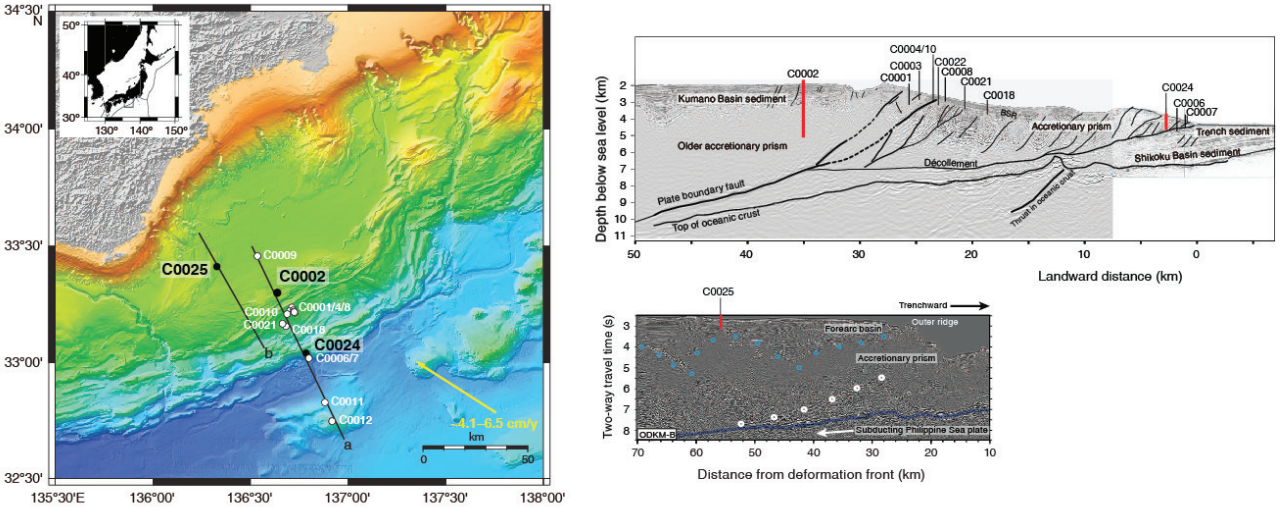


Fig. 1: Bathymetric map of the Nankai Trough region (left), showing the locations of Sites C0002, C0024, and C0025, and interpreted seismic reflection images showing Sites C0002 and C0024 (upper right) and Site C0025 (lower right). Modified from *Tobin et al. (2019), Expedition 358 Preliminary Report, International Ocean Discovery Program, https://doi.org/10.14379/iodp.pr.2019*

IODP Expedition 358 is the final expedition of the multi-phase Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE), which had the ultimate goal of penetrating a seismogenic plate-boundary for the first time. This was attempted at IODP Site C0002 (Fig. 1), with the goal of deepening the holes previously drilled on earlier NanTroSEIZE expeditions. Expedition 358 was carried out on board the drilling vessel Chikyu from October 2018 to March 2019. The interpreted plate boundary was expected to be encountered at ~5200 mbsf based on seismic reflection data. Over the course of the drilling from ~2800 mbsf to the target, the acquisition of logging while drilling (LWD) data, along with recovery of cuttings, mud gas, and sporadic coring was planned in order to characterize the inner accretionary prism. The drilling required a technically demanding system of drilling sidetracking stemming from a previously-drilled hole. Ultimately, the drilling proved to be too operationally challenging and the seismogenic plate boundary was not reached. The final drilling depth at Site C0002 reached 3262.5 mbsf, establishing the greatest depth to date in scientific ocean drilling.

When the deep target was no longer be feasible, focus was shifted to contingency drilling at Sites C0024 and C0025 (Figure 1). Site C0024 is located in the frontal thrust region, in the toe of the accretionary prism seaward of Site C0002. Operations at this site included sampling and logging the hanging wall rocks and the shallow portion of the frontal plate boundary fault zone at >800 mbsf. LWD data indicate a ~40 m wide fractured and deformed zone, interpreted to be the plate boundary décollement. Site C0025 is located in the Kumano forearc basin, landward of Site C0002. Drilling here penetrated Kumano forearc basin sediments, with cores recovered from ~400-580 mbsf. The scientific goal of Site C0025 is to provide information on the historical development of the Kumano forearc basin.

Despite extensive difficulties at Site C0002, continuous cuttings were obtained along with three cores of minimal recovery from 2836.5 to 2848.5 mbsf. Four different rock types with could be distinguished: silty claystone as the dominant litholo-

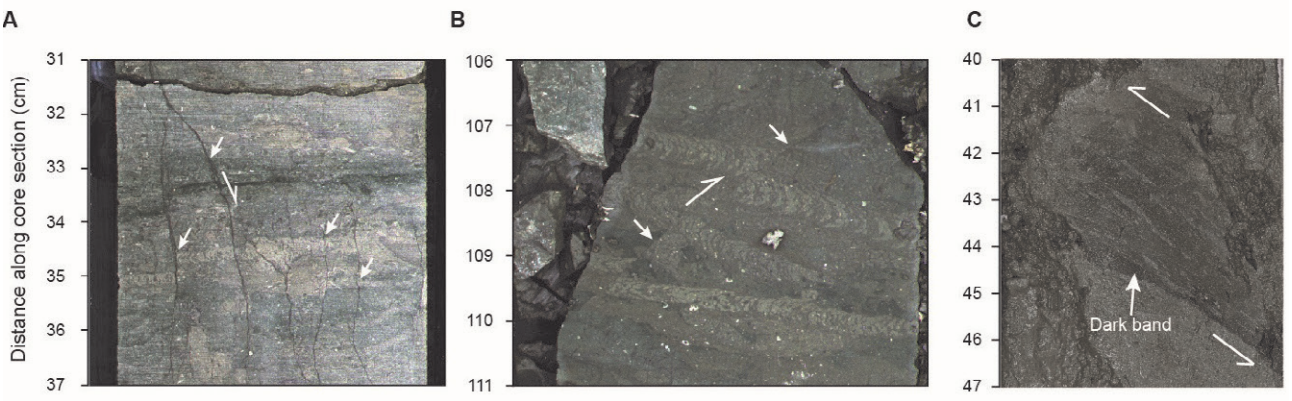


Fig. 2: Structures from Site C0024. (A) Small normal faults offsetting bedding. (B) Small reverse faults offsetting burrows. (C) Shear zone in trench-wedge sediments. White arrows indicate faults.

gy, unconsolidated and sticky fine silty claystone, a fine grained unconsolidated sandstone, and a very fine grained sandstone. The mineralogy shows that clay minerals are the most abundant constituents, along with quartz and feldspar. The facies was interpreted to be a hemipelagic depositional environment with sporadic turbidity currents. Porosity obtained from moisture and density (MAD) measurements decreases slightly from 2800-3250 mbsf, consistent with results from previous expeditions. In addition, mud gas composition was found to exhibit similar trends to results from the previous expedition at C0002, IODP Expedition 348. Methane concentrations indicate that the hydrocarbon gas is thermogenic. Three small peaks of elevated H_2 and ^{222}Rn are also observed, which is suspected to reflect fluid migration in minor fault zones.

From cores recovered at Site C0024, four lithological units could be distinguished: silty clay to clayey silt slope sediments, trench wedge sediments ranging from silty clay to sand, silty claystone to clayey siltstone representing a transition from the trench wedge to hemipelagic setting, and bioturbated silty claystone to clayey siltstone representing accreted units of the Shikoku Basin at >555 mbsf. A sharp increase in porosity marks the transition from trench wedge to Shikoku Basin sediments. Also observed around the unit boundary are a decrease in magnetic susceptibility and a gradual decrease in *P*-wave velocity and electrical resistivity.

Deformation structures at Site C0024 are minor and mainly related to sediment compaction and gravitational instability (Fig. 2). Deformation structures that clearly indicate contractional deformation within the frontal prism are restricted to conjugate sets of moderately inclined deformation bands, small reverse faults accommodating cm-scale displacements, and a cm-thick shear zone encountered at ~295 mbsf corresponding with a seismically-imaged backthrust that splays from the frontal imbricate thrust, which has accommodated about 50 m of displacement. Taken together, the structural observations at Site C0024 indicate little overall deformation and a scarcity of compressive structures. This finding suggests that deformation in frontal prism is strongly localized along mechanically weak faults and that the prism is in a fragile state of stress varying between compressive and tensile failure.

At Site C0025, two lithologic units were defined starting at 400 mbsf. Both are hemipelagic mud, with the lower unit distinguished by secondary attributes such as dark clay-rich bands, organic matter and pyrite concentration, trace fossils, fine sand laminae, pumice clasts and thin ash beds. The lithologic boundary is also indicated by a rapid decrease in magnetic susceptibility. Deposition probably occurred in a trench-slope environment with slow sediment accumulation rates, consistent with the early Pleistocene deposition that occurred during the initial stages of filling the Kumano forearc basin.

A wide range of post-cruise research is planned using Expedition 358 samples and data. For example, detailed structural analyses on C0024 samples will better constrain the distribution and style of deformation at Site C0024 and implications for the state of stress along faults and in accreted units at the frontal prism. To estimate the amount of fluids migrating along faults, permeability after shear experiments of core samples from C0002 will be measured and compared with borehole monitoring data from previous expeditions to constrain the role of faults in fluid-mediated processes in subduction zones. Laboratory consolidation and shearing experiments will investigate the influence of sediment compaction on frictional slip behaviour, helping better understand the processes underlying seismic slip and its distribution in the Nankai accretionary complex.

IODP Expedition 379: Development and sensitivity of the West Antarctic Ice Sheet tested from drill records of the Amundsen Sea Embayment

K. Gohl[1], J. S. Wellner[2], A. Klaus[3], T. Bauersachs[4], T. Frederichs[5], J. P. Klages[1], Johan Renaudie[6], IODP Expedition 379 Scientists

[1] Alfred Wegener Institute Helmholtz-Centre for Polar and Marine Research, Bremerhaven, Germany
[2] University of Houston, TX, USA
[3] IODP, Texas A&M University, College Station, TX, USA
[4] University of Kiel, Germany
[5] University of Bremen, Germany
[6] Johan Renaudie (Museum für Naturkunde, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Berlin, Germany

The Amundsen Sea sector of Antarctica has long been considered the most vulnerable part of the West Antarctic Ice Sheet (WAIS) because of the great water depth at the grounding line and the absence of substantial ice shelves. Glaciers in this configuration are thought to be susceptible to rapid or runaway retreat. Ice flowing into the Amundsen Sea Embayment is undergoing the most rapid changes of any sector of the Antarctic Ice Sheet outside the Antarctic Peninsula, including changes caused by substantial grounding-line retreat over recent decades, as observed from satellite data. Recent models suggest that a threshold leading to the collapse of WAIS in this sector may have been already crossed and that much of the ice sheet could be lost even under relatively moderate greenhouse gas emission scenarios.

Drill cores from the Amundsen Sea provide tests of several key questions about controls on ice sheet stability. The cores offer a direct record of glacial history offshore from a drainage basin that receives ice exclusively from the WAIS, which allows clear comparisons between the WAIS history and low-latitude climate records. Today, warm Circumpolar Deep Water (CDW) is impinging onto the Amundsen Sea shelf and causing melting of the underside of the WAIS in most places. Reconstructions of past CDW intrusions can assess the ties between warm water upwelling and large-scale changes in past grounding-line positions. Carrying out these reconstructions offshore from the drainage basin that currently has the most substantial negative mass balance of ice anywhere in Antarctica is thus of prime interest to future predictions.

The scientific objectives for this expedition are built on hypotheses about WAIS dynamics and related paleoenvironmental and paleoclimatic conditions. The main objectives are

1. To test the hypothesis that WAIS collapses occurred during the Neogene and Quaternary and, if so, when and under which environmental conditions;

2. To obtain ice-proximal records of ice sheet dynamics in the Amundsen Sea that correlate with global records of ice-volume changes and proxy records for atmospheric and ocean temperatures;

3. To study the stability of a marine-based WAIS margin and how warm deep-water incursions control its position on the shelf;

4. To find evidence for earliest major grounded WAIS advances onto the middle and outer shelf;

5. To test the hypothesis that the first major WAIS growth was related to the uplift of the Marie Byrd Land dome.

International Ocean Discovery Program (IODP) Expedition 379 completed two very successful drill sites on the continental rise of the Amundsen Sea. Site U1532 is located on a large sediment drift now called Resolution Drift and penetrated to 794 m

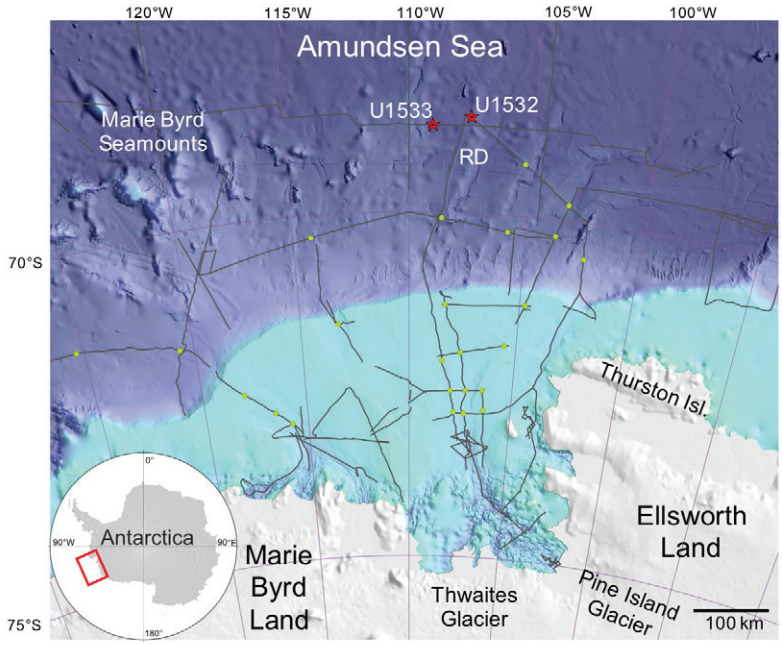


Fig.1: Bathymetry map of the southern Amundsen Sea, West Antarctica, with the two drill sites of IODP Expedition 379 (red stars), the proposed primary and alternate sites of the proposal (yellow dots) and the seismic lines (grey lines). RD denotes Resolution Drift.

with 90% recovery. We collected almost-continuous cores from the Pleistocene through the Pliocene and into the late Miocene. At Site U1533, we drilled 383 m (70% recovery) into the more condensed sequence at the lower flank of the same sediment drift. The cores of both sites contain unique records that will enable study of the cyclicity of ice sheet advance and retreat processes as well as bottom-water circulation and water mass changes. In particular, Site U1532 revealed a sequence of Pliocene sediments with an excellent paleomagnetic record for high-resolution climate change studies of the previously sparsely sampled Pacific sector of the West Antarctic margin.

Despite the drilling success at these sites, the overall expedition experienced three unexpected difficulties that affected many of the scientific objectives:

1. The extensive sea ice on the continental shelf prevented us from drilling any of the proposed shelf sites.

2. The drill sites on the continental rise were in the path of numerous icebergs of various sizes that frequently forced us to pause drilling or leave the hole entirely as they approached the ship. The overall downtime caused by approaching icebergs was 50% of our time spent on site.

3. An unfortunate injury to a member of the ship‘s crew cut the expedition short by one week.

Recovery of core on the continental rise at Sites U1532 and U1533 cannot be used to precisely indicate the position of ice or retreat of the ice sheet on the shelf. However, these sediments contained in the cores offer a range of clues about past WAIS sheet extent and retreat. At Sites U1532 and U1533, coarse-grained sediments interpreted to be ice-rafted debris (IRD) were identified throughout all recovered time periods. A dominant feature of the cores is recorded by lithofacies cyclicity, which is interpreted to represent relatively warmer periods variably characterized by higher microfossil abundance, greater bioturbation, and higher counts of IRD alternating with colder periods characterized by dominantly gray laminated terrigenous muds. Initial comparison of these cycles to published records from the region suggests that the units interpreted as records of warmer time intervals in the core tie to interglacial periods and the units interpreted as deposits of colder periods tie to glacial periods.

The cores from the two sites recovered sediments of purely terrigenous origin intercalated or mixed with pelagic or hemipelagic deposits. In particular, Site U1533, which is located near a deep-sea channel originating from the continental slope, contains graded sands and gravel transported downslope from the shelf to the abyssal plain. The channel is likely the path of such sediments transported downslope by turbidity currents or other sediment-gravity flows. The association of lithologic facies at both sites predominantly reflects the interplay of downslope and contouritic sediment supply with occasional input of more pelagic sediment. Despite the lack of cores from the shelf, our records from the continental rise reveal the timing of glacial advances across the shelf and thus the existence of a continent-wide ice sheet in West Antarctica at least during longer time periods since the late Miocene.

Cores from both sites contain abundant coarse-grained sediments and clasts of plutonic origin transported either by downslope processes or by ice rafting. If detailed provenance studies confirm our preliminary assessment that the origin of these samples is from the plutonic bedrock of Marie Byrd Land, their thermochronological record will potentially reveal timing and rates of denudation and erosion linked to crustal uplift. The chronostratigraphy of both sites enables the generation of a seismic sequence stratigraphy not only for the Amundsen Sea rise but also for the western Amundsen Sea along the Marie Byrd Land margin through a connecting network of seismic lines.

Report on IODP Expedition 382 at Iceberg Alley

M. E. WEBER[1], M. E. RAYMO[2], V. L. PECK[3], T. WILLIAMS[4], M. GUTJAHR[5], T. RONGE[6] AND IODP 382 SCIENTISTS

[1] University of Bonn, Germany
[2] Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York, USA
[3] British Antarctic Survey, Cambridge, UK
[4] International Ocean Discovery Program, Texas A&M University, College Station, USA
[5] GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany
[6] Alfred-Wegener-Inst. Helmholtz Center for Polar and Marine Research (AWI), Bremerhaven, Germany

International Ocean Discovery Program (IODP) Expedition 382, Iceberg Alley and Subantarctic Ice and Ocean Dynamics, took place from March 20 to May 20, 2019 with RV JOIDES Resolution (Weber et al., 2019). Our primary goal is to investigate the long-term history of Antarctica in order to better understand the dynamics of the Antarctic Ice Sheet (AIS), how the pace and magnitude of past ice-mass loss responded and contributed to global sea-level evolution. Another goal is to decipher how past changes in ocean bioproductivity and dust deposition in the Antarctic zone might have influenced atmospheric CO2

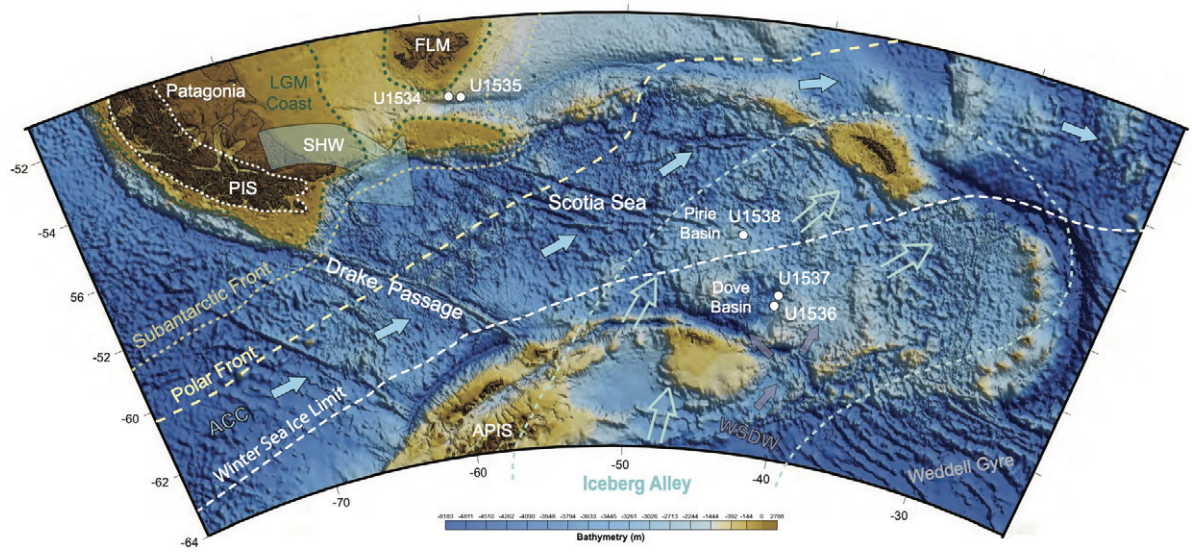


Fig. 1: Top: Location map of Expedition 382 (Iceberg Alley) showing the Scotia arc. Sites U1534 and U1535 are located under the Subantarctic Front. Scotia Sea sites are located in Dove Basin (U1536, U1537) and in Pirie Basin (U1538). Light blue dashed line and arrows indicate Iceberg. Large gray arrow is main wind direction of the Southern Hemisphere westerlies (SHW); blue solid arrows indicate flow direction of the Antarctic Circumpolar Current (ACC); solid purple arrows indicate exit route of Weddell Sea Bottom Water (WSBW); yellow dotted line is the Subantarctic Front; yellow dashed line is the Polar Front; green dotted line is the Patagonian coastline during the Last Glacial Maximum (LGM); white dotted line is the limit of Patagonian Ice Sheet (PIS) at the LGM; white dashed line is the winter sea-ice limit. Underlain map shows satellite bathymetry. Details see Weber et al. (2019).

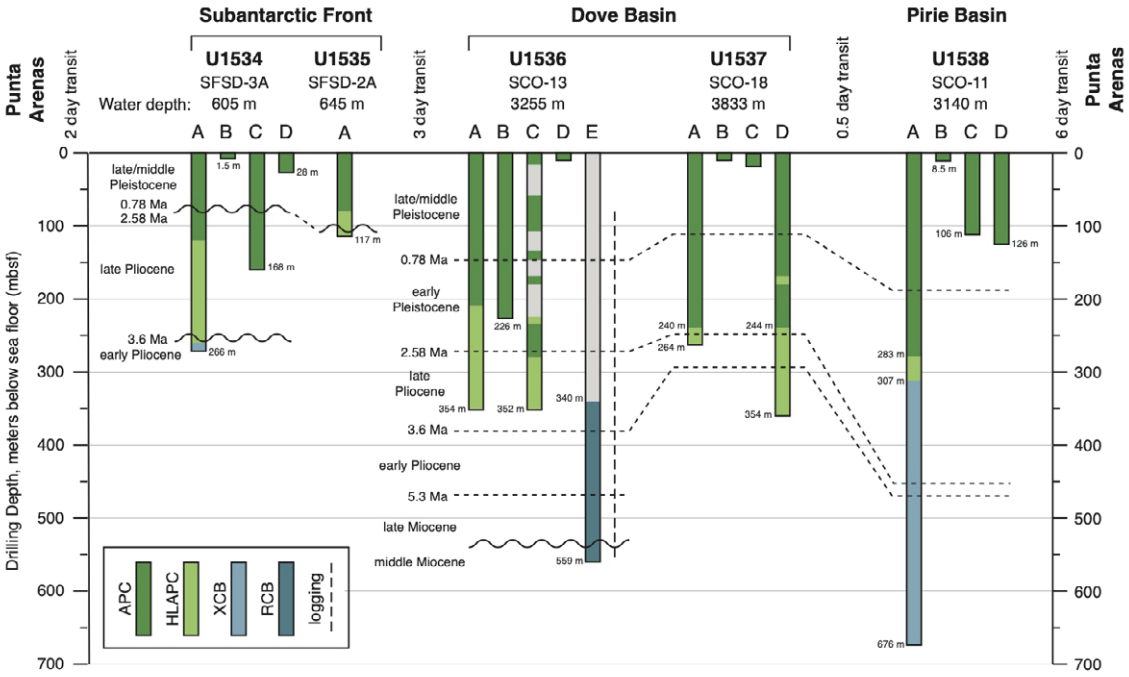


Fig. 2: Top: Expedition 382 drilling plan. After transiting from Punta Arenas to the Subantarctic Front, Sites U1534 and 1535 were drilled over 5 operational days at the beginning of the expedition. After transiting to the southernmost working area Dove Basin, Sites U1536 was drilled. It took 21 days to achieve APC/HAPC and RCB coring as well as logging. Site U1537 was then drilled within 7 days. After transiting to the north to Pirie Basin, the final Site U1538 was drilled over 10 days. Coring type is color coded: dark green, APC; light green, HLAPC; light blue, RCB; dark blue XCB. Expedition 328 cored a total of 3228 m over 18 holes, with an overall core recovery of 2810 m. Details see Weber et al. (2019).

variability. We drilled five sites with multiple holes east of the Drake Passage with a total core recovery of ~2.8 km. Operations were challenging with frequent coring interruptions due to high waves and approaching icebergs (Fig. 1).

The three main sites were collected in the center of Iceberg Alley, between –57.4°S and –59.4°S in the southern Scotia Sea. At Sites U1536 and U1537, we recovered continuously deposited late Neogene sediments covering at least the last 3.5 Ma to reconstruct the past history and variability in AIS mass loss and associated changes in oceanic and atmospheric circulation. The two sites from Dove Basin (U1536 and U1537) both recovered the top 354 m with very good core recovery using the Advanced Piston Corer (APC). At U1536E, we used rotary coring (RCB) to extend the hole to basement, which was expected to be located in ~900 mbsf (Fig. 2). Here, the goal was to inform on the age and nature of the acoustic basement. However, due to iceberg and weather hazards, we had to cancel these operations at 559 mbsf with poor recovery. At Site U1538 in Pirie Basin, we recovered the upper 307 m with APC/Half APC coring and used the extended core barrel (XCB) to extend hole A to 676 mbsf with good recovery. Preliminary biostratigraphic assessment indicates over 45 first and last occurrences of biosiliceous species that are pristinely preserved. Also, all known magnetic boundaries since the Late Neogene are clearly documented. Resulting sedimentation rates are ~20–10 cm/kyr for Sites U1536 and U1537, and ~40–20 cm/kyr for Site U1538. Accordingly, all sediment physical and optical properties determined onboard at 1–2 cm increments, translate into sample resolutions in the upper decadal to lower centennial band. Overall, we retrieved the first high-resolution and long-term, continuous climate and ice-sheet record in the Antarctic zone.

The sites from Iceberg Alley will be used to study the Plio-Pleistocene flux of icebergs through Iceberg Alley, the main pathway along which icebergs calved from the margin of the AIS travel as they move equatorward into the warmer waters of the Antarctic Circumpolar Current (ACC). In particular, the continuous and rather highly-resolved sediment record from Iceberg Alley should enable us to assess the magnitude of iceberg flux during key times of AIS evolution, e.g., the middle glacial intensification of the East Antarctic Ice Sheet, the mid-Pliocene warm period, the late Pliocene glacial expansion of the West Antarctic Ice Sheet, the mid-Pleistocene transition (MPT), "warm interglacials" and glacial terminations of the last 800 kyr. We will use the geochemical provenance of iceberg-rafted detritus (IBRD) and other glacially eroded material to determine regional sources of AIS mass loss. We will also address interhemispheric phasing of ice sheet growth and decay, study the distribution and history of land-based versus marine-based ice sheets around the continent over time, and explore the links between AIS variability and global sea level.

By comparing north–south variations across major atmospheric and oceanic fronts in the Scotia Sea (Fig. 1) between the Pirie Basin (Site U1538) and the Dove Basin (Sites U1536 and U1537), Expedition 382 will also deliver critical information on how climate changes in the Southern Ocean affect ocean circulation through the Drake Passage, meridional overturning in the region, water mass production, ocean–atmosphere CO_2 transfer by wind-induced upwelling, sea ice variability, bottom water outflow from the Weddell Sea, Antarctic weathering inputs, and changes in oceanic and atmospheric fronts in the vicinity of the ACC.

Comparing changes in dust proxy records between the Scotia Sea and Antarctic ice cores will also provide a detailed reconstruction of changes in the Southern Hemisphere westerlies on millennial and orbital timescales for the last 800 kyr. Extending the ocean dust record beyond that time is a critical goal and will help evaluating dust-climate couplings since the Pliocene, the potential role of dust in iron fertilization and atmospheric CO2 drawdown during glacials, and whether changes in dust input to Antarctica played a role across the MPT for subsequently slightly lowered glacial atmospheric pCO2.

Two additional, shorter sites located on a contourite ridge at the northern edge of the Scotia Sea (~53.2°S), were cored to better understand how intermediate water formation in the SW Atlantic responds to changes in connectivity between the Atlantic and Pacific basins, the so-called "cold water route." Site U1534 and U1535 cored the upper 266 and 159 mbsf, respectively. We recovered continuously deposited sediments from this Subantarctic Front drift spanning the late Pleistocene (from ~0.78 Ma to recent) and from the late Pliocene (~3.1–2.6 Ma). The scientific goal is to monitor millennial- to orbital-scale variability in the export of Antarctic Intermediate Water beneath the Subantarctic Front to better understand past changes in the density structure of the Atlantic sector of the Southern Ocean, track migrations of the Subantarctic Front, and give insights into the role and evolution of the cold water route over the preserved time scales.

References

Weber, M.E., Raymo, M.E., Peck, V.L., Williams, T., and Expedition 382 Scientists, 2019. Expedition 382 Preliminary Report: Iceberg Alley and Subantarctic Ice and Ocean Dynamics. International Ocean Discovery Program, 1-40.

IODP Expedition 383 - Dynamics of the Pacific Antarctic Circumpolar Current (DYNAPACC)

F. Lamy[1], H. W. Arz[2], O. Esper[1], L. Lembke-Jene[1], S. Moretti[3], G. Winckler[4], C. A. Alvarez Zarikian[5], IODP Expedition 383 Scientists

[1] Alfred Wegener Institute Helmholtz Zentrum für Polar und Meeresforschung, Germany
[2] Leibniz Institute for Baltic Sea Research Warnemünde, Germany
[3] Max Planck Institute for Chemistry (MPIC)
[4] Lamont-Doherty Earth Observatory, Columbia University, USA
[5] International Ocean Discovery Program, Texas A&M University, USA

The Antarctic Circumpolar Current (ACC) is the world's strongest zonal current system that connects all three major basins of the global ocean, and therefore integrates, forces and responds to global climate variability. In contrast to the Atlantic and Indian sectors of the ACC, and with the exception of drill cores from the Antarctic continental margin and off New Zealand, the Pacific sector of the ACC lacks information on its Cenozoic paleoceanography from deep-sea drilling records.

To advance our knowledge and understanding of Miocene to Holocene atmosphere-ocean-cryosphere dynamics in the Pacific and their implications for regional and global climate and atmospheric CO2, IODP Expedition 383 recovered sedimentary sequences at: (1) Three sites located in the central South Pacific (Sites U1539, U1540 and U1541); (2) two sites at the Chilean Margin (U1542, U1544); and (3) one site from the hemipelagic eastern South Pacific (U1543) close to the entrance to the Drake Passage. Age control based on magneto and biostratigraphically constrained orbital tuning of physical properties in the Plio-Pleistocene sediments is remarkable, with Sites U1541 and U1543 extending the record back to the late Miocene, and Site U1540 to the earliest Pliocene. Pleistocene sedimentary sequences with high sedimentation rates in the order of 40 cm/kyr were drilled in the Central South Pacific (U1539) and along the Chilean Margin. Taken together, the sites represent a

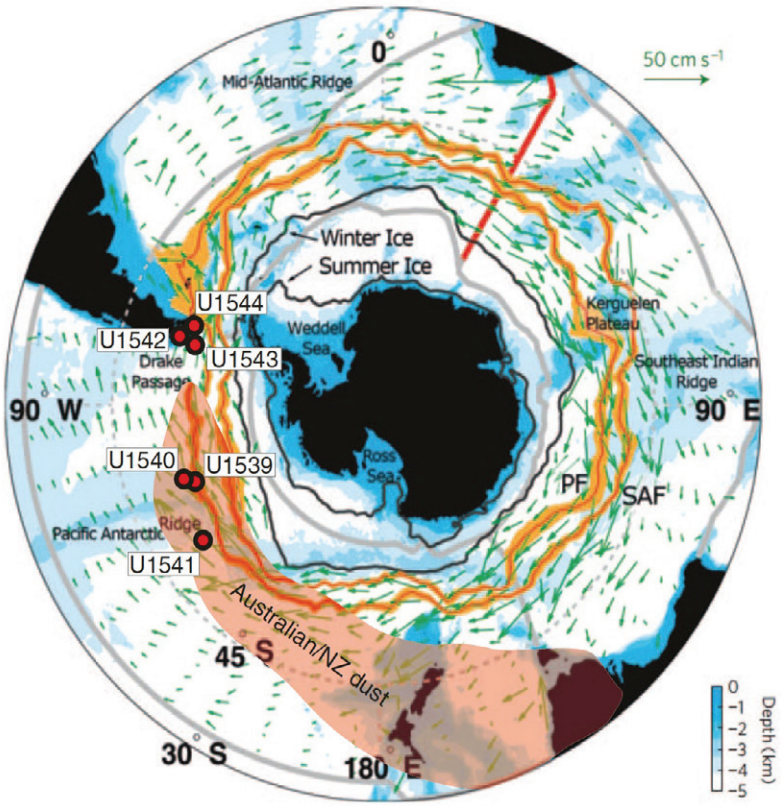


Fig. 1: Bathymetry of Guaymas Basin with Baja California in the southwest and the Sonora Margin in the northeast. Drill sites (circles) and existing seismic transects (solid black and purple lines) are indicated. Inset shows the tectonic setting of the Gulf of California, with Guaymas Basin, being depicted by green shading, and the area of the main site figure indicated by a blue box. Displayed contour lines correspond to 200 m intervals. DSDP = Deep Sea Drilling Project. (Teske et al., in prep.)

depth transect from ~1100 m at the Chilean margin (U1542) to ~4070 m in the Central South Pacific (U1539), and allow reconstructing changes in the vertical structure of the ACC – a key issue for understanding the role of the Southern Ocean in the global carbon cycle- to be investigated. The sites are located at latitudes and water depths where sediments will allow the application of a wide range of siliciclastic, carbonate, and opal-based proxies to address our objectives of reconstructing, with unprecedented stratigraphic detail, surface to deep ocean variations and their relation to atmosphere and cryosphere changes through stadial-to-interstadial, glacial-to-interglacial and warmer than present time intervals.

IODP Expedition 385: Guaymas Basin Tectonics and Biosphere

F. Schubert[1], C. Galerne[2], V. B. Heuer[3], A. Teske[4], D. Lizarralde[5], T. W. Höfig[6], IODP Expedition 385 Scientists

[1] GFZ German Research Centre for Geosciences, Section Geomicrobiology, Potsdam, Germany
[2] GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany
[3] MARUM Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany
[4] University of North Carolina at Chapel Hill, Department of Marine Sciences, Chapel Hill, USA
[5] Woods Hole Oceanographic Institution, Department of Geology and Geophysics, Woods Hole, USA
[6] Texas A&M University, International Ocean Discovery Program, College Station, USA

Guaymas Basin is a young marginal rift basin in the Gulf of California characterized by active seafloor spreading and rapid sediment deposition, including organic-rich sediments derived from biologically highly productive overlying waters and terrigenous sediments from nearby continental margins (van Andel, 1964). The combination of active seafloor spreading and rapid sedimentation within a narrow basin gives rise to a dynamic environment where linked physical, chemical, and biological processes regulate the cycling of sedimentary carbon. This continuum of interconnecting processes from magma to microbe motivated International Ocean Discovery Program (IODP) Expedition 385 (Teske et al., 2018).

IODP Expedition 385 cored sequences of organic-rich sediments with sill intrusions on the flanking regions and in the northern axial graben of Guaymas Basin. This basin is characterized by a widespread and intense heat flow distribution and a very dense sill network that also extends laterally across the flanking regions, contrasting with a classical mid-ocean ridge setting where both heat and magmatism are usually focused at spreading centers (see Teske et al., 2018, and references therein). The large sill network provides multiple transient heat sources that mobilize buried sedimentary carbon, in part as methane and other hydrocarbons, and drive hydrothermal circulation (Teske et al., in prep.). The expedition aimed, among others, to elucidate how the resulting thermal and geochemical gradients are related to the abundance, composition, and activity of the deep subsurface biosphere in Guaymas Basin (Teske et al., 2018).

Drill sites extend from the northwestern to the southeastern flanking regions of the northern axial graben of Guaymas Basin, covering an ~81 km long transect (**F1**). Adjacent Sites U1545 and U1546 recovered the oldest and thickest sediment successions (to ~540 meters below seafloor [mbsf]), one without sill emplacement (Site U1545), and one with a deeply buried sill (~356–430 mbsf) that impacted the sediment column

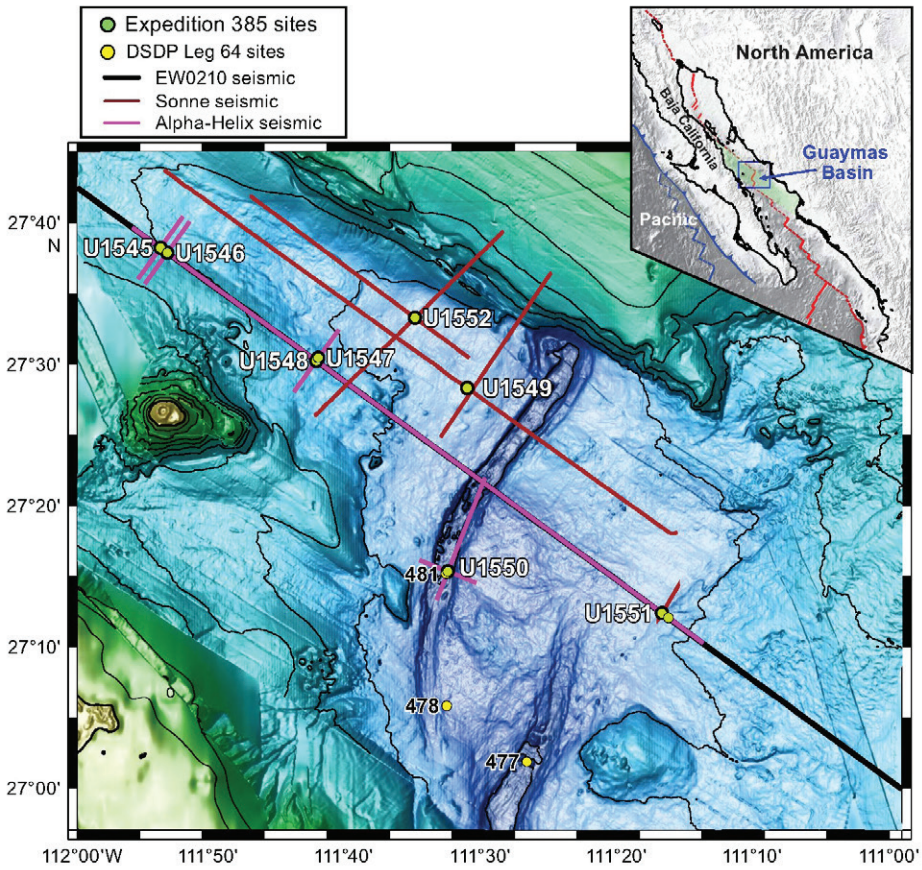


Fig. 1: IODP Expedition 383 - Dynamics of the Pacific Antarctic Circumpolar Current (DYNAPACC)

(Site U1546). Because the two sites are next to each other (~1 km apart) and differ primarily because of the presence or absence of this large sill, they provide a model area for studying the effects of sill emplacement in an older sediment column. A surprising feature of both sites was the strong thermal gradient that enabled us to recover continuous sample sets with in situ temperatures as high as 70–80°C. These two northwestern sites thus provide a reference thermal gradient. Sites U1547 and U1548 are located in the central sedimented bowl and on the outer periphery of a circular hydrothermal mound called Ringvent, where a shallow (≥82 mbsf [Site U1547] and ≥65 mbsf [Site U1548]), slowly cooling sill is driving steep hydrothermal gradients, which in turn shift the zones of authigenic mineral precipitation and compress the microbial abundance profile toward shallower depths. The Ringvent sill was drilled in several holes and yielded remarkably diverse igneous rock textures, sediment–sill interfaces, and hydrothermal alteration, which is mainly expressed by various secondary minerals occurring in veins and vesicles. It was thus targeted by an integrated sampling and interdisciplinary research effort that included geological, geochemical, and microbiological specialties. The thermal, lithologic, geochemical, and microbiological contrasts between the two deep northwestern sites and the Ringvent sites form the scientific centerpiece of the expedition. These observations are supplemented by results from sites that represent attenuated cold seepage conditions in the central basin (Site U1549), gas hydrate occurrence near the Sonora margin (Site U1552), complex sediments and sills in the northern axial trough (Site U1550), and terrigenous sedimentation events on the southeastern flanking regions (Site U1551).

The scientific outcomes of Expedition 385 will (1) revise long-held assumptions about the role of sill emplacement in subsurface carbon mobilization versus carbon retention, (2) comprehensively examine the subsurface biosphere of Guaymas Basin and its responses and adaptations to hydrothermal conditions, (3) redefine hydrothermal controls of authigenic mineral formation in sediments, and (4) yield new insights into many geochemical and geophysical aspects of both architecture and sill-sediment interaction in a nascent spreading center. The generally high quality and high degree of completeness of the shipboard datasets presents opportunities for interdisciplinary and multidisciplinary collaborations during shore-based studies. A total of 4176.2 m of core (i.e., 755 cores with an overall recovery rate of 87.9%) at eight sites encompassing 26 holes was recovered. In comparison to Deep Sea Drilling Project Leg 64 to Guaymas Basin in 1979, numerous technical innovations (for example, the sophisticated advanced piston corer [APC] and half-length APC tools) have greatly improved sample recovery and scientific yield, particularly in the areas of organic geochemistry and microbiology. For example, microbial genomics did not exist 40 years ago. However, these technical refinements do not change the fact that Expedition 385 will in many respects build on the foundations laid by Leg 64 for understanding Guaymas Basin, regardless of whether adjustments are required in the near future.

Referenzen:

Teske, A., Lizarralde, D., and Höfig, T.W., 2018. Expedition 385 Scientific Prospectus: Guaymas Basin Tectonics and Biosphere. International Ocean Discovery Program. https://doi.org/10.14379/iodp.sp.385.2018

Teske, A., Lizarralde, D., Höfig, T.W., and the Expedition 385 Scientists, in prep. Expedition 385 Preliminary Report: Guaymas Basin Tectonics and Biosphere. International Ocean Discovery Program.

van Andel, T.H., 1964. Recent marine sediments of Gulf of California. In van Andel, T.H., and Shor, G.G., Jr. (Eds.), Marine Geology of the Gulf of California: A Symposium (Volume 3): Tulsa, OK (American Association of Petroleum Geologists), 216-310.

Abstracts

ICDP

Unravelling the origin and linking limnological history to diversification dynamics of an extraordinary invertebrate superflock in Lake Tanganyika

C. Albrecht

Institut für Tierökologie und Systematik, Giessen

Understanding the causes of evolution of differential degrees of biodiversity across taxonomic groups and regions is a fundamental aim in evolutionary biology.

Lake Tanganyika, Africa's oldest and deepest lake is well known to be a global hotspot of freshwater biodiversity a spectacular array of endemic species and radiations in many biotic groups. Whereas the effects of sexual selection, hybridization and other concepts of speciation have been studied in detail for cichlid fishes, the role of extrinsic drivers for diversification is less known, specifically for benthic invertebrate organisms in Lake Tanganyika, for which the factors shaping its extraordinary biodiversity remain enigmatic to date. One of the major goals of the upcoming ICDP deep drilling program for Lake Tanganyika is "Identifying drivers of endemic biodiversity through deep time". The project applied for focuses on this and uses the famous species rich superflock of thalassoid (marine like) gastropods and addresses the following scientific goals: (i) Tracing the origin of Lake Tanganyika's enigmatic superflock, (ii) Inferring colonization dynamics, (iii) High-resolution assessment of diversification processes, and (iv) Testing for concordance between major geological/physico-chemical/environmental changes and evolutionary events. The research program is based on a comprehensive sampling from in and around the lake itself but also the watersheds relevant, specifically the Congo Basin. Using ddRAD sequencing, traditional multilocus molecular datasets, and reconstructions of morphospace and habitat evolution, the superflock will be studied and the impact of extrinsic factors on diversification will be quantified. We will link fossil-calibrated molecular phylogenies with temporal geological, environmental and palaeoenvironmental data (sedimentological, tephrostratigraphic, and palaeo-habitat information) in order to infer the drivers of biotic evolution in Lake Tanganyika that caused its extraordinary endemic biodiversity. It will result in new evolutionary and biogeographical scenarios for the gastropod species assemblages, with general implications for biotic evolution in LT. This will also allow evaluating previous geology-based hypotheses for the origin of extant LT in time and space. This study will contribute significantly to the planned ICDP deep drilling program for Lake Tanganyika, because it explicitly addresses the biological main target topic, i.e. understanding evolution in isolation and the biological history of the African continent. This study is probably one of the first instances in which molecular data and time-calibrated phylogenies are used in an attempt to unravel major limnological events in large ancient lakes. Due to the lack of older fossils in many lake sediments, the approach of using molecular data of recent taxa to model major evolutionary events in the past will be of great interest for geologists and palaeontologists.

ICDP

Iron-dominated carbonate solid solutions in a deep CO_2-saturated aquifer of the Hartoušov mofette system (Eger Rift, NW Czech Republic): signals of CO_2 migration or groundwater mixing

K. Adler[1,2], M. Alawi[1], H. Kämpf[1], R. Bussert[3], H.-M. Schulz[1], D. Wagner[1,2], K. Mangelsdorf[1]

[1] GFZ German Research Centre for Geosciences, Potsdam, Germany
[2] University of Potsdam, Institute of Geosciences, Potsdam, Germany
[3] Technische Universität Berlin, Institute of Applied Geosciences, Berlin, Germany

The Hartoušov mofette system (Eger Rift, Czech Republic) is a natural gas vent releasing CO_2-rich gases into the atmosphere. The gases derive from the lithospheric mantle and migrate preferentially either dissolved in water or as a free gas phase along deep-seated faults to the surface (Bräuer et al., 2008). While migration of these fluids lithological units with low porosities can prevent vertical migration and initiate a lateral migration (Nickschick et al., 2019). Previous studies from surface sediments (~9 m depth) of the mofette system showed that ascending CO_2-containing fluids result in significant lithological changes, i.e. mineral dissolution and precipitation (Flechsig et al., 2008). However, a detailed investigation of the impact of fluid migration on the lithology within the deep subsurface is still missing.

In spring 2016 GFZ Potsdam drilled into the Hartoušov mofette system. During drilling a CO_2 blow-out occurred in about 78 m depth related to a low-permeable CO_2-saturated saline aquifer (Bussert et al., 2017). The sediments of the aquifer revealed vertical-oriented bubble and vein-like structures made of zoned siderite spheres ($FeCO_3$). We investigated eight thin sections from different depths within and below the aquifer using a scanning electron microscope (SEM) equipped with an energy dispersal spectroscopy (EDS) detector and mapped the elemental composition of different siderite growth zones from the rim to the centre for about 80 siderite spheres. Along the measured mineral profiles the composition of the zones differed in the relative contents of Fe, Mg, Ca and Mn. According to the abundance of these four elements we defined a solid solution classification and compared the obtained classes for five zones from the rim to the interior of the siderites. In general, Ca-containing siderite zones predominate in or just below the CO_2-saturated aquifer. The core section below shows a mix of Mg- and Ca-containing zones and the deepest part of the investigated core section revealed a dominance of Mg-containing siderite zones. From zone to zone, the mixing signal in the siderite zones in the middle of the profile shows an expanding and shrinking character. These findings suggest that the different siderite zones are caused either by (a) the upward migrating CO2 leading to changes of the hydrogeochemical properties, or (b) due to a Mg-dominated groundwater in the lower part admixed by a lateral migrating Ca-dominated groundwater in the upper core section.

References

Bräuer et al., 2008. Geochemistry, Geophysics, Geosystems Volume 9, N° 4.
Bussert et al., 2017. Scientific Drilling, 5, 1-15.
Flechsig et al., 2008. Zeitschrift für Geologische Wissenschaften, Berlin 36.
Nickschick et al., 2019. Solid Earth, 10, https://doi.org/10.5194/se-10-1951-2019.

ICDP

A new Plio-Pleistocene sedimentary archive from paleo-Lake Idaho (northwestern United States): Magnetostratigraphic analysis and environmental reconstruction

F. J. Allstädt[1], A. Koutsodendris[1], T. Reichgelt[2], E. Appel[3], W. Rösler[3], A. Prokopenko[4], J. Pross[1]

[1] Institute of Earth Sciences, Heidelberg University, Im Neuenheimer Feld 234–236, 69120 Heidelberg, Germany
[2] Department of Geosciences, University of Connecticut, 354 Mansfield Road, Storrs, CT 06269, United States of America
[3] Department of Geosciences, University of Tübingen, Hölderlinstraße 12, 72074 Tübingen, Germany
[4] Institute of Geology and Mineralogy, University of Cologne, Zülpicherstr. 49a, 50674 Cologne, Germany

The Pliocene to early Pleistocene yields a close analogy to near-future climates, with atmospheric pCO_2 between pre-industrial and anthropogenically perturbed levels as they may be reached in few decades. A new sedimentary archive that is well suited to study Plio-Pleistocene climate dynamics in the terrestrial realm has recently become available through the ICDP-sponsored HOTSPOT project on the evolution of the Snake River Plain (Idaho, USA). Due to their geographic position, these sediments can contribute to a better understanding of climate variability across the Plio-Pleistocene transition in western North America, notably with respect to the hypothesis that enhanced moisture transport into the higher latitudes of North America from ~2.7 Ma onwards was an important factor in the initiation of Northern Hemisphere glaciation (Haug et al., 2005).

At the Mountain Home site, HOTSPOT drilling has yielded the MHAFB11 core that comprises 635 m of fine-grained lacustrine sediments (Shervais et al., 2013). As a first step in the evaluation of the MHAFB11 core we have carried out paleomagnetic analyses in order to achieve high-quality age control. Stepwise thermal demagnetization of 179 samples from the 957–439 m depth interval resulted in the identification of the upper boundary of the Kaena Subchron at ~887 m (3.03 Ma) and the Gauss/Matuyama boundary at 568 m (2.59 Ma; Allstädt et al., in review). Based on these age-control points, the lake sediments of the MHAFB11 core span the late Pliocene to early Pleistocene, which makes them the first archive in continental North America that covers this time interval at one site.

To gain insight into the paleoclimatic evolution of northwestern North America during the late Pliocene to early Pleistocene, we have palynologically analyzed 131 samples from the 732–439 m depth interval (corresponding to an age of ~2.8 to ~2 Ma) of the MHAFB11 core. The obtained palynological dataset, which has a mean temporal resolution of ~7 ka, shows that a Pinus-dominated coniferous forest biome prevailed in the catchment area of paleo-Lake Idaho throughout the study interval. However, the percentages of conifer pollen decrease in the latest Pliocene before reaching consistently lower values in the early Pleistocene at ~2.4 Ma. In contrast, pollen taxa representing an open vegetation (e.g., *Artemisia*, Asteraceae) and deciduous trees (e.g., *Quercus, Betula* and *Alnus*) become increasingly abundant in the early Pleistocene (at ~2.4 Ma). We interpret this vegetation shift to an open mixed conifer/deciduous forest to be caused by wetter climate conditions. This interpretation is supported by quantitative climate estimates, which show a gradual increase in mean annual precipitation in the earliest Pleistocene. This trend towards wetter conditions supports the notion that enhanced moisture transport to northern North America from the subarctic Pacific Ocean has indeed contributed to the onset of Northern Hemisphere glaciation at ~2.7 Ma (Haug et al., 2005).

References

Allstädt, F.J., Appel, E., Rösler, W., Prokopenko, A.A., Pross, J., in review. Downward remagnetization of a ~74 m thick zone in lake sediments from palaeo-Lake Idaho (NW United States) – Locating the Gauss/Matuyama geomagnetic boundary within a dual-polarity interval. Geophysical Journal International.

Haug, G.H., Ganopolski, A., Sigman, D.M., Rosell-Mele, A., Swann, G.E., Tiedemann, R., Jaccard, S.L., Bollmann, J., Maslin, M.A., Leng, M.J., Eglinton, G., 2005. North Pacific seasonality and the glaciation of North America 2.7 million years ago. Nature 433, 821-825.

Shervais, J.W., Schmitt, D.R., Nielson, D., Evans, J.P., Christiansen, E.H., Morgan, L.A., Shanks, P. W.C., Prokopenko, A.A., Lachmar, T., Liberty, L.M., Blackwell, D.D., Glen, J.M., Champion, D., Potter, K.E., Kessler, J., 2013. First Results from HOTSPOT: The Snake River Plain Scientific Drilling Project, Idaho, U.S.A. Scientific Drilling 3, 36-45.

ICDP

Depth of magma storage for high silica rhyolites of the Snake River Plain Province, USA. Calibration and application of barometers.

R. R. Almeev, R. Lang , C. Zhang , F. Holtz

Institute of Mineralogy, Leibniz Universität Hannover, Germany

The Snake River Plain – Yellowstone (SRPY) volcanic system of the western United States represents one of the best examples of thermal anomaly related to hotspot volcanism. It is preserved within the continental lithosphere and one of the main goals of the ICDP drilling was to contribute to our understanding of the interaction between lithospheric mantle and continental crust. The hotspot erupted first the Columbia River Basalts (17 Ma) and produced a thermal anomaly in the lithosphere. This anomaly then migrated eastwards to its current position below Yellowstone volcanic system. One key question of the ICDP proposal was how do mantle hotspots interact with continental lithosphere, and how does this interaction affect the geochemical evolution of mantle-derived magmas and the continental lithosphere? The addition of mafic hotspot magma in the lithosphere represents a significant contribution of new mafic material to the crust. However, partial melting of lower crustal rocks leads to the transfer of fusible components to the upper crust as rhyolite lavas and ignimbrites. This “crustal recycling” results in a magmatic activity that is dominated by a bimodal basalt-rhyolite volcanism.

One of the fundamental questions to clarify the generation of the rhyolites is to constrain the “crustal recycling” processes described above. Two main fundamentally different processes may interact: (1) rhyolites are residual melts from extreme differentiation of basalt due to fractional crystallization or (2) rhyolites are formed by partial melting of crustal mafic to felsic rocks. Constraints on the melting processes of crustal material and on the depth of magma generation and storage are particularly missing. For example, recent models for magma plumbing systems relevant for SRPY rhyolites are presented without any indication of depth (Myers et al., 2016) or with very poor constraints on depth (estimations using Rhyolite-MELTS in Fig. 13 in Troch et al., 2017). The magma storage temperatures can be determined from various thermometers (two pyroxene, two feldspars, ilmenite-magnetite pairs, Ti in quartz) but the depth of magma storage is more critical to constrain because of a lack of well calibrated barometers in rhyolites. As a consequence, the exact depth at which rhyolitic magmas may have been stored before eruption is still under debate.

In this proposal, we use two approaches to constrain magma storage pressures: a thermobarometer based on Ti concen-

trations in quartz and a barometer based on the major element composition of cotectic rhyolitic melts (melt coexisting with quartz and one feldspar), calibrated recently by our group (Wilke et al., 2017).

Ti-in-quartz: This thermobarometer is based on the determination of Ti in quartz minerals, which is dependent on both pressure and temperature. The model has been highly debated in the last 10 years because of there are two available independent calibrations, i.e. one from Thomas et al. (2010) and the other from Huang and Audétat (2012). However, they have large and irreconcilable discrepancies between each other, resulting in widespread confusion about the application of Ti-in-quartz thermobarometer for geological issues. In the frame of this proposal, we have recalibrated this barometer for high silica rhyolites using another experimental approach and the model will be applied to quartz minerals from rhyolites drilled in the ICDP project in the next months. Experiments were conducted in high-silica magmatic systems at 0.5−4 kbar and 700−900 °C, which are conditions expected to be applicable to the SRP rhyolites. For 22 experiments, in which both quartz and rutile are present (i.e., activity of TiO_2 in silicate melt equals to unity), or in which only quartz is present (activity of TiO_2 in silicate melt < 1) the Ti concentrations in quartz measured with electron microprobe can be best fit by the following equation:
$\log(C_{Ti}^{Qtz}/a_{TiO2}^{liq\text{-}Rt}) = 5.3226 - 1948.4/T - 981.4*P^{0.2}/T$,
in which C_{Ti}^{Qtz} is Ti concentration (ppm) in quartz, $a_{TiO2}^{liq\text{-}Rt}$ is activity of TiO_2 in the system referring to the saturation of rutile, T in temperature in kelvin and P is pressure in kbar. The dependence of Ti solubility in silicic melt on melt composition was also investigated and we developed a general expression that uses Ti concentrations measured in coexisting quartz and melt (e.g., paired quartz and quartz-hosted melt inclusion) for constraining storage pressure and/or temperature:
$\log(C_{Ti}^{Qtz}/C_{Ti}^{liq}) = -1.2265+(1117.1-515.8*P^{0.2})/T-0.1150*FM$,
in which C_{Ti}^{liq} is Ti concentration (ppm) in melt and FM=(Na+K+2Ca+2Mg+2Fe)/(Si*Al).

Composition of cotectic rhyolitic melts: An empirical model based on the normative proportions of the components Qz, Ab, Or, An (quartz, albite, orthoclase, anorthite) has been proposed to determine pressure from the major element composition of natural glasses (DERP, Wilke et al., 2017). This model is based exclusively on experimental phase equilibria aimed at determining the evolution of the cotectic line separating the quartz and the feldspar primary fields. Such phase equilibria can also be predicted using the thermodynamic model Rhyolite-MELTS. However, the comparison of both models indicate that Rhyolite-MELTS could underestimate significantly pressure when compared to DERP (Fig. 1), especially in An-rich compositions. A preliminary application of DERP to eruptive rocks from the SRPY indicates that magma storage pressure may decrease with time over the last 14 Ma. (Fig. 2). The large variation observed for the Bruneau-Jarbidge eruptive center (some of the rocks are from the ICDP drilling), where most of the data points were obtained so far, could indicate that magmas from one eruption may have been stored at very different pressures. This would imply that different reservoirs in the crust are activated simultaneously during one eruption.

However, absolute pressure variation obtained used DERP were criticized recently by the scientists that developed the thermodynamic model Rhyolite-MELTS (Gualda et al., 2019) and the calibration of DERP is currently tested again, using complementary experimental approaches. For this approach, pressure calculated with DERP and rhyolite-melts will be tested directly by performing experimental phase equilibrium studies on rhyolites with cotectic compositions, collected from the ICDP drilling.

References
Gualda, A.R. (2019) J. Petrol. 60, 855-864
Huang, R., Audetat, A. (2012). Geochimica et Cosmochimica Acta 84, 75–89
Myers, M.L.. et al. (2016) Earth Planet. Sci. Letter, 451: 285-297
Thomas, J. B. et al. (2010). Contributions to Mineralogy and Petrology, 160(5): 743-759.
Troch, J., B. S. et al. (2017). J. Petrol. 58(1), 29-52.
Wilke S. et al. (2017). J Petrol., 58, 789–818.

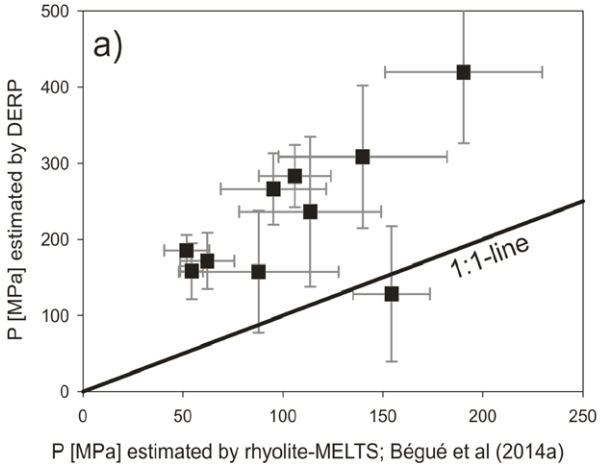


Fig. 1: Pressures estimated for magma storage conditions based on the composition of cotectic glasses using Rhyolite-MELTS by Bégué et al. (2014) (x-axis) and the calibrated barometer of Wilke et al. (2017) (y-axis). Data point refers to the average composition of glasses of a rhyolitic eruption in the Taupo Volcanic Zone. Both approaches are based on the same method, assuming that the compositions of cotectic rhyolitic glasses coexisting with quartz and feldspar is pressure dependent.

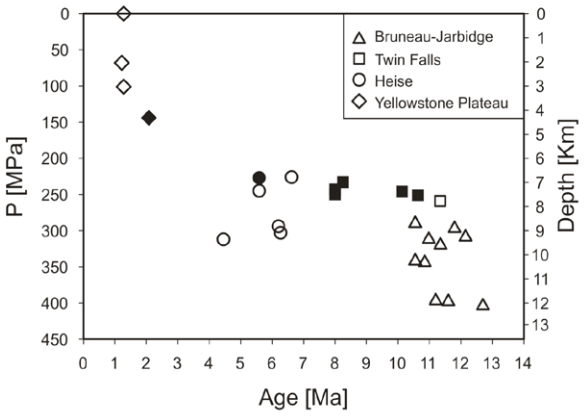


Fig. 2: Pressures estimated using the barometer of Wilke et al. (2017) for volcanic units of the SRPY using own data (full symbols) and literature data (hollow symbols), plotted against their age. The quality of the analyses (especially Na and K concentrations) from the literature data is difficult to assess and need to be tested. The large variation observed for the Bruneau-Jarbidge eruptive center may indicate that magmas from one eruption may have been stored at very different pressures.

IODP

Climate sensitivity of the Eocene warmhouse

E. Anagnostou[1], E. John[2], T. Babila[3], P. Sexton[4], A. Ridgwell[5], D. Lunt[6], P. Pearson[2], R. Pancost[6], G. Foster[3]

[1] GEOMAR, Helmholtz-Zentrum für Ozeanforschung Kiel
[2] Cardiff University
[3] Southampton University
[4] Open University
[5] UC Riverside
[6] Bristol University

The links between atmospheric CO_2 concentrations and evolution of climate during the Eocene greenhouse has advanced greatly in recent years (Cramwinckel et al., 2018, Anagnostou et al., 2016), but many questions still remain unanswered. In particular, some modelling studies have suggested that in order to achieve the global warmth that characterized the early Eocene, warmer climates must be more sensitive to CO_2 forcing than colder climates (Zhu et al., 2019, Caballero et al., 2013). However, such a state-dependence of climate sensitivity has not been detected in the geological record. Here, we test for the existence of state-dependence with a multi-site, continuous, and high-resolution record (1 sample per 0.25 Myr) of planktonic foraminiferal boron isotope-derived CO_2, covering the entire Eocene epoch. By combining this detailed CO_2 reconstruction with new estimates of global mean temperature we are able to describe the temporal evolution of climate sensitivity as the climate cooled. We find that Equilibrium Climate Sensitivity (ECS) was indeed higher during the warmest parts of the Eocene, agreeing well with recent model simulation (Zhu et al., 2019) and declined as the climate cooled towards the late Eocene. These observations indicate that the canonical IPCC range of ECS (1.5 to 4.5 °C per doubling; Ref.5) is unlikely to be appropriate for high-CO_2 warm climates of the past, and may play an increasingly important role in determining the state of future climate as the Earth continues to warm.

References

Cramwinckel, M. J. et al. Synchronous tropical and polar temperature evolution in the Eocene. Nature 559, 382-386, doi:10.1038/s41586-018-0272-2 (2018)

Anagnostou, E. et al. Changing atmospheric CO2 concentration was the primary driver of early Cenozoic climate. Nature 533, 380-384, doi:10.1038/nature17423 (2016)

Zhu, J., Poulsen, C. J. & Tierney, J. E. Simulation of Eocene extreme warmth and high climate sensitivity through cloud feedbacks. Science Advances 5, eaax1874, doi:10.1126/sciadv.aax1874 (2019)

Caballero, R. & Huber, M. State-dependent climate sensitivity in past warm climates and its implications for future climate projections. Proceedings of the National Academy of Sciences, doi:10.1073/pnas.1303365110 (2013)

IPCC Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovermental Panel on Climate Change. 1-1535 (2013)

IODP

Paleoceanography and biogeochemistry of the Amundsen Sea: Preliminary results of IODP Expedition 379 (Amundsen Sea West Antarctic Ice Sheet History)

T. Bauersachs[1], W. Rahaman[2], J.-H. Kim[3], IODP Expedition 379 Scientists

[1] University of Kiel, Kiel, Germany
[2] National Centre for Polar and Ocean Research, Goa, India
[3] Korea Institute of Geosciences & Mineral Resources, Dawjeon, Republic of Korea

The West Antarctic Ice Sheet (WAIS) contains about 10% of Antarctica's total ice volume and currently experiences a dramatic loss of ice mass, contributing between 0.4 and 0.7 mm yr^{-1} to global sea level rise (Shepherd et al., 2018). A region particularly vulnerable to ice loss is the Amundsen Sea. Thwaites Glacier and Pine Island Glacier, both draining into to Amundsen Sea Embayment (ASE), have experienced massive ice sheet thinning due to a strengthened upwelling of relatively warm Circumpolar Deep Water (CDW) onto the continental shelf (Hillenbrand et al., 2017). As a result of ice sheet thinning and ice stream flow acceleration, it is estimated that Pine Island Glacier alone will contribute about 3.5-10 mm to eustatic sea-level rise over the next two decades (Favier et al., 2014). A full collapse of the WAIS, which based on model projections may already be under way, will lead to a sea level rise by 3.3 to 4.3 m but with large uncertainties regarding the timing and velocity of the collapse (Joughin et al., 2014). At present, the ice sheet history of the WAIS and environmental controls affecting ice sheet dynamics (e.g. climate warming and CDW variability) are only little constrained, in particular during geological times with climatic conditions analogous to those expected for the near and distant future. Proxy records may aid in this respect and help to foster our understanding on ice sheet behavior as a function of variable climate states. In turn, this will contribute to ground-truth and improve models to predict the future stability of the WAIS.

IODP Expedition 379: "Amundsen Sea West Antarctic Ice Sheet History" aimed to (1) study the glacial history of the WAIS and (2) determine the response of the WAIS to atmospheric and ocean warming (Gohl et al., 2019). During the expedition two deep-sea sites (U1532 and U1533) were successfully drilled on the continental rise of the Amundsen Sea. Deep-sea sediments recovered from both sites consist mainly of alternating successions of two lithofacies types. First, greenish-colored claystone with signs of bioturbation, a higher content of biosiliceous material and the frequent occurrence of ice-rafted debris (IRD). This lithofacies type is interpreted to be deposited during generally warmer periods. The second lithofacies type, which is thought to reflect colder periods, is composed of gray-beige to brownish sediments that are microfossil-lean, lack of bioturbation and generally contain only little IRD. Together these two lithofacies types may tie to interglacial and glacial periods (Gohl et al., 2019). The sediment sequences recovered during IODP Expedition 379 represent unique archives of West Antarctica's climate and paleoceanographic history and thus will enable studying the cyclicity of ice sheet advance and retreat of the WAIS as well as deep-water circulation, water mass changes and associated biotic responses over the past ~7 million years.

Preliminary geochemical and lipid biomarker analyses of the deep-sea sediments deposited at Sites U1532 and U1533 provide evidence for an only low organic matter content that averages ~0.5 wt%. Despite the overall organic-lean character, sediments contain a highly diverse suite of lipid biomarkers that originate from phytoplankton (including e.g. sea ice and pelagic diatoms, cyanobacteria, dinoflagellates), heterotrophic bacteria and archaea as well as plants likely growing in the coastal hinterland of the ASE. The distribution of intact polar lipids (IPLs) in subsurface sediments of Site U1532 to a depth >700 mbsf suggests the presence of a complex deep biosphere in a yet little studied ecosystem. The investigation of biomarker distributions and abundances in combination with stable isotopes in sediments of both sites will provide information on the paleoceanography, ice sheet history and paleoproductivity of the Amundsen Sea.

References
Favier, L., Durand, G., Cornford, S.L., Gudmundsson, G.H., Gagliardini, O., et al., 2014. Retreat of Pine Island Glacier controlled by marine ice-sheet instability. Nature Climate Change 4, 117-121.
Gohl, K., Wellner, J., Klaus, A., and the Expedition 379 Scientists, 2019. IODP Expedition 379 Preliminary Report: Amundsen Sea West Antarctic Ice Sheet History. International Ocean Discovery Program.
Hillenbrand, C.D., Smith, J.A., Hodell, D.A., Greaves, M., Poole, et al., 2017. West Antarctic Ice Sheet retreat driven by Holocene warm water incursions. Nature 547, 43-48.
Joughin, I., Smith, B.E., Medley, B., 2014. Marine ice sheet collapse potentially under way for the thwaites glacier basin, West Antarctica. Science 344, 735-738.
Shepherd, A., Ivins, E., Rignot, E., Smith, B., Van Den Broeke, M., Velicogna, I., et al., 2018. Mass balance of the Antarctic Ice Sheet from 1992 to 2017. Nature 558, 219-222.

IODP

Magmatic volatiles and ore metals released from intraoceanic arc magmas: Constraints from high pressure experiments and melt inclusions for Brothers volcano, Kermadec arc

P. Beckmann[1], F. Holtz[1], C. Zhang[2]

[1] Leibniz University Hannover, Institute for Mineralogy, Callinstr. 3, Hannover, Germany
[2] Northwest University, Department of Geology, 229 North Taibai Road, 710069, Xi'an, China

The active Brothers volcano of the Kermadec arc is an ideal location to study the magmatic-hydrothermal processes that control the transfer of volatiles and metal elements from Earth's interior to the surface at an intraoceanic subduction zone. Brothers volcano is characterized by relatively evolved compositions (dacitic bulk rocks, dacitic to rhyolitic melts), high melt chlorine contents but probably low melt water contents. Based on previous analyses of whole rock and matrix glasses and melt inclusions entrapped in plagioclase- and clinopyroxene-phenocrysts, a large compositional variety of melts is observed, and this heterogeneity may be due to the interplay of various parameters controlling the differentiation trends (volatile concentrations, f_{O2}, pressure, temperature, contribution of different source rocks). In the frame of the IODP Expedition 376 drillholes with ~351 m depth at five drilling sites were cored, and ~222 m cores were recovered. Three drilling sites (Sites U1527, U1529 and U1531), which are adressed exclusively in this project, consist of fresh volcanic dacitic, unconsolidated pyroclastic materials made of plagioclase-pyroxene-phyric lavas, consolidated lapilli-tuff and/or lapillistone composed of dacite clasts and fine-grained tuffaceous matrix that have been hydrothermally altered. The fresh lavas and volcanoclastics drilled during the expedition provide invaluable materials for unraveling the compositional diversity of eruptions at different time. The nature of magmatic source and the composition of primitive magmas are still controversial. In order to clarify this issue, a large or complete dataset of compositions of bulk volcanic rocks, minerals and melt inclusions for various eruptive stages is crucial for exploring the most "primitive" magmas, as well as the temporal and spacial relations between "primitive" and evolved magmas. In this study, complementary analytical and experimental work will be conducted to understand the origin of the compositional diversity of melt compositions (e.g., role of volatiles in particular Cl/H_2O ratio, crystal fractionation), to determine magma storage conditions (e.g. f_{O2}, pressure, temperature), and to understand the effect of volatiles (e.g. fluid immiscibility) and f_{O2} on the distribution and mobility of metals at magmatic- and hydrothermal stages.

The project started on January 2020 and the planned work packages and preliminary results are presented below:

- Petrography and major- and trace element analysis on glasses in matrix and melt inclusions as well as their host-minerals to acquire a thorough dataset from the three key locations by microscopy, SEM and EPMA. As part of the preliminary work, the Cl and F concentrations have been measured for both apatite phenocrysts in the assemblage of glomerocrysts (i.e. surrounded by matrix) and apatites existing as inclusion in plagioclase and pyroxene (Fig. 1).
- Rehomogenization experiments consisting of prepared mixtures of separated (melt inclusion hosting) Plag-/Cpx-crystals, powder of bulk rocks and differently added volatile proportions in AuPd capsules will be performed with high temperature and pressure in an internally heated pressure vessel (IHPV) in Hannover, Germany.
- Analysis of H_2O and CO_2 concentrations in representative bubble-free- and experimentally rehomogenized melt inclusions with FTIR (Hannover, Germany) and SIMS (Nancy, France).
- Trace element analysis, particularly of ore forming metals (e.g., Cu, Zn, W, Au), in homogeneous melt inclusions (untreated and rehomogenized), as well as in representative hosting minerals by LA-ICPMS.
- Crystallization experiments in Cl-rich dacitic systems: A dry starting glass representing the most mafic bulk rock composition observed so far from Brothers volcano will be synthesized, in order to prepare crystallization experiments, constisting of glass powder with added HCl solutions AgCl salt

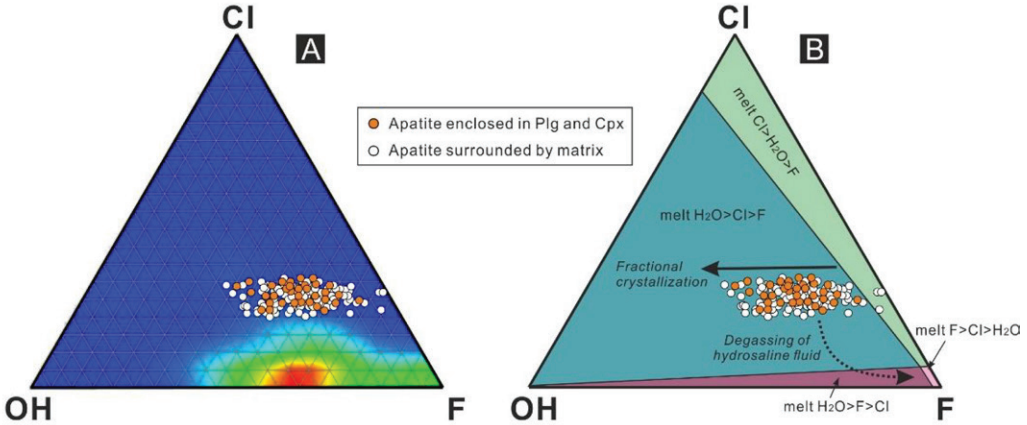


Fig. 1: Composition of apatites in volcanoclastics from Site U1529 (data of preliminary work): (A) Colored contours show maximum concentrations for volcanic-plutonic systems worldwide (red field; Wester and Piccoli, 2015). (B) relative abundance of H2O, F and Cl in melts coexisting with apatites for rhyolitic system (McCubbin et al., 2013). The trends of fractional crystallization and degassing of hydrosaline fluid are after McCubbin et al. (2016).

and $Ag_2C_2O_4$ with different proportions filled in capsules, which will be performed in the IHPV with defined fO2. The experimental products will be investigated with SEM, EPMA and FTIR.

IODP

The Bengal Fan as a quantitate recorder of Himalayan ero-sional fluxes – results from IODP cores-seismic integration

F. Bergmann[1], T. Schwenk[1], V. Spiess[1], V. Galy[2], S. J. Feakins[3], C. France-Lanord[4]

[1] Faculty of Geosciences, University of Bremen, Bremen, Germany
[2] WHOI-MCG, Woods Hole, MA, United States
[3] University of Southern California, Department of Earth Sciences, Los Angeles, CA, United States
[4] CRPG-CNRS-Univ. Lorraine, Centre de Recherches Pétrographiques et Géochimiques, Vandoeuvre les Nancy, France

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, amongst others, single grain thermochronology and quartz in situ cosmogenic analyses conducted at the French partner institutes (CRPG, IsTerre).

As a first step, a 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.

As a next step we transferred the seismic/chrono-stratigraphy to an extended network of seismic profiles, crossing the Bengal Fan at 11°N and 14°N, where IODP Exp 353 Site U1444 is located. 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. This allows for a more spatial investigation of sediment deposition and its potential link to changes in continental erosion. 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 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 Himalayan erosion rates (e.g. thermochronology, geochemistry).

References

Bergmann, F., Schwenk, T., Spiess, V.,& France-Lanord, C. (2020). Middle to Late Pleistocene Architecture and Stratigraphy of the lower Bengal Fan—Integrating multichannel seismic data and IODP Expedition 354 results. Geochemistry, Geophysics, Geosystems, 21, e2019GC008702. https://doi.org/10.1029/2019GC008702

Boos, W. R., & Kuang, Z. (2010). Dominant control of the South Asian monsoon by orographic insulation versus plateau heating. Nature, 463(7278), 218-222. doi: http://www.nature.com/nature/journal/v463/n7278/suppinfo/nature08707_S1.html

Molnar, P., Boos, W. R., & Battisti, D. S. (2010). Orographic controls on climate and paleoclimate of Asia: thermal and mechanical roles for the Tibetan Plateau. Annual Review of Earth and Planetary Sciences, 38(1), 77. doi: https://doi.org/10.1146/annurev-earth-040809-152456

IODP

The Neogene Indian Ocean Record of Asian monsoon Driven Ocean Currents and Winds from the Maldives (IODP Exp. 359)

C. Betzler[1], S. Lindhorst[1], T. Lüdmann[1], G. Eberli[2], D.Kroon[3]

[1] Universität Hamburg
[2] Miami University
[3] Edinburgh University

The Maldives archipelago acts for over 25 myrs as a giant natural sediment trap in the eastern Arabian Sea. Drifts and periplatform deposits bear the record of environmental changes such as sea-level fluctuations but also of monsoon-driven changes of the surface and intermediate water mass current regime, and of wind-driven dust influx. Carbonate drifts in the Inner Sea indicate the establishment of a strong wind-driven current regime in the Maldives at 12.9 – 13 Ma. Ten unconformities, dissecting the Miocene to Recent drift sequences, attest to changes in current strength or direction. A major shift in the drift packages is dated at 3.8 Ma that coincides with the end of stepwise platform drowning and a reduction of the OMZ in the Inner Sea.

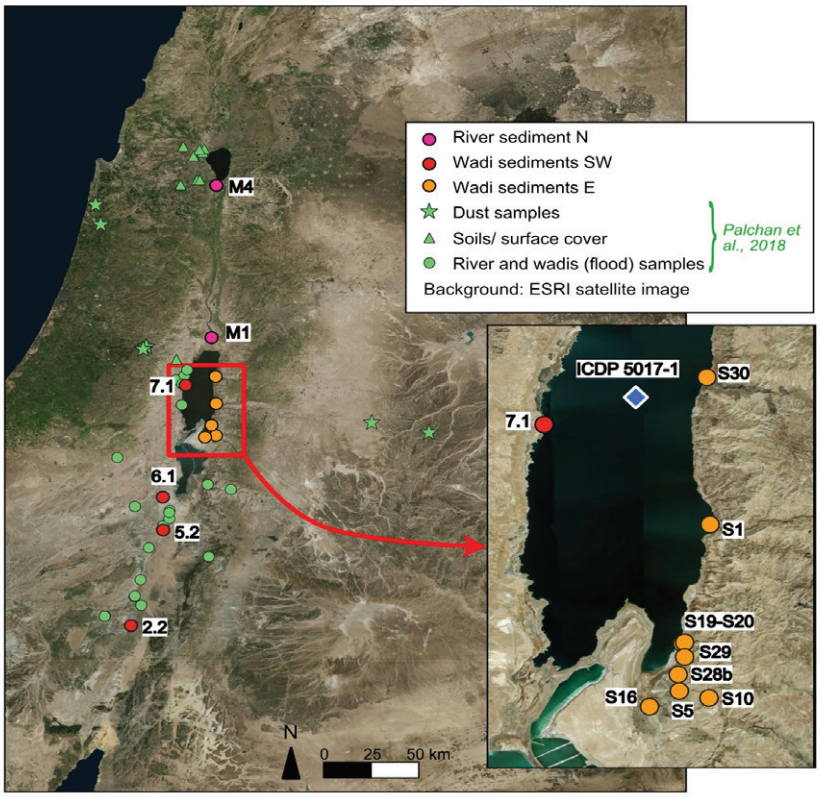
The lithogenic fraction of the Maldives carbonate drifts provides a unique record of atmospheric dust transport during the past 4 myrs as grain size provides proxies for dust flux as well as wind transport capacity. Entrainment and long-range transport of dust in the medium to coarse silt size range is linked to the strength of the Arabian Shamal winds and the occurrence of convective storms which prolong dust transport. Dust flux and the size of dust particles increased between 4.0 and 3.3 Ma, corresponding to the closure of the Indonesian seaway and the intensification of the South Asian Monsoon. Between 1.6 Ma and the Recent, dust flux again increased and shows higher variability, especially during the last 500 kyr. Transport capacity increased between 1.2 and 0.5 Ma but slightly decreased since then. Dust transport varies on orbital timescales, with eccentricity control being the most prominent (400 kyr throughout the record, 100 kyr between 2.0 and 1.3 Ma, and since 1.0 Ma). Higher frequency cycles (obliquity and precession) are most pronounced in wind transport capacity.

ICDP

New insights on sediment provenance in the Dead Sea since the last glacial maximum using grain-size distribution

C. L. Blanchet[1], H. Jurikova[1], J. Fusco[1], R. Tjallingii[1], M. Schwab[1], C. Andermann[2], A. Brauer[1]

[1] Helmholtz Centre Potsdam GFZ, Section Climate Dynamics and Landscape Evolution, Telegrafenberg, 14473 Potsdam, Germany
[2] Helmholtz Centre Potsdam GFZ, Section Geomorphology, Telegrafenberg, 14473 Potsdam, Germany



Sedimentary records from the Dead Sea constitute unique paleoclimatic archives that enable investigating the response of environments to climatic changes. Large lake-level fluctuations (>100 m) occurred during the past glacial-interglacial cycles due to reorganizations of the hydroclimatic regime and drastically modified the morphology of the drainage area. We aim here to reconstruct past sedimentary dynamics at times of varying lake level to gain insights into paleoclimate and landscape evolution.

For this study, we have compared present-day surface sediments (fluvial and soil sediments) retrieved on both the eastern Jordanian and western shores of the present Dead Sea with downcore sediment archives including the ICDP Dead Sea Deep Drilling Program Site 5017-1. Streams originating from various parts of the watershed can be distinguished by their grain-size distribution, with northern and south-western streams having generally finer grain-size modes when compared with streams from the eastern side. We find that all modes identified in the fluvial sediments were present in the ICDP downcore samples from the last deglaciation, when lake levels were up to 250m higher than today. This suggests that the whole watershed contributed to the sediment input at that time. In contrast, Holocene sediments from the deep core and shore deposits are enriched in fluvial particles showing similar grain-size modes as the northern and south-western streams. This suggests that these regions were prime sediment sources during lower lake-level stands. An additional mode, tentatively related to aeolian particles, was also identified in the Holocene samples, pointing to the remobilization of deposited dust in the watershed or to a more arid regional climate.

Our results provide a first synoptic view on sedimentary dynamics in the Dead Sea watershed and help to relate sediment provenance to the drainage morphology and paleo-hydrological regimes. They constitute a solid basis for further assessment of sedimentary provenance using geochemical indicators.

IODP

Deep water production and export in the North Atlantic since MIS3: implications from Nd isotopes

P. Blaser[1], F. Pöppelmeier[1,2], M. Frank[3], M. Gutjahr[3], J. Lippold[1]

[1] Institute of Earth Sciences, Heidelberg University, Heidelberg, Germany
[2] Climate and Environmental Physics, Physics Institute, University of Bern, Bern, Switzerland
[3] GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany

Deep water formation in the North Atlantic represents an integral link between the atmosphere, cryosphere, and the deep ocean: For example, the heat loss of warm surface waters supplies moisture to a region that experienced the buildup of huge ice sheets during the Last Glacial and the subsequent sinking ventilates the deep ocean and sequesters greenhouse gases from the atmosphere. While many studies have improved our insight into these processes during glacials, a comprehensive view including the significance of deep water export from the Nordic Seas is still missing. Furthermore, recent observations suggested the export of a previously unknown bottom water mass from the Subpolar North Atlantic.

In this study we investigate the distribution of different water masses in the subpolar North Atlantic with the help of authigenic Nd isotopes. This application benefits from the large heterogeneity in the isotopic compositions of regional source rocks, although the dissolution of the same inside sediments can also complicate interpretations of individual records. We thus compare several Nd isotope records from the subpolar North Atlantic and Nordic Seas in order to estimate the prevalence of Nordic Seas deep water masses during the last 30 ka. These observations suggest that Nordic Seas deep water overflowing the Greenland-Scotland Ridge reached the deep subpolar North Atlantic during MIS2. Furthermore, the spatial distribution implies that overflow across Denmark Strait into the Irminger Basin was more pronounced than overflow into the Iceland Basin further south. The hydrographic configuration during the Last Glacial Maximum appears thus more complex and more similar to today than previously thought. Comparison of these Nd isotope data with benthic stable carbon isotope reconstructions suggests at least some non-conservative control over the latter.

IODP

Miocene radiogenic isotope record of Indian monsoon induced erosion and its link to global climate and tectonics (IODP Site U1443)

L. Bretschneider[1], E. C. Hathorne[1], M. Frank[1], C. Bolton[2], E. Gray[2], J. Lübbers[3], K. G. D. Kochhann[3,4], A. Holbourn[3], W. Kuhnt[3], N. Andersen[5]

[1] GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany
[2] Centre Européen de Recherche et d'Enseignement des Géosciences de l'Environnement, France
[3] Institute of Geosciences, Christian-Albrechts-University Kiel, Germany
[4] Technological Institute of Micropaleontology, UNISINOS University, São Leopoldo, Brazil
[5] Leibniz Laboratory for Radiometric Dating and Stable Isotope Research, Christian-Albrechts-University Kiel, Germany

IODP Site U1443 covers a complete sequence of Oligocene to recent hemi-pelagic/pelagic sediments in the southern Bay of Bengal on the crest of the Ninetyeast Ridge. We produced orbital resolution geochemical records from this unique sedimentary archive across key climatic intervals of the Miocene (23-5.6 Ma) to better understand the impact of tectonics, global climate and regional monsoon strength on weathering and erosion regimes of the watersheds feeding into the Bay of Bengal. Our new records of radiogenic Sr, Nd, and Pb isotope compositions of clays transported to the central Bay of Bengal suggest that the mixture of contributions from different erosional sources has overall remained remarkably constant during the Miocene despite major tectonic reorganisations in the Himalayas. However, high resolution data from five of the intervals show marked fluctuations of all three isotope systems on orbital timescales. The variability of the fluctuations was much higher during the peak warmth interval from 15.8 to 15.3 Ma and across the major Miocene global cooling step from 14 to 13.5 Ma than during the younger intervals thereafter. This change is attributed to the major reorganisation of the thrusting and the slowdown of exhumation in the Himalayas at that time, which likely led to a major restriction of the supply of High Himalayan erosion products. The transient excursions of the radiogenic isotope signals on orbital time scales reflect changes in the balance of contributions from the High Himalayan Crystalline, the Tethyan Sedimentary Series and the Indo-Burman Ranges, which were climatically driven given that the rapidity and transient nature of these changes cannot have resulted from tectonic events. Increased monsoon precipitation in the Himalayas as well as strengthened surface currents from the SW during the warmer climate intervals were likely responsible for increased Himalayan contributions and vice versa. These findings are compared to late Miocene sections covering the period from 9 to 5 Ma, which formed an important part of the long-term Cenozoic cooling trend into ice-house conditions. Atmospheric CO_2 levels declined accompanied by the expansion of C4 plants, increasing aridity on land and enhanced seasonality (Herbert et al., 2016). The new clay fraction radiogenic isotope data show a pronounced increase of $^{87}Sr/^{86}Sr$ signatures from 6 to 5 Ma, while constant Nd and Pb isotopic compositions indicate stable sediment sources. The Sr isotope shift is consequently interpreted as a result of the preferential release of radiogenic Sr caused by weathering of labile minerals such as micas. Since low resolution clay mineral composition records from the same Site (ODP Site 758) show an increase in the abundance of secondary clay minerals at about the same time as the $^{87}Sr/^{86}Sr$ increase (Ali et al., 2020), we infer a switch to an enhanced chemical weathering regime in the source areas of the lithogenic material feeding into the Bay of Bengal starting at about 6 Ma.

References

Ali, S., Hathorne, E.C., Frank, M., 2020, Persistent South Asian Monsoon induced silicate weathering over the past 27 million years, submitted to PNAS.
Herbert, T.D., Lawrence, K.T., Tzanova, A., Peterson, L.C., Caballero-Gill, R., Kelly, C.S., 2016. Late Miocene global cooling and the rise of modern ecosystems. Nature Geoscience 9, 843-847.

IODP

Multi-isotopes evidencing microbial activity, mineral authigenesis and fluid mixing in interstitial fluids off South-Western Australia (IODP Leg 369)

M. E. Boettcher[1], H.-J. Brumsack[2], I. Schmiedinger[1], T. M. Quan[3], IODP Exp 369 Scientific Party

[1] Leibniz Institute for Baltic Sea Research (IOW), FRG
[2] ICBM, University of Oldenburg, FRG
[3] Boone Pickens School of Geology, Oklahoma State University, USA

Interstitial waters extracted from long sediment cores retrieved during expedition 369 (Sites U1512-U1516) of the International Ocean Drilling Program (IODP) were analysed for the stable water isotopic (O and H isotopes) composition to constrain hydrographic changes in this region prior to modern time and possible changes due to water-rock interaction and fluid mixing. Dissolved sulfate (S and O isotopes), sulfide (S isotopes), and inorganic carbon (C) were analyzed to characterize, in concert with concentration measurements, the impact of diagenetic microbial, water-rock interaction and fluid mixing processes including water, carbon and sulfur.

The measurements demonstrate substantial downcore variations in the water oxygen isotope composition. Net microbial sulfate reduction with depth was observed at all sites, but sulfate was only found to be consumed completely, within the investigated core lengths at Site U1512, that is located off southern Australia. Whereas associated sulfur isotope fractionation is characteristic for medium range fractionation factors, the oxygen isotope composition provides evidence for a much more complex story of sulfur diagenesis at the investigated sites: At Site U1516, for instance, the oxygen isotope composition of dissolved sulfate is equilibrated with pore water, although sulfate concentrations remain above 20 mM. This indicates an intense re-oxidative sulfur cycle. At Site U1513, on the other hand, the

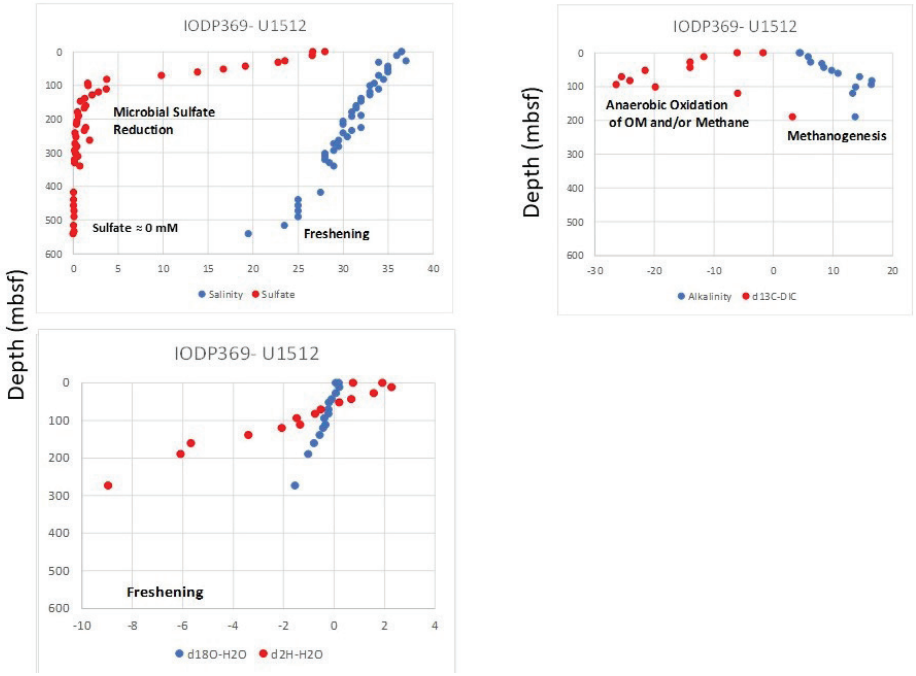


Fig. 1: Vertical profiles of selected pore water characteristics from Site U1512. Salinity, sulfate and TA concentrations are from IODP Leg 369 initial volume, Sulfate and TA in (mM), all isotope data in (‰)

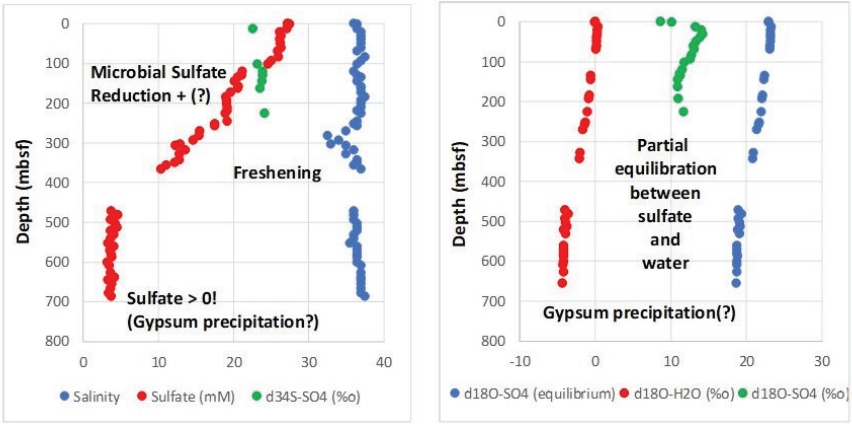


Fig. 2: Vertical profiles of selected pore water characteristics from Site U1513. Salinity and sulfate concentrations are from IODP Leg 369 initial volume.

oxygen isotope composition remains out of isotope exchange equilibrium although sulfate concentrations fall below 20 mM, indicating that the net decrease in dissolved sulfate is dominantly caused by authigenic gypsum precipitation at depth, which is further confirmed by the dissolved Ca concentration.

IODP

Porosity variation in shocked target rock of the Chicxulub impact structure inferred from high-resolution X-ray micro-CT imaging of Expedition 364 drill core

L. A. Buiven, F. M. Schulte, U. Riller

Institut für Geologie, Universität Hamburg, Bundesstrasse 55, 20146 Hamburg, Germany

Bouguer gravity of the Chicxulub impact structure, Mexico, shows that rocks underlying its peak ring and much of the adjacent crater floor are characterized by low density. P-wave velocity models inferred from reflection seismic profiles of the impact structure revealed substantially decreased velocities, and hence rock with low density, several hundred meters above, and up to 200 m below, the crater floor. IODP/ICDP Expedition 364 drilled into the peak-ring of the Chicxulub impact structure and identified these rocks respectively as suevite and uplifted, shocked granitoid target rocks. Petrophysical analysis of the drill core showed that granitoid target rocks have strongly reduced P-wave velocities of 4000–4200 m/s and densities of 2.39–2.44 g/cm^3, but rather large porosities of 8–13%, compared to equivalent rock types outside the impact structure. These physical properties are mostly attributed to volume increase of target rocks caused by intense brittle deformation during cratering. In order to identify the brittle deformation mechanism(s) causing such anomalously high porosities, pore space of thirteen drill core samples of granitoid target rock was investigated, for the first time, with high-resolution X-ray micro-computer tomography (CT). Micro-CT imaging is based on assigning specific grey values to specific densities of a material through X-ray tomography. Typically, dark grey shades indicate low-density materials,

whereas light grey shades portray dense materials. Hence, dark voxels arise from voids, i.e. pore space, in a given solid. We used the software *PerGeos* to stack micro-CT image surface scans to form high-resolution 3-D volumetric images. Moreover, the software was used to differentiate and segment individual grey values, which allowed us to identify the shapes and orientations of individual mineral phases and pores

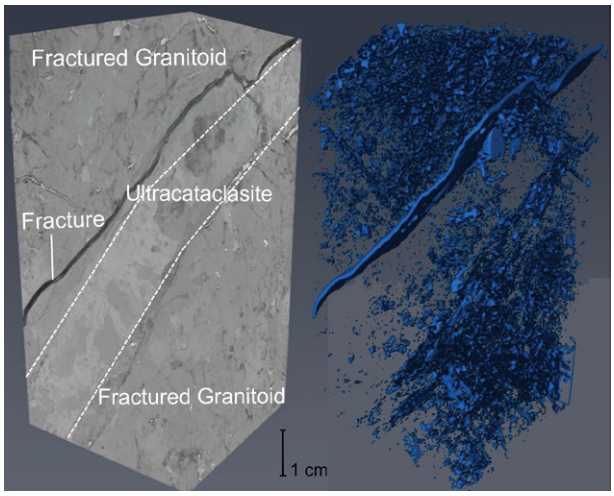


Fig.1: 3-D image of a sample showing an ultracataclasite zone and an open fracture within fractured granitoid target rock. Left: Sample showing density variations. Right: Sample displaying pore space

Overall, our target rock samples have porosities of up to 11 % as opposed to 1% in equivalent target rock outside the impact structure. The samples display several centimeters wide, laminated ultracataclasite and melt rock zones within fractured metagranitoid (Fig. 1). Samples consisting of melt rock only have a porosity of about 2 %, whereas samples with ultracataclasite and fractured granitoid target rock have porosities between 3 % and 5 % with pores only showing up in fractured target rock (Fig. 1). This observation is rather unexpected, and we interpret the apparent lack of pore space in ultracataclasite by tight packing of very small ultracataclasite fragments. Obviously, the bulk of the observed porosity occurs in pervasively fractured target rock and thus in rock that accumulated rather low (shear) strains during cratering.

IODP

A subsurface ocean heat channel that fuelled ice-sheet growth during the Mid-Pleistocene Transition

M. C. A. Catunda[1], A. Bahr[1], S. Kaboth-Bahr[1,2], X. Zhang[3,4], N. Foukal[5], O. Friedrich[1]

[1] Institute of Earth Sciences, Heidelberg University, Im Neuenheimer Feld 234–236, 69120 Heidelberg, Germany
[2] Institute of Geosciences, University of Potsdam, Karl-Liebknecht-Straße 24–26, 14476 Potsdam-Golm, Germany
[3] Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Bussestr. 24, Bremerhaven, D-27570, Germany
[4] College of Earth and Environmental Science, Lanzhou University, Tianshui S. Road 222, Lanzhou, 730000, China
[5] Department of Physical Oceanography, Woods Hole Oceanographic Institution, Woods Hole, MA, USA.

Between 1.2 and 0.6 Ma the character of the glacial/interglacial cyclicity shifted from a 40-kyr period to the characteristic ~100-kyr long, saw-toothed cycles of the Late Pleistocene (Ruddiman et al., 1989; Imbrie et al., 1993). Although there have been numerous studies on the Mid-Pleistocene Transition (MPT) (Ruddiman et al., 1989; Clark et al., 2006; McClymont et al., 2013; Chalk et al., 2017; Hasenfratz et al., 2019), the exact mechanism(s) explaining this shift in the absence of any significant change in the orbital configuration (Imbrie et al., 1993; Lisiecki, 2010) remains elusive. Rapid expansion of high-latitude ice sheets is usually thought to be instrumental in the establishment of this Late Pleistocene glacial/interglacial cyclicity (Imbrie et al., 1993; Clark et al., 2006). The most broadly accepted explanation for such ice-sheet extension during the MPT is the "regolith hypothesis" (Clark and Pollard, 1998). It states that the exposure of bedrock following repetitive erosion of substrate below the ice sheets increased the friction between ice and bedrock allowing for thicker ice sheets to grow in the Northern Hemisphere. This was aided by a global cooling trend, caused by a decrease of atmospheric pCO_2 (Hönisch et al., 2009; Chalk et al., 2017; Hasenfratz et al., 2019), and a potential slowdown of the Atlantic Meridional Overturning Circulation during the so-called "900 ka event" (Pena and Goldstein, 2014) which diminished the northward heat transport at the emergence of the MPT. All of these processes supported conditions ideally suited to sustain large continental ice sheets. However, the reduction of global temperatures and reduced surface-heat transport in the North Atlantic would have decreased the moisture capacity of the ocean's overlaying air masses. Thus, the source of moisture that fueled the intensification of Northern Hemisphere ice-sheet growth across the MPT remains unknown. Here, we apply recent results from physical oceanography that redefines our view on how the North Atlantic meridional heat transport is accomplished to unravel the origin of this moisture source. We present numerical model results and Mg/Ca-derived deep-thermocline temperatures that show a pronounced heat accumulation at subsurface levels within the mid-latitude North Atlantic during the MPT. The observed thermocline warming opposed the simultaneous sea-surface cooling, and thus weakened the upper-ocean stratification within the mid-latitude North Atlantic. We argue that this led to the formation of a subsurface heat channel that enabled heat advection from intermediate-water depths at mid-latitudes towards the high-latitude surface ocean. This outcropping heat at high latitudes provided the moisture source for glacier growth in the Northern Hemisphere.

References

Chalk, T. B. et al. Causes of ice age intensification across the Mid-Pleistocene Transition. PNAS 114, 13114–13119 (2017).
Clark, P. U. & Pollard, D. Origin of the middle Pleistocene transition by ice sheet erosion of regolith. Paleoceanography 13, 1–9 (1998).
Clark, P. U. et al. The middle Pleistocene transition: characteristics, mechanisms, and implications for long-term changes in atmospheric pCO2. Quat. Sci. Rev. 25, 3150–3184 (2006).
Hasenfratz, A. P. et al. The residence time of Southern Ocean surface waters and the 100,000-year ice age cycle. Science 363, 1080–1084 (2019).
Hönisch, B., Hemming, N. G., Archer, D., Siddall, M. & McManus, J. F. Atmospheric Carbon Dioxide Concentration Across the Mid-Pleistocene Transition. Science 324, 1551–1554 (2009).
Imbrie, J. et al. On the structure and origin of major glaciation cycles 2. The 100,000-year cycle. Paleoceanography 8, 699–735 (1993).
Lisiecki, L. E. Links between eccentricity forcing and the 100,000-year glacial cycle. Nat. Geosci. 3, 349–352 (2010).
McClymont, E. L., Sosdian, S. M., Rosell-Melé, A. & Rosenthal, Y. Pleistocene sea-surface temperature evolution: Early cooling, delayed glacial intensification, and implications for the mid-Pleistocene climate transition. Earth Sci. Rev. 123, 173–193 (2013).
Pena, L. D. & Goldstein, S. L. Thermohaline circulation crisis and impacts during the mid-Pleistocene transition. Science 345, 318–322 (2014).
Ruddiman, W. F., Raymo, M. E., Martinson, D. G., Clement, B. M. & Backman, J. Pleistocene evolution: Northern Hemisphere ice sheets and North Atlantic Ocean. Paleoceanography 4, 353–412 (1989).

IODP

Similarities of the Scotia and Caribbean Plates: Implications for a common plate tectonic history?!

C. Burmeister[1], M. Meschede[1], P. Wintersteller[2]

[1] Institute for Geography and Geology, University of Greifswald
[2] University of Bremen, MARUM/Geoscience department

The active volcanic arcs of the Scotia Plate (Fig.1) and Caribbean Plate (Fig.2) are two prominent features along the otherwise passive margins of the Atlantic Ocean, where subduction processes of oceanic crust is verifiable. Both arcs have been, and continue to be, important oceanic gateways during their formation.

Trapped between the large continental plates of North- and South America, as well as Antarctica, both significantly smaller oceanic plates show obvious similarities in size, shape, plate margins and morphology, although formed at different times and locations during Earth's history.

Structural analyses of the seafloor are based on bathymetric datasets by multibeam-echosounders (MBES), including data of the Global Multi Resolution Topography (GMRT), Alfred Wegener Institute (AWI), MARUM/Uni-Bremen, Geomar/Uni-Kiel, Uni-Hamburg and the British Antarctic Survey (BAS). Bathymetric data were processed to create maps of ocean floor morphology with resolution of 150-250 meters in accuracy. The Benthic Terrain Modeler 3.0 (BTM), amongst other GIS based tools, was utilized to analyse the geomorphometry of both plates. Furthermore, we used the bathymetric datasets for three-dimensional modelling of the seafloor to examine large-scale-structures in more detail.

The modelling of ship-based bathymetric datasets , in combination with the GEBCO 2014 global 30 arc-second interval grid, included in the GMRT bathymetric database, delivered detailed bathymetric maps of the study area. With the help of the fine- and broad-scale bathymetric position index (BPI), comparable to the topographic position index (Weiss, 2001), we identified typical morphological features of the abyss, due to the determination of steep and broad slopes, ridges, boulders, flat plains or flat ridge tops and depressions in various scales. Additional data analyses of gravimetric and magnetic properties of the crust should help to understand the plate tectonic history of both areas in more detail.

References

Ryan, W. B. F; Carbotte, S.M.; Coplan, J.; O'Hara, S.; Melkonian, A.; Arko, R.; Weissel, R.A.; Ferrini, V.; Goodwillie, A.; Nitsche, F.; Bonczkowski, J. and Zemsky, R. (2009): Global Multi-Resolution Topography (GMRT) synthesis data set, Geochem. Geophys. Geosyst., 10, Q03014, doi:10.1029/2008GC002332.

Walbridge, S.; Slocum, N.; Pobuda, M.; Wright, D.J. (2018): Unified Geomorphological Analysis Workflows with Benthic Terrain Modeler. Geosciences 2018, 8, 94. doi: 10.3390/geosciences8030094

Weiss, A. D. (2001): Topographic Positions and Landforms Analysis (Conference Poster). Proceedings of the 21st Annual ESRI User Conference. San Diego, CA, July 9-13.

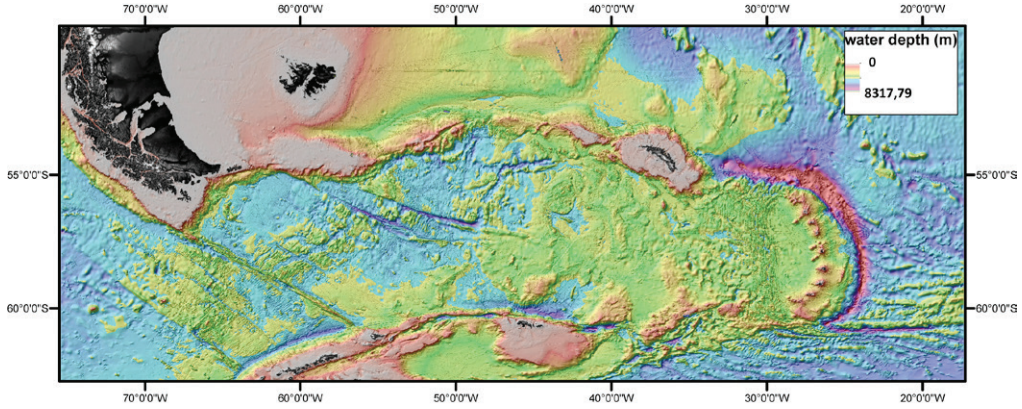


Fig. 1: High-resolution bathymetry (250m) of the Scotia Plate and adjacent regions, containing bathymetric data of GMRT, AWI and BAS.

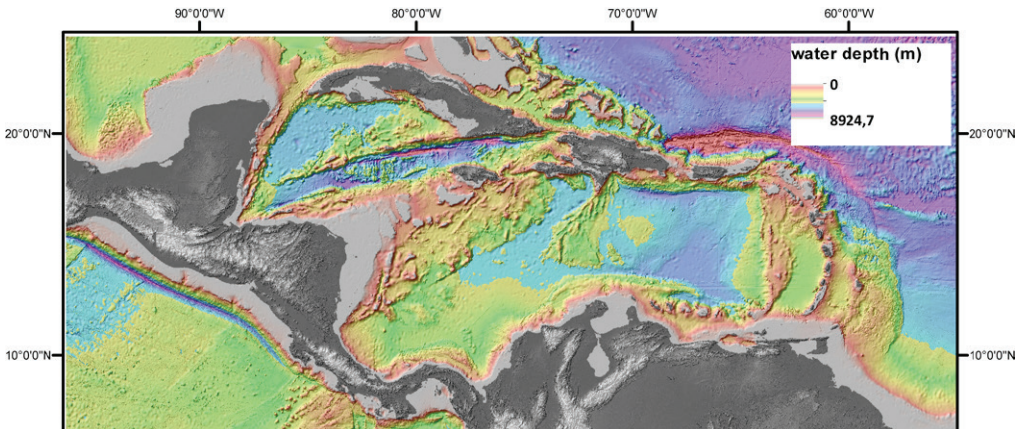


Fig. 2: High-resolution bathymetry (250m) of the Caribbean Plate area and nearby regions, containing bathymetric data of GMRT.

ICDP

Inferring Quaternary vegetation changes in Siberia using lake sedaDNA from El'gygytgyn and Bolshoe Toko

J. Courtin[1], K. Stoof-Leichsenring[1], B. Biskaborn[1], L. A. Pestryakova[2], M. Melles[3], U. Herzschuh[1,4,5]

[1] Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Polar Terrestrial Environmental Systems, Potsdam, Germany
[2] Department of Geography and Biology, University of Yakutsk, Yakutsk, Russia
[3] Institute of Geology and Mineralogy, University of Cologne, Germany
[4] Institute of Earth and Environmental Science, University of Potsdam, Potsdam-Golm, Germany
[5] Institute of Biology and Biochemistry, University of Potsdam, Potsdam-Golm, Germany

Understanding vegetation variability during glacial/interglacial transitions of the Quaternary can provide valuable insights into the future vegetation changes that are expected with the ongoing global warming. The available knowledge about the Quaternary's vegetation decreases with increasing age and even less information can be retrieve from glacial than interglacial periods. High-northern latitudes are ideally suited to detect former non-equilibrium patterns, since climate change there is particularly strong due to polar amplification.

The sediment records from Lake El'gygytgyn, Chukotka, Far East Russian Arctic, contains unique archives of terrestrial paleorecords continuously spanning the last 3.6 million years. This unique site already allowed vegetation reconstruction in Chukotka during all the Quaternary using palynological lacustrine records. The relatively new sedimentary ancient DNA (sedaDNA) metabarcoding method can be used as a complementary proxy to pollen to investigate past vegetation changes. Pollen proxy allows a regional estimation of the vegetation composition with a long-range catchment signal when sedaDNA is predominantly local in origin. This is an advantage over pollen data, because different pollination strategies influence the amount of pollen production and pollen dispersal capacities. Therefore, to avoid a record biased toward high pollen producers' taxa, sedaDNA can be investigated with the P6-loop of the chloroplast trnL (UAA) intron, a universal, plant-specific and short barcode marker. Furthermore, it allows the detection of a higher number of plant taxa at higher taxonomic level and therefore the investigation of diversity changes as well as composition changes. Working with sedaDNA can be challenging as DNA degrades through time and sedaDNA records as sensitive to modern DNA contamination and extracting DNA from lake sediments as old as El'gygytgyn ones can be challenging. Samples from PG1351 cores have been selected for sedaDNA investigation. Unfortunately, the preliminary results of the vegetation reconstruction of the past ~250kyrs inferred from El'gygytgyn lake sediments cores are typical to samples with bad DNA conservation or low DNA content.

Bolshoe Toko is the deepest lake of Yakutia, located in southeastern Siberia. PG2133 a 375cm core spanning the last ~40kyrs was recovered from the lake sediments. The same methodology was applied and vegetation changes were investigated during the last glacial/interglacial transition between the late Pleistocene and the Holocene. The quality of the DNA recovered from those samples was good enough to allow biological and ecological conclusion on the past vegetation changes in southeast Siberia during that time.

We will present results from both site to illustrate the difference between low DNA content samples and standard DNA content and how this is a limit in sedaDNA analysis make biological or ecological conclusions.

ICDP

ICDP project Drilling the Eger Rift – status report

T. Dahm[1,2], T. Fischer[3,4], H. Woith[1], P. Hrubcová[4], M. Korn[5], F. Krueger[1], D. Wagner[1,2], J. Horálek[4], T. Vylita[3], and the ICDP-Eger Science Team

[1] Institute of Geosciences, University of Potsdam, Germany
[2] GFZ German Research Centre for Geosciences, Potsdam, Germany
[3] Institute of Geophysics, Czech Academy of Sciences, Prague, Czechia
[4] Charles University, Faculty of Science, Prague, Czechia
[5] Institute of Geophysics and Geology, University of Leipzig, Germany

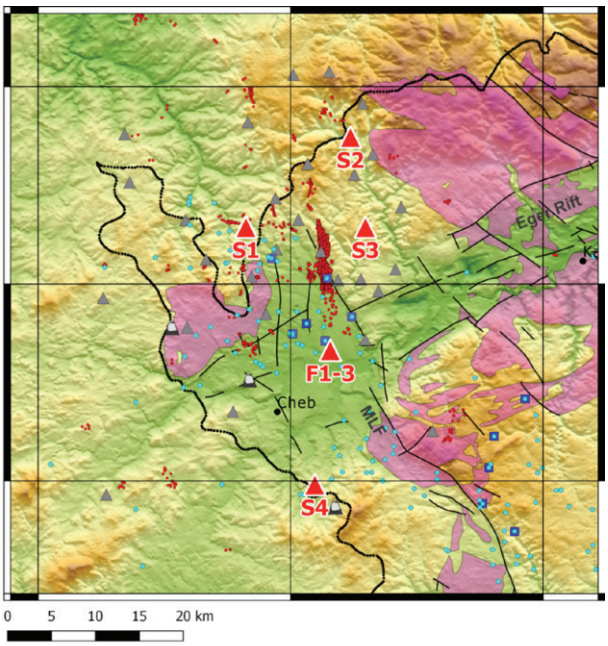


Fig. 1: Overview with seismological (S1-S4) and fluid drillings (F1-F3)

Within the ICDP-Eger drilling project we are developing one of the most modern and comprehensive laboratories at depth worldwide to study the interrelations between the flow of mantle-derived fluids through the crust and their degassing at the surface, the occurrence and characteristics of crustal earthquake swarms, and the relation to the geo-biosphere. The Cheb basin located in the western Eger Rift at the Czech-German border provides an ideal natural laboratory for such a purpose. In October 2016 the ICDP proposal was accepted for drilling four distributed, medium depth (<400 m) seismological monitoring wells S1-S4 and complementing two existing shallow wells (F1 and F2) at the CO_2 mofette at Hartoušov with a 239 m deep fluid and microbial activity monitoring well F3. The fluid monitoring drillings F1-F3 develop a new, unique concept of monitoring at different depth at one site within the active CO_2 mofette of Hartoušov for continuous recordings of fluid composition and fluid flow rate, as well as for intermittent GeoBio fluid sampling. Drillings S1-S4 are planned for seismological monitoring to reach a new level of high frequency, near source observations of earthquake swarms and fluid-induced earthquakes at depth. Instrumentation of the seismic wells S1-S3 will include 8-element geophone chains and a bottom-hole

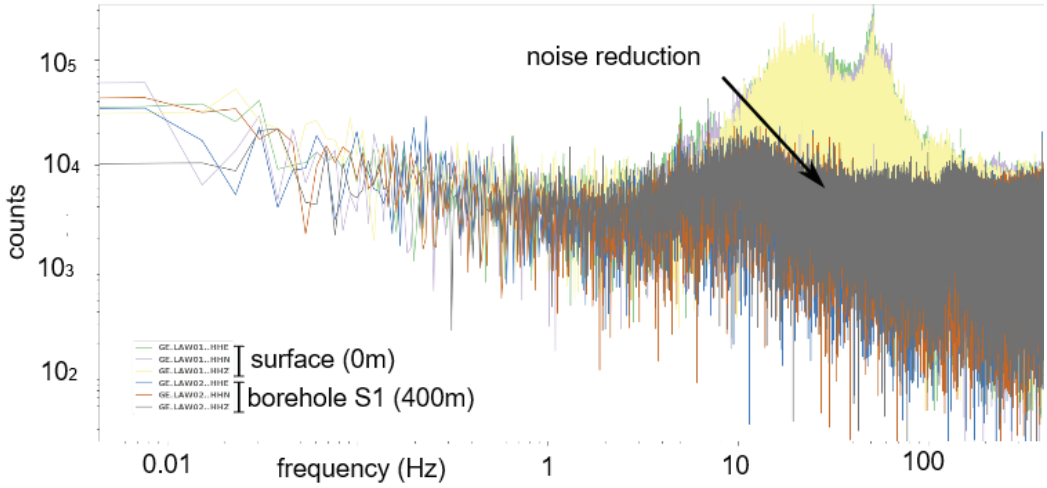


Fig. 2: Comparison of noise amplitude spectra on 3C geophone installed at surface and in 400 m depth in well S1

broadband sensor. The borehole sensors will be complemented at S1 by small-aperture surface array of approximately 400 m diameter to obtain truly 3D-array configurations. If possible, broadband surface stations and other sensors will be added to each drill location.

In August 2019 drillings at sites S1, S2 and S3 with depth of 402, 480 and 400 m, respectively, were completed. The drilling of S4 is planned in 2020 at one of the recently discovered maars at the Czech-German border region. F3 was drilled in August 2019 and completed in January 2020 by perforation operations. Drilling F3 reached several over-pressurized, CO_2 bearing layers including the crystalline bed rocks. The three boreholes F1-F3 have been connected by underground tubes system to the nearby field laboratory equipped by a mass spectrometers, an infrared isotope analyser, and radon detectors (Fig. 1) allowing for long time precise monitoring of the degassing process. The S1 borehole (Landwüst) was instrumented in January 2020 by an eight-sensor geophone vertical chain, along with the distributed acoustic sensor (DAS) fibre-optic cable installed behind casing. An active vertical seismic profiling (VSP) was realized to determine vS velocities and sensor orientations.

The presentation informs about the status of drillings, sensor installation and concepts for the integration of monitoring and data handling.

IODP

The Cenozoic Australian Red Down: persistent aeolian dust supply to the Tasman Sea during the early Eocene greenhouse world

E. Dallanave[1], T. Westerhold[2], C. Agnini[3], L. Alegret[4], L. Chang[5], T. von Dobeneck[1]

[1] Faculty of Geosciences, University of Bremen, Germany
[2] MARUM, University of Bremen, Germany
[3] Department of Geosciences, University of Padova, Italy
[4] Department of Earth Sciences, University of Zaragoza, Spain
[5] School of Earth and Space Sciences, Peking University, China

Atmospheric dust originates in arid and semi-arid regions of the planet, it is an important component of the rock cycle and eventually provides nutrients for oceanic phytoplankton. Dust transport can however take the form of dangerous dust storms. These events strike large and often densely populated area, like southeastern Australia, and have severe impact on society in terms of both economy and casualties. The last major dust storm that affected southeastern Australia occurred in September 2009. It was named the 'Red Down' and covered with a blanket of red dust the cities of Sydney and Canberra, with severe economical consequences and significant increase in hospitalization (De Deckker et al., 2014).

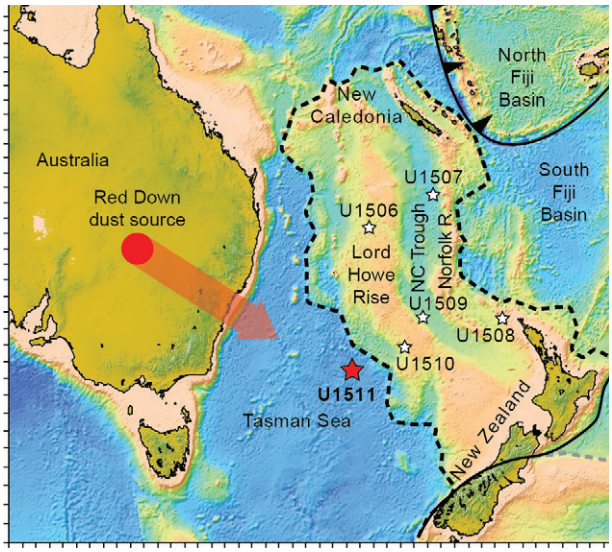


Fig. 1: Bathymetry of the Southwest Pacific-Tasman area. The white stars indicate the sites drilled during Integrated Ocean Discovery Program (IODP) Expedition 371 except for Site U1511, indicated by the red star; the black dashed line envelops the northern part of Zealandia.

Dust storms in Australia are favored by long-lasting droughts, which are in turn modulated by the El Niño-Southern Oscillation (ENSO), a coupled ocean-atmosphere phenomenon that affects global interannual climate variability. Published coupled ocean-atmosphere circulation models recreating the greenhouse condition of the Eocene (i.e., atmospheric pCO_2 >500 ppm) predict higher intensity of El Niño events, which could imply an important intensity increase of the dust storms. Considering the high present-day rate of CO_2 emission (current atmospheric pCO_2 is >400 ppm), dust storms in eastern Australia and in other area affected by similar phenomenon are likely to represent a dangerous hazard. We present preliminary rock-magnetic data from the early to middle Eocene sediments

recovered at Site U1511 of IODP Expedition 371 (Tasman Sea; Sutherland et al., 2019; Fig. 1). The sediments consist of ~260 m of abyssal clay deposited offshore the southeastern coast of Australia during the early to middle Eocene, when the Earth's climate experienced the warmest time of the Cenozoic (early Eocene climatic optimum, EECO, ~52–50 Ma) followed by a cooling eventually leading to the present-day glacial mode (Fig. 2). The age model of Site U11511 is based on robust magnetic polarity stratigraphy (Dallanave and Chang, in press). Preliminary data indicate high relative concentration of high magnetic coercivity minerals (hematite and goethite) during the EECO. These minerals are two of the main components of aeolian dust, and their relative amount seems to be significantly lower in the middle Eocene sediments. Even if more analyses are necessary to investigate the composition (i.e., origin and transport mechanism) of Site U1511 clay, our preliminary data seem to point toward higher intensity/frequency of the dust storms during the Eocene greenhouse world, a problem that in the future could affect large area of the planet and that has been so far underestimated.

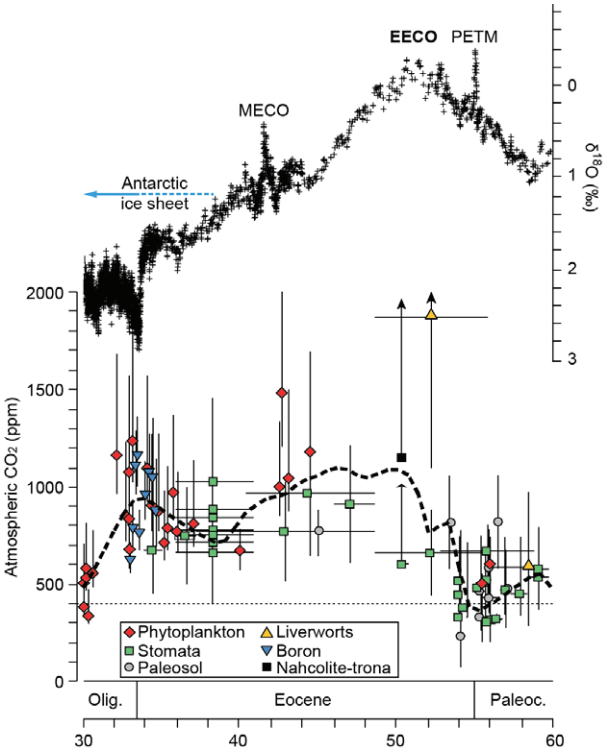


Fig. 2: Evolution of global climate and the atmospheric pCO_2 between 60 and 30 Ma. The climate curve (δ18O) is a stacked deep-sea benthic foraminiferal oxygen-isotope curve from different deep-sea records, while pCO_2 data are a compilation of marine and terrestrial proxy records.

References

Dallanave, E., Chang, L., in press. Early Eocene to early Miocene magnetostratigraphic framework for IODP Expedition 371 (Tasman Frontier Subduction Initiation and Paleogene Climate). Newsletters Stratigr. https://doi.org/10.1127/nos/2019/0556

De Deckker, P., Munday, C.I., Brocks, J., O'Loingsigh, T., Allison, G.E., Hope, J., Norman, M., Stuut, J.B.W., Tapper, N.J., van der Kaars, S., 2014. Characterisation of the major dust storm that traversed over eastern Australia in September 2009; a multidisciplinary approach. Aeolian Res. 15, 133–149. https://doi.org/10.1016/j.aeolia.2014.07.003

Sutherland, R., Dickens, G.R., Blum, P., Agnini, C., Alegret, L., Asatryan, G., Bhattacharya, J., Bordenave, A., Chang, Li., Collot, J., Cramwinckel, M.J., Dallanave, E., Drake, M.K., Etienne, S.J.G., Giorgioni, M., Gurnis, M., Harper, D.T., Huang, H.-H.M., Keller, A.L., Lam, A.R., Li, H., Matsui, H., Morgans, H.E.G., Newsam, C., Park, Y.-H., Pascher, K.M., Pekar, S.F., Penman, D.E., Saito, S., Stratford, W.R., Westerhold, T., Zhou, X., 2019. Tasman Frontier Subduction Initiation and Paleogene climate. Proc. Int. Ocean Discov. Progr. 371. https://doi.org/10.14379/iodp.proc.371.101.2019

IODP

The sedimentary record of sea-level change and near seafloor diagenesis on a subtropical carbonate ramp, SW Shelf of Australia

H. Deik[1], L. Reuning[2], B. Petrick[3], M. Courtillat[4], M.-A. Bassetti[5]

[1] Geological Institute, RWTH Aachen University, Aachen, Germany
[2] Paleontology and Historical Geology, Institute of Geosciences, Kiel, Germany
[3] School of Geography, Politics and Sociology, Newcastle University, Newcastle upon Tyne, UK
[4] Université de Perpignan Via Domitia, UMR 5110, 52 Avenue Paul Alduy, Centre de Formation et de Recherche sur les Environnements Méditerranéens, Perpignan cedex, France
[5] Géosciences Marines, IFREMER, BP 70, Plouzané, France

In the last decades our understanding of temperate carbonate systems has improved considerably, but their development over glacial-interglacial timescales and their early diagenesis is still understudied in comparison to their tropical counterparts. The Carnarvon Ramp on the SW Shelf of Australia is situated at the transition between cool and warm water environments, and its depositional history since the early Pliocene was recovered at IODP Site U1460. The origin and composition of the sediments in the upper 25 m CSF-A were investigated using scanning electron microscopy and X-ray diffraction. The aragonite content reaches up to 36 % and originates mainly from gastropods, bivalves, cheilostomes bryozoans, ascidian spicules and some azooxanthellate corals. The high-Mg calcite contributes ~ 44 % to the bulk sediments and is mainly produced by bryozoan, echinoderms, benthic foraminifers and some serpulids worms. The Middle Pleistocene to Holocene sequence at IODP Site U1460 contains a record of sea-level controlled sedimentary cycles. Carbonate sediments deposited during sea-level highstands are fine grained and dominated by low-Mg calcite. The lowstand intervals, instead are coarser-grained and relatively rich in aragonite and high-Mg calcite. The preservation of pteropod shells shows significant aragonite dissolution within the sediment below a depth of around 6 m CSF-A. The degree of dissolution generally increases with depth but seems to be higher in organic matter (alkenone) rich interglacials compared to glacials. A comparison to geochemical porewater profiles indicates that the extend of aragonite dissolution is controlled by organic matter limited sulphate reduction. Dolomite cement forms preferentially in the interglacial deposits, due to sulphate reduction related increases in alkalinity. Overall the more intense diagenetic alteration in the interglacials amplifies the primary mineralogical differences in the sedimentary cycles.

ICDP

The impact of drilling on gas composition at depth in neighboring wells of the Hartousov Mofette, Czech Republic.

K. Daskalopoulou[1], H. Woith[1], M. Zimmer[1], S. Niedermann[1], J. A.C. Barth[2], C. D. Bag[1,3], Ralf Bauz[1]

[1] German Research Centre for Geosciences-GFZ, Potsdam, Germany
[2] Department Geographie und Geowissenschaften, GeoZentrum Nordbayern, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany
[3] Department of Geological Engineering, Middle East Technical University-METU, Cankaya, Turkey

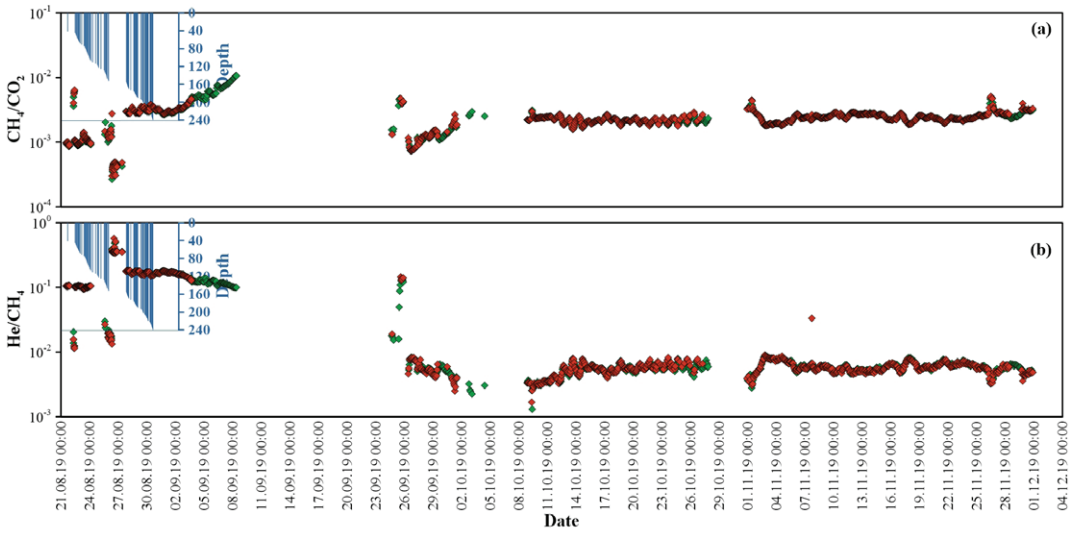


Fig. 1: Temporal variations of a) CH_4/CO_2 and b) He/CH_4 ratios for the period of August-December 2019. The bottom depth of the core is plot for August, when the drilling occurred.

The Cheb Basin (Czech Republic) is characterized by emanations of magma-derived gases and recurrence of mid-crustal earthquake swarms with small to intermediate magnitudes (M_L < 5). Intense degassing is detected at the Hartoušov Mofette (Cheb Basin), where carbon dioxide is the prevailing gas component (concentrations above 99.5%). Isotope signatures at the mofette area for both He (R/R_A ratios up to 5.86) and carbon ($\delta^{13}C_{CO2}$ around an average of -2.8 ‰ vs VPDB) suggest a mantle origin for the fluids. To investigate the relation between migration and composition fluids and the anomalous earthquake activity, an interdisciplinary well-based observatory is built up in the area for continuous monitoring at depth.

Two drillings with depths of 30 and 108 m (F1 and F2, respectively) are being monitored since August 2019 for the composition of ascending fluids. Additionally, the environmental air composition is monitored. Gas concentrations have been determined in-situ at 1-min intervals, while direct sampling campaigns took place periodically and samples were analyzed for their chemical and isotopic composition. Samples of gases emerging in the "natural" mofette were also collected. In August, a third borehole (F3) with a depth of 238 m was drilled.

Atmospheric contributions are negligible in both F1 and F2, even though during the drilling of F3 enrichments in components such as Ar and N_2 have been observed. An increase in both CH_4 and He was noticed in F2 (108 m borehole) when F3 reached 40 m depth, whilst a decrease in He in both F1 and the natural mofette was observed at a drilling depth of 193 m. Enrichments in less soluble gases (eg. He, CH_4 and N_2) at various depths accompanied by a minor CO_2 decrease were also noticed. Such variations may have been caused by the different solubilities of gases in water. Results of continuous monitoring suggest a similar behavior for both drillings. Variations up to two orders of magnitude were noticed for He, CH_4 and C_xH_y during August and September 2019. Moreover, a decrease in CO_2 followed by a subsequent enrichment of CH_4 and C_xH_y during the first days after the initial drilling and in the last phase of the F3 drilling, when the well reached a depth >200 m, supports the hypothesis of the generation of microbially derived CH_4 (Fig. 1). Diurnal variations were observed for the majority of the gas components during the last phase of the F3 drilling and continued during the months of October and November.

ICDP

Critical fluid volumes and the start of ‚self-sustaining' fracture ascent

T. Davis, E. Rivalta

German Research Centre for Geosciences-GFZ, Potsdam, Germany

In theory, pockets of fluid in brittle media can be transported large distances, provided that both the fluid volume is large enough, such that fluid pressures can fracture the rock, and that stress gradients exist causing asymmetric growth of the fracture's front. Currently, industrial injections are deemed safe based on empirical observations of volumes, rates and pressures from closed-access industrial data. Existing theoretical models are difficult to use a priori to predict the critical volume of fluid that will cause unhindered fracture ascent, as they are expressed in terms of the fracture's length, which is hard to predict a priori and difficult to measure. Here we constrain scale-independent critical volumes as a function of only rock and fluid properties by supplementing simple analytical models with numerical simulations in three dimensions. We apply our model to laboratory and natural settings, showing that the volumes we estimate match well with laboratory data and can be used as a conservative estimate in geological applications.

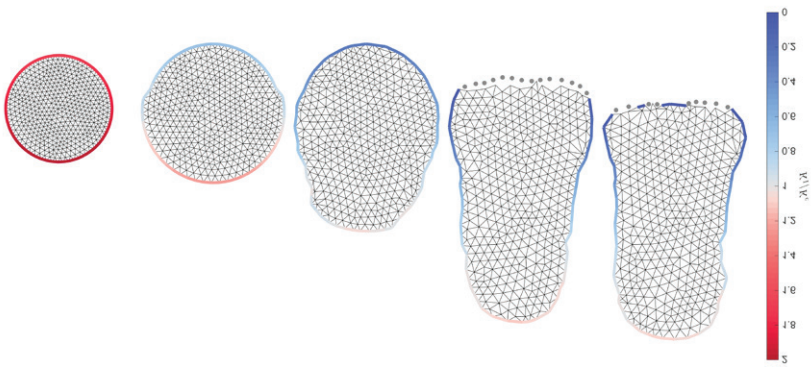


Fig. 1: Numerical simulation of crack ascent

IODP

Tracing Tasman Leakage since the middle Miocene

D. De Vleeschouwer

University of Bremen, MARUM/Center for Marine Environmental Sciences

The southern hemisphere oceans are strongly coupled. The exchange of water and heat between the South Pacific, Indian and South Atlantic oceans is fundamental to the global thermohaline circulation. However, the relevance of interocean exchange at intermediate water depths between the Pacific and Indian oceans has only recently been established for the present-day. Different contemporary oceanographic models identify significant transport from the Pacific into the Indian Ocean at ~1000 m water depth, originating in the Tasman Sea. The so-called Tasman Leakage has however never been identified in a paleoceanographic context. This proposal aims to evaluate the onset of this pathway of interocean exchange, and is designed to constrain Tasman Leakage variability in response to climatic (north-south migration of climate belts) as well as to tectonic processes (northward movement of the Australian continent). Ocean Drilling Program (ODP) Sites 752 and 754 on Broken Ridge (eastern Indian Ocean) provide well-suited sedimentary archives to address these questions: Both sites are situated within the Tasman Leakage flow path, at a present-day intermediate water depth of ~1070 m. Their late Oligocene to recent intervals consist of sub-horizontal pelagic carbonate-rich sequences that allow for the use of different isotopic and elemental proxies. When compared to a series of existing sedimentary archives in the southern Indian Ocean and southwest Pacific, the newly-generated proxy records for Site 752 and 754 will provide a unique opportunity to evaluate the role of Tasman Leakage in regulating Pacific-Indian Ocean exchange since the late Oligocene.

ICDP

What have we learned so far about low-temperature fires of northeastern Siberia from 420 kyrs old Lake El'gygytgyn sediments?

E. Dietze[1], K. Mangelsdorf[2], A. Andreev[3], U. Herzschuh[4]

[1] Alfred-Wegener-Institute Helmholtz-Centre for Polar and Marine Research, Research Unit Potsdam, Polar Terrestrial Environmental Systems Group, Telegrafenberg, 14473 Potsdam, Germany
[2] GFZ German Research Centre for Geosciences, Section Organic Geochemistry, Telegrafenberg, 14473 Potsdam, Germany
[3] Institute of Environmental Sciences and Geography, University of Potsdam, Karl-Liebknecht-Str. 24-25, 14476 Potsdam-Golm, Germany
[4] Institute of Biochemistry and Biology, University of Potsdam, Karl-Liebknecht-Str. 24-25, 14476 Potsdam-Golm, Germany

Forest fires are an important factor in the global carbon cycle and high-latitude ecosystems. East Siberian tundra, summergreen larch-dominated forests on permafrost and evergreen spruce- and pine-dominated boreal forests have characteristic fire regimes with varying fire frequencies and intensities. However, it is unknown which role fire plays in climate-vegetation-permafrost feedbacks and how high-latitude fire regimes and ecosystems will change in a warmer world – questions which are crucial considering that boreal and permafrost regions have been identified as tipping elements in the climate system (Lenton et al., 2008, PNAS).

Here, we investigate fire regime shifts during previous interglacials, i.e. marine isotope stages (MIS) 5e, 7e, and 11c including the preceding late glacials, to better understand long-term natural feedbacks beyond human activities. We use specific biomass burning residues, i.e. monosaccharide anhydrides (anhydrosugars), which are mainly produced by low-temperature fires. We analyzed these molecular markers using ultra high-performance liquid chromatography coupled to a high-resolution mass spectrometer and found them preserved in up to 420 kyr old sediment of Lake El'gygytgyn (ICDP Site 5011-1). In comparison to pollen-based vegetation reconstructions from the same time intervals we suggest that these molecular markers are suitable proxies for fires in Siberian summergreen boreal forests. Surprisingly, the ratios of the anhydrosugars levoglucosan to its isomers, mannosan and galactosan, were exceptionally low compared to published emission ratios from modern biomass burning, pointing to either a specific local biomass source and/or isomer-specific preservation. We present our current state of knowledge on formation and transport of anhydrosugars from source to deposition and their stability in sediments. We suggest ways on how to better constrain the (degradation) pathways that determine the proxy meaning of sedimentary anhydrosugars in northeastern Siberia – providing a step forward to understand the regional pyrogenic carbon cycles and long-term feedbacks that are crucial for model predictions of future fire regime shifts in the northern latitudes.

IODP

Sensitivity of North Atlantic Contouritic Sedimentation to Climate Variability in a Coupled-Regional Ocean-Sediment Model

C. Drinkorn[1], J. Saynisch[1], G. Uenzelmann-Neben[2], M. Thomas[1,3]

[1] GFZ German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam, Germany
[2] Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Am Handelshafen 12, 27570 Bremerhaven, Germany
[3] Freie Universität Berlin, Carl-Heinrich-Becker Weg 6-10, 12165 Berlin, Germany

In the project TRANSPORTED (Transport, Removal and Accumulation of sediments Numerically Simulated for Paleo-Oceans and Reconstructed from Cores of the Eirik Drift) we aim to link tectonic events and climate changes to alterations of the strength and flow paths of the Western Boundary Undercurrent (WBUC) and, hence, to sedimentation rates and grain sizes recorded in the cores from Sites 646 and U1305-1307 (Expedition 303 Scientists (2006), Shipboard Scientific Party (1987)) in the Eirik Drift, a contouritic sediment body southwest of Greenland. The Regional Ocean Model System (ROMS) (Shchepetkin and McWilliams (2005) tightly coupled to a comprehensive sediment model (Warner et al. (2005)) enables numerical investigation of sediment processes linked to ocean current systems for a wide range of sediment materials. With the knowledge from sedimentological and seismological observations and investigations (e.g., Müller-Michaels and Uenzelmann-Neben (2014, 2015)) a sophisticated model of the WBUC-Eirik Drift system could be assembled, reconstructing distinct features of density-driven currents and associated sediment structure (Rebesco et al. (2014)) at a high horizontal and vertical resolution.

Currently, we are conducting several numerical experiments regarding the role of climate variability for the simulated system. These studies show a significant response to the modifi-

cations of climate conditions and are therefore demonstrating a distinct sensitivity of contouritic sedimentation processes in the North Atlantic to climate forcing. Preliminary results regarding relative changes of deposition and erosion subject to changes of climatic boundary conditions are to be presented.

References
Expedition 303 Scientists, 2006, Expedition 303 summary, in Channell, J. E. T., Kanamatsu, T., et al, eds., Proc. IODP, Volume 303/306: College Station, Integrated Ocean Drilling Program Management International, p. 30.
Müller-Michaelis, A. and Uenzelmann-Neben, G., 2015. Using seismic reflection data to reveal high-resolution structure and pathway of the upper Western Boundary Undercurrent core at Eirik Drift. Mar. Geophys. Res. 36, 343–353.
Müller-Michaelis, A., and Uenzelmann-Neben, G., 2014, Development of the Western Boundary Undercurrent at Eirik Drift related to changing climate since the early Miocene: Deep Sea Research Part I: Oceanographic Research Papers, v. 93, p. 21-34
Rebesco, M., Hernández-Molina, F. J., Van Rooij, D., Wåhlin, A., 2014, Contourites and associated sediments controlled by deep-water circulation processes: State-of-the-art and future considerations, Marine Geology, Volume 352, p. 111-154
Shchepetkin, A. F. , McWilliams, J. C., 2005. The regional oceanic modeling system (ROMS): a split-explicit, free-surface, topography following-coordinate oceanic model. Ocean Model. 9(4), 347–404.
Shipboard Scientific Party, 1987a, Site 646, in Srivastava, S. P., Arthur, M., Clement, B., and et al., eds., Init. Repts, Volume 105: College Station, Ocean Drilling Program, p. 419-674.
Warner, J., Armstrong, B., He, R., Zambon, J. B., 2010, Development of a Coupled Ocean–Atmosphere–Wave–Sediment Transport (COAWST) Modeling System, Ocean Modelling, Volume 35, Issue 3, p. 230-244, doi: 10.1016/j.ocemod.2010.07.010.

ICDP

Climate beats from Africa: a statistical analysis of the 620 kyr Chew Bahir climate record, eastern Africa

W. Duesing[1], A. Asrat[2], A. S. Cohen[3], V. Foerster[4], S. Kaboth-Bahr[1], H. Kraemer[5], H. F. Lamb[6], N. Marwan[5], H. M. Roberts[6], F. Schaebitz[4]

[1] University of Potsdam, Institute of Geosciences, Potsdam, Germany
[2] Addis Ababa University, School of Earth Sciences, Addis Ababa, Ethiopia
[3] University of Arizona, Department of Geosciences, Tucson, USA
[4] University of Cologne, Institute of Geography Education, Cologne, Germany
[5] Potsdam Institute for Climate Impact Research, Potsdam, Germany
[6] Aberystwyth University, Departm. of Geography and Earth Sciences, Aberystwyth, UK

The sediment cores of the Chew Bahir drilling project, part of the Hominin Sites and Paleolakes Drilling Project (HSPDP), from southern Ethiopia, were used to reconstruct climatic changes by analyzing the sediment geochemistry with high-resolution XRF scanning. To interpret the multidimensional XRF dataset we computed a principal component analysis. We used the first principal component (PC1) to detect changes in variability by running a windowed standard deviation analysis and additionally a change point analysis to detect the exact timing of variability changes.

Additionally we used the established Chew Bahir log(K/Zr) aridity proxy, representing clay mineral chemistry- detrital input ratio and compared it to a new Chew Bahir climate indicator, the log(Ca/Ti) proxy, an evaporation signal that is probably inversely related to lake level stands. We find that the log(Ca/Ti) record is also an exceptionally good climate indicator because, compared to the established log(K/Zr) proxy, it reacts with greater amplitude to insolation-controlled signals such as orbital precession. This is confirmed by the log (Ca/Ti) record showing a very clear signal during the African Humid Period, which is however less pronounced in the log(K/Zr) record.

To gain a deeper understanding of the climate cycles and their temporal evolution, we computed a continuous wavelet transformation (CWT) for each of the climate proxies, and studied temporal changes in their cyclicity. Our results indicate that in addition to the precession cycle (~ 20 kyr), the Chew Bahir climate record contains earth eccentricity cycles (~ 100 kyr), as well as half-precession cycles during high eccentricity. During low eccentricity (450-350 kyr ago), we find reduced variability, three of five changes in standard deviation, damped precession and half precession cycles, and an abrupt transition from dry to wet climate, possibly due to climatic change in high latitudes which may be related to the Mid-Bruhnes event (MBE).

The results confirm that during high eccentricity the tropics are insolation controlled, largely independent of the high latitudes, whereas during low eccentricity the climate of tropical eastern Africa is sensitive to climatic drivers other than precession, possibly originating from high latitudes. Such a period occurring 450 to 350 kyr ago could have led to large regional differences in moisture availability and may have affected early humans by habitat separation, which by isolating populations, resulted in technological diversification. This possible scenario may help to explain the technological transition from Middle Stone Age (MSA) to Acheulean technology that was documented in the Olorgesailie basin during the same time period.

IODP

Driving mechanisms of organic carbon sequestration in the Early Cretaceous South Atlantic Cape Basin (DSDP Site 361)

W. Dummann[1,2], S. Steinig[3,4], P. Hofmann[1], M. Lenz[1], S. Kusch[1], S. Flögel[3], J. O. Herrle[5,2], C. Hallmann[6,7], J. Rethemeyer[1], H. U. Kasper[1], T. Wagner[8]

[1] Institute of Geosciences, Goethe-University Frankfurt, D-60438 Frankfurt am Main, Germany
[2] Institute of Geology and Mineralogy, University of Cologne, D-50674 Cologne, Germany
[3] GEOMAR Helmholtz Centre for Ocean Research, D-24148 Kiel, Germany
[4] School of Geographical Sciences, University of Bristol, Bristol, BS8 1SS, UK
[5] Biodiversity and Climate Research Centre (BIK-F), D-60325 Frankfurt am Main, Germany
[6] MARUM, University of Bremen, D-28359 Bremen, Germany
[7] Max Planck Institute for Biogeochemistry, D-07745 Jena, Germany
[8] Lyell Centre, School of Energy, Geoscience, Infrastructure and Society, Heriot-Watt University, Edinburgh, EH14 4AS, UK

The Mesozoic break-up of the supercontinent Pangaea led to the opening of several ocean basins, including the South Atlantic Ocean. During their early evolutionary stages, these basins provided favorable conditions for enhanced sequestration of organic carbon (OC), which is documented in basin-wide occurrences of OC-rich marine black shales. Young ocean basins thereby removed large quantities of carbon from the atmosphere and stored them over geological time scales. This turned young ocean basins into potent drivers of global carbon cycle and climate dynamics during the Mesozoic greenhouse. Modeling studies suggest that exceptionally high OC sequestration rates occurred in the Early Cretaceous South Atlantic basin, accounting for around 16% of global excess OC sequestration in an area that covered only around 1% of the total global ocean (McAnena et al., 2013). To unravel the processes that controlled the magnitude of OC sequestration in the Early Cretaceous (Aptian–Albian) South Atlantic basin across different time

scales (10^4 – 10^7 yrs), we present new bulk and molecular geochemical data from DSDP Site 361, located in the deep Cape Basin offshore SW Africa. Based on our multi-proxy data we develop a depositional concept of OC sequestration, which we evaluate with the help of a general circulation model.

On a multi-million year time scale, the magnitude of OC sequestration in the Cape Basin decreased in two steps from Early Aptian (TOC generally >3%) to Late Aptian (TOC 0.5 – 3%) and Late Aptian to Albian (TOC <0.1%) times, closely paralleled by a stepwise increase in water column oxygenation. Consistent with previous studies (Dummann et al., 2020), we link this long-term decline (over at least 13 Myr) in OC sequestration to the progressive opening of two gateways in the Falkland Plateau region, which induced large-scale changes in deep water circulation patterns. Increasing deep water circulation incrementally ventilated the deep Cape Basin, which ultimately terminated the conditions conducive to enhanced OC preservation in the Albian.

Superimposed on this long-term trend, we identify several short-term events (<1 Ma) of enhanced OC sequestration during the Early Aptian. These events are reflected in TOC maxima of up to ~20% TOC, which occur in narrow stratigraphic intervals punctuating the background sedimentation (TOC ~3%). "High-TOC" black shales (5-20% TOC) were deposited during OAE 1a, an episode of globally enhanced OC sequestration during the Early Aptian, but also at other stratigraphic horizons below and above OAE 1a. Combined evidence from lipid biomarker, Fe-S-TOC, and redox-sensitive trace metal data suggests that all "high-TOC" events, regardless of their stratigraphic position, reflect epsiodes of enhanced production and preservation of marine OC under strictly anoxic to probably euxinic bottom water conditions. In all cases, enhanced production and sequestration of marine OC coincided with strong influxes of sediments derived from the proximal southern African continent, which left a distinct immobile trace element and REE fingerprint in the sedimentary record at Site 361.

Based on these results, we propose that short-term changes in OC sequestration in the deep Cape Basin were tightly coupled to fluctuations in river run-off from the African continent. Our modeling experiment, geared to represent OAE 1a conditions, suggests that fluctuations in river run-off, in turn, were triggered by continental aridity/humidity variations, induced by shifts in the precipitation pattern in the temperate mid-latitude climate belt. To explain the repetitive occurrence of "high-TOC" black shales before and after OAE 1a, we propose that changes in atmospheric circulation similar to those during OAE 1a may have occurred in response to orbitally-paced shifts of climate belts on the African continent (e.g. latudinal migration of the southern Hadley Cell). Testing this hypothesis, however, requires new, high-resolution sediment records from the study area, as the incomplete stratigraphic coverage at Site 361 prevents us from pinpointing the exact timing, duration, and pacing of the repetitive "high-TOC" intervals.

Our results suggest that basin configuration exerted a primary control over OC sequestation on geological times scales. On time scales <1 Myr, the magnitude of OC sequestration in the Cape Basin reacted sensitively and directly to fluctuations in riverine nutrient fluxes. We explain this high sensitivity of biogeochemical cycling in the deep (>2000 m) Cape Basin to river nutrient supply by the lack of wide and mature continental shelf seas that could have acted as a barrier or filter for nutrient transfer from continents into the deep ocean.

References

Dummann, W., Steinig, S., Hofmann, P., Flögel, S., Osborne, A., Frank, M., Herrle, J., Bretschneider, L., Sheward, R. and Wagner, T. (2020) The impact of Early Cretaceous gateway evolution on ocean circulation and organic carbon burial in the emerging South Atlantic and Southern Ocean basins. Earth Planet Sc Lett 530, 115890.

McAnena, A., Flögel, S., Hofmann, P., Herrle, J.O., Griesand, A., Pross, J., Talbot, H.M., Rethemeyer, J., Wallmann, K. and Wagner, T. (2013) Atlantic cooling associated with a marine biotic crisis during the mid-Cretaceous period. Nature Geoscience 6, 558-561.

IODP

Felsic veins in gabbros drilled by IODP at Atlantis Bank (Southwest Indian Ridge; Expedition 360): Formation, metamorphism and their role for fluid and mass transfer: first results

A. Engelhardt, J. Koepke, F. Holtz

LUH, Institut für Mineralogie

Hole U1473 (32° 42.3622' S; 057° 16.6880' E), located on the summit of Atlantis Bank at the ultra-slow spreading Southwest Indian Ridge was drilled to 789.7 m below seafloor (mbsf) during IODP Expedition 360. It consists of massive gabbros cut by nearly 400 felsic veins, which are evolved, SiO_2-enriched lithologies comprising ~1.5 vol% of the drill core. They vary in composition from diorite to trondhjemite (Dick et al., 2015). For their formation 3 endmember models are discussed: (1) fractional crystallization as consequence of oxide saturation at a late stage of tholeiitic magma evolution; (2) anatexis of mafic rocks in the deep oceanic crust, triggered by hydrothermal fluids; (3) liquid immiscibility in an evolved MORB system. This project aims to clarify their formation, their metamorphic evolution and their role to act as pathways for transporting fluids into the deep crust.

Felsic veins are ubiquitous throughout hole U1473 crosscutting the host gabbros. Mineral assemblages in the felsic veins include plagioclase, amphibole, Fe-Ti oxides ± quartz, sometimes associated with accessory minerals as zircon, apatite, ± titanite, ± biotite, ± K-feldspar. The vein minerals often show strong zoning, which is especially expressed in amphiboles easily visible by their color ranging from brown to green (Fig. 1 a) corresponding to compositions from pargasite via pargasitic amphiboles, magnesiohornblendes to tremolite/actinolite. An contents of plagioclases in the veins vary from 33.55 down to 4.75, which is distinctly lower than in the plagioclases of the host gabbros. Clinopyroxenes directly on the contact between felsic veins and host gabbros show reactions towards amphibole (Fig. 1 d). In order to monitor the transition between magmatic and metamorphic processes amphiboles are well suited, with focus on the concentration of Ti, which is a function of formation temperatures (Ernst & Liu, 1998). Preliminary results display that TiO_2 is generally strongly enriched in the host rock (up to ~4.5 wt%), decreasing gradually in the veins to very low contents (Fig. 1b).

The contents of F and Cl help to distinguish between magmatic and seawater derived fluids controlling the amphibole formation. Preliminary results show profiles in which Cl parallels the zoning pattern for TiO_2, whereas F seems to be unaffected (Fig. 1 c).

Characteristic features observed in ~1/3 of all samples are granophyric textures exposed as intergrowth of quartz and (albitic) plagioclase (Fig. 2a). Only in one sample we observed a special variety of this intergrowth. Here, both domains of the granophyric texture are plagioclase slightly varying in average composition, instead of plagioclase and quartz, (Fig. 2b, 2c).

We believe that in this special situation quartz was replaced by albite, due to the presence of SiO_2 undersaturated hydrothermal fluids.

References

Dick, H. J., MacLeod, C. J., & Blum, P. (2015). Southwest Indian Ridge lower crust and Moho: the nature of the lower crust and Moho at slower spreading ridges (SloMo-Leg 1). International Ocean Discovery Program Scientific Prospectus, 360.

Ernst, W. G., & Liu, J. (1998). Experimental phase-equilibrium study of Al-and Ti-contents of calcic amphibole in MORB—A semiquantitative thermobarometer. American mineralogist, 83(9-10), 952-969.

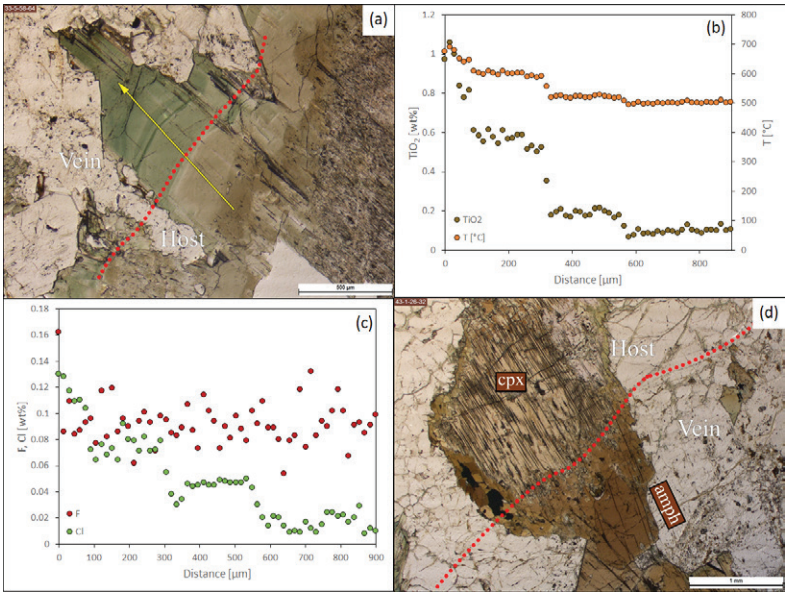


Fig. 1: (a) Microphotograph of the sample 33-5-58-64 showing a strongly zoned amphibole close to a felsic vein. The yellow arrow corresponds to the EPMA profile. The red dotted line shows the boundary between host rock and felsic vein.
(b) Diagram showing TiO_2 content decreasing from the brown part to the green part of the amphibole. The formation temperatures correlate with the TiO_2 content and reached its maximum in the dark brown areas of the amphibole.
(c) Like Ti, Cl also shows a distinct zoning, decreasing towards the pale greenish parts of the crystal corresponding to tremolite/actinolite. In contrast, no zoning is visible for F. (d) Microphotograph showing the replacement of clinopyroxene by brown amphibole in the proximity of the felsic vein, taken from sample 43-1-26-32.

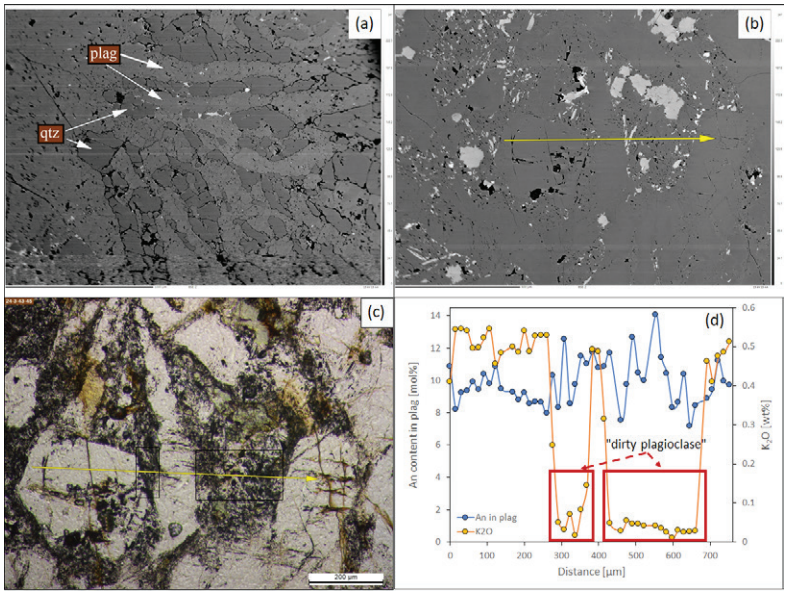


Fig. 2: (a) BSE image of 34-3-24-30 showing a typical granophyric texture exposed as intergrown quartz (darker grains) and plagioclase (lighter).
(b, c) BSE Image and microphotograph showing a special type of granophyric intergrowth found in 24-3-43-45. We assume that the original quartz was replaced by albitic plagioclase. The yellow arrow marks an EPMA profile shown in (d).
(d) Anorthite and K_2O content for the profile shown in b, c plotted against the distance. The two types of plagioclase can also be distinguished by the K_2O content decreasing abruptly. Striking is the change in An content from a steady behavior to a wavy, slightly elevated one.

IODP

Pleistocene evolution of eastern Pacific Southern Ocean surface water conditions

O. Esper

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Am Handelshafen 12, 27570 Bremerhaven, Germany

Paleoceanographic and -climatic research during the last decade has documented that biological and physical processes occurring in the Southern Ocean and changes in volume and extent of the Antarctic ice sheets play a crucial role in defining and shaping Earth´s climate. A first step to decipher Late Pleistocene eastern Pacific Southern Ocean processes has been done analysing short sediment cores (up to 25-meter-long), reaching back only a few hundred thousand years in time. However, our picture of long-term Southern Ocean climate development is incomplete because only little information is available from the Early and Middle Pleistocene. In the coming years, there will be increasing demand on marine records from the Southern Ocean matching the time span of the new "Oldes Ice" ice core initiative intended to reaching back to 1.5 million years. To improve our knowledge on present sediment deposition and Pleistocene paleoceanographic development in the eastern Pacific Southern Ocean the recovery of four sediment cores drilled during IODP Expedition 383 is an advantage to go further back in time to unravel sea surface processes from coastal and open ocean environments of the Subantarctic Zone. The Subantarctic IODP material will be complimented by one low-resolution POLARSTERN piston cores from the Antarctic Zone, covering the entire Pleistocene epoch. To establish time series of sea surface temperature variation, sea ice extent and productivity changes, diatom associations will be extracted from the sediments. Diatom counts will be converted quantitatively to temperature estimates with transfer functions recently developed. Main aim is to establish millennial-scale temperature records from three Subantarctic central eastern Pacific sites, one coastal site and one Antarctic site to reveal Pleistocene changes in temperature gradients, sea ice extent and marine frontal positions. A focus will be the peak interglacials and especially the super interglacial of Marine Isotope Stage 31. In addition, downcore diatom variation might give information on Patagonian ice sheet development and West Antarctic Ice Sheet Stability via melt water pulses. A further opportunity of diatom analysis will be the refinement of the diatom biostratigraphy, were little is known yet from the Pacific Southern Ocean. Diatom biostratigraphic events will be correlated with magnetostratigraphic events and biostratigraphic events from other microfossils retrieved from the same sediment material to establish an improved stratigraphic framework for the target region.

IODP

Southern Ocean Plankton and export productivity changes across the Eocene-Oligocene Transition

G. R. de Faria, V. Özen, U. Struck, G. Asatryan, J. Renaudie, D. Lazarus

Museum für Naturkunde, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Berlin, Germany.

The Eocene-Oligocene Transition is characterised by significant changes in the global climate system and, in connection, changes in the oceans' circulation and carbon export production. Understanding the role of phytoplankton on the global climate and the impact of those changes on the diversity of phytoplankton are essential for understanding the dynamics of oceans' carbon export production, and thus to support the prediction of future climate change.

Aiming to understand the interaction between changes on plankton composition and carbon export productivity as well as the evolutionary impact of climate change on phytoplankton, we are generating diatom diversity and abundance data, radiolarian biogeographic data and multiproxy-based paleotemperature and paleoproductivity reconstructions from various South Atlantic and Southern Ocean DSDP and ODP Sites. These data will be integrated to an ocean circulation and climate model.

We will present our preliminary results (oxygen and carbon isotope on the bulk fine fraction, as well as radiolarian and diatom diversity estimates) generated from the subantarctic ODP Site 1090B (South Atlantic), and Antarctic ODP Site 689B (Weddell Sea). Oxygen isotope analysis on the bulk fine fraction (<45µm) at both sites show a significant SST cooling during the Eocene Oligocene Transition, while the carbon isotope signal in the Antarctic site shows changes in exported productivity after the cooling. Newly generated radiolarian and diatoms diversity data from the same sites will also be presented.

ICDP

600 thousand years of climate change from Chew Bahir, S Ethiopia, and human evolution, migration and innovation

V. E. Foerster[1], A. Asrat[2], A. S. Cohen[3], M. S. Chapot[4], A. Deino[5], D. M. Deocampo[6], W. Duesing[7], C. Günter[7], A. Junginger[8], S. Kaboth-Bahr[7], H. F. Lamb[4], C. Lane[9], C. Bronk Ramsey[10], H. M. Roberts[4], C. Vidal[8], F. Schaebitz[1], M. Trauth[7], and HSPDP Science Team

[1] University of Cologne, Institute of Geography Education, Cologne Germany
[2] Addis Ababa University, School of Earth Sciences, Addis Ababa, Ethiopia
[3] University of Arizona, Department of Geosciences, Tucson AZ, USA
[4] Aberystwyth University, Department of Geography and Earth Sciences, Aberystwyth, UK
[5] Berkeley Geochronology Center, Berkeley, USA
[6] Georgia State University, Department of Geosciences, Atlanta, USA
[7] University of Potsdam, Institute of Geosciences, Potsdam, Germany
[8] Eberhard Karls Universität Tübingen, Department of Earth Sciences, Tübingen
[9] University of Cambridge, Department of Geography, Cambridge, UK
[10] University of Oxford, School of Archaeology, Oxford, UK

What role did climate dynamics play in the evolution and dispersal of *Homo sapiens* within and beyond Africa, and in key cultural innovations? Were gradual climatic changes, rapid shifts from wet to dry, or short-term climate flickers the main driver of human evolution and migration? As a contribution towards an enhanced understanding of those possible human-climate interactions the Chew Bahir Drilling Project, part of the Hominin Sites and Paleolakes Drilling Project (HSPDP) and the Collaborative Research Center (CRC) 806 "*Our way to Europe*", recovered two ~280 m-long sediment cores from a deep, tectonically-bound basin in the southern Ethiopian rift in late 2014. The Chew Bahir record covers the past ~600 ka of environmental history, a critical time period that includes the transition from the Acheulean to the Middle Stone Age, and the origin and dispersal of *Homo sapiens*.

Here we present the results from our multi-proxy study of the Chew Bahir 280 m-long composite core, providing a de-

tailed and high-resolution record of eastern Africa's climate oscillations during the last ~600 ka. To determine sediment age we used a Bayesian model to combine ages derived from radiocarbon dating of ostracodes, optically-stimulated luminescence (OSL) dating of quartz, Argon-Argon ($^{40}Ar/^{39}Ar$) dating of feldspar grains from some key (micro)tephra layers, and correlation on the basis of geochemistry of a tephra unit in the core to a known and dated tephra in the outcrop. We used high-resolution geophysical and geochemical indicators, such as the established aridity proxy K, sediment colour and authigenic minerals to differentiate between climate fluctuations on different time scales and magnitudes.

Our results show that the full proxy record from Chew Bahir can be divided into three phases with similar trends in central tendency and dispersion. Phase I from ~600 to ~430 kyr BP shows a long-term shift from humid to arid conditions while slightly increasing the variability and ending with the most extreme oscillations between full humidity and extreme aridity. The transition into Phase II (~430 to ~200 kyr BP) is marked by a pronounced millennial-scale humidity increase. Phase II reflects generally more humid conditions and there is evidence of double humidity increase tendency. Firstly, between ~430 and ~315 kyr BP (Phase IIa), and again from ~280 to ~195 kyr BP (Phase IIb), with only slight changes in long-term variability. Since ~200 kyr BP (Phase III), a long-term aridification trend sets in, similar to Phase I, but with a distinct increase in variability and amplitudes. All of these changes would have had significant implications for shaping our ancestors' living environments, both broadening and limiting their options in response to the different degrees and rates of climatic stress. The Chew Bahir record, one of the very few long terrestrial environmental records from continental eastern Africa, can contribute to testing the influence of low versus high latitude climate change in driving the expansion, contraction and fragmentation of early human habitats.

IODP

Open Ocean Antarctic Intermediate Water Variability

M. Frank, E. C. Hathorne

GEOMAR Helmholtz Centre for Ocean Research Kiel

As part of the thermohaline circulation Antarctic Intermediate Water (AAIW) not only redistributes heat and salt but also ventilates the intermediate depths and transports nutrients from the Southern Ocean (SO) to the nutrient deprived tropics. AAIW is therefore of global importance to biogeochemistry and carbon cycling. AAIW formation has been intrinsically tied to Circumpolar Deep Water (CDW) upwelling in the SO and is modulated by westerly winds and a seasonal freshening related to sea ice export and melt. Such a strong dependance on seasonal changes in surface ocean conditions makes AAIW formation sensitive to a range of climate modes including ENSO and orbital forcing. Even though it is clear AAIW transport and composition played an important role in the last deglaciation there are very few longer records of AAIW variability. Proxy records of AAIW variability have often provided conflicting views of changes in AAIW strength although a consensus has started to emerge in the relatively data rich Atlantic of a persistent, if slightly weaker AAIW during the last glacial maximum. Neodymium isotope records that suggested greater and more rapid variability have been shown to be biased by sedimentary overprinting which is a problem inherent to the continental shelf settings where most AAIW depth cores are recovered.

To avoid potential sedimentary overprinting and to provide a longer term understanding of AAIW variability we propose a new study utilising intermediate water depth drill cores from open ocean locations in the South Atlantic (DSDP Site 516), the SE Pacific (ODP Site 1236) and the Tasman Sea (DSDP Site 592 and IODP Site U1510). Although the sedimentation rates at these locations are low, first prelimineray results indicate that the full amplitude of glacial/interglacial benthic oxygen isotope variability has been recorded and thus also other parameters will be valid without significant effects of bioturbation. The advantage of these sites is that the sediments have remained oxic which allows the employment of rare earth element patterns as a complementary water mass proxy. This will complement benthic foraminiferal stable C & O isotopes and trace metal proxies for temperature (Mg/Ca, Li/Mg) and nutrient content (Cd/Ca, Ba/Ca), as well as mixed foraminiferal coating Nd isotopes as proxy for intermediate depth water mass mixing. These tools will allow the reconstruction of the water mass sources contributing to AAIW, its nutrient content and its temperature evolution, spanning approximately the last 1.5 million years and covering the important mid Pleistocene transition (MPT). After a high resolution benthic isotope stratigraphy will have been established at each site, samples spanning key glacial and interglacial intervals from before, during and after the MTP will be analysed for all proxies. Taken together, these records from different basins will provide important new insights into the potential role of AAIW in shaping the evolution of glacial terminations given that AAIW directly connected the Southern Ocean with the low latitude ocean basins. New insights will also be gained into how ocean circulation responded to orbital and increasing ice sheet forcing during the Pleistocene.

IODP

Magnetostratigraphic framework for IODP Expedition 379 (Amundsen Sea West Antarctic Ice Sheet History): preliminary results

T. Frederichs[1], L. Gao[2], S. M. Bohaty[3], M. Courtillat[4], M. A. De Lira Mota[5], M. Iwai[6], J. G. Prebble[7], J. Renaudie[8], R. P. Scherer[9], Exp. 379 scientists

[1] Fachbereich Geowissenschaften, Universität Bremen
[2] School of Ocean Sciences, China University of Geosciences
3 School of Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton
[4] Université de Perpignan Via Domitia, Centre de Formation et de Recherche sur les Environnements Méditerranéens
[5] School of Geography, Earth and Environmental Sciences University of Birmingham
[6] Kochi University Kochi Core Center (KCC)/Center for Advanced Marine Core Research
[7] Paleontology Department GNS Science
[8] Museum für Naturkunde Leibniz-Institut für Evolutions und Biodiversitätsforschung
[9] Geology and Environmental Geosciences Northern Illinois University

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 glaci-

al–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, 270 km north of the Amundsen Sea Embayment shelf edge. Sediments recovered at Site U1532 include silty clay with dispersed sand and gravel and variable biogenic content. Site U1533 is located 62 km west-southwest of Site U1532 on the westernmost lower flank of Resolution Drift (Fig. 1). Site U1533 sediments are similar to Site U1532, consisting mainly of silty clay with varying biogenic content and degree of bioturbation and include 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. The drill sites on the continental rise can (indirectly) provide records documenting the configuration of grounded ice on land and advance/retreat of the ice sheet across the shelf, because the sediments recovered at Site U1532 and U1533 are of terrigenous origin intercalated or mixed with pelagic or hemipelagic deposits, which provide clues on the state of the WAIS from the late Miocene to late Pleistocene (Gohl et al., 2019).

A reliable shipboard magnetostratigraphy was obtained at Site U1532 (maximum drilled depth 794 m). The interpreted magnetic polarity at Site U1532 was correlated with the Geomagnetic Polarity Timescale (GPTS) of Gradstein et al. (2012), and the resulting key paleomagnetic data were then integrated with biostratigraphic data to produce an age model. The interpreted 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).

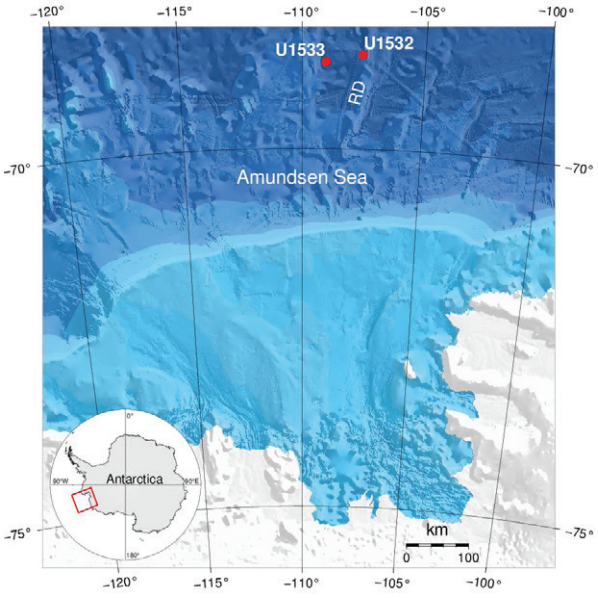


Fig. 1: Eastern Amundsen Sea continental shelf and rise bathymetry. Red dots mark Expedition 379 sites on Resolution Drift (RD). Map generated using data provided by GEBCO Compilation Group (2019) GEBCO 2019 Grid (doi:10.5285/836f016a-33be-6ddc-e053-6c86abc0788e).

Demagnetization of Natural Remanent Magnetization at 20 mT at Site U1533 (maximum drilled depth 383 m) identified a full sequence of latest Miocene to Pleistocene chrons/subchrons, allowing for a reliable shipboard 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.

References

Gohl, K., Wellner, J.S., Klaus, A., and the Expedition 379 Scientists, 2019. Expedition 379 Preliminary Report: Amundsen Sea West Antarctic Ice Sheet History. International Ocean Discovery Program. https://doi.org/10.14379/iodp.pr.379.2019

Gradstein, F.M., Ogg, J.G., Schmitz, M.D., and Ogg, G.M. (Eds.), 2012. The Geological Time Scale 2012: Amsterdam (Elsevier). https://doi.org/10.1016/C2011-1-08249-8

IODP

Dynamics of the Laurentide Ice Sheet during recent glacials: An initiative for an amphibious IODP-ICDP drilling project, shelf-to-inland eastern Canada

C. Gebhardt[1], C. Ohlendorf[2], F. Gross[3]

[1] AWI Bremerhaven
[2] Universität Bremen
[3] Universität zu Kiel

The eastern Canadian margin off Labrador is a key area for paleoclimatic and paleoceanographic investigations, as major past and recent ice sheets drained into this area, either directly (Laurentide Ice Sheet, LIS) or indirectly (Innuitian and Greenland ice sheets through Baffin Bay/Davis Strait). Many past studies have addressed the intercorrelations between the LIS dynamics and Holocene and Pleistocene climate variability. According to these studies, repeated collapses of the LIS may have resulted in northern Hemisphere climate instabilities by releasing large volumes of fresh water into the North Atlantic. Also, during the last glacial, intermediate water was not formed in the Labrador Sea in a way as it is today. With the anticipated reduction in Atlantic meridional overturning circulation strength associated with the current increased release of greenhouse gases, it is crucial to understand the dynamics of the ice sheets surrounding the Labrador Sea and North Atlantic. Hence, reconstruction of the dynamics of the LIS is a key to the understanding of climate changes during the Quaternary. From this point of view, the Labrador coast deserves special attention, as it constituted a main terminus area for the eastern LIS margin in the northwestern North Atlantic.

Lakes, fjords and inlets on the Canadian shield have long been considered as having been excavated by glaciers completely during the last (Wisconsinan) glaciation, hence holding sediments of glacial and post-glacial age, but not from before the last glacial. Only during the past years, an increasing number of studies discovered sites with thick sediment packages that likely date back before the Wisconsinan glacial.

We here propose to study three promising sites on a shelf-to-inland transect across eastern Canada. These three sites form the backbone of a **potential future amphibious IODP-ICDP drilling** proposal.

Site 1: Labrador Shelf (marine site). The Labrador Shelf seafloor morphology is relatively poor in glacial features. In addition, the mid-late Wisconsinan glacial sequence on the shelf is relatively thin. So far, this was interpreted as signs of intense erosion during the last glacial, and a fast LIS retreat during the last deglaciation. During recent Maria S. Merian expedition MSM84 (2019), we acquired a large dataset of high-resolution seismic profiles. Our data show the presence of older glacial landforms buried in the cross-shelf troughs off Labrador, contradicting the theory of complete removal of signs of older glacials. These buried landforms will be used to reconstruct the extent and dynamics of the LIS, and to identify suitable drill sites for a future drilling campaign.

Site 2: Lake Melville (marine/lacustrine site). Lake Melville is a fjord inlet at the Labrador coast that was ice-free between 10 and 8 ka after the last deglaciation. It was long thought to have been excavated during the last glacial, but new data acquired during recent Maria S. Merian expedition MSM84 indicate (a) that ice was grounded only in the westernmost part of the lake (documented by morphological features). (b) The thick sediment packages in the eastern part of the lake contain sediments that were most likely deposited well before the lake was ice-free at the last deglaciation. This suggests that the lake persisted as a subglacial lake underneath the LIS during the last glaciation, hence potentially holding a preserved record of the paleoclimate conditions during the last glaciation, unique for the Canadian realm. We will test the sediment cores for paleoclimate sensitivity, and we will identify suitable drill sites for a future drilling campaign.

Site 3: Lake Manicouagan (lacustrine site). Lake Manicouagan is situated further inland in an old meteorite impact crater, in the province of Québec some 220 km north of the Saint Lawrence River. Seismic data acquired during an expedition in 2016 indicate that the valleys/gorges in the lake are relicts of a pre-glacial, fluvial system. It is quite likely that the thick sediment packages were not excavated during the last glacial, and Lake Manicouagan, similar to Lake Melville, was a subglacial lake underneath the LIS. This suggests that the sedimentary infill would also hold records of pre-Wisconsinan age. The seismic profiles will be processed, interpreted and suitable drill sites for a future drilling project will be identified.

IODP

Evolution of the Australian Monsoon across the Mid-Pleistocene Transition: Preliminary results from IODP Site U1483, off NW Australia

L. Gong[1], A. Holbourn[1], W. Kuhnt[1], K. Matsuzaki[2], S. Bova[3], N. Andersen[4], Y. Rosenthal[3], D. Kulhanek[5]

[1] Institute of Geosciences, Christian-Albrechts-University, D-24118 Kiel, Germany
[2] Atmosphere and Ocean Research Institute, The University of Tokyo, 5-1-5 Kashiwanoha, Japan
[3] Institute of Marine and Coastal Sciences and Department of Geology, Rutgers University, New Brunswick, NJ 08901-8521, USA
[4] Leibniz Laboratory for Radiometric Dating and Stable Isotope Research, Christian-Albrechts-University, D-24118 Kiel, Germany
[5] International Ocean Discovery Program, Texas A&M University, TX77845, USA

The mid-Pleistocene Transition (MPT) stands out as a period of exceptional interest within the long-term cooling trend of the Quaternary. However, the driving mechanisms of this shift from a warmer climate phase, characterized by low-amplitude ~41 kyr variability, to high-amplitude ~100 kyr glacial-interglacial cycles remain highly enigmatic. In particular, the role of low latitude processes during the MPT are still poorly understood, as few detailed tropical records extend beyond the past ~500 kyr. The Australian Monsoon, at the edge of the southernmost displacement of the Intertropical Convergence Zone (ITCZ), is a sensitive monitor of tropical climate variability and is ideally suited to unravel linkages between high- and low-latitude climate evolution and the interhemispheric coupling with Asian monsoon subsystems. Recently, IODP Expedition 363 drilled a complete, highly resolved carbonate- and clay-rich succession spanning the past 2 Myr at Site U1483 off NW Australia (13°5.24′S, 121°48.25′E, water depth: 1733 m). Here, we integrate X-ray fluorescence (XRF) core scanning at 2 cm intervals with benthic foraminiferal stable isotopes to reconstruct riverine runoff and aeolian dust input over the MPT. A preliminary age model was developed, based on tuning the *C. wuellerstorfi* $\delta^{18}O$ record to the global LR04 stack (Lisiecki and Raymo, 2005). Log(Ca/(Al+K+Ti+Fe)), used here as a proxy for terrigenous runoff, exhibits a distinct change in frequency and amplitude at ~900 ka. High-amplitude precessional variability dominates prior to ~900 ka, whereas a strong response to both precession and obliquity is evident between ~400 and ~900 ka. These preliminary results suggest that the intensification of glacial-interglacial cycles during the MPT coincided with a major shift in the delivery of monsoonal precipitation over NW Australia. We will further investigate the coupling of the summer (monsoon precipitation/runoff) and winter (monsoon/trade wind upper ocean mixing and related productivity change) components of the Australian Monsoon using XRF-scanner derived biogenic silicon, radiolarian and benthic foraminiferal distribution, carbon accumulation rates and vertical carbon isotope gradients.

References

Lisiecki and Raymo, 2005. A Pliocene-Pleistocene stack of 57 globally distributed benthic δ18O records. Paleoceanography, 20, PA1003, doi:10.1029/2004PA001071

IODP

A 15 Ma History of Sediment Deposition in the Arctic-Atlantic Gateway Derived from an Improved Core-Log-Seismic Integration for the Central Fram Strait

J. Gruetzner, W. Geissler, C. Gebhardt, J Matthiessen, M Schreck

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany

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

References

Mattingsdal, R., Knies, J., Andreassen, K., Fabian, K., Husum, K., Grøsfjeld, K., De Schepper, S. (2014). A new 6 Myr stratigraphic framework for the Atlantic–Arctic Gateway. Quaternary Science Reviews 92, 170-178.

Myhre, A. M., Thiede, J., Firth, J. V., Ahagon, N., Black, K. S., Bloemendal, J., et al. (1995). Site 909. Proceedings of the Ocean Drilling Program, Part A: Initial Reports, 151, 159-220.

Rudels, B., Korhonen, M., Schauer, U., Pisarev, S., Rabe, B., Wisotzki, A. (2015). Circulation and transformation of Atlantic water in the Eurasian Basin and the contribution of the Fram Strait inflow branch to the Arctic Ocean heat budget. Progress in Oceanography, 132, 128-152.

Winkler, A., Wolf-Welling, T., Stattegger, K., Thiede, J. (2002). Clay mineral sedimentation in high northern latitude deep-sea basins since the Middle Miocene (ODP Leg 151, NAAG). International Journal of Earth Sciences 91, 133-148

IODP

Reaction-transport modeling of seafloor hydrothermal system

Z. Guo[1], L. Rüpke[1], S. Fuchs[1,2]

[1]GEOMAR Helmholtz Centre for Ocean Research Kiel, Wischhofstr. 1-3, 24159 Kiel, Germany

[2]Federal Institute for Geosciences and Natural Resources, Stilleweg 2, 30566 Hannover, Germany

Seafloor hydrothermal circulation plays a leading role in the cycling of mass and energy between the solid earth and the oceans. The accompanying chemical reaction, heat and metal transport significantly influence hydrothermal convection patterns, permeability of crust, vent temperature and heat flux, and massive sulphide ore deposits formation. Mineral precipitation reactions are one plausible mechanism that can affect hydrothermal flow and inhibit mixing processes (Fontaine et al., 2001; Lowell et al. 2003; Kawada & Yoshida, 2010) and probably build chimney-like structure from subseafloor to seafloor. In most cases, they are cemented by and/or enveloped by anhydrite (Hannington et al., 1998; Tivey, 2007). The seafloor chimneys focus the discharge of hot fluids over tens of meters into the cold water column. It is likely that similar mineral precipitations focus the upflow of hydrothermal fluids below the seafloor, for example in "pipe-like" vein networks that tap the geothermal reservoir (Lowell et al., 2003; Tivey, 2007). Large volumes of anhydrite may precipitate near the surface (e.g. in the chimney, mound and stockwork structures), and are also found in the deeper hydrothermal feeder zones (e.g. Humphris et al., 1995). This is evident in the ODP 158 data from the TAG hydrothermal mound, which was found to mainly consist of anhydrite, pyrite, silica, and chalcopyrite pointing to the importance of hydrothermal precipitates in focusing hydrothermal upflow towards individual vent sites (Humphris et al., 1995).

We have recently developed a relative general methodology of including precipitation reactions into hydrothermal flow models. This method is based on tracking the concentrations of Ca^{2+}, SO_4^{2-}, Fe, Cu, S in the fluid and using a thermodynamic reaction path model to compute the solubility products of anhydrite, pyrite and chalcopyrite. The model results suggest that chimney-like low permeability structure formed by anhydrite precipitation reaction provided an effective discharge path for hot upwelling hydrothermal fluid. The establishment of such anhydrite-sealed zones reduces mixing between the hydrothermal fluid and seawater and results in an increase in vent temperature. Pyrite subsequently precipitates close to the seafloor within the anhydrite chimney, providing long-term stability of the upflow zone.

References:

Fontaine, F. J., Rabinowicz, M., & Boulègue, J. (2001). Permeability changes due to mineral diagenesis in fractured crust: implications for hydrothermal circulation at mid-ocean ridges. Earth and Planetary Science Letters, 184(2), 407–425. https://doi.org/10.1016/S0012-821X(00)00332-0

Lowell, R. P., Yao, Y., & Germanovich, L. N. (2003). Anhydrite precipitation and the relationship between focused and diffuse flow in seafloor hydrothermal systems. Journal of Geophysical Research: Solid Earth, 108(B9), EPM–3. https://doi.org/10.1029/2002JB002371

Kawada, Y., & Yoshida, S. (2010). Formation of a hydrothermal reservoir due to anhydrite precipitation in an arc volcano hydrothermal system. Journal of Geophysical Research: Solid Earth, 115(B11106). https://doi.org/10.1029/2010JB007708

Hannington, M. D., Galley, A. G., Herzig, P. M., & Petersen, S. (1998). Comparison of the TAG mound and stock work complex with Cyprus-type massive sulfide deposits. In P. M. Herzig, S. E. Humphris, D. J. Miller, R. A. Zierenberg (Eds.), Proceedings of the Ocean Drilling Program, Scientific Results (Vol. 158, pp. 389–415). Texas, Texas A&M University (Ocean Drilling Program). https://doi.org/10.2973/odp.proc.sr.158.217.1998

Tivey, M. K. (2007). Generation of seafloor hydrothermal vent fluids and associated mineral deposits. Oceanography, 20(1), 50–65. https://doi.org/10.5670/oceanog.2007.80

Humphris, S. E., Herzig, P., Miller, D., Alt, J., Becker, K., Brown, D., Brügmann, G., et al. (1995). The internal structure of an active sea-floor massive sulphide deposit. Nature, 377(6551), 713–716. https://doi.org/10.1038/377713a0

IODP

Assessing the state of Weddell Sea-sourced Antarctic Bottom Water export throughout the Pleistocene

M. Gutjahr[1], S. R. Hemming[2], A. Eisenhauer[1]

[1] GEOMAR Helmholtz Centre for Ocean Research Kiel, 24148 Kiel, Germany
[2] Lamont Doherty Earth Observatory, Columbia University, USA

Antarctic Bottom Water (AABW) formed within the Weddell Sea is one of the most important deep-water masses of the Southern Hemisphere that ventilates large parts of the deep Southern Ocean. More specifically, today Weddell Sea-derived AABW is generated at several ice-proximal locations on the Antarctic shelf, most prominently in front of the Filchner, Ronne and Larsen ice shelfs in the southern and western Weddell Sea. Initially Weddell Sea Bottom Water is formed, representing the coldest and densest variety of Antarctic Bottom Water within the Weddell Sea. This oxygen-rich water mass mixes with the overlying Weddell Sea Deep Water and modified Warm Deep Water that is advected into the Weddell Sea within the Weddell Gyre, eventually leaving the basin again to the north and northeast as Weddell Sea Deep Water. Recent evidence suggests that Weddell Sea AABW was not exported outside of the Weddell Sea during past extreme climates, including the past two glacial maxima as well as the last peak interglacial. While the position and state of Southern Hemisphere polar westerlies will have an effect on Antarctic ice melt and AABW formation via transfer of warm Circumpolar Deep Water to Antarctic waters, a concomitant reduction in polar easterly winds may equally be important.

This new IODP research proposal seeks to provide new reconstructions towards the state and stability of Weddell Sea Deep Water export during key climatic intervals over the Pleistocene. We will target sediments recovered during IODP Expedition 382 into the southern Scotia Sea that recovered a complete Pleistocene interval of well-preserved undisturbed sediments at IODP Site U1537 (59°6.65′S, 40°54.37′W, in 3713 m water depth). We will first investigate which fraction in the sediment is best suited for our paleo-circulation reconstructions in this setting. To this end we will extract the authigenic Nd and Pb isotope composition from bulk sediments covering Termination 1 (T1, 25 ka until present) and T2 (150-117 ka BP), complemented by various detrital Nd and Pb isotopic records: (i) the bulk detrital signature will be compared with detrital compositions extracted from (ii) the silt-sized, as well as (iii) the pure clay fraction for T1 and T2 sediments. Since the depositional regime at IODP Site U1537 was likely relatively vigorous under non-extreme climatic conditions, the drift sediments targeted at our site are expected to contain fine-grained sediments derived from both East and West Antarctic sources in varying proportions, which are isotopically clearly distinguishable and provide important provenance information. All samples will further be complemented by elemental concentrations and ratios (Li, Al, P, Ti, Mn, Fe, Mo, Ba, Ce, Nd, Sm, Pb, Th, U).

Once acquisition and interpretation of the T1 and T2 records is finalised, the most suitable archive(s) identified will be employed for paleoclimatic reconstructions covering either some or all terminations within T3 to T10, hence extending the data set into the Mid-Pleistocene Transition (MPT). In order to set millennial-scale changes seen following the MPT in context with reported different orbital boundary conditions experienced during the early Pleistocene, an early Pleistocene time window (ca. 2.05 to 1.85 Ma) will be scrutinised in a third step. As a very final measure, the most intriguing climatic intervals identified in our records will be selected for additional $^{40}Ar/^{39}Ar$ dating, aiming to confirm the sediment provenance information obtained previously via Nd and Pb isotopic analyses.

Overall, we expect to resolve substantial changes in sediment delivery due to weakened Weddell Gyre and Weddell Sea Deep Water advection during both extreme cold (e.g. MIS2, 6, 10, 22) and warm (e.g. MIS 5e, 9 11, 21) stages. Our findings will provide essential new information towards the vulnerability on Weddell Gyre dynamics and Weddell Sea-sourced AABW export during climatically unstable times that will be closely tied with Antarctic ice sheet dynamics.

IODP

Geochemical constraints on the intensity of early diagenetic processes in sediments drilled during IODP Expedition 382 in the Southern Ocean

M. Gutjahr[1], B. Kenlee[2], O. Seki[3], J.-H. Hwang[4], M. E. Weber[5], M. Raymo[6], V. L. Peck[7], T. Williams[8], & Expedition 382 Scientists

[1] GEOMAR Helmholtz Centre for Ocean Research Kiel, 24148 Kiel, Germany
[2] Department of Earth Sciences, University of California, Riverside CA 92521, USA
[3] Institute of Low Temperature Science, Hokkaido University, Sapporo Hokkaido 060-0819, Japan
[4] Earth & Environmental Sciences, Korea Basic Science Institute, Chungbuk Cheongju, Republic of Korea
[5] Steinmann-Institute, University of Bonn, Bonn, Germany
[6] Lamont Doherty Earth Observatory, Columbia University, USA
[7] British Antarctic Survey, High Cross, Cambridge CB3 0ET, United Kingdom
[8] International Ocean Discovery Program, Texas A&M University, USA

International Ocean Discovery Program (IODP) Expedition 382 was realized in early 2019, drilling two sites at 53.2°S at the northern edge of the Scotia Sea and three sites at 57.4°–59.4°S in the southern Scotia Sea within the Atlantic sector of the Southern Ocean (Weber et al., 2019). The two northern Subantarctic Front Sites U1534 and U1535 will largely be of interest for questions surrounding dynamics in intermediate water formation and changes in the connectivity of the Atlantic and Pacific basins on glacial-interglacial timescales during the Plio-Pleistocene. The three southern drill sites (U1536-U1538) are located in the center of the so-called Iceberg Alley, i.e. the major export route of icebergs from Antarctic waters. Given the excellent recovery of Iceberg Alley sediments, geochemical, micropaleontological, sedimentological and geophysical approaches will provide key insights into past Southern Ocean circulation states and climatic excursions, equally allowing for the identification of periods of elevated iceberg rafting throughout the Pleistocene and beyond. The geochemical signature of interstitial waters in marine sediments provide valuable in-

formation towards past and present sedimentary conditions at the core sites. On the other hand, particularly geochemical and paleomagnetic approaches require sedimentary material that did not experience severe diagenetic alteration. In this contribution we will present key diagenetic features of Expedition 382 sediments.

The two northern sites display typical continental margin geochemical interstitial water profiles with the observation of a sulphate-methane transition zone at 20-30 mbsf and the presence of methane below. While Site U1534 features near-surface maxima in dissolved phosphate concentrations and alkalinity levels, these are observed deeper in the sediment at Site U1535. Evidence for diagenetic organic matter degradation is seen in various parameters, including elevated phosphate, alkalinity and ammonium concentrations as well as increasing Br/I ratios downcore. While dissolved interstitial water strontium concentrations are not elevated relative to ambient seawater, both northern sites define clear trends towards lower $^{87}Sr/^{86}Sr$ downcore, suggesting exchange with relatively unradiogenic terrigenous material in sedimentary porewaters (as low as 0.70852 in 178 mbsf at Site U1534). The Sr isotopic trends observed at the two sites is remarkably reproducible in the respective depths between these two sites.

The three southern drill sites display diagenetic trends that can be closely linked to the respective average sedimentation rate. Sites U1536 and U1537 were drilled close to each other in the Dove Basin, while U1538 was drilled in the Pirie Basin to the northwest of the two other sites. Site U1537 experienced the lowest, while Site U1538 received the highest average sedimentation rates. Equally, all diagenetic redox indicators scale accordingly between the three sites. While U1537 experienced lowest degrees of porewater alteration, Site 1538 witnessed the most pronounced changes. All three sites are depleted in dissolved sulphate (SO_4) below depths of within 60 to 100 mbsf. However, in striking contrast to the two northern sites (U1534 and U1535), methane concentrations that usually would be elevated below this SO4 depletion horizon remain indistinctively low. Conversely, ammonium, alkalinity and phosphate show variable degrees of enrichments in interstitial waters as a function of diagenetic redox reactions, with most extreme concentrations seen between 80 to 300 mbsf at Site U1538. Intriguingly, dissolved SO_4 concentrations increase again further downcore. While dissolved SO_4 is barely detectable below 540 mbsf at Site U1538, its re-emergence is clearly observable already at ~270 mbsf (U1536) and ~145 mbsf at Site U1537. All three sites also bear evidence for pronounced barite dissolution at depths that do not contain dissolved SO_4. Dissolved barite concentrations return to zero downcore at Site U1536 and U1537, and close to zero at Site U1538. Last but not least, interstitial water $^{87}Sr/^{86}Sr$ generally tend to less radiogenic compositions downcore, yet equally suggesting an apparent change in sediment delivery at some stage during the Mid-Pleistocene transition (MPT). To be more precise, interstitial water $^{87}Sr/^{86}Sr$ are in fact elevated relative to ambient seawater $^{87}Sr/^{86}Sr$ in sedimentary depths postdating the MPT at Sites U1537 and U1538, while interstitial waters are generally lower than ambient seawater in older sections. Given the striking diagenetic zonation at Sites U1536 to U1538, we will also discuss the potential presence of non-steady state diagenetic conditions at our targeted drill sites.

Expedition 382 Scientists: Linda Armbrecht, Ian Bailey, Stefanie Brachfeld, Zhiheng Du, Gerson Fauth, Marga Garcia, Anna Glüder, Michelle Guitard, Sidney Hemming, Ivan Hernandez-Almeida, Frida Snilsveit Hoem, Mutsumi Iizuka, Yuji Kato, Yasmina Martos, Suzanne O'Connell, Lara F. Perez, Brendan Reilly, Thomas Ronge, Lisa Tauxe, Shubham Tripathi, Jonathan Warnock, Xufeng Zheng

References

Weber, M.E., Raymo, M.E., Peck, V.L., Williams, T. and Expedition 382 Scientists (2019). Expedition 382 Preliminary Report: Iceberg Alley and Subantarctic Ice and Ocean Dynamics. International Ocean Discovery Program. https://doi.org/10.14379/iodp.pr.382.2019

ICDP

Evaluation of sensor types and installation in Landwüst as part of a 3D seismic monitoring array within the ICDP project Drilling the Eger Rift

K. Hannemann[1], N. Lerbs[1], J. Umlauft[1], M. Ohrnberger[2], F. Krüger[2], S. Mikulla[3], D. Vollmer[2], M. Korn[1], T. Dahm[2,3]

[1] Institut für Geophysik und Geologie (Universität Leipzig)
[2] Institut für Geowissenschaften (Universität Potsdam)
[3] GFZ Deutsches Geoforschungszentrum (Potsdam)

The ICDP project "Drilling the Eger Rift" focuses on the investigation of geo¬dynamic processes in W-Bohemia/Vogtland, such as earthquake swarms and sub-surface fluid flows accompanied by Co2 degassing at the Earth's crust. Three boreholes were drilled that are intended for the installation of eight-element borehole chains and a bottom-hole broadband sensor to get new insight into the dynamics of these processes. One of the boreholes is located 1.5 km south of Landwüst (Vogtland, Germany) with a depth of 402 m. The borehole instrumentation at this location will be complemented with a surface array consisting of 12 seismic stations with an aperture of 400 m.

The aim of the presented measurement is to test different sensor types and their installation depths in the field for the planned surface array. Furthermore, we present data retrieved with an eight-sensor geophone chain during an active vertical seismic profiling (VSP) in January 2020 to evaluate the combination of surface and borehole sensors. We used PE-6/B geophones with an eigen¬fre¬quency of 4.5 Hz and HG-7 geophones with an eigenfrequency of 10 Hz. The sampling rate during the measurement was 400 Hz, since very small high-frequency seismic events are of main interest. Three sensors were buried in depths of 35 cm and 50 cm and one 10 Hz-sensor was placed in a post-hole at a depth of 3 m to evaluate the dependency of the signal-to-noise ratio (SNR) on different installation depths by calculating the ratio of the root mean square amplitudes of local seismic signals and seismic noise. As the seismic sensors are located at a forest, we evaluate the influence of the wind and trees on the sensors at different depths. We therefore calculated PPSDs (probabilistic power spectral density) to estimate the seismic noise level in different sensors depths. We used local seismic events to measure the SNR of the recorded seismic signals. We restituted the transfer functions to lower frequencies to investigate its stability limit, as the frequency range of seismic signals generated by fluid flows extends below the eigenfrequency of the HG-7 geophones.

The results of the restitution show that the frequency range of the PE-6/B geophones can be extended down to 2 Hz and the one of the HG-7 geophones down to 4 Hz. The PPSDs show the lowest seismic noise level at 3 m depth that is about 5 dB to 13 dB smaller in the frequency range between 10 Hz to 80 Hz than the sensors at shallower depths. The SNR in this frequency range is about 40 % to 60 % smaller compared to the SNR at the shallower sensors.

Fig. 1: Installation of 10 Hz geophone in 3 m deep post-hole.

The poster informs about the current status of the surface array installation.

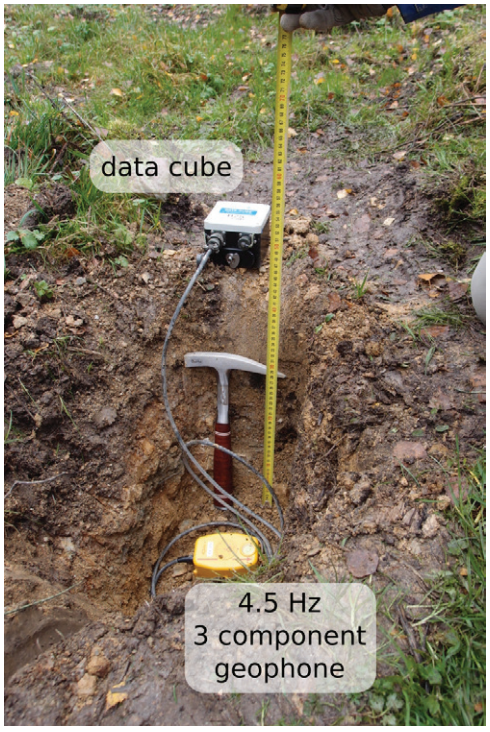


Fig. 2: Installation of 4.5 Hz geophone in 50 cm depth.

IODP

New Insights into Extinction and Ecological Recovery around the K-Pg boundary

M. J. Henehan[1], A. Bornemann[2], P. M. Hull[3]

[1] Section 3.3 Earth Surface Geochemistry, GFZ German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam, Germany
[2] Bundesanstalt für Geowissenschaften und Rohstoffe, 30655 Hannover, Germany.
[3] Department of Geology and Geophysics, Yale University, New Haven, CT 06511, USA.

While evidence for the Chicxulub bolide impact at at the Cretaceous–Paleogene (K-Pg) boundary 66 million years ago is now undisputed, the temporal coincidence of this event within the emplacement of Deccan flood basalts has led some to advocate a joint cause (or indeed a sole volcanic cause) for the K-Pg mass extinction. Partly, uncertainty stems from a lack of empirical evidence as to exactly how either of these protagonists could have driven observed extinction patterns and carbon cycle perturbations. Here, I will summarise the results of several of our recent investigations into these, questions (Henehan et al., 2019, Hull et al., 2020),, including new boron isotope measurements in foraminifera, a comprehensive global stack of temperature change around the K-Pg, and the comparison of these new datasets with numerical earth system models. Amongst the main findings, we could document a geologically rapid surface-ocean pH drop following the Chicxulub impact, supporting impact-induced ocean acidification as a key mechanism for ecological collapse in the marine realm. Subsequently, surface water pH rebounded sharply with the extinction of marine calcifiers and the associated imbalance in the global carbon cycle. In addition, we show that any climatic perturbation due to Deccan large igneous province volcanism was largely over well before bolide impact, which does not support the idea that the Earth was progressively stressed by continued volcanism and somehow more prone to extinction. In the aftermath of extinction, Our reconstructed water-column pH gradients, combined with Earth system modeling, indicate that there was a partial ~50% reduction in global marine primary productivity in the initial 10s of kyr after impact. While primary productivity then recovered, inefficiency in carbon export to the deep sea lasted much longer. In sum, we provide insights into the drivers of the last mass extinction, and the protracted nature of recovery of marine carbon cycling in a postextinction world.

References
Henehan, M. J., et al. (2019) Proc. Natl. Acad. Sci. U.S.A. 116, 22500–22504.
Hull, P. M., Bornemann, A., et al. (2020) Science 367 (6475), 266-272.

IODP

Studying past ocean-cryosphere interactions from a paleobathymetric grid series of the Southern Ocean since 34 Ma

K. Hochmuth[1], K. Gohl[1], I. Sauermilch[2], J. Whittaker[2], G. Leitchenkov[3], G. Uenzelmann-Neben[1]

[1] Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany
[2] Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Australia
[3] All Russia Scientific Research Institute for Geology and Mineral Resources of the Ocean, St. Petersburg, Russia

The Southern Ocean is a key player in the climate, ocean and atmospheric system. As the only direct connection between

all three major oceans since the opening of the Southern Ocean gateways, the development of the Southern Ocean and its relationship with the Antarctic cryosphere has controlled the climate on the entire planet. Although the depths of the ocean floor have been recognized as an important factor in climate and paleoclimate models, appropriate paleobathymetric models including a detailed analysis of the sediment cover, are still not available. After more than 40 years of seismic reflection data acquisition along the margins of Antarctica and their conjugate margins of South Africa, Australia, New Zealand and South America, along with multiple drilling campaigns by the International Ocean Discovery Program (IODP) and its predecessor programs, we are able to combine and update the seismic stratigraphy of the various regions of the Southern Ocean and calculate ocean-wide paleobathymetry grids via a backstripping method. We present a suite of paleobathymetric grids from the Eocene-Oligocene Boundary to modern times. The grids help analyse the development from isolated basins to the onset and vigor of an Antarctic Circumpolar Current as well as the glacial sedimentation and erosion of the Antarctic continent. The ocean-wide comparison of relevant time slices exposes patterns of ice sheet development such as switching of main glacial outlets and the change from wet-based to dry-based ice sheets.

The earliest presented time slice (Eocene-Oligocene Boundary) shows isolated basins within the Southern Ocean with limited deep-water exchange through the Southern Ocean gateways. The establishment of the ACC and the onset of stronger bottom currents throughout the Southern Ocean reforms sedimentation patterns within the Oligocene with the onset of drift deposits along the Antarctic continental rises. Throughout the glacial history of the Antarctic continent, the main sedimentation has been located in similar main depositional areas. Especially in East Antarctica, changes in regional main glacial outlets can be observed, and today's main regional outlets (e.g., Totten glacier) only gain importance after the complete transition into full glacial conditions during the late Miocene. We observe two main phases of glacial deposition in the Southern Ocean which are related to the first occurrence of the continental ice sheet in the early Oligocene and during the late Miocene after the re-establishment of full glacial conditions after the Mid-Miocene Climatic Optimum. Submarine-based portions of both ice sheets recover slower back to full glacial conditions. After the Miocene, sedimentation patterns concentrate along the shelf edges, leading to shelf progradation that enlarged the Antarctic continental shelves towards our modern bathymetry.

IODP

Investigating the evolution of the western tropical South Atlantic SST across three glacial-interglacial cycles and the impact on continental precipitation in eastern Brazil

A. Hou[1], A. Bahr[1], C. Strebl[1], J. Raddatz[2], A. L. Aluquerque[3], C. M. Chiessi[4], O. Friedrich[1]

[1] Institute of Earth Sciences, Heidelberg University, Heidelberg, Germany
[2] Institute of Geosciences, Goethe University Frankfurt, Frankfurt, Germany
[3] Programa de Geociências (Geoquímica), Universidade Federal Fluminense, Niterói, Brazil
[4] School of Arts, Sciences and Humanities, University of São Paulo, São Paulo, Brazil

The western tropical Atlantic warm pool is the major source of heat and salinity for the poleward-flowing, upper-branch of the Atlantic Meridional Overturning Circulation (AMOC). When the AMOC is in a sluggish state, a reduction in northward heat transport may cause warm and saline water masses to accumulate in the surface layer of the western tropical South Atlantic (WTSA). While sea-surface temperature (SST) records spanning several glacial-interglacial cycles are available for the equatorial Atlantic (ODP Site 662) and the western tropical North Atlantic (ODP Site 999), such records are lacking from the WTSA. To investigate surface ocean changes in the WTSA and thereby assess interhemispheric heat transfer across multiple glacial-interglacial transitions, we performed stable isotope and Mg/Ca analyses on Globigerinoides ruber (pink) specimens from a sediment core retrieved off the coast of eastern Brazil (offshore the Doce River, 20°S). Our ~320 kyr SST record reveals broad similarities to existing tropical Atlantic SST records from Site 999 and Site 662, indicating that long-term SST variations in the WTSA are likely governed by large-scale processes characteristic of the tropical Atlantic warm pool. We determine that atmospheric pCO_2 is the primary driver of glacial-interglacial SST variations in the WTSA, however, its influence was strongly diminished during Marine Isotope Stage (MIS) 6. The lack of pronounced glacial-interglacial fluctuations in the cross-equatorial heat distribution along the tropical Atlantic western boundary suggests that AMOC strength did not have a strong influence on low-frequency variability in WTSA SSTs. Based on these findings, we hypothesize that an increase in the concentration of greenhouse gases derived from anthropogenic activities may cause the WTSA to become warmer and thermally homogenous, which may subsequently impact continental moisture-availability over tropical South America.

We subsequently performed X-ray fluorescence scanning on the same core to reconstruct long-term rainfall changes in the hinterland to evaluate the sensitivity of eastern Brazilian continental climate to WTSA SST variations. Our Ti/Ca record reveals that during the past ~320 kyr, precession-paced insolation forcing is the primary pacemaker of variations in SASM precipitation over the Doce basin. On the other hand, we found no evidence for a direct link between monsoonal rainfall in eastern Brazil and SST changes in the WTSA. However, we surmise that inter- and intrahemispheric latitudinal temperature gradients computed using SST data from this study, Site PS2489 and ODP Site U1313 provide a potential feedback mechanism through which greenhouse gas forcing indirectly modulates monsoonal rainfall intensity. In particular, we suggest that the anomalous interval of weak monsoonal response to insolation forcing observed in our record during MIS 6 may be attributed to enhanced wintertime precipitation due to exceptionally strong southeast trade winds created by a steep South Atlantic latitudinal temperature gradient. Based on our findings, we hypothesize that SASM rainfall intensity over tropical eastern Brazil will likely be suppressed by rising CO_2 emissions in the future.

IODP

Sea level and deep-ocean temperature of the Late Pliocene to Early Pleistocene (~3.35–2.05 Myr)

K. A. Jakob[1], S. L. Ho[2], A. N. Meckler[3], J. Pross[1], O. Friedrich[1]

[1] Institute of Earth Sciences, Heidelberg University, Germany
[2] Institute of Oceanography, National Taiwan University, Taiwan
[3] Bjerknes Centre for Climate Research and Department of Earth Science, University of Bergen, Norway

Sea-level rise represents a component of anthropogenic climate change with exceptionally high societal relevance. In light of the need for high-fidelity, quantitative projections of future sea-level rise, it is mandatory to understand ice-volume/sea-level change associated with climate variability of warmer-than-modern periods of Earth's history. However, such records are yet sparse, partially inconsistent, and/or typically of low temporal resolution. We therefore generated a new, temporally highly resolved (~1 kyr) deep-sea temperature and inferred sea-level record for the Late Pliocene to Early Pleistocene (~3.35–2.05 Myr, corresponding to Marine Isotope Stages [MIS] MG1 to 78) from the tropical East Pacific Ocean (Ocean Drilling Program Site 849, 3851 m water depth). The studied time interval comprises the critical transition from early Late Pliocene warmer-than-modern conditions with "Anthropocene-like" CO_2 concentrations to stronger glacial-interglacial cycles associated with declining atmospheric CO_2 and cooler temperatures towards the mid-Early Pleistocene. It thus covers the full range of climatic boundary conditions relevant for our understanding of future warming and sea-level change. Our deep-ocean temperature and sea-level estimates are derived through an integrated geochemical approach based on oxygen-isotope ($\delta^{18}O$) and Mg/Ca data from the benthic foraminiferal species *Oridorsalis umbonatus*. To test the robustness of our approach, clumped-isotope data were generated from mixed epifaunal to shallow infaunal benthic foraminifera of the same site as an independent deep-ocean temperature proxy. Our study required refinement of the previously available age model for Site 849 of Mix et al. (1995), which was limited by the relatively low temporal sample resolution. This refinement was achieved by tuning our new benthic $\delta^{18}O$ record to the LR04 stack (Lisiecki & Raymo, 2005).

The deep-ocean temperatures reconstructed from our Mg/Ca data fluctuate between approximately -0.5 and 6 °C, with glacial-interglacial oscillations of up to ~4 °C. The majority of clumped-isotope-derived temperatures matches those derived from the Mg/Ca data and therefore underscores the reliability of our Mg/Ca- (and $\delta^{18}O$-)based sea-level reconstructions. Our reconstructed sea-level values show maximum and minimum values of ~65 m above and ~130 m below modern levels, respectively. The intensification of Northern Hemisphere Glaciation (3.6–2.4 Ma, Mudelsee & Raymo, 2005) is documented in our data by a decreasing sea level during both glacial and interglacial periods to values typically below the present-day level since ~3 Ma. Exceptions are prominent sea-level highstands of ~45 m above modern during interglacials MIS G7, G1 and 101 at ~2.76 Ma, ~2.63 Ma and ~2.57 Ma, respectively.

Due to its high temporal resolution, our record allows to resolve the internal anatomy of glacials within the studied interval, which enables us to compare them with the relatively well-understood glacials of the Late Pleistocene. Such a comparison is instrumental for identifying the mechanisms underlying the dynamics of Late Pliocene to Early Pleistocene ice sheets that formed during times of markedly higher atmospheric CO_2 concentrations as they are expected for the near future. We find that the sea-level structure identified for MIS 100 (~2.52 Ma) is strikingly reminiscent of those reported for Late Pleistocene glacials (e.g., Bintanja & Van de Wal, 2008; Walbroeck et al., 2002). Both exhibit a "sawtooth"-like structure with rapid deglaciations and a final sea-level drop before the termination. This implies a similar mechanistic behavior of Early and Late Pleistocene ice sheets. We thus hypothesize that MIS 100 possibly was an early attempt of Earth's climate to shift into the asymmetric glacial-interglacial cyclicity of global sea-level/ice-volume change of the Late Pleistocene as it was finally established ~1.5 Myr later. Ultimately, our detailed records add to a growing body of work to better understand global sea-level/ice-volume change under warmer-than-modern climate boundary conditions and therefore have important implications for sea-level predictions in a future greenhouse world.

References

Bintanja, R. & Van de Wal, R. North American ice-sheet dynamics and the onset of 100,000-year glacial cycles. Nature 454, 869–872 (2008).
Lisiecki , L.E. & Raymo, M.E. A Pliocene-Pleistocene stack of 57 globally distributed benthic δ18O records. Paleoceanography 20, doi:10.1029/2004PA001071 (2005).
Mix, A.C., et al. Benthic foraminiferal stable isotope record from Site 849 (0-5 Ma): local and global climate changes. Proc. ODP, Sci. Res. 138, 371–412 (1995).
Mudelsee, M. & Raymo, M.E. Slow dynamics of the Northern Hemisphere glaciation. Paleoceanography 20, doi:10.1029/2005PA001153 (2005).
Waelbroeck, C., et al. Sea-level and deep water temperature changes derived from benthic foraminifera isotopic records. Quat. Sci. Rev. 21, 295–305 (2002).

IODP

Indian Monsoon variability in the Andaman Sea during the late Miocene: New insights from IODP Site U1448

J. Jöhnck[1], W. Kuhnt[1], A. Holbourn[1], N. Andersen[2]

[1] Institute of Geosciences, Christian-Albrechts-University, Kiel, Germany
[2] Leibniz Laboratory for Radiometric Dating and Stable Isotope Research, Christian-Albrechts-University, Kiel, Germany

The past variability of the Indian Monsoon and its response to changes in orbital forcing and climate boundary conditions, such as atmospheric greenhouse gases and global ice volume is still a matter of intense debate. We investigate the evolution of the Indian monsoon in a new sediment succession recovered at International Ocean Discovery Program (IODP) Site U1448 (10°38.03'N/93°00'E, 1098 m water depth), which spans the latest Miocene to early Pliocene transition (6.25 to 4.9 Ma). This crucial interval allows investigation of monsoon variability during intense cooling/warming episodes with background climate conditions comparable to today's. Integration of high-resolution benthic stable isotope records with paired mixed layer isotope and Mg/Ca temperature data reveals a change in the amplitude and frequency of monsoonal precipitation from a dominantly precession-paced to a dominantly obliquity-paced regime at ~5.5 Ma. Our record indicates at the same time a change from a cool and dry background climate with summer monsoon failure during transient Northern Hemisphere glaciation events, to a warmer episode with an increased "monsoonality" of the rainfall suggesting that the change in response to orbital forcing of the Indian monsoon was coupled to the latest Miocene global warming (Herbert et al., 2016; Holbourn et al., 2018). During this interval an increasing influence of obliquity may have transferred heat and moisture from the Southern Hemisphere into the Andaman Sea, thereby amplifying the seasonality of precipitation. A comparison with the East Asian mon-

soon (ODP Site 1146 (Holbourn et al., 2018)) uncovers striking similarities in the evolution of SST and productivity records associated with summer monsoon intensification, suggesting that the entire Asian monsoon system became highly sensitive to obliquity forcing across the Miocene/Pliocene boundary.

References
Herbert, T.D., Lawrence, K.T., Tzanova, A., Peterson, L.C., Caballero-Gill, R., Kelly, C.S., 2016. Late Miocene global cooling and the rise of modern ecosystems. Nat. Geosci. 9, 843-847. https://doi.org/10.1038/ngeo2813
Holbourn, A.E., Kuhnt, W., Clemens, S.C., Kochhann, K.G.D., Jöhnck, J., Lübbers, J., Andersen, N., 2018. Late Miocene climate cooling and intensification of southeast Asian winter monsoon. Nat. Commun. 9. https://doi.org/10.1038/s41467-018-03950-1

ICDP

Tracking palaeo-hydroclimatic evolution of the Dead Sea using boron geochemistry

H. Jurikova[1], I. Neugebauer[1], B. Plessen[1], M. Henehan[2], R. Tjallingii[1], M. J. Schwab[1], A. Brauer[1], C. Blanchet[1]

[1] GFZ German Research Centre for Geosciences – Helmholtz Centre Potsdam, Section Climate Dynamics and Landscape Evolution, Germany

[2] GFZ German Research Centre for Geosciences – Helmholtz Centre Potsdam, Section Earth Surface Geochemistry, Germany

Fig. 1. Secondary electron microscope (SEM) image of an authigenic aragonite sample from the ICDP 5017-1 deep-drilling core. By visual and chemical pre-screening, carbonate layers from the core consisting of pure aragonite only may be clearly distinguished from those containing secondary influences such as detrital material or gypsum, permitting reliable extraction of primary geochemical signals.

Sedimentary sequences of the Dead Sea provide a unique high-resolution archive of past climatic changes in the Mediterranean-Levant, a key region for human migration out of Africa at the boundary of hemispheric climate belts. The well-preserved record of the Holocene Dead Sea and its Last Glacial precursor Lake Lisan is characterised by annual laminations – varves – composed of alternate layers of aragonite and detritus. Past lake level reconstructions suggest large fluctuations in the regional hydrological balance driven by abrupt climatic events, including a pronounced transition from lake level high-stand during the Last Glacial Maximum (LGM) to a low-stand at the onset of the Holocene (Torfstein et al., 2013). On millennial timescales these changes have been associated with temperature variations recorded in the Greenland ice core, underscoring the potential of the Dead Sea to offer both regional and global perspectives on high-amplitude climatic events in the past. However, our ability to fully read the Dead Sea record critically depends on reliable extraction of palaeo-climatic and palaeo-environmental data from lacustrine carbonates, and an improved understanding of their formation.

Within the project PRO-HYDRO we aim to unravel past hydrological balance in the Levant using novel geochemical fingerprints. Here we present carbon, oxygen, boron isotope and trace element composition of hand-picked authigenic aragonite (Fig. 1) from the ICDP 5017-1 deep-drilling core (Neugebauer et al., 2014) complemented by newly recovered shore outcrops (Masada, Ein Gedi). While traditionally used as a pH-proxy (Jurikova et al., 2019) we examine the possibility of applying boron geochemistry for reconstructing the source water and brine composition (Vengosh et al., 1991). Using our innovative combined approach, we elucidate the palaeo-hydroclimatic evolution of the Dead Sea during intervals of major environmental changes since the end of the LGM.

References
Torfstein A., et al. (2013) Quat. Sci. Rev. 69, 1–7.
Neugebauer I., et al. (2014) Quat. Sci. Rev. 102, 149–165.
Jurikova H., et al. (2019) Geochim. Cosmochim. Acta 248, 370–386.
Vengosh A., et al. (1991) Geochim. Cosmochim. Acta 55, 1689–1695.

ICDP

Rapid paleomagnetic reversals recorded in greigite-rich sediments of Lake Ohrid (ICDP 5045-1) and their implications for stratigraphic correlation

J. Just[1], L. Sagnotti[2], N. R. Nowaczyk[3], A. Francke[4], B. Wagner[5]

[1] Geowissenschaften (FB5 Uni Bremen), Bremen
[2] Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy
[3] Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences, Potsdam, Germany
[4] School of Earth, Atmosphere, and Life Science, University of Wollongong, Australia
[5] Institute of Geology and Mineralogy, University of Cologne, Germany

Unravelling the interrelationships in the climate system from the regional to the global scale and its response to orbital forcing strongly depends on the reliability of climate-independent time-equivalent markers for paleoclimatic records. Because geomagnetic reversal are global events and independent of climatic conditions, they are considered excellent age constraints. However, spatial differences in the timing and internal dynamics during paleomagnetic reversals modify their expressions around the globe. Our 1.2 Ma high-resolution (~25 cm/kyr) sediment record ICDP 5045-1 from Lake Ohrid is promising to precisely depict the Matuyama-Brunhes reversal and the Jaramillo subchron. Nevertheless, we detected two generations of diagenetic iron-minerals, which mask the polarity record in glacial intervals. Early diagenetic greigite, which formed 1-2 kyrs after deposition, acquired a quasi-syn-sedimentary chemical magnetization. At a later stage, upward diffusing H_2S-rich waters initiated the formation of late-diagenetic greigite, which exclusively carries a normal chemical magnetization. Interglacial intervals, which are associated with low iron concentrations in Lake Ohrid, are unaffected by greigite formation. Based on an orbitally-tuned age model with excellent tephrostratigraphic markers, we can date the base of Jaramillo subchron to 1072.4 ka, and the Matuyama-Brunhes reversal to 778.5 ka, which are recorded in interglacial intervals. Both reversals appear very fast in our record, lasting 2.3 kyr and 1 kyr, respectively. Such a rapid Matuyama-Brunhes reversal has been previously observed in the Mediterranean region, while it appears much longer (> 10 kyrs) in records from the Atlantic and Pacific. Our results reveal that the dipole component of the Earth´s Magnetic Field fell below the non-dipole components only for a short period in the Mediterranean region. Despite the variable durations in sedimentary archives around the globe, the onsets of directional change at the Matuyama-Brunhes transition are consistent within ~2 kyrs. Thus, we advocate that using the onset of the reversal is a much more robust age marker than the often-used midpoint age, and should be used for stratigraphic correlation.

References

Brown, M.C., Jicha, B.R., Singer, B.S., Shaw, J., 2013. Snapshot of the Matuyama-Brunhes reversal process recorded in 40Ar/39Ar-dated lavas from Guadeloupe, West Indies. Geochem. Geophys. Geosyst. 14, 4341-4350, doi:10.1002/ggge.20263.

Channell, J.E.T., 2017. Complexity in Matuyama–Brunhes polarity transitions from North Atlantic IODP/ODP deep-sea sites. Earth Planet. Sci. Lett. 467, 43-56, doi:10.1016/j.epsl.2017.03.019.

Channell, J.E.T., Curtis, J.H., Flower, B.P., 2004. The Matuyama–Brunhes boundary interval (500–900 ka) in North Atlantic drift sediments. Geophys. J. Int. 158, 489-505, doi:10.1111/j.1365-246X.2004.02329.x.

Channell, J.E.T., Hodell, D.A., Singer, B.S., Xuan, C., 2010. Reconciling astrochronological and 40Ar/39Ar ages for the Matuyama-Brunhes boundary and late Matuyama Chron. Geochem. Geophys. Geosyst. 11, n/a-n/a, doi:10.1029/2010GC003203.

Channell, J.E.T., Hodell, D.A., Xuan, C., Mazaud, A., Stoner, J.S., 2008. Age calibrated relative paleointensity for the last 1.5 Myr at IODP Site U1308 (North Atlantic). Earth Planet. Sci. Lett. 274, 59-71, doi:10.1016/j.epsl.2008.07.005.

Channell, J.E.T., Kleiven, H.F., 2000. Geomagnetic palaeointensities and astrochronological ages for the Matuyama-Brunhes boundary and the boundaries of the Jaramillo Subchron: palaeomagnetic and oxygen isotope records from ODP Site 983. Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences 358, 1027-1047, doi:10.1098/rsta.2000.0572.

Channell, J.E.T., Raymo, M.E., 2003. Paleomagnetic record at ODP Site 980 (Feni Drift, Rockall) for the past 1.2 Myrs. Geochem. Geophys. Geosyst. 4, doi:10.1029/2002gc000440.

Coe, R.S., Singer, B.S., Pringle, M.S., Zhao, X., 2004. Matuyama–Brunhes reversal and Kamikatsura event on Maui: paleomagnetic directions, 40Ar/39Ar ages and implications. Earth Planet. Sci. Lett. 222, 667-684, doi:10.1016/j.epsl.2004.03.003.

Dreyfus, G.B., Raisbeck, G.M., Parrenin, F., Jouzel, J., Guyodo, Y., Nomade, S., Mazaud, A., 2008. An ice core perspective on the age of the Matuyama–Brunhes boundary. Earth Planet. Sci. Lett. 274, 151-156, doi:10.1016/j.epsl.2008.07.008.

Horng, C.-S., Lee, M.-Y., Palike, H., Wei, K.-Y., Liang, W.-T., Iizuka, Y., Torii, M., 2002. Astronomically calibrated ages for geomagnetic reversals within the Matuyama chron. Earth, Planets and Space 54, 679-690, doi:10.1186/BF03351719.

Hyodo, M., Biswas, D.K., Noda, T., Tomioka, N., Mishima, T., Itota, C., Sato, H., 2006. Millennial- to submillennial-scale features of the Matuyama-Brunhes geomagnetic polarity transition from Osaka Bay, southwestern Japan. Journal of Geophysical Research: Solid Earth 111, doi:10.1029/2004jb003584.

Hyodo, M., Kitaba, I., 2015. Timing of the Matuyama–Brunhes geomagnetic reversal: Decoupled thermal maximum and sea-level highstand during Marine Isotope Stage 19. Quatern. Int. 383, 136-144, doi:10.1016/j.quaint.2015.01.052.

Lisiecki, L. E. and M. E. Raymo (2005). ‚A Pliocene-Pleistocene Stack of 57 Globally Distributed Benthic Δ18o Records.‘ Paleoceanography 20(1).

Macri, P., Capraro, L., Ferretti, P., Scarponi, D., 2018. A high-resolution record of the Matuyama-Brunhes transition from the Mediterranean region: The Valle di Manche section (Calabria, Southern Italy). Phys. Earth Plant. Int. 278, 1-15, doi:10.1016/j.pepi.2018.02.005.

Mark, D.F., Renne, P.R., Dymock, R.C., Smith, V.C., Simon, J.I., Morgan, L.E., Staff, R.A., Ellis, B.S., Pearce, N.J.G., 2017. High-precision 40Ar/39Ar dating of pleistocene tuffs and temporal anchoring of the Matuyama-Brunhes boundary. Quaternary Geochronology 39, 1-23, doi:10.1016/j.quageo.2017.01.002.

Niespolo, E.M., Rutte, D., Deino, A.L., Renne, P.R., 2017. Intercalibration and age of the Alder Creek sanidine 40Ar/39Ar standard. Quaternary Geochronology 39, 205-213, doi:10.1016/j.quageo.2016.09.004.

Nowaczyk, N.R., Haltia, E.M., Ulbricht, D., Wennrich, V., Sauerbrey, M.A., Rosén, P., Vogel, H., Francke, A., Meyer-Jacob, C., Andreev, A.A., Lozhkin, A.V., 2013. Chronology of Lake El'gygytgyn sediments – a combined magnetostratigraphic, palaeoclimatic and orbital tuning study based on multi-parameter analyses. Clim. Past 9, 2413-2432, doi:10.5194/cp-9-2413-2013.

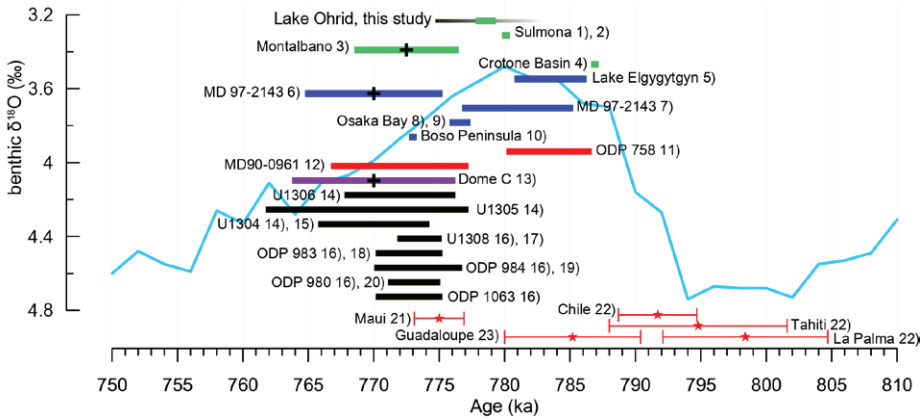


Fig. 1: Timing of the Matuyama-Brunhes (MB) reversal plotted with respect to the LR04 benthic δ18O stack (Lisiecki and Raymo, 2005). Length of bar indicates duration of MB reversal in the various records. Colors relate to geographic regions. Green: Mediterranean, blue: Pacific, red: Indian Ocean, purple: Antarctica, black: North Atlantic. 1) Sagnotti et al. (2014), 2) Niespolo et al. (2017), 3) Simon et al. (2017), 4) Macrì et al. (2018), 5) Nowaczyk et al. (2013), 6) Suganuma et al. (2010), 7) Horng et al. (2002), 8) Hyodo et al. (2006), 9) Hyodo and Kitaba (2015), 10) Okada and Niitsuma (1989), 11) Mark et al. (2017), 12) Valet et al. (2014), 13) Dreyfus et al. (2008), 14) Channell (2017), 15) Xuan et al. (2016), 16) Channell et al. (2010), 17) Channell et al. (2008), 18) Channell and Kleiven (2000) , 19) Channell et al. (2004), 20) Channell and Raymo (2003), 21) Coe et al. (2004), 22) Singer et al. (2005), 23) Brown et al. (2013).

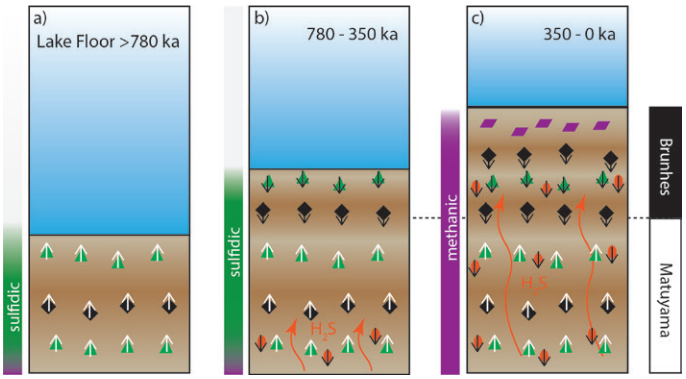


Fig. 2: Schematic development of the magnetic minerals in Lake Ohrid. a) During the Matuyama chron interglacial sediments were dominated by magnetite (black prisms). Early diagenetic greigite (green triangles) formed in glacial intervals. b) During the Brunhes chron, upward migrating H2S rich fluids initiated the growth of a second generation of greigite (orange ellipses) of normal polarity at greater sediment depth. c) During the last 350 siderite formation (purple prisms) in shallow sediment depth.

Okada, M., Niitsuma, N., 1989. Detailed paleomagnetic records during the Brunhes-Matuyama geomagnetic reversal, and a direct determination of depth lag for magnetization in marine sediments. Phys. Earth Plant. Int. 56, 133-150, doi:10.1016/0031-9201(89)90043-5.

Sagnotti, L., Scardia, G., Giaccio, B., Liddicoat, J.C., Nomade, S., Renne, P.R., Sprain, C.J., 2014. Extremely rapid directional change during Matuyama-Brunhes geomagnetic polarity reversal. Geophys. J. Int. 199, 1110-1124, doi:10.1093/gji/ggu287.

Simon, Q., Bourlès, D.L., Bassinot, F., Nomade, S., Marino, M., Ciaranfi, N., Girone, A., Maiorano, P., Thouveny, N., Choy, S., Dewilde, F., Scao, V., Isguder, G., Blamart, D., 2017. Authigenic 10Be/9Be ratio signature of the Matuyama–Brunhes boundary in the Montalbano Jonico marine succession. Earth Planet. Sci. Lett. 460, 255-267, doi:10.1016/j.epsl.2016.11.052.

Singer, B.S., Hoffman, K.A., Coe, R.S., Brown, L.L., Jicha, B.R., Pringle, M.S., Chauvin, A., 2005. Structural and temporal requirements for geomagnetic field reversal deduced from lava flows. Nature 434, 633-636, doi:10.1038/nature03431.

Suganuma, Y., Yokoyama, Y., Yamazaki, T., Kawamura, K., Horng, C.-S., Matsuzaki, H., 2010. 10Be evidence for delayed acquisition of remanent magnetization in marine sediments: Implication for a new age for the Matuyama–Brunhes boundary. Earth Planet. Sci. Lett. 296, 443-450, doi:10.1016/j.epsl.2010.05.031.

Valet, J.-P., Bassinot, F., Bouilloux, A., Bourlès, D., Nomade, S., Guillou, V., Lopes, F., Thouveny, N., Dewilde, F., 2014. Geomagnetic, cosmogenic and climatic changes across the last geomagnetic reversal from Equatorial Indian Ocean sediments. Earth Planet. Sci. Lett. 397, 67-79, doi:10.1016/j.epsl.2014.03.053.

ICDP

Core-log-seismic data integration in a metamorphic environment: A study on the ICDP drilling project COSC-1, Sweden

F. Kästner[1,2], S. Pierdominici[2], A. Zappone[3], J. Elger[1], C. Berndt[1], J. Kück[2], A.M. Schleicher[2]

[1] GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany
[2] Helmholtz Centre Potsdam GFZ, German Research Centre for Geosciences, Potsdam, Germany
[3] ETH Zurich, Department of Earth Sciences, Zurich, Switzerland

Integration and linkage of rock geophysical properties from laboratory investigations, borehole measurements, and reflection seismic data is rare in metamorphic environments. Here, we present a study testing core-log-seismic integration applied on the ICDP drilling project COSC-1, Sweden, which was drilled in 2014 in the western Scandinavian Caledonides to better understand the deep orogenic processes in mountain belts. Our project aims on calculating synthetic seismograms from core and borehole logs and matching them to 2D and 3D seismic data to identify lithological boundaries that represent seismic reflectors and to correlate them to changes in composition, structure, and metamorphic overprint. In terms of compositional variations, our initial results suggest that reflections mainly correspond to interfaces between mafic (amphibole-rich) and felsic (quartz-feldspar-rich) rock units. A second approach is to compare different P-wave velocities. Discrepancies between data from the multi-sensor core logger and the downhole sonic log are likely ascribed to the formation of microcracks during depressurization of the cores. Laboratory seismic velocity and anisotropy measurements on selected core samples under in situ pressure conditions confirm this relationship. Using these samples, we also derived an anisotropy-depth profile along the borehole showing strong variations in anisotropy at depths with highest values (up to 25 %) for the phyllitic mica schists. It also emphasizes that seismic velocity and anisotropy are of complementary importance to better distinguish lithological units, which may show strong structural characteristics such as metamorphic foliation but exhibit only weak compositional variations. To constrain the effects of composition and microstructure on seismic anisotropy at macro- to microscopic scales, we performed additional mineralogical and compositional analyses using optical and electron-based microscopy and X-ray powder diffractometry, correlated with the seismic anisotropy from electron-backscatter diffraction (EBSD) analysis on thin sections. Calculated Hill averages show significant lower values of anisotropy for the heterogeneous samples than the laboratory measurements. In contrast, the rather homogenous samples provide consistent results for both calculated and measured anisotropy. We attribute the deviation to a scale effect, indicating that the core plug measurements are relatively unaffected by small-scale mineral misorientations as observed in the EBSD data. Extending our results to seismic scales this can help to better estimate the effect of seismic anisotropy at very heterogeneous formations in strongly deformed thrust zones.

ICDP

X-ray microtomography (µ-CT) survey of samples from ICDP SUSTAIN boreholes 5059-1-C and D on Surtsey: the nucleus of a Digital Core Repository

W.-A. Kahl[1], A. Türke[1,2,3], W. Bach[1,3]

[1] Department of Geosciences, University of Bremen, Klagenfurter Straße (GEO), 28359 Bremen, Germany
[2] K.G. Jebsen Centre for Deep Sea Research, Department of Earth Science, University of Bergen, Bergen, Norway
[3] MARUM, Center for Marine Environmental Sciences, 28359 Bremen, Germany

Here we present first results of a X-ray µ-CT survey on drill core material recovered from Holes 5059-1-C and 5059-1-D by the SUSTAIN drilling project (Surtsey Underwater volcanic System for Thermophiles, Alteration processes and INnovative Concretes, see Jackson et al. 2019 for details) on Surtsey volcano (Vestmannaeyjar archipelago, Iceland). In late summer 2017, three boreholes were drilled: two vertical, cored holes (5059-1-B, 152 m; and 5059-1-C, 192 m) that run parallel to a hole cored in 1979 (181 m), and a third borehole (5059-1-D, 354 m length to a depth of 290 m), inclined 35° from vertical. From the latter two drill cores, 30 out of 33 reference samples were scanned as quarter cores: (i) 17 samples from Hole 5059-1-C (ranging from 22.66 to 180.65 m vertical depth, sampling roughly every 10 m), and (ii) 13 samples from Hole 5059-1-D (ranging from 180.47 to 282.12 m, sampling roughly every 10 m). The X-ray µ-CT scans were performed using the ProCon CT-ALPHA system of the Petrology of the Ocean Crust research group at the University of Bremen, Germany.

This µ-CT survey has been conducted as part of our DFG SPP 1006 grant „Rates and Processes of Tephra Alteration on Surtsey: Observations and Experiments“. In order to avoid imaging of void space due to the quarter core shape, and to achieve a higher magnification, the scans were performed as „out-of-area“-scans (see, e. g. Kahl et al., 2016), restricting observations to the inner regions of the samples. The reconstructed image material is of cylindrical shape with a resolution of ca. 7.5 µm/voxel, and represents virtual drill cores of ca. 15 mm diameter and 15 mm height. The µ-CT-derived image volumes comprise the true 3-D spatial arrangement of fabric compounds in the rock. In the reconstructed 16-bit greyscale volume data, areas of highly attenuating phases (e.g. magnetite, olivine) are encoded in light grey values, whereas areas of low X-ray absorption are colour-coded in dark grey (e.g. clays) or black (e.g. voids, cracks).

These image data allow us to derive empirical relations between porosity, the extent of replacement of primary phases, and

the nature and distribution of secondary phases. This is achieved by filtering of the raw data, volume reconstruction, segmentation, and rendering using Avizo 2019.2 software (FEI). These „digital drill cores“ will also be used to retrieve tortuosity information of the effective porosity, which can be related to permeability, and the mineral chemical and textural information in order to gain specific insights into the relations between pore space evolution and mass transfer reactions.

Following completion of our scientific work using quantitative 3-D digital image analysis on the digital drill cores we plan to transfer the image material to the GFZ data services as Data Reports. The datasets will be published standalone with a data report, and the GFZ German Research Centre for Geosciences will assign Digital Object Identifiers (DOI) to the datasets.

References
Jackson, M.D. and 42 co-authors, including W.Bach and A.Türke (2019) SUSTAIN drilling at Surtsey volcano, Iceland, tracks hydrothermal and microbiological interactions in basalt 50 years after eruption. Scientific Drilling, 25, 35–46. https://doi.org/10.5194/sd-25-35-2019.
Kahl, W.-A., Hansen, C., and Bach, W., 2016, A new X-ray-transparent flow-through reaction cell for a μ-CT-based concomitant surveillance of the reaction progress of hydrothermal mineral-fluid interactions. Solid Earth, v. 7, p. 651– 658. https://doi.org/10.5194/se-7-651-2016.

ICDP

Methanogenesis and organic matter mineralization in ferruginous sediments

J. Kallmeyer[1], A. Friese[1], K. Bauer[2], C. Glombitza[3], L. Ordonez[4], D. Ariztegui[4], V. B. Heuer[5], A. Vuillemin[6], C. Henny[7], S. Nomosatryo[1], R. Simister[2], D. Wagner[1], S. Bijaksana[8], H. Vogel[9], M. Melles[10], J. M. Russell[11], S. A. Crowe[2]

[1] GFZ Potsdam
[2] University of British Columbia
[3] ETH Zürich
[4] University of Geneva
[5] MARUM-Uni Bremen
[6] Ludwig-Maximilians-Universität München
[7] Indonesian Institute of Sciences (LIPI)
[8] Institut Teknologi Bandung, Indonesia
[9] Universität Bern
[10] Universität zu Köln
[11] Brown University

Organic matter mineralization and diagenesis in ferruginous (Fe-rich) sediments played a key role in biogeochemical cycling during the Archean and Proterozoic eons. However, knowledge of organic matter mineralization in ferruginous sediments remains almost entirely conceptual, as analogous modern systems are extremely rare and largely unstudied. Lake Towuti on Sulawesi Island, Indonesia is one of those rare examples and in 2015 the ICDP Lake Towuti Drilling project recovered long sediment cores from the lake, including a 115 m-long core, drilled with strict contamination control, to be exclusively used for destructive geomicrobiological and biogeochemical analyses.

The lake sediment receives large amounts of reactive iron from the ultramafic bedrock in the catchment, leading to sediment with >20 wt% iron content. The lake water is poor in sulfate and other electron acceptors and anoxic below 130 m. We used a large suite of biogeochemical analyses to assess rates and pathways of organic matter mineralization in these modern ferruginous sediments. Despite an abundance of ferric iron minerals known to support microbial respiration in laboratory experiments, organic matter degradation proceeds predominantly through methanogenesis. Iron reduction appears to be quantitatively important only in the upper one centimeter of the sediment column, whereas below this zone ferric iron minerals are still present. This implies that ferric iron can be buried over geologic timescales, even in the presence of labile organic carbon. Co-existence of methane and ferric iron throughout the sediment further suggests negligible iron-dependent anaerobic methane oxidation. Tendency towards methanogenesis, without anaerobic methane oxidation, implies that methanogenesis could have been important to organic matter mineralization in Precambrian times, potentially supporting high atmospheric CH_4 concentrations. However, this depends critically on the reactivity of primary Fe(III) minerals towards biological Fe(III) reduction and this reactivity thus likely played a key role in regulating Earth's early climate.

IODP

North Atlantic cooling and freshening from 3.65–3.5 Ma sets conditions for Northern Hemisphere ice sheet growth?

C. Karas[1], N. Khélifi[2], A. Bahr[3], D. Naafs[4], D. Nürnberg[5], J. Herrle[6]

[1] Instituto de Geografía, Pontificia Universidad Católica de Chile, Santiago, Chile
[2] Springer, a part of Springer Nature, Tiergartenstrasse 17, 69121, Heidelberg, Germany
[3] Ruprecht-Karls-Universitaet Heidelberg, Institut fuer Geowissenschaften, Im Neuenheimer Feld 234, 69120 Heidelberg, Germany
[4] Organic Geochemistry Unit, School of Chemistry and Cabot Institute, University of Bristol, Bristol, UK
[5] GEOMAR Helmholtz Centre for Ocean Research Kiel, Wischhofstrasse 1-3, 24148 Kiel, Germany
[6] Goethe-University Frankfurt, Altenhoeferallee 1, 60438, Frankfurt am Main, Germany

The North Atlantic Current (NAC) as part of the Atlantic Meridional Overturning Circulation (AMOC) is the major supplier of heat and salt into the northern North Atlantic. Pliocene changes of AMOC strength were speculated to either have amplified or diminished the Northern Hemisphere Glaciation (NHG) 2.7 million years ago (Ma). However, from the North Atlantic, little evidence is known about AMOC changes at around 3.6 Ma. At this time the intensification of NHG started and culminated in the first major glacial M2 event at 3.3 Ma. To elaborate the climatic effects of variations in the NAC during this early stage of NHG, we here present millennial-scale resolved records from Deep Sea Drilling (DSDP) Site 610A in the northern North Atlantic (Fig. 1). Our data of planktic foraminiferal Mg/Ca-based sea surface temperatures ($SST_{Mg/Ca}$) and ice volume corrected salinity approximations ($\delta^{18}O_{IVC\text{-}seawater}$) span the critical time period 4-3.3 Ma (Fig. 1a, b). From 3.65 to 3.5 Ma, we observe a distinct ~3.5ºC cooling and ~0.7‰ freshening of the sea surface, which we interpret to reflect a weakened NAC. At the same time Arctic sea ice grew and benthic $\delta^{13}C$ in the South Atlantic suggest a weakened AMOC (Fig. 1c, d). We conclude that the weakened NAC in response to a sluggish AMOC fostered sea ice formation in the Arctic Ocean and high-latitude North Atlantic, which might have preconditioned the climate for subsequent continental glaciations (Fig.1a-e).

References
Bachem, P.E., et al., 2018. Highly variable Pliocene Sea surface conditions in the Norwegian Sea. Clim. Past 13, 1153–1168. https://doi.org/10.5194/cp-13-1153-2017.
Bell, D.B., et al., 2014. Local and regional trends in Plio-Pleistocene ?18O records from benthic foraminifera. Geochem. Geophys. Geosyst. 15 (8), 3304–3321.
de Boer, B., et al., 2014. Persistent 400,000-year variability of Antarctic ice volume and the carbon cycle is revealed throughout the Plio-Pleistocene. Nat. Comm. 5, 2999. https://doi.org/10.1038/ncomms3999.

De Schepper, S., et al., 2013. Northern hemisphere glaciation during the globally warm early late Pliocene. PLoS One 8 (12), e81508. https://doi.org/10.1371/journal.pone.0081508.
Karas, C., et al., 2017. Pliocene oceanic saways and global climate. Sci. Rep. 7, 39842.
Karas, C., Khelifi, N., Bahr, A., Naafs, B.D.A., Nürnberg, D, Herrle, J. O., 2020. Did North Atlantic cooling and freshening from 3.65-3.5 Ma precondition Northern Hemisphere ice sheet growth?. Global Planet. Change 185, doi:10.1016/j.gloplacha.2019.103085.
Knies, J., et al., 2014a. The emergence of modern sea ice cover in the Arctic Ocean. Nat. Comm. 5. https://doi.org/10.1038/ncomms6608.
Knies, J., et al., 2014b. Effect of early Pliocene uplift on late Pliocene cooling in the Arctic–Atlantic gateway. Earth Planet. Sci. Lett. 387, 132–144.
Mudelsee, M., Raymo, M.E., 2005. Slow dynamics of the northern hemisphere glaciation. Paleoceanography 20, https://doi.org/10.1029/2005PA001153. PA4022.

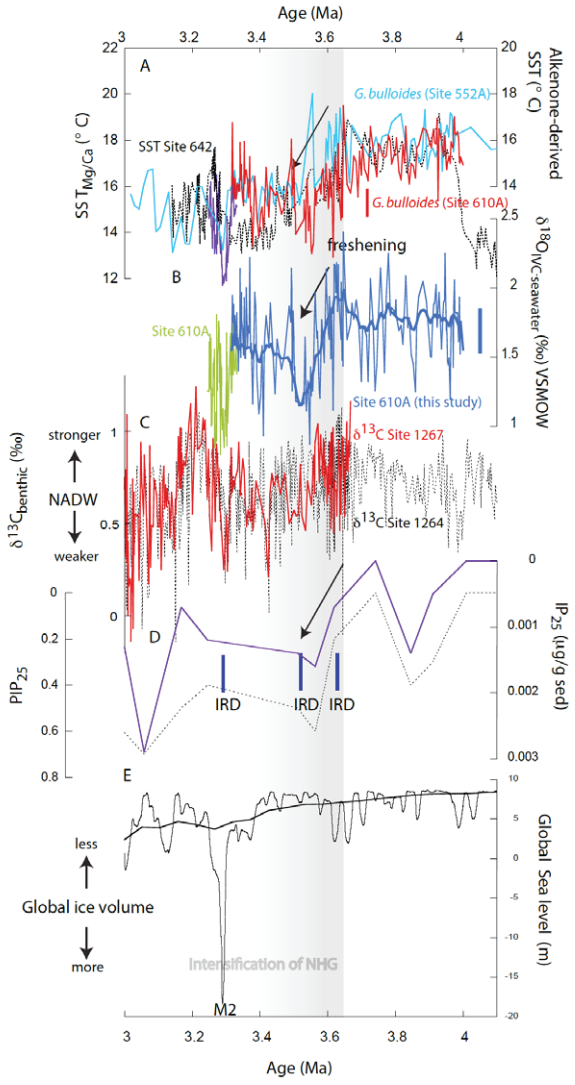


Fig. 1: Pliocene development of the North Atlantic (from Karas et al., 2019). (A) G. bulloides SSTMg/Ca from North Atlantic Site 610A (red; this study) and during M2 (short record in purple; De Schepper et al., 2013) in comparison to G. bulloides SSTMg/Ca from Site 552A (light blue; Karas et al., 2017), alkenone-derived SST from Norwegian Sea Site 642 (dashed; Bachem et al., 2018). (B) δ18OIVC-seawater records from Site 610A (blue; this study) and from a previous study during glacial M2 event

IODP

Diagenetic overprint of Fe minerals in deep subseafloor sediments from the Nankai Trough offshore Japan: New insights from geochemical and rock magnetic analyses

M. Köster[1], M.Kars[2], M.-Y. Tsang[3], V. B. Heuer[4], Y. Morono[5], F. Inagaki[5,6], S. Kasten[1,4,7], S. Henkel[1,4], and IODP Exp. 370 Scientists

[1] Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
[2] Center for Advanced Marine Core Research, Kochi University, Nankoku, Japan
[3] Department of Earth Sciences, University of Toronto, Toronto, Canada
[4] MARUM – Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany
[5] Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Sciences and Technology, Nankoku, Japan
[6] Mantle Drilling Promotion Office, Institute for Marine-Earth Exploration and Engineering, Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan
[7] University of Bremen, Faculty of Geosciences, Bremen, Germany

IODP Expedition 370 (Temperature Limit of the Deep Biosphere off Muroto) drilled Site C0023 down to 1180 mbsf in the Nankai Trough off Shikoku Island, Japan, to explore the upper temperature limit of microbial life in the deep sedimentary biosphere. The sediments at Site C0023 consist of turbidite-deposited mud, silt and sand accumulated on a sequence of basin-style-deposited hemipelagic mudstones. The turbidite deposition led to a significant increase in sedimentation rates (Heuer et al., 2017).

Fe cycling is considered an important process in the deep biosphere and its role, especially the coupling between Fe and S, is subject of current research (e.g., Riedinger et al., 2010; Meister et al., 2019). Fe (oxyhydr)oxides are main carriers of the sedimentary magnetic signal (e.g., Roberts et al., 2015). Diagenetic cycling, in particular the reductive dissolution of Fe (oxyhydr)oxides driven by microbial degradation of organic matter and/or by reactions with hydrogen sulfide, may lead to transformations of primary ferrimagnetic Fe (oxyhydr)oxides to secondary paramagnetic Fe sulfides (Berner, 1970), and thus, to modification of rock magnetic properties.

In this study, we aim at assessing the alteration of the primary sedimentary record at Site C0023, including pyritization, authigenic formation of secondary minerals as well as effects on rock magnetic properties such as magnetic susceptibility. To investigate the Fe mineralogy, sequential extractions of differently reactive Fe (oxyhydr)oxides as well as Fe sulfides are combined with end-member unmixing of isothermal remanent magnetization (IRM) acquisition curves and scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS).

Our results show that the total Fe content in sediments of Site C0023 is relatively constant at ~4.2 wt%. The reactive Fe pool including Fe carbonates and Fe (oxyhydr)oxides represents 25% of the total Fe. Based on sequential extractions, the fraction associated with amorphous Fe oxides such as ferrihydrite and lepidocrocite is the dominant Fe fraction with ~0.7 wt%. This indicates that significant amounts of bioavailable Fe is present even at greater sediment depth at Site C0023. The end-member unmixing revealed that fine-grained magnetite is the main carrier of the sedimentary signal. It is enriched between 630 and 940 mbsf, coinciding with high magnetic susceptibility values. Large (titano-)magnetite grains (>10 µm) are also present in the same depth interval. Fe sulfide, mainly pyrite, is ubiquitous in all investigated intervals. Pyrite peaks

at 552 and 1033 mbsf correlate with zones of low magnetic susceptibility, indicating the conversion of ferrimagnetic Fe oxides into paramagnetic pyrite. However, pyritization only affects 5 to 30% of the reactive Fe pool. Rock magnetic properties also show the presence of the metastable Fe sulfide greigite in the upper interval between 200 and 450 mbsf. The preservation might be caused by limited hydrogen sulfide availability and/or the increase in sedimentation rates.

Combining our geochemical and rock magnetic data improves the understanding of Fe cycling in subseafloor sediments and the role of Fe minerals in maintaining life in the deep biosphere.

Acknowledgements - This research used samples and data provided by the International Ocean Discovery Program (IODP). We would like to thank all personnel involved in the operations aboard the *DV Chikyu* during Expedition 370 and the support team at Kochi Core Center. We further would like to thank the German Research Foundation (DFG) for funding this project (project number: 388260220) in the framework of the priority program 527 (Bereich Infrastruktur – International Ocean Discovery Program). We are also grateful to the Japan Society for the Promotion of Science (JSPS) for funding M. Köster's research stay at Kochi Core Center in the framework of the JSPS Summer Program 2019.

References

Berner, R.A., 1970. American Journal of Science 268.
Heuer, V.B. et al., 2017. In Proceedings of the IODP Volume 370.
Meister, P. et al., 2019. Scientific Reports 9.
Riedinger, N. et al., 2010. Geology 38.
Roberts, A., 2015. Earth-Science Reviews 151.

IODP

Terrestrial climate and ecosystem dynamics in SE Africa during the emergence, persistence and extinction of archaic hominids (4–2 Ma) based on cores from IODP Expedition 361

A. Koutsodendris, J. Pross

Institute of Earth Sciences, Heidelberg University, Im Neuenheimer Feld 234–236, 69120 Heidelberg, Germany

This project aims to unravel terrestrial ecosystem and climate dynamics – and thus the extrinsic boundary conditions for the evolution of early hominids – in SE Africa during the 'mid'-Pliocene to early Pleistocene (c. 4–2 Ma). To achieve this goal, a land-sea correlation off SE Africa will be established based on cores from IODP Expedition 361 (Hall et al., 2017) providing the first continuous record of terrestrial ecosystem and climate change in SE Africa for the 'mid'-Pliocene to early Pleistocene interval. Methodologically, the project goal will be reached through the integration of palynological (pollen and spores) and XRF core scanning analyses from IODP Site U1478 (off the Limpopo River mouth, Mozambique Channel). Site U1478 is ideally suited for the proposed research because of its (i) exceptional stratigraphical completeness and high sedimentation rates, (ii) proximity to the Limpopo River delta, which warrants high input of terrigenous material, (iii) high sensitivity in recording terrestrial climate variability as inferred by previous studies on short cores from the near vicinity (e.g., Caley et al., 2018), (iv) excellent preservation and high diversity of terrestrial palynomorphs, and (v) proximity to the 'Cradle of Humankind' paleoanthropological site in South Africa.

The integration of the palynological and element geochemical proxy data will allow detailed assessment of the character, timing, magnitude, and tempo of ecosystem and climate variability in the Limpopo River catchment during critical intervals of archaic hominid evolution (notably *Australopithecus africanus*). Thus, it will become possible not only to clarify whether intervals of particularly strong environmental change indeed coincided with steps in hominid emergence and extinction, but also to identify the exact nature of this change shedding new light on the potential causal links between environmental forcing and human evolution.

References

Caley, T., Extier, T., Collins, J.A., Schefuß, E., Dupont, L., Malaize, B., Rossignol, L., Souron, A., McClymont, E.L., Jimenez-Espejo, F.J., Garcia-Comas, C., Eynaud, F., Martinez, P., Roche, D.M., Jorry, S.J., Charlier, K., Wary, M., Gourves, P.Y., Billy, I., Giraudeau, J., 2018. A two-million-year-long hydroclimatic context for hominin evolution in southeastern Africa. Nature 560, 76–79.
Hall, I.R., Hemming, S.R., LeVay, L.J., and the Expedition 361 Scientists, 2017. South African Climates (Agulhas LGM Density Profile). Proceedings of the International Ocean Discovery Program, volume 361.

IODP

Stratigraphic overview of the Marie Byrd Land sector of the West Antarctic continental margin from a new geophysical survey in conjunction with IODP Expedition 379

R. Lamb[1], K. Gohl[1], G. Leitchenkov[2], IODP Expedition 379 Scientists

[1] Alfred Wegener Institute Helmholtz-Centre for Polar and Marine Research, Bremerhaven, Germany
[2] VNIIOkeangeologia, St. Petersburg, Russia

During the Antarctic Summer season of 2019, a marine geophysical survey took place in the understudied Marie Byrd Land sector of the West Antarctic continental margin, between the Amundsen Sea and Ross Sea. This research was undertaken by the Polar Marine Geosurvey Expedition onboard the RV Academic Alexander Karpinsky as part of the 64th Russian Antarctic Expedition (RAE). The survey forms a network of regional seismic lines, totaling 2260 km in length, connecting the Ross Sea sector to the Amundsen Sea sector, including a key tie to the IODP Expedition 379 drill sites via pre-existing lines. The geophysical data collected during the survey includes seismic reflection data, differential magnetic and gravimetric observations as well as multibeam swath bathymetry.

The most significant data obtained is eight seismic reflection profiles covering the continental rise, collected with a 7 km streamer of 560 active channels. Across the working area the sedimentary succession reached a maximum thickness of 2-2.5 km with sedimentary ages estimated, in-line with other studies, from 79 Ma to present. The seismic sedimentary package has been divided into key units, after Lindeque et al. (2016), from AS-1 to AS-10, representing the preglacial (79-34 Ma), „transitional" (34-16 Ma) and synglacial (16-0 Ma) complexes. Preliminary correlation to the 2019 IODP sites has identified an unconformity of probable top-Miocene age (5.33 Ma) which can be traced across the working area, providing one of the first direct ties to a core-derived age model for this sector of the West Antarctic continental margin.

Stratigraphic and geomorphic analysis shows that the sedimentary package has been affected to varying degrees by both downslope processes and depositional processes from oceanographic currents. As is expected from a continental slope environment, downslope processes are more dominant closer to the continental shelf, while the style of sedimentation has changed through time as the continental shelf has developed and extended. However, there is also an east-west pattern of sedimentati-

on which reflects differences in the dominant sedimentary processes between the Amundsen and Ross Seas. Previous studies along the continental margin have linked changes in sedimentary processes to changes in climate and the advance and retreat of the ice sheets. The new data will be further analysed in order to reconstruct the palaeo-environmental conditions, particularly in regard to ice advance and retreat, based on the pattern of sedimentary processes.

Further processing and interpretation of the new data obtained during the PMGE-2019 expedition is currently undertaken in a joint research project between VNIIOkeangeologia (Russian Federation) and the Alfred Wegener Institute.

References

Lindeque, A., Gohl, K., Henrys, S., Wobbe, F., Davy, B. (2016). Seismic stratigraphy along the Amundsen Sea to Ross Sea continental rise: A cross-regional record of pre-glacial to glacial processes of the West Antarctic margin. Palaeogeography, Palaeoclimatology, Palaeoecology, 443, 183-202, doi:10.1016/j.palaeo.2015.11.017.

IODP

Hydroclimate and vegetation changes in SE Africa across the last interglacial period reconstructed from the sediment record of IODP Site U1477, Mozambique Channel

S. Lauterbach[1,2], N. Andersen[2], T. Blanz[1], J. van der Lubbe[3], R. R. Schneider[1,2]

[1] Institute of Geosciences, Kiel University, 24118 Kiel, Germany
[2] Leibniz Laboratory for Radiometric Dating and Stable Isotope Research, Kiel University, 24118 Kiel, Germany
[3] Cluster Geochemistry & Geology, Department of Earth Sciences, VU University Amsterdam, 1081 HV Amsterdam, The Netherlands

Subtropical SE Africa is generally expected to face substantial hydroclimatic changes in response to progressive global warming. However, their extent and socio-economic impacts are still difficult to assess. In this context, investigating regional hydroclimate variability and associated vegetation changes during the last interglacial, a time interval with higher temperatures than today, might provide important information about the mechanisms that control climate variability in the area and thus allow better forecasts of future climate development. Furthermore, improved knowledge about last interglacial hydroclimate variability in SE Africa could also provide insights into key episodes of human evolution, including the cultural evolution of the first anatomically modern humans and their migration out of Africa.

To reconstruct past changes in terrestrial hydroclimate and vegetation in subtropical SE Africa, we have started to analyse marine sediments from IODP Site U1477, located at the western margin of the Mozambique Channel about 85 km off the Zambezi River delta. Here we present initial results on the stable hydrogen (δD) and carbon isotope (δ13C) composition of odd-numbered long-chain *n*-alkanes (*n*-C29, *n*-C31) preserved in the IODP Site U1477 sediments. These organic compounds are major constituents of the epicuticular waxes of higher terrestrial plants and transported to the study site by runoff from the Zambezi River. As *n*-alkane δD primarily records amount-controlled changes in the δD of regional precipitation through time, it can be used to reconstruct past hydroclimate variability in the Zambezi River catchment. In addition, *n*-alkane δ13C allows to trace past changes in the relative abundance of C3 (e.g. trees) and C4 plants (e.g. savanna grasses) in the catchment. These data are complemented by measurements of the concentration of long-chain alkenones (n-$C_{37:2}$, n-$C_{37:3}$) in the sediments. These are synthesized by surface water-growing marine haptophyte algae and their ratio, known as the $U^{K'}_{37}$ index, is largely dependent on the sea surface temperature (SST) at the time of haptophyte growth, allowing to reconstruct past SST variability in the SW Indian Ocean.

The preliminary chronostratigraphic framework for the part of the IODP Site U1477 sediment sequence that has been investigated so far is provided by a record of the stable oxygen isotope composition of benthic foraminifera ($\delta^{18}O_{benthic}$), indicating that it covers the time interval between ~80 and ~140 ka BP. Comparison of the $\delta^{18}O_{benthic}$ record with the $U^{K'}_{37}$-based SST reconstruction reveals a distinct warming of the SW Indian Ocean surface waters by ~1.5 °C at Termination II, which, however, apparently started slightly before the isotopically defined onset of Marine Isotope Stage (MIS) 5e. Maximum SSTs of ~28.0–29.0 °C occurred during MIS 5e before they progressively decreased to ~27.0–28.0 °C during MIS 5a-d. The δD signal of n-C_{29} and n-C_{31} reveals a distinct and unexpected variability across Termination II and MIS 5e. Most notable is a decrease by ~20 ‰ during Termination II, most likely reflecting a pronounced humidity increase in SE Africa at the onset of the last interglacial. Furthermore, a considerable variability of δD by up to 40 ‰ is observed throughout MIS 5e with a distinct episode of relatively high δD values between ~120 and ~125 ka BP, most likely representing an interval of pronounced dryness. This is in accordance with low n-alkane concentrations, which most probably reflects reduced input of terrestrial material by the Zambezi River. In the following, decreasing δD values during late MIS 5 likely indicate progressively increasing humidity over SE Africa during the transition into the last glacial.

These preliminary results clearly highlight the unique potential of the IODP Site U1477 sediments for reconstructing hydroclimatic changes in SE Africa across the last interglacial and elucidating the possible influence on the cultural evolution of early modern humans and their migration out of Africa.

ICDP

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

N. Leicher[1], B. Giaccio[2], B. Wagner[1], G. Mannella[3], L. Monaco[4], G. Zanchetta[3], S. Scheidt[1], E. Regattieri[5], S. Nomade[6], A. Pereira[7,6], T. Wonik[8], D. M. Palladino[4], E. M. Niespolo[9,10], P. R. Renne[9,10]

[1] Institute of Geology and Mineralogy, University of Cologne, Germany
[2] Istituto di Geologia Ambientale e Geoingegneria, Consiglio Nazionale delle Ricerche, Rome, Italy
[3] Department of Earth Sciences, University of Pisa, Italy
[4] Dipartimento di Scienze Della Terra, Sapienza-Università di Roma, Rome, Italy
[5] Istituto di Geoscienze e Georisorse, Consiglio Nazionale delle Ricerche, Pisa, Italy
[6] Laboratoire des Sciences du Climat et de l'Environnement (CEA-CNRS-UVSQ), Gif-sur-Yvette, France
[7] Ecole française de Rome, Rome, Italy
[8] Leibniz Institute for Applied Geophysics, Hannover, Germany
[9] Berkeley Geochronology Center, Berkeley, USA
[10] Department of Earth and Planetary Science, University of California, Berkeley, USA

The Fucino Basin is the largest and probably the only Central Apennine basin that hosts a thick, continuous lacustrine sediment succession documenting the environmental history from the Early Pleistocene to recent historical times. The basin is

located downwind of the Italian volcanic districts (< 150 km), which makes it the best candidate available in the central Mediterranean to construct a long and continuous tephrostratigraphic and tephrochronological record. Tephrostratigraphic investigations conducted on a first core (F1-F3) revealed 21 tephra layers of different Italian volcaoes. Among them several widespread and well-dated key Mediterranean marker tephra layers (e.g., Neapolitan Yellow Tuff, Y-1, Campanian Ignimbrite, Y-7, X-5, X-6 and Taurano Ignimbrite) were recognized and allowed to date, together with $^{40}Ar/^{39}Ar$ ages directly obtained from the Fucino tephra layers the record back to 190 ka (Giaccio et al., 2017; Giaccio et al., 2015). These tephrochronological information provided the basis for an age depth model of the F1-F3 core, which allowed to correlate sedimentological and (bio-) geochemical data from F1-F3 to climate variability (Mannella et al., 2019).

Based on these promising results, a new drilling site with a lower sedimentation rate was targeted, bringing forth two ~ 87 m long cores (F4-F5) of grey-whitish lacustrine calcareous marl, with a variable proportion of darkish clay. Borehole logging was carried out at the F4 site down to ~80 m. A composite succession of ~98 m was correlated based on line scan imaging, XRF scanning (ITRAX, COX Ltd), and whole-core paleomagnetic data (760 SRM, 2-G Enterprises). The core composite was then used for continuous subsampling at ~4 cm resolution for further (bio-) geochemical, sedimentological, and paleomagnetic analyses.

In addition to the already recognised tephra layers occurring in the section that overlaps with core F1-F3, ~110 additional tephra and cryptotephra horizons were identified in the composite sediment succession of the F4-F5 record, providing new insights into the Italian volcanic history for the poorly explored interval beyond 200 ka (Giaccio et al., 2019).

Here we present the first tephrostratigraphic and tephrochronological results for this interval, which is dominated by eruptions from the Sabatini, Vulsini, Vico, and Colli Albani volcanoes. Several important known eruptions were identified and dated for the first time in distal settings: e.g., Canino (256.8 ± 1.1 ka), Tufo Giallo di Sacrofano (288.0 ± 2.0 ka), Magliano Romano Plinian Fall (315.0 ± 2.0 ka), Orvieto-Bagnoregio Ignimbrite (335.8 ± 1.4 ka), Villa Senni (367.5 ± 1.6 ka), Pozzolane Nere and its precursor (408.5 ± 1.3 ka, and 407.1 ± 4.2 ka, respectively). Finally, a tephra located at the base of the succession was directly dated by $^{40}Ar/^{39}Ar$ at 424.3 ± 3.2 ka, thus extending the record back to the MIS 12/11 transition (~430 ka).

Ongoing geochemical analysis, including trace elements, Sr and Nd isotopes, and $^{40}Ar/^{39}Ar$ dating of both Fucino tephra and potential proximal counterparts will help to reveal their volcanic sources and enable further tephrostratigraphic correlations supported by independent age determinations. First results confirm the frequent activity of the Roman volcanoes, but also shed light on the volcanic activity of the Roccamonfina volcano and the Campanian Volcanic Zone. These results will contribute towards an improved MIS 11-MIS 7 Mediterranean tephrostratigraphy, which is still poorly characterized and exploited.

The recognition and dating of the numerous tephra layers from the F4-F5 record can be directly combined to construct a comprehensive age-depth series of biogeochemical proxies and geomagnetic excursions derived from the lacustrine sediments, forming the backbone for an independent, radioisotopically anchored chronology for the F4-F5 multi-proxy record. Through paleoclimatic alignments and geomagnetic excursion synchronizations, the independent Fucino chronology can be propagated to the North Atlantic records, and possibly on a global scale, setting the framework for a better understanding of the spatio-temporal variability, magnitude, and different expressions of Quaternary orbital and millennial-scale paleoclimatic changes.

References

Giaccio, B, E Regattieri, G Zanchetta, B Wagner, P Galli, G Mannella, E Niespolo, E Peronace, PR Renne, S Nomade, GP Cavinato, P Messina, A Sposato, C Boschi, F Florindo, F Marra and L Sadori (2015), A key continental archive for the last 2 Ma of climatic history of the central Mediterranean region: A pilot drilling in the Fucino Basin, central Italy, Scientific Drilling, 20 13-19.

Giaccio, B, EM Niespolo, A Pereira, S Nomade, PR Renne, PG Albert, I Arienzo, E Regattieri, B Wagner, G Zanchetta, M Gaeta, P Galli, G Mannella, E Peronace, G Sottili, F Florindo, N Leicher, F Marra and EL Tomlinson (2017), First integrated tephrochronological record for the last □190 kyr from the Fucino Quaternary lacustrine succession, central Italy, Quaternary Science Reviews, 158 211-234.

Giaccio, B, N Leicher, G Mannella, L Monaco, E Regattieri, B Wagner, G Zanchetta, M Gaeta, F Marra, S Nomade, DM Palladino, A Pereira, S Scheidt, G Sottili, T Wonik, S Wulf, C Zeeden, D Ariztegui, GP Cavinato, JR Dean, F Florindo, MJ Leng, P Macrì, E Niespolo, PR Renne, C Rolf, L Sadori, C Thomas and PC Tzedakis (2019), Extending the tephra and palaeoenvironmental record of the Central Mediterranean back to 430 ka: A new core from Fucino Basin, central Italy, Quaternary Science Reviews, 225 106003

Mannella, G, B Giaccio, G Zanchetta, E Regattieri, EM Niespolo, A Pereira, PR Renne, S Nomade, N Leicher, N Perchiazzi and B Wagner (2019), Palaeoenvironmental and palaeohydrological variability of mountain areas in the central Mediterranean region: A 190 ka-long chronicle from the independently dated Fucino palaeolake record (central Italy), Quaternary Science Reviews, 210 190-210.

IODP

Deep water circulation patterns in the Atlantic during MIS 11

J. M. Link, N. Frank

Institute of Environmental Physics, Heidelberg University

Ocean circulation plays a key role in modulating the Earth's climate, especially over glacial-interglacial cycles. During Marine Isotope Stage (MIS) 11, a higher-than-present seal level was recorded (Dutton et al., 2015) as well as an extreme warmth in the Artic realm (Melles et al., 2012) despite relatively weak orbital forcing (Laskar et al., 2004). While traditional proxies like benthic stable carbon isotopes indicate a strong Atlantic Meridional Overturning Circulation (AMOC) during MIS 11 (e.g. Dickson et al., 2009), concern arose regarding the deep water formation in the Nordic Seas because of the freshwater input coming from a melting Greenlandic Ice Sheet (Kandiano et al., 2016).

In order to reconstruct the dynamics of the AMOC, we investigate the routing of deep water masses in the Atlantic. Therefore, the authigenic fraction of deep sea sediment cores from all over the Atlantic is analyzed for its Nd isotopic composition.

Sediment cores from close to the Greenland-Scotland-Ridge show persistent overflow waters and therefore an active deep water formation throughout MIS 11 only disrupted by a short deterioration. These northern sourced water masses are exported to the south and show an almost undiluted presence even in the south eastern Atlantic. Thus, one can conclude, that an overall strong overturning circulation prevailed during MIS 11.

References

Dickson, A. J., Beer, C. J., Dempsey, C., Maslin, M. A., Bendle, J. A., McClymont, E. L., and Pancost, R. D. (2009): Oceanic forcing of the Marine Isotope Stage 11 interglacial. Nature Geoscience 2, 428-433.

Dutton, A., Carlson, A. E., Long, A. J., Milne, G. A., Clark, P. U., DeConto, R., Horton, B. P., Rahmstorf, S., and Raymo, M. E. (2015): Sea-level rise due to polar ice-sheet mass loss during past warm periods. Science 349, 153.

Kandiano, E. S., van der Meer, M. T. J., Bauch, H. A., Helmke, J., Damsté, J. S. S., and Schouten, S. (2016): A cold and fresh ocean surface in the Nordic Seas during MIS 11: Significance for the future ocean. Geophysical Research Letters 43, 10,929–910,937.

Laskar, J., Robutel, P., Joutel, F., Gastineau, M., Correia, A. C. M., and Levrard, B. (2004): A long-term numerical solution for the insolation quantities of the Earth. A&A 428, 261-285.
Melles, M., Brigham-Grette, J., Minyuk, P. S., Nowaczyk, N. R., Wennrich, V., DeConto, R. M., Anderson, P. M., Andreev, A. A., Coletti, A., Cook, T. L., Haltia-Hovi, E., Kukkonen, M., Lozhkin, A. V., Rosén, P., Tarasov, P., Vogel, H., and Wagner, B. (2012): 2.8 Million Years of Arctic Climate Change from Lake El'gygytgyn, NE Russia. Science 337, 315-320.

ICDP

Genomic Explorations into the Microbial Metabolism of an Active Rift System

D. Lipus[1], Q. Liu[1], M. Alawi[1], D. Wagner[1], K. Tinker[2], D. Gulliver[2], J. Kallmeyer[1]

[1] GFZ Geoforschungszentrum Potsdam, Telegrafenberg, Potsdam, Germany
[2] National Energy Technology Laboratory, Pittsburgh, Pennsylvania, United States.

With frequent seismic activity, consistently high CO2 concentrations, and temperatures beyond 100° C, the Eger Rift in Western Bohemia represents a worldwide unique subsurface ecosystem and scientifically relevant location to study microbial behavior and bio-geo interactions under extreme conditions. To investigate microbial life in this rare environment we collected sediment samples from a core drilled across 240m into an active Mofette as part of the Intercontinental Drilling Program "Drilling the Eger Rift". Applying an innovative DNA extraction approach we were able to recover DNA for genomic investigations from this low biomass environment. Microbial abundance was assessed using qPCR, ranged between 10^2 to 10^7 16S rRNA gene copy numbers, and demonstrated microbial life to persist in the terrestrial subsurface below 200m. Highest microbial abundances were observed around a CO^2 reservoir at a depth of 70 – 90 meters. Using a next generation sequencing approach, we are in the process of exploring this novel microbial ecosystem. First results predict a community dominated by acidophilic and fermentative Proteobacteria and Firmicutes that is driven by pH and has adapted to thrive in the unique subsurface settings. In addition, both qPCR and amplicon sequencing revealed the presence of methanogenic Archaea across core sediments, which together with the identification of CO^2 fixating taxa confirms CO^2 to be a major energy and driving force in this ecosystem. Going forward metagenomic binning will allow the reconstruction of a distinct array of metagenome assembled genomes (MAGs). Annotation of draft genomes will allow us to investigate metabolic processes, build metabolic networks, and identify bio-geo interactions potential. Altogether, our results advance the current understanding of microbial life in tectonic subsurface systems under CO^2 degassing conditions and provide valuable data for future explorations.

Fig. 1: Impressions from 2019 Eger Rift Drilling Campagin

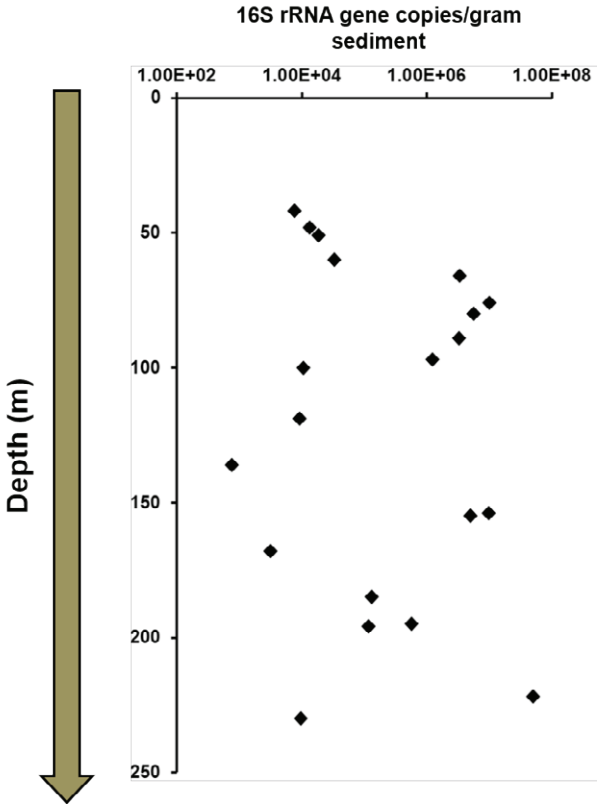


Fig. 2: Microbial 16S rRNA gene abundance across the recovered 250m drill core

IODP

Changes in Pacific Meridional Overturning Circulation during the Miocene transition from an almost ice-free to a permanently glaciated Earth: Preliminary results from Western Pacific IODP Site U1490

J. Lübbers[1], A. E. Holbourn[1], W. Kuhnt[1], N. Andersen[2], D. Kulhanek[3]

[1] Institute of Geosciences, Christian-Albrechts-University, Kiel, Germany
[2] Leibniz Laboratory for Radiometric Dating and Stable Isotope Research, Christian-Albrechts-University, Kiel, Germany
[3] International Ocean Discovery Program, Texas A&M University, TX77845, USA

During IODP Expedition 363, an extended, undisturbed Miocene sediment succession was retrieved at a strategic location at the heart of the Western Pacific Warm Pool (Site U1490, 5°48.95′N, 142°39.27′E in 2341 m water depth on the Eauripik Rise, north of Papua New Guinea). This well-preserved, carbonate-rich sediment archive is ideal to monitor changes in Pacific water masses and meridional overturning circulation through different mean states of Earth's climate variability during the transition from an almost ice-free to a permanently glaciated world. Our project focuses on the interval ~18 to 9 Ma, which was marked by several fundamental climate re-organizations offering the opportunity to investigate the relationships between changes in radiative forcing, variations in the Equator-to-pole temperature gradient and shifts in atmosphere-ocean circulation on a warmer-than-modern Earth. We are currently developing

a high-resolution benthic isotope cyclostratigraphy, which will be integrated with the well-resolved shipboard magnetostratigraphy, thus allowing direct correlation to the Geomagnetic Polarity Time Scale (GPTS). Our results will be combined with high-resolution records from IODP Site U1443 in the central Indian Ocean, ODP Site 1146 in the South China Sea and IODP Sites U1337 and U1338 in the eastern equatorial Pacific to assess changes in ocean circulation, productivity and inter-basinal connectivity and their implications for the large-scale overturning circulation and climate evolution.

ICDP

Trophic level reconstruction of hominins in the Southern African Early Pleistocene

T. Luedecke[1], J. N. Leichliter[2], N. Duprey[3], O. Kullmer[4,5], D. Stratford[6], H. Vonhof[3], M. Bamford[7], A. Mulch[1,8], A. Martinez-Garcia

1 Senckenberg Biodiversity and Climate Research Centre, Frankfurt, Germany
2 Institute of Geosciences, Johannes Gutenberg University, Mainz, Germany
3 Max Planck Institute for Chemistry, Mainz, Germany
4 Department of Paleoanthropology, Senckenberg Research Institute and Natural History Museum Frankfurt, Germany
5 Institute for Ecology, Evolution and Diversity, Department of Paleobiology and Environment, Goethe University, Frankfurt, Germany
6 School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand, Johannesburg, South Africa
7 Evolutionary Studies Institute and School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa
8 Institute of Geosciences, Goethe University Frankfurt, Frankfurt, Germany

Direct evidence regarding when and to what degree our early ancestors incorporated animal resources into their diets is sparse. The strongest, but indirect, evidence for meat (and bone marrow) consumption so far are cut and percussion marks on fossil bone material. Yet, meat eating has major implications for the evolution of the hominin lineage, as it is a calorie-dense, high-quality food whose consumption has been linked to brain expansion and other significant adaptations in the genus *Homo*. Moreover, the shift from a mainly vegetarian diet represents an encroachment of hominins into the large carnivore guild, presenting our ancestors with entirely new competitive pressures. A better understanding of animal resource consumption by early hominins, for example in the genus *Australopithecus*, is crucial to reconstruct the timing of changes in hominin dietary behavior and to evaluate their position in (paleo)food-webs.

Nitrogen isotope ($\delta^{15}N$) data are frequently used in conjunction with carbon isotopes ($\delta^{13}C$) to reconstruct diet because $\delta^{15}N$ values reveal information about an individual's position in their (paleo-)food web. Until now, $\delta^{15}N$ has only been determined in hominin specimens younger than 100,000 years because large quantities of relatively unaltered collagen are required.

Here, we utilize a novel biogeochemical method, which measures nitrogen isotope ratios with high precision on extremely small sample sizes (~5 nanomoles of N) of diagenetically resistant tooth enamel and hence permits to analyze early and mid-Pleistocene fossil (hominin) tooth enamel samples for the first time. We present $\delta^{15}N_{enamel}$ data of modern fauna from a well-constrained ecosystem (Gorongosa National Park, Mozambique), and compare these to $\delta^{15}N_{enamel}$ values of a fossil fauna assemblage associated with *Australopithecus* from Early Pleistocene Sterkfontein Member 4.

IODP

Delta Drift – a new type of drift discovered during IODP Expedition 359, Maldives

T. Lüdmann, C. Betzler

Universität Hamburg - Institut für Geologie

Based on high-resolution reflection seismic and core data from IODP Expedition 359 we introduce a new channel-related drift type attached to a carbonate platform slope, which we termed delta drift. Like a river delta, such sedimentary bodies are comprised of several stacked lobes and connected to a point source. The delta drifts were deposited at the exit of gateways that connected the Inner Sea of the Maldives carbonate platform with the open ocean. The channels served as conduits focusing and accelerating the water flow; Entrained material was deposited at their mouth where the flows relaxed. The lobe-shaped calcareous sediment drifts must have formed under persistent water through flow. Sediment supply was relatively high and continuous, resulting in an average sedimentation rate of 17 cm ka^{-1}. The two delta drifts occupy 342 and 384 km^2, respectively; with a depositional relief of approximately 500 m. They have a sigmoidal clinoform reflection pattern with a particular convex upward bending of the foresets. In the Maldives the drift onset marks the transition from a sea-level controlled to a progressively current dominated depositional regime. This major event occurred in the Serravallian about 13 Ma ago, leading to the partial drowning of the carbonate platform and the creation of shallow seaways.

The depositional environment of the delta drifts changed from deep water (>500) to shallow-water conditions at their topsets, indicated by the overall coarsening upward trend in grain size and the presence of shallow water large benthic foraminifers at their top. Similar deposits have been recently identified in the in the Montagna della Maiella, Italy. Here, the Upper Cretaceous (Campanian–Maastrichtian) bioclastic wedge of the Orfento Formation comprises all characteristics of a delta drift including depositional architecture, dimension, sedimentary facies and the association with a gateway. Because delta drift bodies share several characteristics with carbonate ramp depositional systems, we propose that other delta drift examples in the geological record may have been miss-interpreted, especially in areas where depositional geometries cannot be observed at a seismic scale.

IODP

Serpentinite mud volcanism and exhumation of fore arc- and lower plate material in the Mariana convergent margin system (IODP Expedition 366)

I. Miladinova, W. Kurz, A. V. Del Gaudio, W. E. Piller, K. Krenn

Institute of Earth Sciences, NAWI Graz Geocenter, University of Graz, Heinrichstrasse 26, 8010 Graz, Austria

Serpentine seamounts located in the forearc region of a subduction zone setting represent an excellent natural laboratory for studying the geochemical processes acting along convergent plate margins and the associated natural hazards as well as the forearc structure and fault patterns. Active serpentinite mud volcanoes are currently restricted only to the Izu-Bonin-Mariana system, where old (presumably Cretaceous) oceanic lithosphere is subducting in the absence of an accretionary prism.

IODP Expedition 366 recovered cores from three serpentinite mud volcanoes at increasing distances from the Mariana trench (Yinazao, Fantangisña and Asùt Tesoru). Most of the material consists of serpentinite mud containing lithic clasts from the underlying forearc crust and mantle as well as from the subducting Pacific plate. Pelagic sediments and volcanic ash deposits underlying the mud volcanos were also recovered. Recycled materials from the subducted slab consist of metavolcanics rocks, metamorphosed pelagic sediments including cherty limestone as well as fault rocks.

Preliminary investigation of recovered sedimentary clasts from the summit of Fantangisña Seamount revealed that they contain primary calcite veins, whereas the latest veins are composed of aragonite ($CaCO_3$) and barite ($BaSO_4$).

Recovered clasts from the flank consist mainly of ultramafic rocks with various degrees of serpentinization. The serpentinite veins consist of lizardite and chrysotile, which suggests rather low temperatures of serpentinization (below 200 °C). Petrological analysis of metabasalt clast from the same drilling hole shows changes in the mineral composition within the different intervals of the core. The composition of clinopyroxene varies between aegirine-augite and omphacite, but augite is also present. The presence of phengite with Si content of 3.5-3.8 a.p.f.u. indicates minimum pressure of 0.7 GPa at ~250 °C.

Furthermore, providing a detailed characterization of the fluids composition and transport would allow the better constraining of the tectonic and metamorphic history as well as the physical properties of the subducting Pacific Plate. Obtaining data on that point is in progress and will be presented additionally.

ICDP

Drillcore GT1 of the ICDP Oman Drilling Project: Implications on the accretion of lower oceanic crust

D. Mock[1,2], B. Ildefonse[2], D. Garbe-Schönberg[3], S. Müller[3], D. A. Neave[4], J. Koepke[2], The Oman Drilling Project Phase 1 Science Party4

[1] Géosciences Montpellier, Université de Montpellier, CNRS, Université des Antilles, Montpellier, France
[2] Institut für Mineralogie, Leibniz Universität Hannover
[3] Institut für Geowissenschaften, Christian-Albrechts-Universität zu Kiel
[4] Department of Earth and Environmental Sciences, University of Manchester
[5] different institutions of Earth Sciences worldwide

Since several decades, the Sumail ophiolite at the northeastern coast of the Sultanate of Oman has been regarded as the best-exposed analogue of fast-spreading oceanic crust on land. Therefore, it provides an ideal field laboratory for investigating the processes taking place in the crust and upper mantle section beneath fast-spreading mid-ocean ridges (MORs). As a part of the International Continental Drilling Program (ICDP), the Oman Drilling Project drilled five 300 to 400 m long cores from the mantle to the dyke/gabbro transition in order to sample the large regions of interest along the crust. Drill site GT1 is located in the Wadi Gideah (Wadi Tayin massif) which has already been subject of many surface field studies. The GT1 core obtained from the lower layered gabbro section can be embedded into a reference profile through the entire Oman paleocrust defined in Wadi Gideah (Kelemen et al.,1997). The core was investigated with diverse petrographic, petrological, geochemical and microstructural tools in order to better understand the accretion of the gabbroic lower crust at fast-spreading MORs.

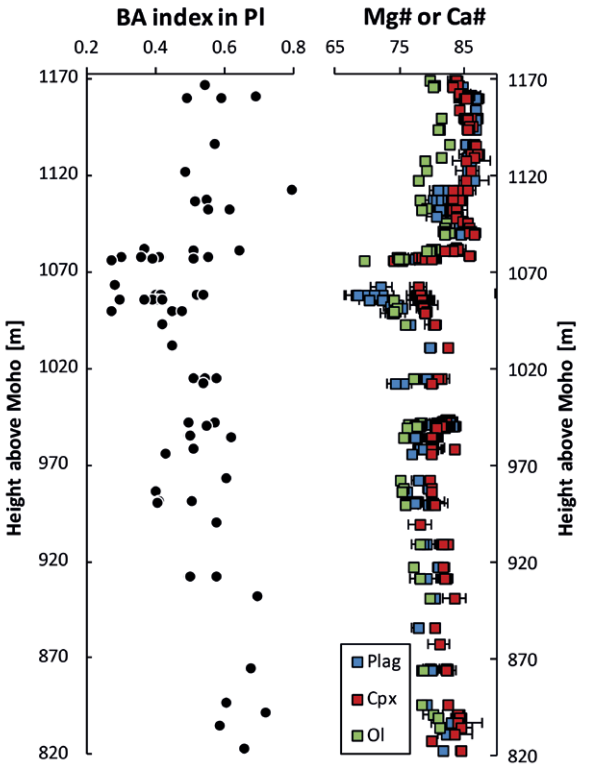


Fig. 1: BA-index of plagioclase (left) and petrological parameters of olivine, clinopyroxene and plagioclase plotted versus the height above the Moho. Note the significant minimum of all data sets at 1050 m above the Moho. Black bars in the rightern plot give the standard deviation from the mean.

Beside olivine gabbro and gabbro, which form the vast majority of the obtained samples, there are a few coherent, cm-thick layers of wehrlite and troctolite. The presence of these lithologies in the drill cores emphasizes the importance of drilling, since wehrlites have not been sampled within the weathered outcrop samples of the reference profile, and troctolites only in the lowermost part of the crust. Wehrlitic layers are of particular interest since they indicate the presence of moderate water activities that suppressed plagioclase nucleation during primary crystallization. Mg#s (Mg# = Mg / (Mg+Fe)x100; molar basis) in clinopyroxene vary between 74 and 86, and Mg#s of some primary olivine relicts vary between 70 and 83. Ca# (Ca# = Ca / (Ca+Na)x100; molar basis) in plagioclase varies between 68 and 87. The high spatial resolution of the drilled samples shows that these values are not only in good agreement with the surface samples but show clear trends on a scale of tens of meters, that have not been observed within the reference profile: at a crustal height of 1050 m, both Mg#s and Ca# show distinct minima with progressively increasing trends both up and down section (Fig. 1). To quantify the pole figure symmetry, i.e. fabric, of plagioclase, we use the BA index (Koepke et al., 2014) which varies between 0 for a purely foliated and 1 for a purely lineated symmetry. This index, obtained by Electron Backscattered Diffraction, correlates with the petrological data indicating a more foliated plagioclase fabric that correlates with the minima in Mg#s and Ca# (Fig. 1), which may imply a stronger influence of compaction and a lesser influence of shearing at this horizon. We interpret the correlation between petrological and microstructural data as indicator for the influx of more

evolved melt leading to a concurrent weakening in plagioclase lineation. This interpretation calls for in-situ crystallization of multiple sills forming the lower gabbroic crust (Satsukawa et al., 2008).

References
Kelemen, P. B., Koga, K., & Shimizu, N. (1997). Geochemistry of gabbro sills in the crust-mantle transition zone of the Oman ophiolite: Implications for the origin of the oceanic lower crust. Earth and Planetary Science Letters, 146(3-4), 475-488.
Koepke, J., Garbe-Schoenberg, D., Mueller, T., Mueller, M., Mock, D., Strauss, H., Schuth, S., Ildefonse, B., 2017. A Reference Section through the Lower Fast-spreading Oceanic Crust in the Wadi Gideah (Sumail ophiolite, Sultanate Oman): Drill Sites GT1A and GT2A within the ICDP Oman Drilling Project Abstract V43G-2737: presented at 2017 Fall Meeting, AGU, New Orleans.
Satsukawa, T., Ildefonse, B., Mainprice, D., Morales, L. F. G., Michibayashi, K., & Barou, F. (2013). A database of plagioclase crystal preferred orientations (CPO) and microstructures-implications for CPO origin, strength, symmetry and seismic anisotropy in gabbroic rocks. Solid Earth, 4(2), 511.

ICDP

Field and laboratory insight on the multiple explosive events at Krafla's Vití crater, Iceland

C. Montanaro

Department of Earth and Environmental Sciences, LMU München, Germany

The Krafla geothermal area in Iceland is a valuable infrastructure characterized by the presence of both explosively-generated craters and lava fields. The *Vití* steam-driven (phreatic) eruption occurred at Krafla prior to the effusive fissures of Mývatn Fires (1724-29): trigger of the eruption and cause for its location far outside the main eruptive fissures, are unknown. In this light, the recent findings from the IDDP 1 - a rhyolite melt at about 2 km depth under Krafla Caldera, and a conductive boundary layer separating the magmatic source from the overlying hydrothermal system - raised a key question: If the intrusion formed during the last Krafla Fires eruption (1975 84), why did it not produced any explosive eruption (as Vití)? Rock's permeability, which determines whether overpressurized fluid may either fragment the surrounding rocks or escape from it via effective outflowing, may represents a prime lithological barrier above the rhyolite magma.

With the aim of shed light on the nature of host rock exploded during the Vití eruption, a fieldwork campaign was carried to investigate the deposit surrounding the Vití crater area. The characterization of the deposit allowed to i) distingush at least five explosive events producing the observed craters and breccias, and ii) define the main lithologies involved in the eruptions. Collected breccia matrix and block samples were analysed for their grain sizes and petrophysical properties, particularly permeability and porosity. Samples from the identified lithologies were also used in decompression experiments to determine their fragmentation threshold, and test fragmentaion behavior under decompresion from high pressure-temperature conditions.

The knowledge acquired yield important insights into the hydrothermal systems host rock response in dependence of their lithological nature and rock permeability.

ICDP

High-resolution microfacies analyses of deep Dead Sea sediments reveal hydroclimatic fluctuations during the last deglaciation

D. Müller[1], I. Neugebauer[1], R. Tjallingii[1], A. Beer[2], M. J. Schwab[1], Y. Enzel[3], J. Hasan[4], A. Brauer[1]

[1] Section Climate Dynamics and Landscape Evolution, GFZ German Research Centre for Geosciences, Potsdam, Germany
[2] Faculty of Geosciences, University of Münster, Münster, Germany
[3] The Fredy and Nadine Herrmann Institute of Earth Sciences, Hebrew University of Jerusalem, Jerusalem, Israel
[4] Earth and Environmental Sciences Department, Al-Quds University, Jerusalem, Palestine

The Dead Sea drainage basin is the largest hydrological system in the Levant, which covers the boundary between the sub-humid to semi-arid Mediterranean and arid to hyper-arid Saharo-Arabian climate zones. The Dead Sea is a terminal lake and past hydroclimatic changes resulted in large-scale lake level fluctuations and heterogeneous lacustrine sedimentation (Neugebauer et al., 2014; Torfstein et al., 2013).

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 analyze the sediments in core 5017-1-A between ca 88.5-99.2 m core depth, which covers the last Glacial/Interglacial transition between ~16.5-11 ka. This interval is marked by a general trend towards dry conditions in the Dead Sea watershed resulting in a lake level drop by ~160 m (Torfstein et al., 2013), allowing to study changes in frequency and amplitude of event sedimentation processes triggered by extreme floods. Using high-resolution microfacies analyses and XRF core scanning, we examine variability in seasonal precipitation and frequency of extreme floods to decipher consequences of a major hydroclimatic change.

The observed sequence comprises the upper Lisan Formation, which primarily consists of aad (alternating aragonite and detritus) sediments, massive gypsum deposits, turbidites, slumps and seismites. Deposition of massive gypsum indicates periods of pronounced lake-level drop (Torfstein et al., 2008). Composition and structure of flood layers are analyzed to establish a high-resolution time series of flood events. Flood events are marked by elevated amounts of detrital input and gypsum occurrence is tracked using Ti/Ca and S/Ca element ratios from XRF scanning, respectively. Similar deposits of the western Dead Sea margin have been associated with eastern Mediterranean low-pressure systems and occasionally also by the Active Red Sea Trough and the Cyprus low, often causing local and regional flash floods (Ahlborn et al., 2018). Possibly, the flood layers in the deep Dead Sea basin are linked with similar rainstorms as well.

References
Ahlborn, M., Armon, M., Ben Dor, Y., Neugebauer, I., Schwab, M.J., Tjallingii, R., Shoqeir, J.H., Morin, E., Enzel, Y., Brauer, A., 2018. Increased frequency of torrential rainstorms during a regional late Holocene eastern Mediterranean drought. Quat. Res. (United States) 89, 425–431. https://doi.org/10.1017/qua.2018.9

Neugebauer, I., Brauer, A., Schwab, M.J., Waldmann, N.D., Enzel, Y., Kitagawa, H., Torfstein, A., Frank, U., Dulski, P., Agnon, A., Ariztegui, D., Ben-Avraham, Z., Goldstein, S.L., Stein, M., 2014. Lithology of the long sediment record recovered by the ICDP Dead Sea Deep Drilling Project (DSDDP). Quat. Sci. Rev. 102, 149–165. https://doi.org/10.1016/j.quascirev.2014.08.013Torfstein, A., Gavrieli, I., Katz, A., Kolodny, Y., Stein, M., 2008. Gypsum as a monitor of the paleo-limnological-hydrological conditions in Lake Lisan and the Dead Sea. Geochim. Cosmochim. Acta 72, 2491–2509. https://doi.org/10.1016/j.gca.2008.02.015

Torfstein, A., Goldstein, S.L., Stein, M., Enzel, Y., 2013. Impacts of abrupt climate changes in the Levant from Last Glacial Dead Sea levels. Quat. Sci. Rev. 69, 1–7. https://doi.org/10.1016/j.quascirev.2013.02.015

ICDP

Mass transfer at hydrothermal fault zones in the lower oceanic crust: An example from Wadi Gideah, Samail ophiolite, Oman

S. J. Müller[1], B. Zihlmann[2], D. Garbe-Schönberg[1], D. A. H. Teagle[2], J. Koepke[3]

[1] Institut für Geowissenschaften, Christian-Albrechts-Universität zu Kiel, Germany
[2] Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, SO14-3ZH, UK
[3] Institut für Mineralogie, Leibniz Universität Hannover, Germany

Hydrothermal circulation and alteration within the deep oceanic crust are crucial processes for the exchange of mass and heat between the solid earth and the oceans. Although there is good knowledge about how and where shallow hydrothermal circulation occurs, there remain major shortcomings in our understanding about the geometry and intensity of deep hydrothermal circulation within the lower oceanic crust, as these systems cannot be studied in-situ at active ridge segments.

Here we present a petrographic and geochemical field study of a hydrothermal fault zone located within the deep layered gabbro section of the Cretaceous Samail ophiolite (Wadi Gideah transect, Wadi Tayin block, Sultanate of Oman). This fault (Fig. 1) is located very close to the GT1 drill site of the ICDP Oman drilling project (OmanDP) and most likely also present in the drillcore. Field observations reveal a one-meter thick normal fault comprising weakly foliated chlorite±epidote rocks with disseminated pyrite and chalcopyrite, which surround heavily altered gabbro clasts. This fault zone offsets a coherent series of layered gabbros and is oriented subparallel to the sheeted dikes that crop out to the south of the Wadi Gideah. Gabbro in both hanging and footwall of the fault is altered and abundantly veined. As inferred by experimental studies (Beermann et al., 2017) and petrographic observations initial sea water-related hydrothermal alteration of gabbro follows mainly two reactions: (I) clinopyroxene + fluid => tremolite ± actinolite, and (II) clinopyroxene + plagioclase + fluid => chlorite. Epidote if present, is partially growing into open cavities. Chlorite thermometry reveals formation temperatures of about 275°C for chlorites in the walls and roughly +50°C more for chlorites in the fault rock. The late stage of alteration mainly forms prehnite and laumontite, mostly along veins.

Whole-rock mass balance calculations (Fig. 2) reveal a substantial depletion of alkali elements (Li, Na, Rb, Cs) for all altered rock types. Ni, Cr, Sc and light rare earth elements (LREE) undergo intense leaching from the layered gabbro. Mn, Co and Fe are leached as well but precipitated into the fault rock which additionally shows a considerable gain in Zn, Cu, and U, pointing towards a highly charged, reactive fluid composition present in the lower oceanic crust. The formation of hydrous phases leads to a pronounced increase of water within all fault-related lithologies. Based on silica loss and solubility, the intensity of alteration requires a fluid to rock mass ratio of 450:1 to 900:1.

Strontium isotope whole rock data of the fault rock yield 87Sr/86Sr ratios of ~0.7046, which is considerably more radiogenic than fresh layered gabbro from this locality (87Sr/86Sr = 0.7030 – 0.7034), and based on epidote similar to black smoker hydrothermal signatures found in Wadi Tayin. Altered gabbro clasts within the fault zone show comparable values with 87Sr/86Sr ratios of ~0.7045 – 0.7050, whereas hanging wall and footwall display values only slightly more radiogenic than fresh layered gabbro. The strongly focussed fluid flow contributes significantly to mine the latent heat of the crystalizing lower crust, enabling for both convective heat transport close to the fault zone and enhanced conductive cooling within more remote regions of the hydrothermal system.

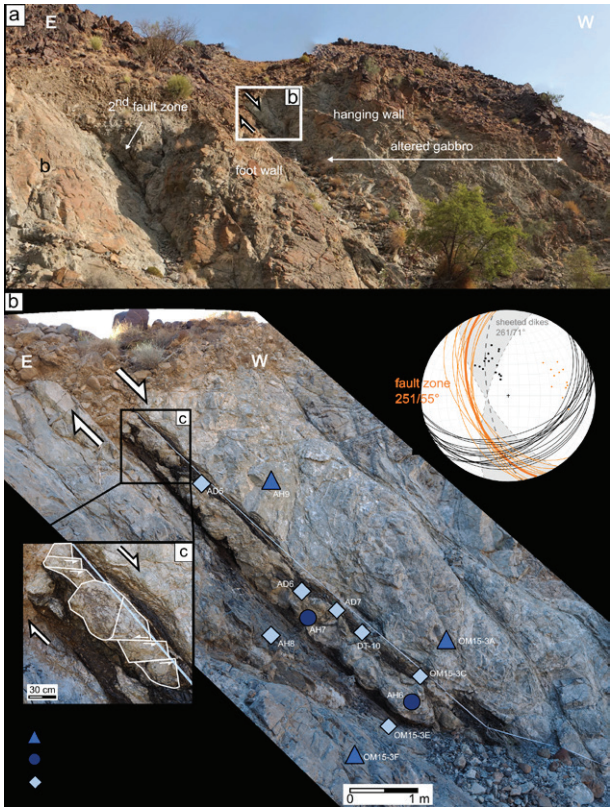


Fig. 1: (a) Photo of the fault zone outcrop. Especially in the hanging wall, gabbros are intensely altered. (b) Detailed overview of the fault zone. Samples; chlorite-rich fault zone (light blue diamonds), clasts (dark blue circles), hanging wall and footwall (royal blue triangles). See stereographic projection for the orientational embedding of the fault in the crustal system. (c) Blow-up of the shear sense indicating a normal fault by top to the left domino-type fracturing of the clasts.

References

Beermann et al. (2017). Geochimica Et Cosmochimica Acta, 197, 167–192.

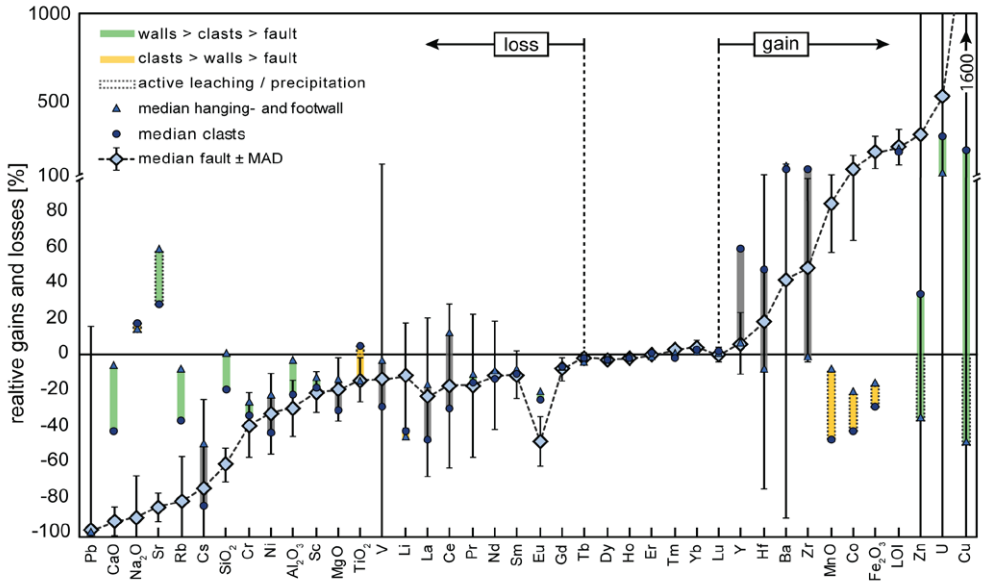


Fig. 2: Major-and trace element gains and losses for all three rock types shown relative to the median value of fresh background layered gabbro (n = 8). Elements are ranged by highest loss (left-hand side) to highest gain (right-hand side) plotted for the median fault rock. Note change in scale for gains greater than 100%.

IODP

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

B. Najjarifarizhendi[1], G. Uenzelmann-Neben[1], T.Westerhold[2]

[1] Alfred-WegenerInstitut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven
[2] MARUM, Universität Bremen, Bremen

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

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

ICDP

CryptoTEPHrochronology in the ICDP Dead Sea deep core as a key to synchronise past hydroclimate changes in the eastern Mediterranean: First results of the TEPH-ME project

I. Neugebauer[1], M. J. Schwab[1], S. Blockley[2], C. S. Lane[3], B. Plessen[1], R. Tjallingii[1], S. Wulf[4], A. Brauer[1]

[1] GFZ German Research Centre for Geosciences, Section Climate Dynamics and Landscape Evolution, Potsdam, Germany
[2] Royal Holloway, University of London, Department of Geography, Egham, Surrey, UK
[3] University of Cambridge, Department of Geography, Cambridge, UK
[4] University of Portsmouth, School of the Environment, Geography and Geosciences, Portsmouth, UK

The hypersaline Dead Sea is a key palaeoclimate archive in the south-eastern Mediterranean region, situated at a critical position between more humid Mediterranean climate and the hyper-arid Saharo-Arabian desert belt. The ca 450 m long ICDP drill core 5017-1, recovered from the deepest part of the Dead Sea, spans the last ~220,000 years as constrained by radiocarbon, U-Th dating and floating δ18O stratigraphy methods (Neugebauer et al. 2014; Torfstein et al. 2015; Kitagawa et al. 2017). Nevertheless, an independent dating method is much needed because (i) radiocarbon dating is limited to the last ~40,000 years; (ii) U-Th dating of authigenic carbonates requires a complex correction procedure leading to large age uncertainties; and (iii) wiggle matching of oxygen isotope data is not independent and, hence, does not allow the identification of lead- and lag-phase relationships of changing hydroclimate in comparison to other palaeoclimate records.

Tephrochronology has been demonstrated a powerful tool for dating and synchronisation of palaeoclimate records for regional and global comparison (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 are still absent. Recently, the first cryptotephra ever identified in Dead Sea sediments has been associated with the early Holocene S1-tephra from central Anatolia (Neugebauer et al. 2017). This discovery encouraged a systematic search for

tephra time-markers in the ICDP deep-basin core 5017-1, with the aim of improving the chronology of the deep record significantly and providing a tool for precise regional synchronisation of proxy records.

In the first phase of the TEPH-ME project focusing on the early last glacial (ca 100-110 ka) and lateglacial (ca 11-15 ka) time intervals in the ICDP core, we have identified more cryptotephra layers than expected. First glass geochemical data suggest that the majority of volcanic ash in the Dead Sea sediments originates from Anatolian volcanic provinces. Even though proximal Anatolian tephra data 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. through synchronising the Dead Sea and Lake Van (eastern Anatolia) sediment records, but also with archaeological and palaeoenvironmental sites that are currently investigated in the Levant and in Arabia.

References

Kitagawa, H., Stein, M., Goldstein, S.L., Nakamura, T., Lazar, B., 2017. Radiocarbon Chronology of the DSDDP Core at the Deepest Floor of the Dead Sea. Radiocarbon 59, 383-394.

Lane, C.S., Lowe, D.J., Blockley, S.P.E., Suzuki, T., Smith, V.C., 2017. Advancing tephrochronology as a global dating tool: Applications in volcanology, archaeology, and palaeoclimatic research. Quat. Geochronol. 40, 1-7.

Neugebauer, I., Brauer, A., Schwab, M.J., Waldmann, N.D., Enzel, Y., Kitagawa, H., Torfstein, A., Frank, U., Dulski, P., Agnon, A., Ariztegui, D., Ben-Avraham, Z., Goldstein, S.L., Stein, M., DSDDP Scientific Party, 2014: Lithology of the long sediment record recovered by the ICDP Dead Sea Deep Drilling Project (DSDDP). Quat. Sci. Rev. 102, 149-165.

Neugebauer, I., Wulf, S., Schwab, M.J., Serb, J., Plessen, B., Appelt, O., Brauer, A., 2017: Implications of S1 tephra findings in Dead Sea and Tayma palaeolake sediments for marine reservoir age estimation and palaeoclimate synchronisation. Quat. Sci. Rev. 170, 269-275.

Torfstein, A., Goldstein, S.L., Kushnir, Y., Enzel, Y., Haug, G., Stein, M., 2015. Dead Sea drawdown and monsoonal impacts in the Levant during the last interglacial. Earth Planet. Sci. Lett. 412, 235-244.

IODP

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

A. H. Osborne[1], M. Frank[1], D. Kroon[2], J. D. Wright[3], E. C. Hathorne[1], M. Gutjahr[1], L. Reuning[4]

[1] GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany
[2] School of Geosciences, University of Edinburgh, UK
[3] Department of Earth and Planetary Sciences, Rutgers University, USA
[4] Christian-Albrechts-University, Institute of Geosciences, Kiel, Germany

This project examines the hydrography of the Gulf Stream during the final stages of the closure of the Central American Seaway (CAS) in the Pliocene and Early Pleistocene. Using material from ODP Sites 1006 (Florida Straits) and 1000 (central Caribbean), we test the hypothesis that there was a direct link between CAS closure, warming and increased salinity of the Gulf Stream, and a major strengthening of the Atlantic Meridional Overturning Circulation (AMOC), which led to the present day Atlantic circulation and climate system. This study builds on our recently published 12 million-year record from Site 1006, in which we present evidence that export of Caribbean water via the Florida Strait was closely related to AMOC strength (Kirillova et al., 2019).

A detailed age model for Site 1006 (658 m water depth), a key site positioned ideally at the start of the Gulf Stream, has been established on the basis of new stable oxygen isotope compositions of benthic foraminifera. The radiogenic isotope composition of neodymium (Nd) in weakly cleaned sedimentary foraminifera is measured to reconstruct intermediate water mass composition and mixing and thus the strength of the AMOC during repeated episodes of CAS closure and reopening as a consequence of sea level changes. We use trace and rare earth elemental compositions of the same foraminifera to assess the impact of changes in local terrestrial sources on the Nd isotope signal. High rare earth element (REE) concentrations and a pronounced middle REE enrichment could indicate an overprinting of the advected seawater Nd isotope signal by locally sourced Nd (Osborne et al., 2019).

Results from ODP Site 1006 show a semi-precessional cyclicity in the Nd isotope composition of intermediate depth waters during the early Pliocene, synchronous with changes in mixed layer temperature and salinity and with changes in the percentage of aragonite in the sediment (Reuning et al., 2006). Ongoing investigations based on trace and rare-earth element compositions of the same foraminifera will help us to determine whether the Nd isotope record is a local weathering signal such as observed in the central Caribbean (Osborne et al., 2019) or a circulation signal.

The upper water column hydrography during the Late Pliocene and Early Pliocene is reconstructed by measuring □18O in mixed-layer and thermocline dwelling planktonic foraminifera. There are precessionally-paced fluctuations in both planktonic foraminifera δ18O records of Site 1006 during MIS 95-100 that closely correspond to the mixed-layer trends reported for the central Caribbean (Groeneveld et al., 2014). In contrast, variability in the planktonic δ18O at Site 1006 around MIS M2 is more similar to the obliquity-paced benthic δ18O records and deviates from the Caribbean trend during the glaciation itself (De Schepper et al., 2013; Haug and Tiedemann, 1998).

Together, these high-resolution records suggest that there was a shift from high- to low-latitude forcing of upper water column properties in the Florida Strait between the Late Pliocene and Early Pleistocene. Completion of the Nd isotope records for these same time intervals will allow us to directly compare changes in the surface ocean with those at intermediate depth and assess the impact of short-term CAS closure events on the functioning of the Gulf Stream and the AMOC.

References

De Schepper, S., J. Groeneveld, B. D. A. Naafs, C. Van Renterghem, J. Hennissen, M. J. Head, S. Louwye, and K. Fabian (2013), Northern Hemisphere Glaciation during the globally warm early Late Pliocene, PLOS ONE, 8(12), e81508.

Groeneveld, J., E. C. Hathorne, S. Steinke, H. DeBey, A. Mackensen, and R. Tiedemann (2014), Glacial induced closure of the Panamanian Gateway during Marine Isotope Stages (MIS) 95-100 (similar to 2.5 Ma), Earth and Planetary Science Letters, 404, 296-306.

Haug, G. H., and R. Tiedemann (1998), Effect of the formation of the Isthmus of Panama on Atlantic Ocean thermohaline circulation, Nature, 393(6686), 673-676.

Kirillova, V., A. H. Osborne, T. Storling, and M. Frank (2019), Miocene restriction of the Pacific-North Atlantic throughflow strengthened Atlantic overturning circulation, Nature Communications, 10. 1038/s41467-019-12034-7

Osborne, A. H., E. C. Hathorne, P. Boning, J. Groeneveld, K. Pahnke, and M. Frank (2019), Late Pliocene and Early Pleistocene Variability of the REE and Nd Isotope Composition of Caribbean Bottom Water: A Record of Changes in Sea Level and Terrestrial Inputs During the Final Stages of Central American Seaway Closure, Paleoceanography and Paleoclimatology, 10.1029/2019pa003654.

Reuning, L., J. J. G. Reijmer, C. Betzler, A. Timmermann, and S. Steph (2006), Sub-Milankovitch cycles in periplatform carbonates from the early Pliocene Great Bahama Bank, Paleoceanography, 21(1).

IODP

Calibration of temperature proxy records from modern Tahiti corals and application to IODP Expedition 310 corals

C. Oster[1], T. Felis[1], E. Hathorne[2], P. Deschamps[3], R. Asami[4], M. Kölling[1], U. Merkel[1]

[1] MARUM – Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany
[2] GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany
[3] CEREGE –Centre Européen de Recherche et d'Enseignement des Géosciences de l'Environnement, Aix-en-Provence, France
[4] Department of Earth Science, Graduate School of Science, Tohoku University, Sendai, Japan

IODP Expedition 310 "Tahiti Sea Level" has provided important information about the amplitude and timing of meltwater pulse 1A (MWP-1A) in the tropical South Pacific Ocean. U-Th dating results of fossil shallow water corals drilled offshore Tahiti (17.4°S, 149.2°W) illustrate that MWP-1A started no earlier than 14,650 years ago and ended before 14,310 years ago. It was concluded that MWP-1A is coeval with the Northern Hemisphere Bølling warming. During MWP-1A a sea level rise between 12 - 22 metres, most probably between 14 - 18 metres was inferred at Tahiti with a significant contribution of meltwater from the Southern Hemisphere (Deschamps et al., 2012). Reconstructions of seasonality, interannual variability and mean temperature conditions in the tropical South Pacific Ocean during the Northern Hemisphere cold periods of the Younger Dryas and Heinrich Stadial 1 were possible through measurements of geochemical proxies in IODP Expedition 310 corals (Asami et al., 2009; Felis et al., 2012). These fossil *Porites* corals were extensively screened for potential diagenesis (Hathorne et al., 2011). The results revealed indications for relatively cold conditions during the Younger Dryas (Asami et al., 2009) and for pronounced interannual variability of sea surface temperature at typical El Niño-Southern Oscillation periodicities during Heinrich Stadial 1 (Felis et al., 2012) at Tahiti.

Our ongoing work suggests that many IODP Expedition 310 corals grew during MWP-1A. These fossil *Porites* corals are analysed at monthly resolution for Sr/Ca, $\delta^{18}O$, Mg/Ca, and $\delta^{13}C$, which are proxies for sea surface temperature and hydrological balance, secondary skeletal aragonite, and biological derived environmental changes affecting the coral. In this study we show preliminary results from modern *Porites* corals that were recently collected near the IODP Expedition 310 drilling sites around Tahiti. The proxies Sr/Ca, $\delta^{18}O$, Mg/Ca, and $\delta^{13}C$ were analysed on these modern corals at approximately monthly resolution. For construction of an internal chronology for each coral record, the application of different age models using fixed and varying anchor points was investigated. We performed statistical calibrations between the monthly interpolated coral skeletal Sr/Ca (and $\delta^{18}O$) temperature proxies and various local instrumental temperature data sets derived from different sites and water depths at Tahiti and nearby Moorea. Moreover, we investigate calibrations using gridded sea surface temperature products derived from ship- and satellite-based observations with low to ultrahigh spatial resolutions. These statistical calibrations of coral proxy records with instrumental observations aim at providing a robust present-day benchmark in terms of seasonality, interannual variability and mean climate in order to assess the uncertainties in the paleoclimate reconstructions derived from fossil IODP Expedition 310 corals. Our preliminary results based on mean Sr/Ca concentrations in IODP Expedition 310 corals reveal a tendency for an apparent warming trend at Tahiti during the Northern Hemisphere Bølling warming. Furthermore, we present new evidence for relative cooling at Tahiti during the Younger Dryas. Our preliminary results could suggest a reflection of a Northern Hemisphere warming pattern at 17.4°S in the central tropical South Pacific during the last deglaciation.

References

Asami, R., Felis, T., Deschamps, P., Hanawa, K., Iryu, Y., Bard, E., Durand, N., & Murayama, M. (2009). Evidence for tropical South Pacific climate change during the Younger Dryas and the Bølling–Allerød from geochemical records of fossil Tahiti corals. Earth and Planetary Science Letters, 288(1-2), 96-107.

Deschamps, P., Durand, N., Bard, E., Hamelin, B., Camoin, G., Thomas, A. L., Henderson, G. M., Okuno, J., & Yokoyama, Y. (2012). Ice-sheet collapse and sea-level rise at the Bolling warming 14,600 years ago. Nature, 483(7391), 559-564. doi:10.1038/nature10902

Felis, T., Merkel, U., Asami, R., Deschamps, P., Hathorne, E. C., Kölling, M., Bard, E., Cabioch, G., Durand, N., & Prange, M. (2012). Pronounced interannual variability in tropical South Pacific temperatures during Heinrich Stadial 1. Nature Communications, 3, 965.

Hathorne, E. C., Felis, T., James, R. H., & Thomas, A. (2011). Laser ablation ICP-MS screening of corals for diagenetically affected areas applied to Tahiti corals from the last deglaciation. Geochimica et Cosmochimica Acta, 75(6), 1490-1506.

ICDP

New Project: Linking terrestrial and marine ecosystem responses to climate variability since the Last Interglacial in southeast European refugia (Lake Ohrid and Gulf of Corinth)

K. Panagiotopoulos[1], P. Diz Ferreiro[2], F. Marret-Davies[3], B. Wagner[1], K. Kouli[4]

[1] Institute for Geology and Mineralogy, University of Cologne, Germany
[2] Department of Marine Geosciences and Territorial Planning, University of Vigo, Spain
[3] School of Environmental Sciences, University of Liverpool, UK
[4] Department of Geology and Geoenvironment, National and Kapodistrian University of Athens, Greece

This hybrid ICDP/IODP project aims to: (a) link the sensitive vegetation response from two refugial sites across the Balkan peninsula (Ohrid/ICDP in the north and Corinth/IODP in the south) over the last climatic cycle at a centennial scale, (b) examine lead-lag relationships between terrestrial and marine ecosystem response to global climate variability at a local and regional scale in specific stratigraphical horizons since the Last Interglacial. The two study areas are strategically positioned in the Eastern Mediterranean that is highly sensitive to abrupt climate variability (e.g. Wagner et al., 2019) allowing to detect influences from both higher (e.g North Atlantic) and lower latitudes (African monsoon). Constraining the vegetational composition, abundance and succession in the northern- and southernmost refugial sites across the Pindus mountain range will enable us to reconstruct bioclimatic thresholds and vegetation dynamics during a period of abrupt high-amplitude climate oscillations. Besides vegetation shifts, sediments from the Gulf of Corinth also capture changes in marine ecosystems. Hence, leads and lags in the local expression of climate variability between the terrestrial and marine realms can be determined bypassing chronological uncertainties. Understanding the interplay between climatic, environmental and tectonic factors at sub-orbital scale within the rift system will thus allow us to pursue the major objective laid out in the IODP Exp. 381 (McNeill et al., 2019). Whereas, by examining the diversity and abundance of temperate tree populations during the Last Glacial, this project tackles one of the principal scientific goals of

the SCOPSCO ICDP project dealing with plant resilience and conservation strategies in southeastern Europe.

References
McNeill, L.C., Shillington, D.J., Carter, G.D.O., Everest, J.D., Gawthorpe, R.L., Miller, C., Phillips, M.P., Collier, R.E.L., Cvetkoska, A., De Gelder, G., Diz, P., Doan, M.L., Ford, M., Geraga, M., Gillespie, J., Hemelsdaël, R., Herrero-Bervera, E., Ismaiel, M., Janikian, L., Kouli, K., Le Ber, E., Li, S., Maffione, M., Mahoney, C., Machlus, M.L., Michas, G., Nixon, C.W., Oflaz, S.A., Omale, A.P., Panagiotopoulos, K., Pechlivanidou, S., Sauer, S., Seguin, J., Sergiou, S., Zakharova, N.V., and Green, S., (2019a): High-resolution record reveals climate-driven environmental and sedimentary changes in an active rift., Sci Rep, 9, 3116. DOI: https://doi.org/10.1038/s41598-019-40022-w

Wagner, B., Vogel, H., Francke, F., Friedrich, T., Donders, T., Lacey, J., Leng, M., Regattieri, E., Sadori, L., Wilke, T., Zanchetta, G., Albrecht, C., Bertini, A., Combourieu-Nebout, N., Cvetkoska, A., Giaccio, B., Grazhdani, A., Hauffe, T., Holtvoeth, J., Joannin, S., Jovanovska, E., Just, J., Kouli, K., Kousis, I., Koutsodendris, A., Krastel, S., Leicher, N., Levkov, Z., Lindhorst, K., Masi, A., Melles, M., Mercuri, A. M., Nomade, S., Nowaczyk, N., Panagiotopoulos, K., Peyron, O. Reed, J. M., Sagnotti, L., Sinopoli, G., Stelbrink, B., Sulpizio, R., Timmermann, A., Tofilovska, S., Torri, P., Wagner-Cremer, F., Wonik, T., Zhang, X., 2019. Mediterranean winter rainfall in phase with African monsoon during past 1.36 million years, Nature, 573, 256-260. DOI: https://doi.org/10.1038/s41586- 019-1529-0

IODP

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

K. Pank[1], J. L. Hopkins[2], S. Kutterolf[1]

[1] GEOMAR, Helmholtz Centre for Ocean Research, Kiel, Germany
[2] Victoria University of Wellington

During IODP Expeditions 372 and 375 marine sediments were drilled and sampled down to the Cretaceous and included intercalated tephra layers from the Miocene to Holocene. The offshore drill sites are located ~250 km downwind (east) of the Taupo Volcanic Zone (TVZ), one of largest and most frequently active silicic centers on earth, and also close to the Coromandel Volcanic Zone (CVZ), a sparsely investigated Neogene volcanic arc. The tephra inventories of these intermediate sites provide the missing link between the proximal (on-land, <100 km) and distal (ODP drill cores, ~1000 km) sites, allowing the establishment of a near-complete eruptive history from the early Miocene to recent.

Geochemical, petrological, and volcanological approaches for tephra and sediment characterization are used to quantitatively and qualitatively decrypt their provenance and the eruption succession even for smaller eruptions potentially found as cryptotephras. Preliminary results show about 95 primary ash layers, and 80 reworked ash pods/layers within the IOPD 372 and 375 cores. First correlations to subaerial deposits show for example, that tephras from the Taupo, Waimihia, Kawakawa, and Rotoehu, eruptions are present in the cores, as well as some older CVZ sourced tephra. Additionally, a difference in the major element composition between deposits has been observed, and hypothesized to be linked to provenance. For example, the CVZ has K_2O wt.% = 2.95 - 3.7 whereas, the TVZ has K_2O wt.% = ~ 2.8. Additionally, the tephras linked to the CVZ show systematic changes with age for example, a decrease in K_2O with decreasing age.

ICDP

Geothermal studies of the COSC-1 scientific drillhole, Sweden

C. Pascal, R. Löwe

Ruhr-Universität Bochum

The scientific drilling project "Collisional Orogeny in the Scandinavian Caledonides" (COSC), supported by ICDP and the Swedish Research Council, involves the drilling of two boreholes through carefully selected sections of the Paleozoic Caledonian orogen in Central Sweden. COSC-1, the first of the two planned boreholes, was drilled and fully cored down to 2.5 km depth during spring and summer 2014 near the town of Åre. The COSC working group is organised around six thematic teams including us, the geothermal team. The major objectives of the COSC geothermal team are: a) to contribute to basic knowledge about the thermal regime of Palaeozoic orogenic belts, ancient shield areas and high heat-producing plutons; b) to refine knowledge on climate change at high latitudes (i.e. Scandinavia), including historical global changes, recent palaeoclimate development (since last ice age) and expected future trends; c) to determine the vertical variation of the geothermal gradient, heat flow and thermal properties down to 2.5 km, and to determine the required corrections for shallow (< 1 km) heat flow data; d) to explore the geothermal potential of the Åre-Järpen area; e) to explore to what degree the conductive heat transfer is affected by groundwater flow in the uppermost crust and f) to evaluate the heat generation input and impact from the basement and the alum shales. To reach these targets the following tasks were carried out or are planned: 1) heat flow predictions from shallow boreholes; 2) geophysical logging; 3) analyses of logs and well tests; (3) determination of rock thermal properties on core samples; 4) determination of heat generation rates from radiometric and geochemical studies; 5) fracture characterisation for permeability and convective heat flow estimations; 6) analysis of convective signals; 7) analysis of paleoclimatic signals; 8) heat flow modelling and evaluation of geothermal potential and 9) Fennoscandia heat flow map compilation. The purpose of the present contribution is to summarise the tasks completed so far and to present the on-going research by the COSC geothermal team.

References
Lorenz, H., Rosberg, J.-E., Juhlin, C., Bjelm, L., Almqvist, B.S.G., Berthet, T., Conze, R., Gee, D.G., Klonowska, I., Pascal, C., Pedersen, K., Roberts, N.W.W., and Tsang, C.-F., 2015. COSC-1 – drilling of a subduction-related allochthon in the Palaeozoic Caledonide orogen of Scandinavia, Scientific Drilling, 19, 1-11.

ICDP

Studying glacial/interglacial cycles from downhole logging data and mineralogical composition: an application to the ICDP drilling project Lake Junín, Peru.

S. Pierdominici[1], A. M. Schleicher[1], C. Zeeden[2], J. Kück[1], D. T. Rodbell[3], M. B. Abbott[4]

[1] Helmholtz-Zentrum Potsdam - GFZ
[2] Leibniz Institute for Applied Geophysics, Hannover, Germany
[3] Union College, Schenectady, NY 12308, USA
[4] Dep. Of Geology and Planetary Science, University of Pittsburg, PA 15260-3332, USA

A common and well-establish procedure to reconstruct the history of lake records covering the glacial-interglacial cycles

is using high-resolution data derived from core analysis. Here, we present the identification of glacial-interglacial alternations as from downhole logging data. The main advantages of using the borehole logs over core data is that (i) they are continuous in depth, which is essential when applying depth/time series analysis, (ii) are continuous without splicing and do not have core breaks, and (iii) the fast availability of downhole logging data. A glacial-interglacial reconstruction based on downhole logging data has been applied on the ICDP Lake Junín drilling project sites, using a suite of cyclostratigraphic methods.

Lake Junín is located at 4082 m above sea level in the Andes and is the largest lake (300 km2) entirely within Peruvian territory. Lake Junín is controlled by a thick sediment package (>125 m) dominated by alternating packages of carbonate and glaciogenic silts with thin peat and organic-rich mud layers. The lake predates the maximum extent of glaciation, and is in a geomorphic position to record the waxing and waning of glaciers in the nearby Cordillera. Drilling was performed in 2015 at three sites and a suite of downhole logging measurements were applied. Here we present a study in which downhole logging data are used to identify the glacial and interglacial cycles and to reconstruct an age–depth model. The first step was to investigate the consistency of cyclic sediment behavior and see that the interval from ~30-90 m shows a rather stable cyclicity with a wavelength of ~10 m. Natural and spectral gamma ray data were used for cyclostratigraphic analysis, and the astronomical spectral misfit (ASM) method was used to reconstruct the sedimentation rate. The results indicate a sedimentation rate of between 5 and 20 cm/kyr in the Lake Junín record. For the second step, the TimeOpt method was applied to test for a fit of precession amplitude with eccentricity; it results in an average sedimentation rate of 15 cm/kyr. Both ASM and TimeOpt are astronomical testing approaches for untuned stratigraphic data in the depth domain that comprehensively evaluate a range of plausible time scales for the deposition history. This method suggests a good fit of the precession amplitude and an eccentricity filter when applying an average sedimentation rate of 14-15 cm/kyr. Based on these information on sedimentation rate, the final step was to correlate the spectral gamma ray data with the LR04 benthic isotope stack. Furthermore, the downhole logging data have been used for cluster analysis to construct a lithological profile, called the electrofacies log. Three major groups (carbonate-silt, peat and silt) have been identified by spectrum gamma ray, magnetic susceptibility, and p-wave velocity borehole logs. Finally, the properties of the clusters are analyzed and converted into lithological units according to the lithological information from the visual core description or mineralogical analysis or core material. To achieve this, 68 samples were taken in total from two cores (Hole 1D and Hole 3B), in order to compare and characterize the minerals in the lake sediments at different depths. The mineralogical analyses performed by X-ray diffraction (XRD) show quartz, calcite, feldspar and clay minerals. The clay size fraction (< 2 micron) contains illite, smectite and kaolinite in different amounts. Linking the abundance and the lack of clay minerals in core samples with the downhole logging data, a relationship between geological history of the lake and climate change processes can be recognized. Consequently, the different mineralogical composition of the sediments, especially the presence or absence of smectite in the clay bulk, reflects a glacial/interglacial climate cyclicity.

ICDP

3D imaging of the subsurface electrical conductivity structure in West Bohemia covering mofettes and Quaternary volcanic structures by using magnetotellurics

A. Platz[1], U. Weckmann[1,2], J. Pek[3], S. Kováčiková[3], R. Klanica[3], J. Mair[1,4], B. Aleid[1,2]

[1] Helmholtz Centre Potsdam - German Research Centre for Geosciences GFZ, Potsdam, Germany
[2] University of Potsdam, Institute of Geosciences, Potsdam, Germany
[3] Institute of Geophysics of the Czech Academy of Sciences, Prague, Czech Republic
[4] Freie Universitaet Berlin, Department of Earth Sciences, Berlin, Germany

The West Bohemian Massif represents the easternmost part of the geo-dynamically active European Cenozoic Rift System. This region hosts different tectonic units, the NE-SW trending Eger Rift, the Cheb Basin and a multitude of different faults systems. Furthermore, the entire region is characterised by ongoing magmatic processes in the intra-continental lithospheric mantle. These processes take place in absence of active volcanism at surface, but are expressed by a series of phenomena, including e.g. the occurrence of repeated earthquake swarms and massive degassing of CO_2 in the form of mineral springs and mofettes. Active tectonics is mainly manifested by Cenozoic volcanism represented by different Quaternary volcanic structures e.g. the Železná hůrka (Eisenbühl), the Komorní hůrka (Kammerbühl) and different maars. All these phenomena make the Eger Rift a unique target area for European intra-continental geo-scientific 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 are applied to image the subsurface distribution of the electrical conductivity from shallow surface down to depths of several tens of kilometres. The electrical conductivity is a physical parameter that is particularly sensitive to the presence of high-conductive phases such as aqueous fluids, partial melts or metallic compounds. First MT measurements within this ICDP project were carried out in winter 2015/2016 along two 50 km long perpendicular profiles with 30 stations each and a denser grid of 97 stations close to the mofettes with an extension of 10 x 5 km2. Muñoz et al. (2018) presented 2D images along the NS profile of one regional profile. They reveal a conductive channel at the earthquake swarm region that extends from the lower crust to the surface forming a pathway for fluids into the region of the mofettes. A second conductive channel is present in the south of the model. Due to the given station setup, the resulting 2D inversion allows ambiguous interpretations of this feature: It can e.g. represent a feeder channel for the Quaternary volcanoes or it resembles the conductivity image of a nearby fault or the suture zone between the different tectonic units. 3D MT data and inversions are required to distinguish between different scenarios and to fully describe the 3D structure of the subsurface. Therefore, we conducted a large MT field experiment in autumn 2018 by extending the study area towards the south. Broad-band MT data were measured at 83 stations along three 50-75 km long profiles and some additional stations across the region of the maars, the Tachov fault and the suture zone allowing for 2D as well as 3D inversion on a crustal scale. To improve the data quality, advanced data processing techniques were applied leading to good quality transfer functions. Furthermore, the previously collected MT data were reprocessed using the new approaches. This entire MT data set

across the Eger Rift environment together with old MT data collected within the framework of the site characterisation in the surrounding of the KTB drilling are used to compute 3D resistivity models of the subsurface, with combining different transfer functions. These 3D inversion results will be introduced and discussed with regard to existing geological hypotheses.

References

Munoz, G., Weckmann, U., Pek, J., Kováčiková, S., Klanica, R. (2018) Regional two-dimensional magnetotelluric profile in West Bohemia/Vogtland reveals deep conductive channel into the earthquake swarm region, Tectonophysics

IODP

Reconstruction of the Atlantic Meridional Overturning Circulation during the past 100,000 years

F. Pöppelmeier[1,2], J. Lippold[2], P. Blaser[2], M. Gutjahr[3]

[1] Institute of Earth Sciences, Heidelberg University, Heidelberg
[2] Climate and Environmental Physics, Physics Institute, University of Bern, Bern
[3] GEOMAR Helmholtz Center for Ocean Research Kiel, Kiel

It is assumed that the CO_2 sequestered from the atmosphere during the last glacial cycle was stored away in the deep oceans for thousands of years, yet the water mass structure accommodating such increased carbon storage continues to be debated. Inconsistent results are largely a consequence of the limited data covering the entire glacial cycle. Especially scarce are deep water mass reconstructions for the past 100,000 years with the neodymium (Nd) isotope proxy. As part of the rare earth elements Nd is not affected by biological cycling making the Nd isotopic composition of seawater particularly valuable in helping to disentangle changes in carbon cycling from the deep ocean's ventilation state. Based on the difference in the Nd isotopic signatures between Northern Sourced Water and Southern Sourced Water a number of studies reported significantly different water mass structures in the Atlantic Ocean in the past. Previous studies mostly based their interpretations on the assumption of invariable Nd isotope end members, but recently it emerged that this may not hold true for all times. Without well-constrained end members paleoceanographic reconstructions of past water mass distributions remain uncertain. Currently, no Nd isotope record from the North Atlantic, representing the northern end member, exists that spans the entire glacial cycle, hence the water mass structure facilitating increased carbon storage remains elusive. The here proposed study will take advantage of the well-established methodology and extensive knowledge about the Nd isotope proxy at Heidelberg University and aims to close this critical data gap by defining a northern Nd isotope end member over the past 100,000 years from a sediment core (IODP U1313) from the subpolar North Atlantic with a sufficiently high sedimentation rate and located outside the influence of benthic nepheloid layers or volcanic material, avoiding in situ alterations.

ICDP

Hipercorig - a new system for deep lake sediment sampling

U. Raschke[1], U. Harms[2], V. Wittig[3], F. Anselmetti[4], M. Wessels[5], R. Bracke[3], A. Schwalb[1]

[1] Institute of Geosystems and Bioindication, Technische Universität Braunschweig, Langer Kamp 19c, 38106 Braunschweig, Germany
[2] GFZ German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam, Germany
[3] Fraunhofer IEG (was International Geothermal Centre until 31.12.2019) Lennershofstrasse 140, 44801 Bochum, Germany
[4] Quaternary Geology and Paleoclimate Institute of Geological Sciences and Oeschger Centre for Climate Change Research, Baltzerstrasse 1+3, 3012 Bern, Switzerland
[5] Landesanstalt fuer Umwelt, Messungen und Naturschutz Baden-Wuerttemberg, Institut fuer Seenforschung Langenargen, Germany

Soft sediments represent key archives for understanding rapid climate and environmental change but investigations are often impeded by the lack of continuous, complete and undisturbed records. The new coring system Hipercorig was developed to overcome these issues, and we have tested this system successfully on perialpine Lakes Mondsee and Constance at up to 204 m water depth and down to 64 m core length.

Fig. 1: Hipercorig at Lake Constance, summer 2019

Hipercorig is designed for deep piston coring utilizing a specialized hydraulic hammer system capable to reach up to 100 m core length in up to 250 m water depth. The well-established piston system ensures high quality, intact cores, while the hydraulic DTH hammer allows penetrating compacted layers such as sand, gravel or tephra. The wireline piston-coring hammer system, casing string and ground plate is connected via Kevlar ropes to the coring rig on the platform. Working progress is controlled by underwater cameras.

For lake, estuarine and shallow offshore, marine projects the buoyancy and working space is provided via the modular, floating barge anchored in place. The complete system transports in four 20-foot-containers including two zodiacs with outboard motors. Hipercorig allows about a 10 to 20 m core run per shift, obtaining cores with a diameter of 8 cm and 2 m long core runs.

A first deployment in 2018 on Lake Mondsee (Austria) to test and modify Hipercorig recovered 64 m sediment core from glacial tills. A second coring campaign on Lake Constance in 2019 served as the deep-water test and to sample so far unequaled pre-Holocene sediments about 10 m below lake floor. This coring was performed May 13 to July 19, 2019 in 204 m water depth, 2 km SSW off Hagnau, Germany. The site was se-

lected by seismic profiles and is located close to the deepest part of this sub-basin with best possible preservation of a continuous and undisturbed depositional record. Two sediment cores of 24 and 20.5 m length, respectively, were obtained and complemented by three 2-m-long surface cores. The uppermost 11 m of sediments consist of Holocene lacustrine clays with increasing intercalations of silt, while late Quaternary glacial sands dominate below this depth.

The core barrel can also be equipped with a closed piston mechanism to allow for penetration of rigid sand layers. However, extra care must be taken in heaving sands, slowing down core recovery and potentially causing core loss of appr. ~15 cm with each run. Overlapping and / or shorter coring was used to compensate this loss. While samples for microbiology have been taken immediately, core opening, description, and sampling was performed at the University of Bern, Switzerland, in October 2019.

Hipercorig received final improvements and upgrades for safety and flexibility so that the entire system is now available for scientific coring projects on a non-profit base to teams with funded research projects. They will have to pay transport and operations costs as well as a maintenance fee that will serve to sustain the tool. The German Scientific Earth Probing Consortium GESEP will provide an oversight board to prioritize projects and support projects in implementation.

IODP

Geomorphological and geophysical observations of the glacier-covered, sub-Antarctic Mount Michael volcano (Saunders Island), South Sandwich Islands

N. Richter[1,2], P. Leat[3], A.Derrien[2], P. Wintersteller[4], M. Meschede[5], T. R. Walter[1]

[1] OVPF-IPGP, Paris
[2] GFZ, Potsdam
[3] BAS, Cambridge
[4] Marum, Bremen
[5] IGG-UG, Greifswald

The nine active volcanoes of the South Sandwich Islands are a particularly remote region of active volcanism. Remote sensing methods, including satellite monitoring and aerial surveys, besides rare ship visits during austral summers, are the only means of investigating the uninhabited and largely snow- and ice-covered volcanoes. Mount Michael volcano on Saunders Island hosts an active lava lake within its summit crater, which had been identified a permanent feature throughout the period between early 1989 and early-mid 2018. This persistent volcanic activity is a sure indicator of the existence of a shallow magmatic storage and transport system of unknown architecture and depth. According to our investigations, a glacier is covering more than 75 % of the island's area, and amounts to roughly 42 % of the island's subaerial volume, which makes the island an important study site for investigating volcano-glacier interactions during times of accelerated changes of climatic conditions in the sub-Antarctic climate zone and worldwide.

We collected and analysed new data for the active Mount Michael volcano on Saunders Island, including marine bathymetric data, both radar and optical satellite imagery, UAV-derived topographic information, and infra-red camera observations. These data together provide much higher resolution understanding of the island- and glacier geomorphology, glacier dynamics, as well as status of volcanic activity than has been previously achieved. We present a geomorphological and structural analysis of the outer subaerial and shallower submarine flanks of Saunders Island, estimate glacier volumes, morphologies and motion rates, and relate this to the underlying volcano morphology, structural architecture, and edifice stability. All of this is pioneer work at a remote volcano that can be largely regarded as terra incognita. With this study we highlight the unprecedented detail and the valuable information that can be retrieved from modern generation satellites, such as TerraSAR-X and Sentinel-2, as well as UAV-based photogrammetry in particularly remote and inaccessible locations on Earth. Our results have direct and indirect implications for a better understanding of interactions between active volcanism and dynamic glaciers, edifice stability of small volcanoes that host shallow magmatic plumbing systems and related hazards to near and distant shorelines, as well as Atlantic lithosphere recycling and related subduction zone volcanism.

IODP

A Spatially Integrated Signal of Antarctic Ice Sheet Dynamics and Paleoclimate

T. R. Ronge[1], M. E. Weber[2], Science Party Expedition 382

[1] Alfred-Wegener-Institut
[2] Universität Bonn

A key uncertainty in the currently changing climate system is the extent and impact of melting/retreating Antarctic ice sheets on global sea level. A recent study – re-analyzing land elevation data – estimates that by the year 2050 up to 300 Million people might live below projected annual flood levels, even if the 2°C target – as agreed upon in the Paris Climate Agreement – is met (Kulp and Strauss, 2019). These findings emphasize the importance of understanding which Antarctic glaciers might become unstable under future climate conditions.

From March to May 2019, IODP Expedition 382 drilled five Sites at the Falkland/Malvinas slope and in Iceberg Alley of the Scotia Sea. Focusing on two Sites from the Scotia Sea (U1537 – Dove Basin; U1538 – Pirie Basin), we aim to reconstruct past Antarctic ice sheet dynamics and Southern Ocean Paleoceanography over the last five glacial-interglacial cycles. A majority of Antarctic icebergs (length >5 km) is transported counterclockwise via the Antarctic coastal current (Stuart and Long, 2011). In the Weddell Sea, the coastal current becomes part of the Weddell Gyre that transports the icebergs into the Antarctic Circumpolar Current (ACC; Stuart and Long, 2011). In our research area, the icebergs encounter the warmer waters of the ACC, leading to increased melt rates (Silva et al., 2006) and hence the deposition of Iceberg Rafted Debris (IBRD). Both sediment records (splices of U1537 and U1538) have a temporal resolution on par with the EDC ice core (Lambert et al., 2008) and consist of a continuous sedimentary record. Using these records, we will apply a novel approach of combined non-destructive sediment scans – such as XRF and CT – and traditional grain size analyses. This combination will allow for the first continuous reconstruction of spatially integrated iceberg discharge from East and West Antarctica over the last ~450,000 years, covering super interglacials such as MIS 11 and MIS5e.

ICDP

Late Quaternary history of Issyk Kul, Kyrgyzstan, inferred from surface, outcrop, and abyssal core sediments

R. Scheuer[1], B. Wagner[1], N. Leicher[1], K. Abdrakhmatov[2]

[1] Universität zu Köln - Institut für Geologie und Mineralogie
[2] National Academy of Sciences of the Republic of Kyrgyzstan, Institute of seismology

Issyk Kul is the world' s second largest mountain lake and is located at a height of 1607 m above sea level in an intra orogenic basin in the northern Tian Shan (Kyrgyzstan). The local continental climate is affected by a transition zone between the Siberian anticyclonic circulation and the mid latitude westerlies, while tectonics are strongly dominated by the ongoing uplift of the surrounding ranges. Seismic studies and sediment cores indicated a sediment fill of several hundred meters and a succession of fine-grained, laminated sediment interspersed by hemi-pelagites and mass movement deposits.

Already in 2011, an ICDP workshop evaluated the potential of Issyk Kul for a deep drilling. Potential drill sites were discussed, but crucial information about sedimentation characteristics, particularly in the up to 680 m deep central part, of the lake was missing. The here presented new project at Issyk Kul is intended to provide this missing sedimentological information from the lake basin. The work focuses on the recent sedimentological processes of the lake and a better evaluation of the most promising sites for a deep drilling, i.e. a bathymetrical height formed by an anticline and its two adjacent sub-basins in the more than 500 m deep south-eastern part of the basin center.

On a first ship-based field campaign in September 2019 we recovered 73 surface sediment samples aligned on a quasi equidistant raster to characterize the lakes recent spatial distribution of sedimentological and (bio-)geochemical processes via multi proxy approaches. Sampling was conducted utilizing a gravity corer in water depths ranging between 10 and 650 m. Also two outcrops of lake-level high-stand terraces at the southern and the western shores of the lake were sampled for comparison of information to sediment successions from the basin center. Moreover, 12 river samples from Issyk Kul's main tributaries were taken for an integrated provenance study. Recent analytical work includes granulometrical-, CNS-, TOC- and XRF measurements of the samples recovered in 2019.

Our preliminary results allow us to determine distinct provinces and gradients of lateral deviating processes in terms of salinity, carbon sources and transportation energy. Also first assumptions of water currents and source-to-sink-dynamics can be made.

A second field campaign is planned for March 2020 and is intended to recover 6 to 10-m-long sediment successions from the southeastern part of the lake. The investigation of (bio-) geochemical, mineralogical, and grain-size characteristics of the sediments will help to examine, if Issyk Kul can provide a continuous high-resolution record of climate change and shifts in atmospheric circulation patterns, in phase relationships of local Alpine glaciers and continental ice sheet advances, and the roles of tectonics and climate change in affecting erosion rates in the catchment. This project seeks to overcome the missing knowledge of sedimentation characteristics and sedimentation rates from the abyssal part of Issyk Kul and to provide information on potential deep drilling sites in the central part of the basin.

IODP

Benthic Foraminifera as bottom current proxy in Contourite Drift Systems

J. Schmidt, A. Saupe, P. Grunert

Institute of Geology and Mineralogy, University of Cologne, Otto-Fischer-Straße 14, 50674 Cologne, Germany

In the Iberian Margin Contourite Drift System, abundances of a distinct group of benthic foraminifera are controlled by the strength and nutrient load of bottom currents. This *bottom current fauna* (BCF) represents highly specialized suspension feeding benthic foraminifera attached to elevated substrates as an adaptation to strong bottom currents. Schönfeld (1997, 2002) demonstrated a direct relation between BCF abundances and Mediterranean Outflow Water strength at the Iberian Margin and established BCF abundances as a bottom current proxy.

Faunal and geochemical data from Pliocene-Pleistocene contourites drilled during IODP Exp. 339 in the Gulf of Cádiz, however, showed a poor correlation of BCF abundances with other bottom current proxy data. The data indicate that taphonomic processes like downslope transport and loss of foraminiferal shells during early fossilization lead to potential biases on the interpretation of fossil faunal assemblages and the BCF proxy. Our understanding of these taphonomic and diagenetic biases on fossil foraminiferal assemblages is still poor.

The aim of the present study is to quantify the effect of taphonomic and diagenetic processes on fossil foraminiferal assemblages and to develop a more robust BCF proxy method. Based on Pleistocene samples from IODP sites U1385-U1391, taphonomic and diagenetic influences on fossil assemblages will be determined from geochemical analyses ($\delta^{18}O$, $\delta^{13}C$) and normalization of BCF taxa to sediment accumulation rates. The improved BCFAR (BCF accumulation rate) proxy will provide researchers with a reliable, well-calibrated and easily applicable tool for bottom current reconstruction.

References

Schönfeld, J., 1997. The impact of the Mediterranean Outflow Water (MOW) on benthic foraminiferal assemblages and surface sediments at the southern Portuguese continental margin. Mar. Micropaleontol. 29, 211–236. https://doi.org/10.1016/S0377-8398(96)00050-3

Schönfeld, J., 2002. A new benthic foraminiferal proxy for near-bottom current velocities in the Gulf of Cadiz, northeastern Atlantic Ocean. Deep. Res. Part I-Oceanographic Res. Pap. 49, 1853–1875.

IODP

The High Pressure Temperature Gradient Block - A Novel Tool to Explore the Thermal Biotic Fringe

F. Schubert, J. Kallmeyer, A. Kitte

GFZ German Research Centre for Geosciences, Section Geomicrobiology, Potsdam, Germany

Our newly constructed High Pressure Temperature Gradient Block (HPTGB) offers the possibility to simultaneously incubate multiple samples under 15 different temperatures and three different pressures. The HPTGB consists of a 1.5 m long thermally insulated aluminum block with three lines of 15 sample slots each. Each slot holds a high-pressure cylinder with a maximum pressure rating of 60 MPa that can accommodate up to three incubation vials of 10 ml each. Each line has an individual pressure system, consisting of a modified HPLC pump and a back-pressure regulator. There are individual shut-off valves for each high-pressure cylinder, allowing the termination of in-

cubation for single cylinders without interruption of the entire pressure line. A linear temperature gradient with a maximum range of -20 to +150°C can be established. Heating and cooling is achieved by recirculating liquid thermostats.

This system provides the opportunity for incubation experiments in a variety of temperature and pressure conditions. It allows for rapid screening of preferential P/T conditions by simultaneously incubating a large number of samples over a wide P/T range. Initially, the HPTGB will be used to explore the upper temperature limit of life on samples from IODP Exp. 370 (Temperature Limit of the Deep Biosphere off Muroto) by executing ^{35}S-radiotracer measurements and examining bacterial sulfate reduction rates (SRR), samples from IODP Exp. 385 (Guaymas Basin Tectonics and Biosphere) will follow. Elevated pressure is expected to have a positive effect on SRR and allows for analysis up to the currently known thermal limit of life.

As previous studies have shown (1), not only high temperature but also high pressure is necessary to cultivate microorganisms from the biotic fringe. The HPTGB will be a crucial tool to develop a better understanding of microbial activity at the upper temperature limit of life.

References

Takai K, et al. (2008) Cell proliferation at 122 degrees C and isotopically heavy CH(4) production by a hyperthermophilic methanogen under high-pressure cultivation. Proceedings of the National Academy of Sciences of the United States of America 105(31):10949-10954.

IODP

Response of microbial lipids to increasing temperatures and decreasing microbial populations in the Nankai Trough subduction zone, IODP Exp. 370

F. Schubotz[1], I. Hölscher[1], Y. Morono[2], F. Inagaki[2,3], V. B. Heuer[1], K.-U. Hinrichs[1]

[1] MARUM – Center for Marine Environmental Sciences, University of Bremen, Leobener Str. 8, 28359 Bremen, Germany
[2] Kochi Institute for Core Sample Research, X-star, JAMSTEC, Kochi 783-8502, Nankoku, Japan
[3] Research and Development Center for Ocean Drilling Science, JAMSTEC, Yokohama, Kanagawa 236-0001, Japan

Site C0023 was established during IODP Exp. 370 within the Moroto Transect of the Nankai Trough to explore factors that control microbial life at temperatures close to the limit of life. The location is characterized by an extremely high heat flow with an exceptionally high geothermal gradient of ~110°C km-1 (Heuer et al., 2017). Cores were recovered down to the basement at 1177 meter below seafloor (mbsf) where temperatures reach 120 ± 2°C, which corresponds to the curently known temperature limit of life (Takai et al., 2008). In this study, we explore distributions of intact polar lipids (IPL) along this steep temperature gradient and evaluate them as potential life markers at Site C0023. Furthermore, we compare IPL with fossil core lipid compositions and put them into context of expected biotic and abiotic processes that may affect lipid profiles.

We observe distinct IPL patterns that respond to biogeochemical processes and to temperature regimes at Site C0023. Within the methanogenic zone, where temperatures transition from mesophilic to thermophilic conditions we observe an increase in butanetriol and pentanetriol dialkyl glycerol tetraethers with glycosidic headgroups (G-BDGTs and G-PDGTs; Zhu et al., 2013). These compounds are suggested markers for sedimentary methanogens and unclassified heterotrophic archaea (Meador et al., 2015; Becker et al., 2016; Coffinet et al., 2020), which are both expected to exist at these depths. Notably, IPL concentrations in the ng-per-g-sediment range are high in relation to the detected cell counts (Heuer et al., 2017; Morono and Exp. 370 Scientists, unpubl. results). This suggest substantial accumulation of fossil IPL over time at these depths (ca. 360 mbsf) and temperatures of ca. 45 to 50°C. This zone is followed by a strong decline in IPL concentrations until values fall below detection (ca. 20 fg per g sediment) at ~770 mbsf (~87°C). While the correspoding fossil core lipid pool of glycerol dialkyl glycerol tetraethers (GDGTs) and related compounds remains fairly constant until ~600 mbsf, a similar steady decline to values below detection is observed at depths of ~860 mbsf and temperatures of ~95°C. As these depths and temperatures coincide with the onset of a thermogenic zone and the start of catagenic processes (Horsfield et al., 2006; Heuer et al., 2017; Tsang et al., 2019), and there is no significant change in depositional environment, the most plausible explanation for this strong decline in overall lipid concentrations is their thermal breakdown with rising temperatures. To date, little is known about the temperature effects involved in the degradation of GDGTs and related compounds. At Site C0023, we observe a selective removal of GDGTs according to the number of rings in their core structure. These results have important implications for the application of the sea surface temperature proxy TEX_{86}, which is based on the variations in GDGT ring distribution, particularly if the proxy is applied to sediments that have been thermally overprinted.

References

Becker KW, Elling FJ, Yoshinaga MY, Söllinger A, Urich T, et al. (2016). Unusual butane- and pentanetriol-based tetraether lipids in Methanomassiliicoccus luminyensis, a representative of the seventh order of methanogens. Appl. Environ. Microb., 82, 4505–4516.

Coffinet S, Meador TB, Mühlena L, Becker KW, Schröder J, et al. (2020). Structural elucidation and environmental distributions of butanetriol and pentanetriol dialkyl glycerol tetraethers (BDGTs and PDGTs). Biogeosciences 17, 317-330.

Heuer VB, Inagaki F, Morono Y, Kubo Y, Maeda L, and the Expedition 370 Scientists (2017). Expedition 370 Preliminary Report: Temperature Limit of the Deep Biosphere off Muroto. International Ocean Discovery Program. http://dx.doi.org/10.14379/iodp.pr.370.2017

Horsfield B, Schenk HJ, Zink K, Ondrak R, Dieckmann V, et al. (2006). Living microbial ecosystems within the active zone of catagenesis: Implications for feeding the deep biosphere. Earth Planet. Sci. Lett. 246, 55-69.

Meador TB, Bowles M, Lazar CS, Zhu C, Teske A, et al., (2015) The archaeal lipidome in estuarine sediment dominated by members of the Miscellaneous Crenarchaeotal Group. Environ. Microbiol. 17, 2441-2458.

Takai K, Nakamura K, Toki T, Tsunogai U, Miyazaki M, et al. (2008). Cell proliferation at 122°C and isotopically heavy CH4 production by a hyperthermophilic methanogen under high-pressure cultivation. Proc. Natl. Acad. Sci. USA 105(31), 10949-10954.

Tsang M-Y, Bowden S, Wang Z, Mohammed A, Tonai S, et al., (2020) Hot fluids, burial metamorphism and thermal histories in the underthrust sediments at IODP 370 Site C0023, Nankai Accretionary complex. Mar. Petr. Geol. 112, 104080.

Zhu C, Meador TB, Dummann W, Hinrichs K-U (2013). Identification of unusual butanetriol dialkyl glycerol tetraether and pentanetriol dialkyl glycerol tetraether lipids in marine sediments. Rap. Comm. Mass. Spec. 28, 332-338.

IODP

Causes of garnet growth in impact melt rock of the Chicxulub crater, Mexico

F. M. Schulte, U. Riller

Institut für Geologie, Universität Hamburg, Bundesstrasse 55, 20146 Hamburg, Germany

Carbonate-bearing target rocks are associated with almost one third of the known impact craters on Earth. The presence of such target rocks may have a profound influence on the post-impact climate development, caused particularly by large impacts. However, the transformation of carbonate-bearing target rocks during cratering is not well understood, especially when mingled with silicate target rocks in impact melt breccias. Previous studies proposed that the presence of Ca-rich garnet serves as an indicator mineral for post-shock decomposition of carbonate target rocks and points to the importance of post-impact degassing of CO_2. Based on electron microprobe investigation of 9 impact-melt rock samples from IODP/ICDP Expedition 364 from the Chicxulub peak-ring and samples from ICDP Yaxcopoil-1 drill core from the crater rim, we provide insight on garnet formed from carbonate.

Impact-melt rock drilled during Expedition 364 from two major units. A texturally homogeneous tagamite at the base consists of microcrystalline feldspar and pyroxene pervasively altered to phyllosilicates. Target-rock fragments are rare and chiefly derived from granitoid basement rocks. Melt-rock breccia overlies this unit and shows evidence for ductile flow. The breccia contains fragments of tagamite as well as sedimentary and basement target rocks embedded in a fine-grained carbonate matrix. Six samples of this unit contain euhedral, poikilitic andradite-grossular garnet enveloping inclusions of a Ca-rich mineral phase, most likely wollastonite. Garnet occurs in carbonate-rich zones close to silicate melt rock. In contrast to tagamite, the matrix of the melt rock comprises well-preserved diopsidic to hedenbergitic pyroxene. Yaxcopoil-1 drill core contains only impact-melt breccia with euhedral andradite garnet located at the top of the breccia and devoid of any inclusions. Moreover, the content of grossular in this drill core is significantly lower than in Expedition 364 drill core.

The location of andradite-grossular garnet at contacts of carbonate-rich zones with entrained silicate clasts in Expedition 364 drill core points to garnet formation akin to that in skarns. Initially superheated impact melt would be far too hot for the formation of garnet, as $CaCO_3$ would thermally dissociate at such high temperatures. However, ejecta deposits emplaced through tsunami surges on top of initially superheated impact melt would effectively lower the temperature of this melt and, last not least, would bring carbonate material in contact with silicate melt. This process provides a plausible explanation for the presence of andradite-grossular garnet in Expedition 364 drill core, but may not account for the presence of andradite garnet in Yaxcopoil-1 drill core, which is devoid of a coherent tagamite. Andradite in this drill core may have formed hydrothermally as a consequence of the development of a hydrothermal cell below the crater.

ICDP

Acoustic facies analysis of the high-resolution sedimentary archive Nam Co, Tibetan Plateau, aiming at the reconstruction of lake-level changes

N. Schulze[1], V. Spiess[1], G. Daut[2], T. Kasper[2], T. Haberzettl[3], J. Wang[4], L. Zhu[4]

[1] University of Bremen, Department of Geosciences, MTU, Klagenfurter Straße | 28359 Bremen | Germany
[2] Friedrich-Schiller-University Jena, Institute of Geography, Physical Geography, Loebdergraben 32 | 07743 Jena | Germany
[3] University of Greifswald, Institute of Geography and Geology, Physical Geography, Friedrich-Ludwig-Jahn Str. 16, 17489 Greifswald | Germany
[4] Chinese Academy of Sciences, Institute of Tibetan Plateau Research, 16 Lin Cui Road | Chaoyang District | Beijing 100101 | P.R. China

The sedimentary archive at Lake Nam Co (SE Tibetan Plateau, China) comprises an almost 1000 m thick high-resolution lacustrine sedimentary succession, which is estimated to reach back more than one million years. Unravelling the Nam Co archive will provide details on how the Late Quaternary climatic forcing influenced the hydrologic cycle at the Tibetan Plateau, thereby contributing important constraints on future climate change scenarios. This is primarily important as the Tibetan Plateau acts as the 'water tower' of Asia whilst being the source area of the seven largest rivers of Asia.

Sediments older than 24 ka have not yet been studied from the endorheic Nam Co basin. Therefore, sediment echo sounder and high-resolution 2D multi-channel seismic data were analyzed to support the ICDP drilling proposal '*The Nam Co Drilling Project, Tibet (NamCore): A one million year sedimentary record from the third pole*'. Since 2014, over 800 km of high-resolution 2D multi-channel seismic data have been acquired in Nam Co in the frame of the ICDP project '*Seismic Pre-Site Survey for ICDP Drilling Locations at Lake Nam Co*'. The analysis of the extensive dataset provides the opportunity to gain insight into tectonics and stratigraphy and hence climate control.

Lake level is a climatic indicator recorded in the lake's stratigraphy. Lake level fluctuations are mainly driven by monsoon variability, changes on glacial-interglacial periodicities, temperature, insolation/albedo, and the resulting change of the precipitation/evaporation ratio. Sediment is entering the 98 m deep lake primarily via >60 streams, which drain the catchment radially. Additional to summer precipitation, eastern and southern streams discharge glacial meltwater from the Nyainqêntanglha Mountain Range. Climatic changes and length of transport pathways influence the amount and composition of the deposited sediments. Sediment coring in the centre of the basin (NC08/01: 10.8 m core length, 24 kyrs) revealed grain sizes of clayey silt during dry and silty clay during moist climate conditions. Few intermitted thin layers of sand represent either drier stages or inflow events. Respective sedimentation rates are ~2.4 mm yr-1 during the dry LGM and <0,5 mm yr-1 during moist late glacial and Holocene times (Kasper et al., 2015).

Acoustic facies can be very sensitive to environmental changes through depositional processes associated with them resulting in variations in geophysical properties. Those derive from changes e.g., in grain size and/or water depth. We can distinguish several acoustic units in the hydro-acoustic (upper 30 m of sediment) and multi-channel seismic data (down to 700 m), which internally represent uniform acoustic facies, properties, and likely grain sizes throughout the lake. We link the individual acoustic units to changes in climatic conditions, drainage patterns, slope settings, and shoreline positions. Using

the relation between grain size, lateral thickness gradients, and water column stratification, we propose reconstructions of former lake level stands for various time slices.

Interestingly, unit thicknesses resolved with the hydroacoustic data are uniform in the deepest parts of the lake but decrease upslope towards a certain water depth, e.g., Holocene sediments are present only below 75 m. This indicates that sediment primarily enters the basin as part of interflows, rather than, as previously assumed, by hyperpycnal flows. According to our understanding of the LGM to Holocene sediment transport and deposition documented in the strata formation of the uppermost 30 m of sediments, we can draw parallels to older time periods resolved in the multi-channel seismic data set. As a result, we present here also a refined tentative stratigraphy that incorporates the measured sedimentation rates for NC08/01 and the facies interpretation for the entire acoustic dataset.

References

Kasper, T., Haberzettl T., Wang J., Daut G., Doberschütz S, Zhu L., Mäusbacher R., 2015. Hydrological variations on the Central Tibetan Plateau since the LGM and their teleconnection to inter-regional and hemispheric climate variations. Journal of Quaternary Science 30(1), 70-78.

ICDP

The Eastern Mediterranean - Levant late Quaternary climates: Paleohydrology and Extreme Floods from the Dead Sea ICDP Core (PALEX)

M. J. Schwab[1], Y. Enzel[2], J. Hasan[3], N. Lensky[4], A. Brauer[1], PALEX Scientific Team

[1] GFZ German Research Centre for Geosciences, Section Climate Dynamics and Landscape Evolution, Potsdam, Germany
[2] University of Jerusalem, The Fredy and Nadine Herrmann Institute of Earth Sciences, Hebrew Jerusalem, Israel
[3] Al-Quds University, Dept. of Applied Environmental and Earth Studies, Jerusalem, Palestinian Authority
[4] Geological Survey of Israel (GSI), Jerusalem, Israel

Dead Sea lake levels reflect the mean centennial-millennial hydrological budget in the eastern Mediterranean. In contrast, extreme floods in the large watersheds draining into the Dead Sea, are linked to short-term synoptic circulation patterns reflecting hydroclimatic variability. The strong precipitation gradient and extreme environment of the Levante region is exceptionally sensitive to shifts of atmospheric circulation pattern and related hydrological conditions of mid-latitude climatic zones. Investigating origin and mechanisms driving hydrological and environmental changes are emerging challenges for understanding the interplay between climate change and flood frequency. The PALEX project intergrates all aspects of extreme hydro-meteorological events in this region including (i) monitoring and modeling of modern floods and hydroclimatology, (ii) reconstructing extreme floods in the past from the sediment record, (iii) reconstructing sediment provenance and transport processes, and, (iv) tracing source waters in the catchment. In this paper we summarize published key results of the PALEX research approach:

References

Ahlborn, M., Armon, M., Ben Dor, Y., Neugebauer, I., Schwab, M. J., Tjallingii, R., Shoqeir, J. H., Morin, E., Enzel, Y., Brauer, A. (2018): Increased frequency of torrential rainstorms during a regional late Holocene eastern Mediterranean drought. - Quat Res, 89, 2, 425-431. doi.org/10.1017/qua.2018.9

Armon, Moshe & Dente, Elad & Smith, James & Enzel, Yehouda & Morin, Efrat. (2018). Synoptic-Scale Control over Modern Rainfall and Flood Patterns in the Levant Drylands with Implications for Past Climates. Journal of Hydrometeorology. 19. doi.org/10.1175/JHM-D-18-0013.1

Ben Dor, Y., Armon, M., Ahlborn, M., Morin, E., Erel, Y., Brauer, A., Schwab, M. J., Tjallingii, R., Enzel, Y. (2018): Changing flood frequencies under opposing late Pleistocene eastern Mediterranean climates. - Scientific Reports, 8, 8445. doi.org/10.1038/s41598-018-25969-6

Ben Dor, Y., Neugebauer, I., Enzel, Y., Schwab, M. J., Tjallingii, R., Erel, Y., Brauer, A. (2019): Varves of the Dead Sea sedimentary record. - QSR, 215, 173-184. doi.org/10.1016/j.quascirev.2019.04.011

Lensky, N. G., Lensky, I. M., Peretz, A., Gertman, I., Tanny, J., & Assouline, S. (2018): Diurnal Course of evaporation from the dead sea in summer: A distinct double peak induced by solar radiation and night sea breeze. Water Resources Research: 54, 150–160. doi.org/10.1002/2017WR021536

Palchan, D., Neugebauer, I., Amitai, Y., Waldmann, N. D., Schwab, M. J., Dulski, P., Brauer, A., Stein, M., Erel, Y., Enzel, Y. (2017): North Atlantic controlled depositional cycles in MIS 5e layered sediments from the deep Dead Sea basin. - Quat Res, 87, 1, 168-179. doi.org/10.1017/qua.2016.10

Sirota, I., Enzel, Y., Lensky, N.G. (2017): Temperature seasonality control on modern halite layers in the Dead Sea: In situ observations. GSA Bulletin: 129, 9-10, 1181-1194. doi.org/10.1130/B31661.1

Weber, N., Yechieli, Y., Stein, M., Yokochi, R., Gavrieli, I., Zappala, J., Mueller, P., Lazar, B. (2018): The circulation of the Dead Sea brine in the regional aquifer. EPSL 493, 242-261 DOI: doi.org/10.1016/j.epsl.2018.04.027

IODP

Biogeochemistry of dissolved organic matter in Guaymas Basins sediments

M. Seidel[1], B. Engelen[1], A. Coppola[2], J. Brünjes[3], F. Schubotz[3], A. Teske[4], T. Dittmar[1,5]

[1] Institute for Chemistry and Biology of the Marine Environment (ICBM), Carl von Ossietzky University of Oldenburg, Oldenburg, Germany
[2] Department of Geography, University of Zurich, Zurich, Switzerland
[3] MARUM – Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany
[4] University of North Carolina at Chapel Hill, Department of Marine Sciences, Chapel Hill, USA
[5] Helmholtz Institute for Functional Marine Biodiversity (HIFMB), University of Oldenburg, Oldenburg, Germany

The primary goal of our investigations is to understand the biotic and abiotic processes that govern the molecular composition of dissolved organic matter (DOM) in hydrothermally influenced deep subseafloor sediments. To reach this goal, we have received a comprehensive set of porewater and sediment samples from the Guaymas Basin, recovered in the frame of IODP Expedition 385 (Sep. – Nov. 2019). The Guaymas Basin (GB) in the Gulf of California is a young and active spreading center were new oceanic crust is formed. The seafloor is covered by one to two kilometers thick organic-rich sediments because of high primary productivity in the water column and high sedimentation rates of particulate organic matter (POM). At high temperatures, thermal cracking of sedimentary organic matter leads to petroleum catagenesis in the sediments. Large amounts of DOM are released into the water column through the fluids that are discharged from the sediments above magmatic intrusions. Previous research had indicated that these hydrothermal fluids support diverse benthic ecosystems in the shallow subsurface sediments. During our pilot study we have established the DOM groundwork with GB samples from short sediment cores (30 cm) acquired during RV Atlantis cruise 42-05 in November 2018. Through the processing of these short cores we refined our geochemical and molecular biological methods and provide baseline data to understand the thermal mobilization and biogeochemical alteration of recently deposited organic matter in the shallow basin sediments. The deep-subsurface samples from of IODP Expedition 385 were obtained from up to 500-meter-long cores from eight drill sites, exhibiting different hydrothermal gradients. By determining the molecular composition of porewater DOM and water-extractable organic matter from the sediment, we will assess their hydrothermal and microbial alteration. Using ultrahigh-resolution mass spectrometry (FT-ICR-MS), modern molecular biological

methods and sophisticated carbon-isotope analysis, we aim to fill the current knowledge gaps around the molecular properties of deep subsurface DOM. We will 1) characterize the molecular composition of DOM in the high heat-flow and organic-rich sediments versus the off-axis sediments, and 2) decipher the connection of the molecular DOM composition with deep biosphere-related microbial metabolism along temperature and redox gradients. The results will also be compared with samples from the water column obtained during the RV Atlantis cruise to investigate the transport of hydrothermal DOM into the deep ocean. The following hypotheses will be tested in the frame of the project: I) Hydrothermal heating of deep subsurface sediments produces and releases large amounts of reactive and refractory DOM, II) Hydrothermal dissolved black carbon (DBC) contributes to the marine stable carbon isotopic signature and the radiocarbon age of the refractory oceanic DBC, III) The subsurface microbial community structure is influenced by geochemical and thermal gradients and is related to specific reactive, hydrothermally produced DOM compounds. Overall, the project offers the unique opportunity to study the biogeochemistry of DOM across hydrothermal gradients in the deep subsurface and across the lithosphere-hydrosphere interface.

ICDP

Deformation Styles and Sedimentation Patterns in Lake Issyk–Kul, Tienshan Mountain Range, Kyrgyzstan – Evidence from a Recent Seismoacoustic Survey to Support ICDP Drilling

V. Spiess[1], H. Keil[1], J. Geils[1], D. Cammarata[1], E. Rahimdinov[2], A. Reusch[1], B. Wagner[3], K. Abdrakmatov[2],

[1] University of Bremen, Faculty of Geosciences, Klagenfurter Straße, 28359 Bremen, Germany
[2] Institute of Seismology, Bishkek, Kyrgyztan
[3] University of Cologne, Germany

Lake Issyk-Kul in the North of the Kyrgyz Tien Shan mountain range in Central Asia is a large intermontane basin and the second largest high-altitude lake in the world (250 by 145 km; 1607 m elevation; 6236 sq.km area), as well as one of the deepest lakes worldwide (668 m) with a drainage area of 22.080 sq.km. The compressional regime developing out of the Indian-Eurasian collision created one of the Earth's tectonically most active intra-continental mountain belts of 4-7 km elevation, overthrusted onto adjacent basins. Since the presumed uplift in Late Oligocene times and accelerated exhumation since ~10 Ma, larger lacustrine basins have formed comprising several kilometers of glacial, fluvioglacial, fluvial and lacustrine formations.

Due to these characteristics, extreme shortening across and its long evolution, the lake itself likely hosts a long-term archive of climatic conditions and tectonic activity, which should ultimately become target of an ICDP drilling campaign. To document its sedimentary setting and decipher the depositional history, several seismoacoustic campaigns had been carried out by Russia in 1984, by Belgian colleagues in 1997 and 2001 and by University of Bremen in 2013, and again most recently during 12 operation days in May/June 2019. This last expedition for the first time collected >1500 km multichannel seismic data with a 220 m long, 96 channel streamer using a micro (0.1 L) and standard GI Gun (1.7 L) in combination with an Innomar sediment echosounder and an ELAC Seabeam 1000 multibeam system.

In the deepest lake sedimentation seems continuous as erosional surfaces are absent, despite lake level variations of several hundred meters were found by Gebhardt et al (2017). Several almost parallel anticlines were identified, apparently aligned with similar deformation on land. Uplifted crests reveal reduced sedimentation rates from turbidity or suspension flows and expose older lake sediments for potential drilling. Few deeper penetrating seismic lines were shot to image bounding faults to test models of lake formation/development in Quaternary times. Together with steep minor faulting in the deep lake floor, the data seem to indicate a predominantly strike-slip and transpressional setting.

While in the deep basin, high accumulation rates are relatively uniform across the lake floor, locations with reduced thickness of younger sediments are present above several anticlines, and early Quaternary or Pliocene units may become accessible for deep lake drilling. The preparation of ICDP lake drilling will be complemented by a shallow coring campaign of Cologne University in early summer 2020. Due to strong multiple reflections and complex subsurface geology in areas of deformation, identification of suitable drilling locations require careful further seismic data processing.

ICDP

Quality vs. quantity – challenges of radiocarbon dating pollen concentrates separated by flow cytometry

C. Steinhoff, N. Pickarski, T. Litt

Institut für Geowissenschaften Bonn

The sedimentary section of the PALEOVAN deep drilling project at Lake Van (Eastern Anatolia) still provides one of the longest and most comprehensive climate archives in the Near East. In 2010 an ICDP supported campaign carried out a 220 m continental record at the Ahlat Ridge in the center of the lake. On the basis of multiproxy analyses on its composite profile, it is possible to reconstruct the lake's sedimentological evolution as well as the paleoclimatic development in Eastern Anatolia for the past 600.000 years.

So far the chronostratigraphy of the continental record was formed using climatostratigraphic alignments, tephrostratigraphy and radiometric age estimations, such as argon-argon single crystal dating or radiocarbon dating. Furthermore, the sediments of Lake Van are partly laminated so that varve counting provides an additional tool to calibrate its chronology. However, the varve chronology established for the Holocene indicates a hiatus in the deposits and requires further radiometric analysis to clearly identify and bridge missing varves. But the infrequency of relevant material for radiometric measurements in the sedimentary section of the Holocene outlines the difficulty to validate and refine the existing chronology.

Traditionally the AMS radiocarbon dating of terrestrial plant-remains in limnic archives is the method of choice. The absence of sufficient large plant macrofossils in the sedimentary sections of interest demand for a satisfactory alternative, such as carbon-containing microfossils. Several studies showed that especially pollen grains seem to be suitable for radiocarbon dating due to their ubiquitous presence in lake sediments. In consequence, radiocarbon ages can be used as an independent time control for the existing chronologies of Lake Van. Nevertheless, isolating pollen concentrates of a sufficient purity without carbon contamination remained challenging. A high-

ly promising alternative to remove contaminants and generate pure pollen concentrates is flow cytometry, which offers the possibility to rapidly isolate large quantities of pollen grains from heterogeneous sediments.

In this study we present a new approach to identify and isolate pollen grains from the sediments of Lake Van by flow cytometry. We are now able to produce purified pollen concentrates in a sufficient quantity suitable for AMS radiocarbon dating. However, preliminary age estimations show that the radiocarbon ages of pollen concentrates are older compared to the expected ages derived from the varve chronology. The significant discrepancy is either an indicator of contamination with old carbon, a consequence of difficult handling of the pollen concentrates due to ultra-small weight and unexpected precipitates or possibly errors in the existing varve chronology.

These results demonstrate the importance to further improve the quality of the purified pollen concentrates and therefore the efficiency during the cytometric analysis. It is inevitable to increase the yield of the sorting process and decrease the amount of possible contaminants in the sample to create optimum conditions for AMS dating. In conclusion we will be able to refine the existing chronology of Lake Van and will establish radiocarbon dating of pollen concentrates from deep drilling archives.

ICDP

Structural control on hydrothermal-magmatic processes at the Campi Flegrei caldera revealed by 3D seismics to support an amphibious ICDP-IODP drilling effort

L. Steinmann[1], V. Spiess[1], M. Sacchi[2]

[1] Faculty of Geosciences, University of Bremen, Bremen, Germany
[2] Institute of Marine Sciences - Italian Research Council (ISMAR-CNR), Naples, Italy

The Campi Flegrei caldera (CFc) – situated in southern Italy at the border of the densely populated city of Naples – represents one of the world's highest volcanic risk areas as proven by its history of catastrophic eruptions, caldera resurgence, as well as recent volcanic unrest. To understand the mechanisms of caldera-forming eruption, the most explosive and dangerous type of volcanism, and to be able to reliably evaluate future volcanic hazards, the CFc has become subject to a joint approach in the ICDP-IODP programmes.

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

Here, we present the first 3D multichannel seismic dataset (25 m line spacing; 10-100 Hz) from a (partly) submerged caldera, providing the unique opportunity to image the entire caldera's architecture down to 2 km subsurface depth. Moreover, the achieved imaging of down to 2.9 s TWT (~2.5 km) in the caldera provides an ideal foundation for a precise targeting of relevant ICDP-IODP drill sites (e.g. hydrothermally and magmatically altered zones, complete caldera fill, undisturbed extra-caldera sedimentary succession) as well as for guiding the diverted ICDP onshore drilling into the Gulf of Pozzuoli.

Our data show clear evidence for the existence of a ~1 km deep caldera depression filled with ignimbrites and reworked volcanoclastic/sedimentary deposits, which is bordered by a ~2 km wide, arcuate ring-fracture zone. We propose that the ring-fracture zone represents an eruption site of the Campanian Ignimbrite (CI) leading to a coeval caldera collapse. As the location and style of the high-impact CI eruption remains strongly debated, this finding contributes significantly to our knowledge on the caldera's formation and associated eruption kinematics. Moreover, our data suggest that the ring-fracture zone has a strong control on the post-collapse ascent of hydrothermal fluids and magma as evidenced by the presence of intrusions, submarine vents, and shallow subsurface fluids. Hence, the caldera ring-fault zone depicts a key location for the interconnectivity between the surface and the deep magmatic-hydrothermal system. In fact, it may also play an important role during the recent unrest episodes e.g. by acting as stress-release pathways. Moreover, since the fracture zone has been prone to the rise of magma, it may represent a favourable site for future eruptions with crucial implications for the hazard and risk assessment.

Overall, this study demonstrated the effectiveness of 3D seismic data in providing reliable constraints on the structural framework and magmatic-hydrothermal processes in (partly) submerged volcanic settings. Our work clearly showed that the submerged portion must be considered to be able to fully understand magmatic, hydrothermal, and volcanic processes at partly marine or lacustrine calderas.

References

Steinmann, L., Spiess, V., Sacchi, M., 2016. The Campi Flegrei caldera (Italy): Formation and evolution in interplay with sea-level variations since the Campanian Ignimbrite eruption at 39ka. Journal of Volcanology and Geothermal Research, Volume 327, p. 361-374.

Steinmann, L., Spiess, V., Sacchi, M., 2018. Post-collapse evolution of a coastal caldera system: Insights from a 3D multichannel seismic survey from the Campi Flegrei caldera (Italy). Journal of Volcanology and Geothermal Research, Volume 349, 2018, p. 83-98.

IODP

Disentangling the effects of particles and circulation on 231Pa/230Th during Heinrich Stadials

F. Süfke[1], J. Grützner[2], F. Pöppelmeier[1,3], J. Lippold[1]

[1] Institute of Earth Sciences, Heidelberg University, Heidelberg, Germany
[2] AWI Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany
[3] Climate and Environmental Physics, Physics Institute, University of Bern, Bern, Switzerland

It has been shown that during Heinrich stadials northern deep water production ceased leading to an enhanced inflow of southern sourced water. Although Heinrich events are not considered to represent the primary trigger of Heinrich stadials the reorganization of Atlantic Ocean dynamics during their occurrences is an active field of research. In particular, Heinrich stadial 2 (HS2) is of high interest, based on the observation that the interplay with the climate system was very different during HS2 compared to HS1, although the magnitude of iceberg and freshwater discharge was similar (Hemming, 2004). During HS2 sea-level was still decreasing while the atmospheric CO_2

content was relatively stable unlike the climatic evolution during Heinrich HS1.

The notion of a reduced Atlantic Meridional Overturning Circulation (AMOC) during Heinrich Stadials is mainly strengthened by the $^{231}Pa/^{230}Th$ records from the Bermuda Rise. However, other influencing factors, capable of increasing the sedimentary $^{231}Pa/^{230}Th$ without according decreases in AMOC strength, need to be considered as well. Besides biogenic opal, high dust fluxes may also result in enhanced scavenging rate of both radionuclides and consequently higher sedimentary $^{231}Pa/^{230}Th$ signals, since another distinct feature that accompanies Heinrich Stadials is the high atmospheric concentration of dust in the northern hemisphere. Furthermore, high dust concentrations might be an indicator of a vigorous wind system and therefore strong ocean mixing, which can lead to the enhanced formation of nepheloid layers These layers are suspected to cause strong bottom scavenging and consequently high sedimentary $^{231}Pa/^{230}Th$. Very high dust fluxes were observed e.g. during HS2 and MIS4. Here, we compare $^{231}Pa/^{230}Th$ with dust records in order to disentangle the effects of scavenging and circulation on the recorded sedimentary $^{231}Pa/^{230}Th$ from the northwestern Atlantic.

ICDP

The rhyolitic, trachytic and basaltic euruptive record of Nemrut and Süphan volcanoes, eastern Anatolia: onshore and offshore tephrochronology of Lake Van area (Paleovan ICDP Drilling project)

M. Sumita, H.-U. Schmincke

GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel , Wischhofstr. 1-3, 24148 Kiel, Germany

Chronological, chemical, mineralogical, volcanological and sedimentological data obtained on ca. 170 of a total of ca. 450-500 tephra layers from Site 2 of the ICDP Paleovan project are compared with similar data from the ca. 570 ka onshore record of Nemrut Volcano adjacent to, and underlying, Lake Van.

Nemrut explosive activity extends from ca. 570 ka to historic onshore and from ca. 580 ka to Holocene in the core. Most tephra layers are slightly peralkaline trachytes, larger volumes of rhyolitic tephras having been erupted at intervals of 30-40 ka. Fallout deposits dominate while larger rhyolite eruptions are generally associated with ignimbrites onshore, thick massive tephra deposits drilled being interpreted as syn-ignimbrite turbidites. Stages of caldera collapse were associated with large-volume rhyolitic eruptions. Most larger eruptions are compositionaly zoned from evolved to more mafic, magma mingling being ubiquituous.

Eruptive rates at Nemrut volcano increased in time. Tephras from adjacent subalkalic Süphan volcano dominate the felsic tephras in the core prior to about 200 ka. Nemrut volcanic explosive activity was roughly periodic while that of Süphan was episodic with external forcing (seismic, hydroclastic) having been the characteristic forcing mechanism. Dominantly high-Al basaltic tephras in the lower ca. 100 m are of subaqueous origin and may represent parent magma to subalkalic Süphan system.

The seismically and lithologically most significant interval is the ca. 80 ka old ca. 2-2.5 m-thick hyaloclastite that we interpret to have been erupted from Incekaya hyaloclastite cone rising ca. 400 m at the southern shore of Lake Van. The basaltic magma volume of this eruption is estimated to have been around 20 km3. The Incekaya eruption thus represents the most voluminous basaltic clastic eruption known (Schmincke et al 2018).

We estimate about 30 % of the cored tephra layers to be reworked. Wind-reworked tephras, most common and associated with dry climate intervals, contain many xenocrysts and other nonvolcanic particles. Thick fallout deposits of fine-grained basal tephra and rounded pumice at the top are interpreted as pumice raft deposits reflecting prolonged abrasion in widespread pumice rafts. Poorly sorted reworked tephra deposits with abundant organic debris and ubiquitous gypsum crystals are common and are interpreted as recording extended periods of low lake levels and correlate with seismically defined low lake level periods. Such intervals maybe used as independent criteria for recording significant lake level changes.

The precise stratigraphic and temporal correlation of the upper cores from sites 1 and 2, as well as with the onshore tephra record, was based on fallout tephras defined by chemical composition and highly concordant $^{40}Ar/^{39}Ar$ ages. There is a tentative correlation of higher eruption frequency with warm climate periods.

References

Cukur D, Krastel S, Schmincke H-U, Sumita M, Tomonaga, Çağatay N (2014) Drastic lake level changes of Lake Van (eastern Turkey) during the past ca. 600 ka: climatic, volcanic and tectonic control. J Palelimnol 52: 201-214. DOI 10.1007/s10933-014-9788-0

Macdonald R, Sumita M, Schmincke H-U, Baginski B, White JC, Ilnicki SS (2015) Peralkaline felsic magmatism at the Nemrut volcano, Turkey: impact of volcanism on the evolution of Lake Van (Anatolia) IV. Contrib Min Petrol KKK

Schmincke H-U, Sumita M (2014) Impact of volcanism on the evolution of Lake Van (Anatolia) III: Periodic (Nemrut) vs. episodic (Süphan) eruptions, contrasting eruptive mechanisms and climate forcing causing a tephra gap between ca. 14 ka and ca. 30 ka. J Volcanol Geotherm Res 285: 195-213. DOI 10.1016/j.jvolgeores.2014.08.015

Schmincke Sumita Cukur 2018 Incekaya

Stockhecke M, Sturm M, Brunner I, Schmincke H-U, Sumita M, Kwiecien O, Cukur D, Anselmetti FS (2014a) Sedimentary evolution and environmental history of Lake Van (Turkey) over the past 620,000 years. Sedimentology 61: 1830-1861. DOI 10.1111/sed.12118

Sumita M, Schmincke H-U (2013a) Impact of volcanism on the evolution of Lake Van II: Temporal evolution of explosive volcanism of Nemrut Volcano (eastern Anatolia) during the past ca. 0.4 Ma. J Volcanol Geotherm Res 253: 15-34. doi.org/10.1016/j.jvolgeores.2012.12.009

Sumita M, Schmincke H-U (2013b) Erratum to “Impact of volcanism on the evolution of Lake Van II: Temporal evolution of explosive volcanism of Nemrut Volcano (eastern Anatolia) during the past ca. 0.4”. J Volcanol Geotherm Res 253: 131-133. Doi: 10.1016/j.jvolgeores.2013.01.008

Sumita M, Schmincke H-U (2013c) Impact of volcanism on the evolution of Lake Van I: Evolution of explosive volcanism of Nemrut Volcano (eastern Anatolia) during the past ca. 0.4 Ma. Bull Volcanol 75: 714-. DOI 10.1007/s00445-013-0714-5

ICDP

Fires in north-eastern Siberia during marine isotope stages 12-11c reconstructed from charcoal in Lake El’gygytgyn sediments

T. Tessendorf[1], C. Kraamwinkel[1,2], A. Andreev[1], U. Herzschuh[1,3,4], E. Dietze1

[1] Alfred-Wegener-Institute Helmholtz-Centre for Polar and Marine Research, Research Unit Potsdam, Polar Terrestrial Environmental Systems Group, Potsdam, Germany
[2] Vrije Universiteit Amsterdam, The Netherlands
[3] Institute of Environmental Sciences and Geography, University of Potsdam, Germany
[4] Institute of Biochemistry and Biology, University of Potsdam, Germany

Fires are regarded as one of the most important factors for vegetation disturbances in the Northern Hemisphere forests, where they are not only destructive. There are different types of

fire regimes that reshape entire ecosystems up to the emerge of fire-adapted and even fire-dependent systems. Fossil charcoal particles found in sediment cores can act as a proxy for changing fire regimes throughout time. Since fire activity is always related to climate and vegetation, it is interesting to find out what role fire regimes played when it was significantly warmer than today and human activity did not influence natural processes.

A unique archive for the reconstruction of past fire regimes is Lake El'gygytgyn (Chukotka, Northeastern Siberia), located in the tundra ca. 100 km north of the modern tree line. Since the lake area was never glaciated, the lacustrine sediments provide a continuous record of environmental conditions in the Arctic dating back to ca. 3.6 Myrs. This study focusses on Marine Isotope Stage (MIS) 11c (~424-394 ka BP). It was described as being a so-called "superinterglacial" with earlier pollen-based vegetation reconstructions suggesting the presence of evergreen boreal forests in the lake catchment.

The aim of this study is to answer the following research questions: (i) how did fire activity vary during MIS 11c based on El'gygytgyn lake sediments? (ii) How did vegetation change over time and is there a connection between vegetation development and fire activity? (iii) What type of biomass burned during MIS 11? To answer these questions, continuous sediment samples from MIS 11c and the end of MIS 12 were prepared according to the standard pollen method in order to determine the concentration of microcharcoal particles. The microcharcoal particles were classified according to their morphology. This provides information about the fuel material of the fire, since different forms of vegetation produce different shapes and structures of charred material during the combustion process. Charcoal proxies were then correlated with high-resolution pollen and non-pollen palynomorph data from the same samples to better understand fire-vegetation relationships.

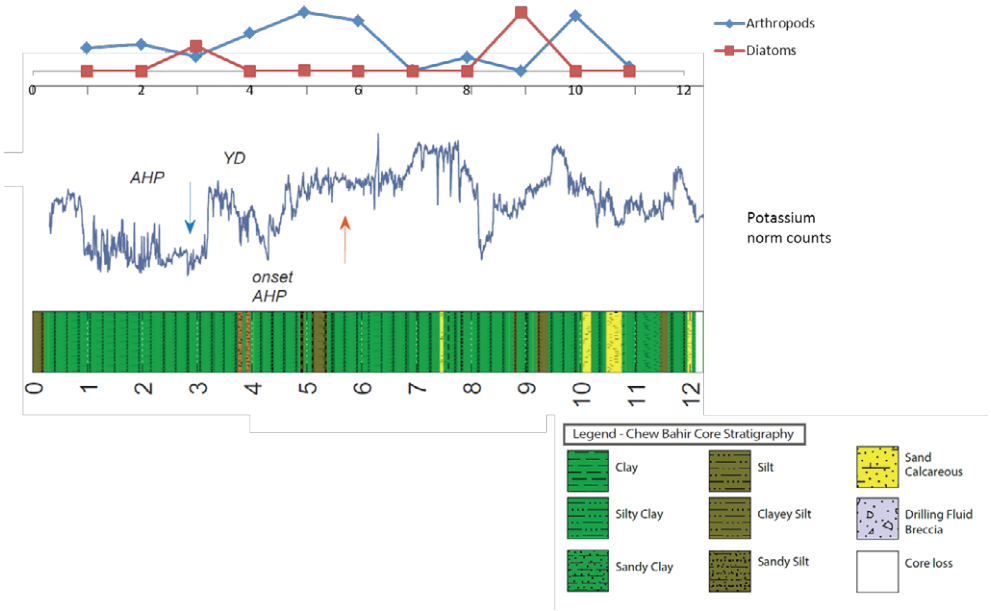
The results show that the vegetation and climate changes during MIS 11c followed the same general shift from cold to warm climate conditions as recorded during other interglacial stages, consisting of an initial establishment of deciduous shrubs and trees followed by conifers. Most charcoal, i.e. the strongest fire activity, was found during the transition from MIS 12 to MIS 11c. Increased fire activity resulted in an opening of the landscape, a short-term change in vegetation and a higher influx of charcoal particles into the lake. Generally, we find that climate-fire-vegetation relations were similar during MIS 11c compared to today suggesting that the recent warming as well as the increased fire activity may strongly affect and possibly completely change the present-day high Arctic ecotones.

ICDP

Metabarcoding of ancient eukaryotic DNA from Chew Bahir, Ethiopia: Reconstruction of past biodiversity responses to drastic environmental change

R. Tiedemann[1], J. Krüger[2], K. Havenstein[1], S. Kaynar[1], V. Förster[3], S. Hartmann[2], M. H. Trauth[4], M. Hofreiter[2]

[1] Unit of Evolutionary Biology/Systematic Zoology, Institute for Biochemistry and Biology, University of Potsdam
[2] Unit of Evolutionary Adaptive Genomics, Institute for Biochemistry and Biology, University of Potsdam
[3] Institute of Geography Education, University of Cologne, Germany
[4] Institute of Earth and Environmental Science, University of Potsdam



R. Tiedemann, Fig. 1: Normalized approximate relative abundance of key eukaryote taxa (arthropods, diatoms; based on DNA metabarcoding sequence counts) for the last 25,000 years (about 10 m depth), relative to the potassium record. Diatom occurrence coincides with decreasing potassium (wetter climate; blue arrow), arthropod occurrence coincides with increasing potassium (drier climate; red arrow). AHP=African humid period, YD=Younger Dryas.

The Chew Bahir Drilling Project (CBDP) provides tropical sediment samples presumably spanning the last ~650 kyrs. DNA metabarcoding across these cores provides a record of a tropical lake environment, unique in resolution and time span. In a pilot study, we could analyze ancient eukaryotic DNA from the ~280 m long Chew Bahir cores in sediment layers down to 70 m, corresponding to 150 kyrs BP by hybridization-capture-based metabarcoding. Sediment samples were subjected to taxon- and gene-specific DNA-enrichment with specific probes

("baits") and analyzed by Next-Generation-Sequencing. We specifically target sediment layers before, at, and after drastic environmental perturbations (mostly wet-dry and dry-wet transitions). We evaluate possibilities and limits of semiquantitative abundance estimation (via Next Generation Sequencing (NGS) read counts or quantitative RealTime PCR (qPCR)) across strata of the core (corresponding to timepoints) and taxa. We relate taxon-specific sequence read numbers as a proxy for relative abundances to lithological data and thereby infer how past ecosystems reacted to short-term, but significant disturbances, e.g., dramatic droughts or increased humidity. So far, this analysis has been performed for the uppermost 10m of the core, corresponding to about 25,000 years. It reveals interesting organismal responses to inferred climatic changes (see Figure 1 for the example of arthropods and diatoms).

ICDP

The Bushveld Complex Drilling Project probes the biggest and richest intrusion on Earth

R. B. Trumbull[1], S. Webb[2], L. Ashwal[2], F. Roelofse[3], R. Klemd[4]

[1] Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum
[2] University of the Witwatersrand, Johannesburg South Africa
[3] University of the Free State, Bloemfontein South Africa
[4] Friedrich-Alexander University, Erlangen-Nürnberg

The Bushveld Igneous Complex (BIC) is the largest igneous intrusion on earth (volume >1 x 10^6 km^3) and the world's largest repository of magmatic ore deposits (PGE, Cr, V, Ni, Cu, Sn, fluorite). The new Bushveld ICDP project will establish the first semi-continuous vertical reference section through the 9 km thick sequence of mafic/ultramafic cumulate rocks and the felsic rocks above them. Scientifically, the ICDP project will coordinate international multi-disciplinary research on this reference section in search of answers to fundamental questions including the nature of magma sources and melting processes that gave rise to such enormous magma volumes about 2000 million years ago, and how these magmas were emplaced and evolved in magma chambers to produce the extensive mineral layering and stratiform mineralization we see today.

An initial project starting in 2020 within the SPP 1006 will study 2700 meters of drill core through the Bushveld Main Zone. Its focus is (1) Testing for evidence of one or more intrusive pulses in the Main Zone by density and mineral-chemistry variations; (2) Evaluating the degree of chemical and textural re-equilibration of the rocks and the vertical variations in those properties, taking account of layering and intrusive cycles (if present); (3) Calculate equilibration temperatures of rock-forming minerals and estimate cooling rates at different levels in the sequence.

ICDP

Basalt Dissolution Experiments with Surtsey Microbes

A. Türke[1,2], W.-A. Kahl[1], C. Hansen[1], W. Bach[1], S. L. Jørgensen[2]

[1] Department of Geosciences and MARUM, University of Bremen, Bremen 28357, Germany
[2] K.G. Jebsen Centre for Deep Sea Research, Department of Earth Science,University of Bergen, Bergen, Norway

The significance of microbial activity in the oceanic crust, covering 60% of Earth's surface and potentially the largest and oldest of all ecosystems is almost unexplored. However, the existence of a deep biosphere and their potential to gain energy by exploiting redox reactions in the ocean crust is undisputed (Orcutt et al., 2011). Potential biosignatures like trace fossils have been detected in subseafloor basalts from various ages, but their occurrence is sparse and difficult to integrate into geological records of the deep biosphere in deep time (McMahon & Ivarsson, 2019).

Surtsey, the youngest of the islands of Vestmannaeyjar, is an oceanic volcano created by explosive basaltic eruptions during 1963-1967 off the southern coast of Iceland. In summer 2017, three cored boreholes were drilled through the active hydrothermal system of the volcano by the International Continental Scientific Drilling Program (ICDP) SUSTAIN Expedition 5059. They serve as samples of „zero-age" basalts and yield cruicial insights into the first colonization of newly formed oceanic crust.

One of the boreholes has been equipped with a subsurface observatory dedicated to in situ experiments for monitoring water-rock interactions and microbial processes in sterile, artificial basaltic glass (Türke et al., 2019). With temperatures ranging from 25 to 125 °C, the subsurface observatory provides a precise geothermal window into an active hydrothermal system and thus represents an exceptional natural laboratory for studying fluid-rock-microbe interactions at different temperature regimes and facilitates experimental validation of active submarine microbial processes at the limit of functional life, about 121 °C.

The experiments have been retrieved after two years in the borehole in summer 2019. Accompanying ex-situ flow-through experiments with basalt glass are carried out. Microbes from the Surtsey boreholes are used as inoculum and environmental conditions in the Surtsey borehole are mimicked to test how microbial community structure and dissolution rates change in this broad temperature range.

First results from the in-situ and ex-situ basalt dissolution experiments will be presented with a focus on alteration rates and textures produced with and without the presence of microbes in basalt glass.

References

B. N. Orcutt, J. B. Sylvan, N. J. Knab, and K. J. Edwards (2011). Microbial ecology of the dark ocean above, at, and below the seafloor. Microbiol. Mol. Biol. Rev. 2011, 75, 361.

McMahon, S. and Ivarsson, M. (2019). A New Frontier for Palaeobiology: Earth's Vast Deep Biosphere. BioEssays, p.1900052.

Türke, A., Jackson, M. D., Bach, W., Kahl, W.-A., Grzybowski, B., Marshall, B., Gudmundsson, M. T., and Jørgensen, S. L. (2019). Design of the subsurface observatory at Surtsey volcano, Iceland. Scientific Drilling, 25, pp.57-62.

ICDP

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

A. Ulfers, K. Hesse, C. Zehen, T. Wonik

Leibniz Institute for Applied Geophysics, Stilleweg 2, 30655 Hanover, Germany

Lake Towuti is a tectonic lake on central Sulawesi, Indonesia. It is located within the Indo Pacific Warm Pool, a convection cell which has major impact on tropical climate and the ability to project its influence on a global scale (Chiang, 2009; De Deckker, 2016). Pre-site surveys using seismic methods and piston cores indicated that sediments in Lake Towuti provide

best conditions to obtain a long-term paleoclimate record in this key region (Russel et al., 2014).

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

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

Sedimentation rates for certain parts were calculated and complement the preliminarily age model derived from 14C- (Russel et al., 2014) and tephra-dating (A. Deino, personal communication, December, 2018). Further refining of the model and omission of an interpretation of long cyclicities results in the most detailed age-depth model for Lake Towuti, and thus is a fundamental step towards our understanding of paleoclimate processes in this region.

References

Baumgarten, H., Wonik, T., Tanner, D. C., Francke, A., Wagner, B., Zanchetta, G., Sulpizio, R., Giacco, B. and Nomade, S. (2015). Age-depth model of the past 630 kyr for Lake Ohrid (FYROM/Albania) based on cyclostratigraphic analysis of downhole gamma ray data.

Chiang, J. C. (2009). The tropics in paleoclimate. Annual Review of Earth and Planetary Sciences, 37, 263-297

De Deckker, P. (2016). The Indo-Pacific Warm Pool: critical to world oceanography and world climate. Geoscience Letters, 3 (1), 20.

Hinnov, L. A. (2013). Cyclostratigraphy and its revolutionizing applications in the earth and planetary sciences. GSA Bulletin, 125(11-12), 1703-1734.

Molinie, A. J. and Ogg, J. G. (1990). Sedimentation Rate Curves And Discontinuities From Sliding-window Spectral Analysis Of Logs. The Log Analyst, 31 (06).

Russell, J. M., Vogel, H., Konecky, B. L., Bijaksana, S., Huang, Y., Melles, M., Wattruse, N., Costa, K. and King, J. W. (2014). Glacial forcing of central Indonesian hydroclimate since 60,000 y BP. Proceedings of the National Academy of Sciences, 201402373.

ICDP

A warmer Mediterranean region at the Miocene to Pliocene transition

I. Vasiliev[1], D. Boehn[2], D. Volkovskaja[2], C. Schmitt[2], K. Agiadi[3], F. Andreetto[4], A. Mulch[1,2]

[1] Senckenberg Biodiversity and Climate Research Centre, Frankfurt am Main
[2] Institute of Geosciences, Goethe University Frankfurt, Frankfurt am Main
[3] National and Kapodistrian University of Athens
[4] Paleomagnetic Laboratoty Fort Hoofddijk, Utrecht University

Between 5.97-5.33 Ma several kilometre-thick evaporite units were deposited in the Mediterranean Basin during the Messinian Salinity Crisis (MSC). The MSC reflects a period featured by a negative hydrological budget, with a net evaporative loss of water exceeding precipitation and riverine runoff. The contemporary changes in continental and marine circum-Mediterranean temperature are, however, poorly constrained. Here we reconstruct continental mean annual temperatures (MAT) using branched glycerol dialkyl glycerol tetraether (GDGT) biomarkers for the time period corresponding to MSC Stage 3 (5.55-5.33 Ma). Additionally, for the same time interval, we estimate sea surface temperatures (SSTs) of the Mediterranean Sea using isoprenoidal GDGTs based TEX86 proxy. The excellently preserved organic biomarkers were extracted from outcrops and DSDP cores spread over a large part of the onland (Malaga, Sicily, Cyprus) and offshore (holes 124 and 134 from Balearic abyssal plane and hole 374 from Ionian Basin) Mediterranean Basin domain. The calculated MATs for the 5.55 to 5.33 Ma interval show values around 16 to 18 ºC for the Malaga, Sicily, and Cyprus outcrops. The MAT values calculated for DSDP Leg 13 holes 124, 134 and Leg 42A hole 374 are lower, around 11 to 13 ºC.

For samples where the branched and isoprenoid tetraether (BIT) index was lower than the 0.4 we could calculate TEX_{86} derived SSTs averaging around 27 ºC for all sampled locations. Where available (i.e. Sicily), we compared the TEX_{86} derived SSTs with alkenone based, U^k_{37} derived SST estimates from the same samples. The TEX_{86} derived SST values are slightly higher than the U^k_{37} derived SST of 20 to 28 ºC. For the Mediterranean region, values between 19 and 27 ºC of the U^k_{37} derived SSTs were calculated for the interval between the 8.0 and 6.4 Ma, close to our calculations for Sicily section (20 to 28 ºC). Independent of common pitfalls that may arise in using molecular biomarkers as temperature proxies, both SST estimates independently hint towards much warmer Mediterranean Sea water during the latest phase (Stage 3) of the MSC. These elevated temperatures coincide with higher δD values measured on alkenones and long chain *n*-alkanes (both records indicating for more arid and/or warmer conditions than today between 5.55 and 5.33 Ma). We therefore conclude that the climate between 5.55 to 5.33 Ma was warmer than present-day conditions, recorded both in the Mediterranean Sea and surrounding basin.

ICDP

Late Miocene intensification of continentality in the Black Sea region

I. Vasiliev[1], A. Feurdean[1,2], G.-J. Reichart[3,4], A. Mulch[1,5]

[1] Senckenberg Biodiversity and Climate Research Centre, Frankfurt am Main, Germany
[2] Institute of Physical Geography, Goethe University, Frankfurt am Main, Germany
[3] Royal Netherlands Institute of Sea Research, Texel, The Netherlands
[4] Department of Earth Sciences, Utrecht University, Utrecht, The Netherlands
[5] Institute of Geosciences, Goethe University Frankfurt, Frankfurt am Main, Germany

The Black Sea basin is the sink for some of the largest European rivers and has acted as such since it was part of the Eastern Paratethys. The late Miocene to Pliocene sedimentary record of the Black Sea documents several phases of strongly evaporitic conditions associated with extreme changes in regional hydrology. Here we present the first combined record of continental temperature, soil type and biomass burning in the circum-Black Sea region from the late Miocene to the transition into Pliocene (~10.0 to 5.0 Ma). We use branched glycerol

dialkyl glycerol tetraethers (brGDGT) to reconstruct mean annual air temperature (MAT) and soil pH within the catchment of the Black Sea basin and complement these data with evidence from charcoal morphology as a proxy for burned biomass. The brGDGT data reveal generally decreasing temperatures and acidic soils between ~10 and 8.5 Ma, overlapping with increase in herbaceous cover in the Black Sea region. The Pontian flooding at 6.12 Ma, is characterized by large quantities of organic debris and charcoal fragments in the basin and is followed by cooling starting at 5.97 Ma, event that is superimposed on the TG 20 and TG 22 glacial peaks (at 5.8 Ma). Between 5.8 and 5.0 Ma, the brGDGTs seem to be primarily derived from a cold steppe environment. Enhanced fire activity coinciding with generally cooler temperatures and a higher proportion of herbaceous plants, are indicative of increased continentality between 5.8 and 5.0 Ma in the Black Sea region.

ICDP

Microbially-mediated formation of diagenetic iron minerals in ferruginous sediments, Lake Towuti, Indonesia.

A. Vuillemin[1,2], J. Kallmeyer[2], A. Friese[2], H. Kemnitz[2], R. Wirth[2], L.-G. Benning[3,2,4], D. Wagner[2,5], A. Luecke[6], C. Mayr[7], J.A. Schuessler[2], A. J. Schleicher[2], F. von Blanckenburg[2], S. Nomosatryo[2,8], L.-G. Ordonez[9], D. Ariztegui[9], V. Heuer[10], C. Glombitza[11], C. Henry[8], K. W. Bauer[12,13], R. Sinister[12], S. A. Crowe[12,13,14], M. Melles[15], J.M. Russell[16], S. Bijaksana[17], H. Vogel[18], ICDP TOWUTI Drilling Project Science Team

[1] Department of Earth and Environmental Science, Paleontology & Geobiology, Ludwig-Maximilians-Universität, 80333 München, Germany

[2] GFZ German Research Centre for Geosciences, Helmholtz Centre Potsdam, 14473 Potsdam, Germany

[3] Department of Earth Sciences, Free University of Berlin, 12249 Berlin, Germany

[4] School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, UK

[5] Institute of Geosciences, University of Potsdam, 14469 Potsdam, Germany

[6] Research Center Juelich, Institute of Bio- & Geosciences 3: Agrosphere, 52428 Juelich, Germany

[7] Institute of Geography, University of Erlangen-Nürnberg, 91054 Erlangen, Germany

[8] Research Center for Limnology, Indonesian Institute of Sciences (LIPI), Cibinong-Bogor, Indonesia

[9] Department of Earth Sciences, University of Geneva, 1205 Geneva, Switzerland

[10] MARUM – Center for Marine Environmental Sciences, University of Bremen, 28359 Bremen, Germany

[11] ETH Zürich, Institute of Biogeochemistry and Pollutant Dynamics, 8092 Zürich, Switzerland

[12] Department of Earth, Ocean, and Atmospheric Sciences, University of British Columbia, Vancouver, Canada

[13] Department of Earth Sciences, University of Hong Kong, Hong Kong, China

[14] Department of Microbiology and Immunology, University of British Columbia, Vancouver, Canada

[15] Institute for Geology and Mineralogy, University of Cologne, 50923 Cologne, Germany

[16] Department of Earth, Environmental, and Planetary Sciences, Brown University,13 Providence, RI, 02912, USA

[17] Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung, 50132 Bandung, Indonesia

[18] Institute of Geological Science, University of Bern, 3012 Bern, Switzerland

Lake Towuti is a deep tectonic basin surrounded by ultramafic rocks and lateritic soils. Its geographic position in central Indonesia and relatively great age (estimated >500 kyrs) makes the lake a prime location to record paleoclimatic changes in the tropical Western Pacific warm pool in its sedimentary sequence (Russell et al., 2016). It was therefore chosen as a drilling target by the International Continental Drilling Program (ICDP). Ultramafic rocks and lateritic soils eroded from the catchment supply Lake Towuti with little sulfate but considerable amounts of iron (oxyhydr)oxides (Vuillemin et al., 2016 and 2017). These iron oxides trap all bioavailable phosphate in the water column and thereby restrain primary productivity. However in the monimolimnion, microbial iron reduction leads to the dissolution of particulate iron (Bauer et al., 2020) and release of phosphorus. The extreme scarcity of sulfate and nitrate/nitrite in Lake Towuti's anoxic bottom waters represents conditions analogous to those of the Archean Ocean (Crowe et al., 2014). These geochemical conditions, which are relatively rare on the

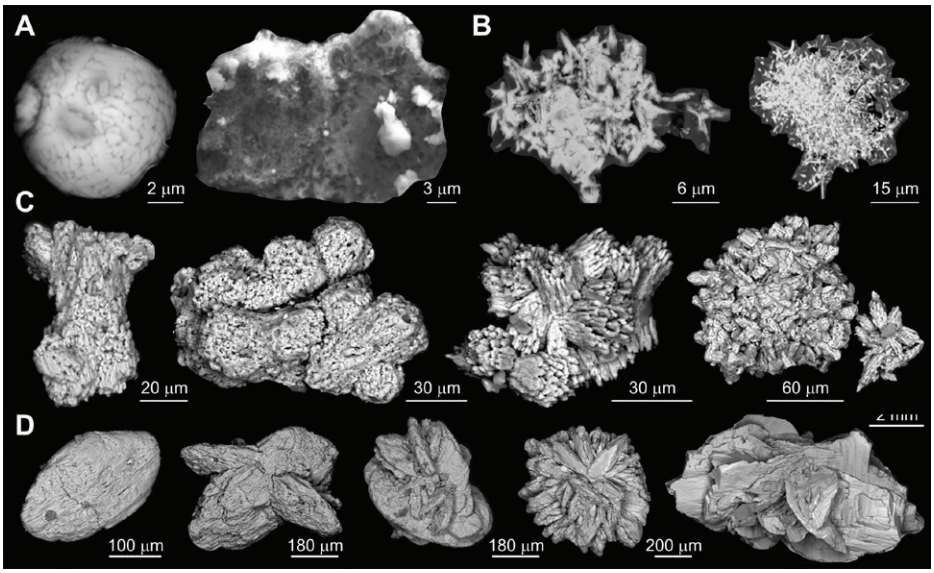


Fig. 1: (A) Framboidal magnetite and partially dissolved detrital magnetite (B) Millerite (C) Siderite developing into aggregates (D) Vivianite, from tabular habitus to rosette.

modern Earth, make Lake Towuti an ideal site to study the (trans)formation of iron minerals and reductive diagenesis under conditions relevant to the early Earth.

In May to July 2015, the Towuti Drilling Project led by the ICDP recovered a total >1000 m of sediment core from three drilling sites (Russell et al., 2016), including a 114 m long core (TDP-1A) drilled with a contamination tracer dedicated to geomicrobiological studies (Friese et al., 2017). In the field, core TDP-1A was sectioned and sampled under protective atmosphere for pore water geochemistry, cell counts, and DNA extractions. Siderites (i.e. $FeCO_3$) were recovered from split core halves in 50 distinct layers, whereas vivianites (i.e. $Fe_2[PO_4]_2 \cdot 8H_2O$) were found in 5 different horizons. These multiple results were integrated to infer mineral formation and recording of microbial processes during early diagenesis (Vuillemin et al., 2018). SEM and TEM imaging showed that siderites grow from micritic phases into mosaic monocrystals, developing into twinings and aggregates with increasing DIC concentrations and depth of burial (Vuillemin et al., 2019a). Green rust (i.e. $Fe_6[OH]_{12} \cdot [CO_3 \cdot 2H_2O]$) and framboidal magnetites (i.e. Fe_3O_4) were observed interlaced within siderites, suggesting successive diagenetic phases related to iron reduction. Elemental mapping revealed Mn/Fe/Ca zonations in siderite crystals, consistent with diagenetic maturation and evolution of pore water chemistry. 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 millerite (i.e. NiS) and siderite reflect diagenetic mineral formation, antecedent to the one of vivianite, that is related to microbial reduction of iron and sulfate (Vuillemin et al., 2019b). Together with pore water profiles, these lines of evidence suggest that the precipitation of magnetite, millerite, siderite, and vivianite in soft ferruginous sediments stems from the gradual microbial reduction of pore water electron acceptors and organic matter remineralization. Based on solute concentrations and modeled mineral saturation indices, we inferred vivianite formation to initiate around 20 m depth in the sediment as the likely result of the decrease in microbial activity and associated P recycling in pore water.

Nevertheless, the presence/absence of siderite and vivianite in specific sedimentary layers may relate to past dynamics in the lake and at the water–sediment interface, since ensuing variability in the relative burial of ferric iron and organic matter are decisive on subsequent diagenetic processes in the sediment. Towuti's iron mineralogy reflects complex source-to-sink processes as iron minerals derived from catchment soils (e.g. ferrihydrite, goethite, hematite, magnetite) and reworked to the lake tend to transform into nanocrystalline phases during reductive dissolution in the water column and sediment (Sheppard et al., 2019; Bauer et al., 2020). This puts into question their use as indicators of past environmental conditions or early diagenesis. Thus, we performed a detailed analysis of siderites and their isotope compositions ($\delta^{18}O$, $\delta^{56}Fe$, $\delta^{13}C$), spanning >500 kyrs of sediment history, with the aim to trace processes behind siderite isotope signatures. Our data show that siderites recorded heavier $\delta^{18}O$ values related to low lake level during the Last Glacial, whereas lightest $\delta^{56}Fe$ values suggested iron cycling in anoxic waters prior to sediment deposition. However, due to continuous siderite overgrowth from pore water solutes on preexisting crystals (Vuillemin et al., 2019a), most of the siderite $\delta^{56}Fe$ values can be interpreted in terms of reductive diagenesis and redistribution of dissolved ferrous iron after deposition. Negative $\delta^{56}Fe$ values measured for vivianite also indicated incorporation of kinetically fractionated light Fe^{2+} into the crystals, likely derived from dissolution of ferric/ferrous phases during diagenesis. The siderite $\delta^{13}C$ values, although variable, indicated continuous incorporation of biogenic HCO_3^- in the crystals during organic matter remineralization, consistent with increasing DIC concentrations and their measured $\delta^{13}C$ compositions.

To conclude, the identification of microbially-mediated minerals, such as magnetite, green rust, millerite, siderite and vivianite, and their local pore water conditions provide a means to trace successive iron phases related to early diagenesis in soft ferruginous sediments. Their morphologies and isotope compositions can be used and extrapolated to better constrain the ancient rock record.

References

Bauer K. W., Byrne J., Kenward P., Simister R., Michiels C., Friese A., Vuillemin A., Henny C., Nomosatryo S., Kallmeyer J., Kappler A., Smit M., Francois R., Crowe S. A. (2020). Magnetite biomineralization in ferruginous waters and early Earth evolution, EarthArXiv Preprint, doi: 10.31223/osf.io/prhuz.

Crowe S. A., Paris G., Katsev S., Jones C. A., Kim S. T., Zerkle A. L., Nomosatryo S., Fowle D. A., Adkins J. F., Sessions A. L., Farquhar J., and Canfield D. E. (2014). Sulfate was a trace constituent of Archaean seawater. Science 346, 735–739.doi: 10.1126/science.1258966

Friese A., Kallmeyer J., Kitte J.A., Martinez I.M., Bijaksana S., Wagner D., the ICDP Lake Chalco Drilling Science Team, and the ICDP Towuti Drilling Science Team (2017). A simple and inexpensive technique for assessing contamination during drilling operations. Limnology and Oceanography: Methods 15, 200-211, doi: 10.1002/lom3.10159.

Morlock M. A., Vogel H., Nigg V., Ordoñez L., Hasberg A. K. M., Melles M., Russell J. M., Bijaksana S., and the TDP Science Team (2019). Climatic and tectonic controls on source-to-sink processes in the tropical, ultramafic catchment of Lake Towuti, Indonesia. Journal of Paleolimnology 61, 279-295, doi: 10.1007/s10933-018-0059-3.

Russell J.M., Bijaksana S., Vogel H., Melles M., Kallmeyer J., Ariztegui D., Crowe S., Fajar S., Hafidz A., Haffner D., Hasberg A., Ivory S., Kelly C., King J., Kirana K., Morlock M., Noren A., O'Grady R., Ordonez L., Stevenson J., von Rintelen T., Vuillemin A., Watkinson I., Wattrus N., Wicaksono S., Wonik T., Bauer K., Deino A., Friese A., Henny C., Imran, Marwoto R., Ngkoimani L.O., Nomosatryo S., Safiuddin L.O., Simister R., and Tamuntuan G. (2016). The Towuti Drilling Project: Paleoenvironments, biological evolution, and geomicrobiology of a tropical Pacific lake. Scientific Drilling 21, 29-40, doi: 10.5194/sd-21-29-2016.

Sheppard R. Y., Milliken R. E., Russell J. M., Darby Dyar M., Sklute E. C., Vogel H., Melles M., Bijaksana S., Morlock M. A., and Hasberg A. K. M. (2019). Characterization of iron in Lake Towuti sediment. Chemical Geology 512, 11-30, doi: 10.1016/j.chemgeo.2019.02.029.

Vuillemin A., Friese A., Alawi M., Henny C., Nomosatryo S., Wagner D., Crowe S. A., and Kallmeyer J. (2016). Geomicrobiological features of ferruginous sediments from Lake Towuti, Indonesia. Frontiers in Microbiology 7, 1007, doi: 10.3389/fmicb.2016.01007.

Vuillemin A., Friese A., Wirth R., Schuessler J. A., Schleicher A. M., Kemnitz H., Lücke A., Bauer K. W., Nomosatryo S., von Blanckenburg F., Simister R., Ordoñez L. G., Ariztegui D., Henny C., Russell J. M., Bijaksana S., Vogel H., Crowe S. A., Kallmeyer J., and the Towuti Drilling Project Science Team (2019b). Vivianite formation in ferruginous sediments from Lake Towuti, Indonesia. Biogeosciences Discussion, in review, doi:.10.5194/bg-2019-426.

Vuillemin A., Horn F., Alawi M., Henny C., Wagner D., Crowe S., and Kallmeyer J. (2017). Preservation and significance of extracellular DNA in ferruginous sediments from Lake Towuti, Indonesia. Frontiers in Microbiology 8: e1440, doi: 10.3389/fmicb.2017.01440.

Vuillemin A., Horn F., Friese A., Winkel M., Alawi M., Wagner D., Henny C., Orsi W. D., Crowe S. A., and Kallmeyer J. (2018). Metabolical potential of microbial communities from ferruginous sediments. Environmental Microbiology 20, 4297-4313, doi: 10.1111/1462-2920.

Vuillemin A., Wirth R., Kemnitz H., Schleicher A. M., Friese A., Bauer K. W., Simister R., Nomosatryo S., Ordoñez L., Ariztegui D., Henny C., Crowe S. A., Benning L. G., Kallmeyer J., Russell J. M., Bijaksana S., Vogel H., and the Towuti Drilling Project Science Team (2019a). Formation of diagenetic siderite in modern ferruginous sediments. Geology 47, 540-544, doi: 10.1130/G46100.1.

ICDP

The Lake Ohrid drilling project SCOPSCO: Scientific results 6 years after the drilling operation

B. Wagner[1], T. Wilke[2], and the SCOPSCO Science Team

[1] Institute of Geology and Mineralogy, University of Cologne, Cologne, Germany

[2] Department of Animal Ecology & Systematics, Justus Liebig University Giessen, Giessen, Germany

The international and multi-disciplinary project „Scientific Collaboration on Past Speciation Conditions in Lake Ohrid" (SCOPSCO) was initiated within the scope of the International Continental Scientific Drilling Program (ICDP) in 2009 and intended (i) to obtain more precise information about the age and origin of the lake, (ii) to unravel the seismotectonic history of the lake area including effects of major earthquakes and associated mass wasting events, (iii) to obtain a continuous record containing information on volcanic activities and climate change in the central northern Mediterranean region, and (iv) to better understand the impact of major geological/environmental events on general evolutionary patterns and shaping an extraordinary degree of endemic biodiversity as a matter of global significance.

The SCOPSCO drilling operation in early April 2013 became one of the most successful ICDP lake drilling campaigns in the past. Using the Deep Lake Drilling System (DLDS) by DOSECC (USA), a total of ~2100 m of sediment were recovered from Lake Ohrid from early April to late May 2013 at four different sites. At the "DEEP" site in the center of the lake, the terminal drilling depth was 568 m below lake floor. The upper 447 m of the composite sediment succession cover the lacustrine history of Lake Ohrid back to the early infill of the basin 1.36 Myr ago.

We present here the major outcome of the overall project, including geophysical, geological, geochronological , palaeoenvironmental, biological and ecological aspects.

IODP

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

T. Westerhold, U. Röhl

MARUM - Center for Marine Environmental Sciences, University of Bremen, 28359 Bremen, Germany

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

Seismic pre-site survey for an IODP site on the Cape Verde Plateau

H. Wilckens[1], S. Krastel[1]

[1] Institute of Geosciences, Kiel University

The IODP full-proposal 973 aims to investigate Neogene climate, sedimentation and ocean productivity along the continental margin of NW Africa by drilling a latitudinal transect. Sediment cores should be retrieved at eight sites between Cape Bojador (~28°N) southeast of the Canary Islands to the Sierra Leone Rise (~5°N). One central site is located on the Cape Verde Plateau. ODP Site 659 was drilled on the Cape Verde Plateau during Leg 108 in 1986. The sediments recovered at this site extend back to the Oligocene. The aim of this study is to identify a new IODP drilling site at the Cape Verde Plateau where the Plio-Pleistocene is thinner and the Miocene is thicker than at ODP Site 659.

This study is based on new high-resolution seismic reflection data that was collected during RV MARIA S. MERIAN Cruise MSM87. During this cruise we collected 28 seismic profiles with a total length of ~1000 km. The seismic data is mainly characterized by well-bedded, sub-parallel and sub-horizontal reflectors. Seismic facies analysis allowed the identification of two seismic units. The Lower Unit shows high amplitude reflectors of good continuity. The Upper Unit is characterized by parallel low amplitude reflectors of very good continuity. South-East of ODP Site 659 several intrusions are visible in the seismic data.

Previous results from ODP Site 659 were used to identify the seismic reflector that marks the boundary between the Plio-Pleistocene and the Miocene sedimentary successions. This reflector is located at the lower part of the Upper Unit. Based on the picked reflector it is possible to calculate the thickness of the Plio-Pleistocene sediments. In most areas, the Plio-Pleistocene sediments have a relatively constant thickness of approx. 0.18 s TWT (~135 m assuming a velocity of 1500 m/s) on the Cap Verde Plateau. South-East of ODP Site 659 the Plio-Pleistocene sediments appear to thin up to 0.08 s TWT (~60 m assuming a velocity of 1500 m/s). This possibly represents an ideal drilling location but further investigation of the seismic data is necessary.

ICDP

Milanković cycles in logging data from Lake Chalco

C. Zeeden[1], M. S. Abadi[1], A. Ulfers[1], K. Hesse[1], T. Wonik[1]

[1] LIAG, Leibniz Institute for Applied Geophysics, Stilleweg 2, 30655 Hannover, Germany

Cyclostratigraphic methods are an efficient way to assess borehole logging data for their timing and deposition rates. This includes sedimentary sequences of lakes, and allows a fast initial assessment of such datasets. In order to obtain a fast and most robust assessment, a good understanding of the potential and specifics of relevant (time/depth) evolutive methods in cyclostratigraphy are an essential prerequisite. Therefore, we apply a suite of evolutive cyclostratigraphic methods to the Lake Chalco logging data, with focus on gamma ray data.

Lake Chalco is located in the vicinity of Mexico City (e.g. Brown et al. 2012) and contains several quasi-cyclic alterations (Brown et al. 2019), which are explored for their time span. More than 400 m were logged to obtain several geophysical properties including magnetic susceptibility and spectral gamma radiation. Datasets from geophysical downhole logging are used in a cyclostratigraphic analysis, which provides further insight into the sedimentation history of Lake Chalco. Here we present initial results from the full succession in this sedimentary archive. Tephra layers are evident, but do not prevent a successful cyclostratigrapic analysis. Especially the alterations between carbonates and diatomites are evident in the logging data and can be interpreted in a quasi-cyclic way.

References

Brown, E.T., Caballero, M., Cabral Cano, E., Fawcett, P.J., Lozano-García, S., Ortega, B., Pérez, L., Schwalb, A., Smith, V., Steinman, B.A., Stockhecke, M., Valero-Garcés, B., Watt, S., Wattrus, N.J., Werne, J.P., Wonik, T., Myrbo, A.E., Noren, A.J., O&Amp, Apos, Grady, R., Schnurrenberger, D., 2019. Scientific drilling of Lake Chalco, Basin of Mexico (MexiDrill). Sci. Drill. 26.

Brown, E.T., Werne, J.P., Lozano-García, S., Caballero, M., Ortega-Guerrero, B., Cabral-Cano, E., Valero-Garces, B.L., Schwalb, A., Arciniega-Ceballos, A., 2012. Scientific Drilling in the Basin of Mexico to Evaluate Climate History, Hydrological Resources, and Seismic and Volcanic Hazards. Sci. Drill. 14, 72–75. https://doi.org/10.2204/iodp.sd.14.12.2012

IODP

Hydroclimate change in subtropical South Africa during the Mid-Piacenzian Warm Period

X. Zhao[1], A. Koutsodendris[2], T. Caley[3], L. Dupont[1]

[1] Zentrum für Marine Umweltwissenschaften (MARUM), Bremen
[2] Institute of Earth Sciences, Heidelberg University
[3] EPOC, UMR 5805, CNRS, University of Bordeaux

The mid-Piacenzian (mid-Pliocene) Warm Period (mPWP, 3.264-3.025 Ma), has become a focus for comparative and detailed numerical climate modelling and data/model comparisons because it is considered an analog for future climate scenarios (Haywood et al. 2013, Salzmann et al. 2013). Many palaeoclimate studies indicate that the subtropical regions were wetter during the mPWP hydroclimate, while drier conditions during climate warming are predicted by most models (Burls and Fedorov 2017). Therefore, the mPWP hydroclimate reconstruction of subtropical regions is crucial, especially in the southern hemisphere where well-dated high-resolution Pliocene palaeorecords are scarce. A new record from the South African Cape will help to fill in a gap of information about the subtropical regions. Thus, to better understand the hydroclimate of subtropical South Africa during the mPWP and to constrain the underlying forcing mechanisms, a pollen record from IODP Exp. 361 Site U1479 (retrieved in ~2630 m water depth some 130 km southwest of Table Mountain and Cape Town; Hall et al. 2017) is investigated for the period between 3.34 and 2.87 Ma at millennial-scale resolution (ca. 3 ka).

The material of U1479 is relatively rich in pollen and spores, which is remarkable because the general wind direction is landwards and no big rivers discharge in the vicinity of the core location to take pollen spores directly offshore. The floral composition of the palynological assemblage clearly points to an origin in Fynbos vegetation. We presume, therefore, that the Angulhas Current is instrumental in the westward transport of

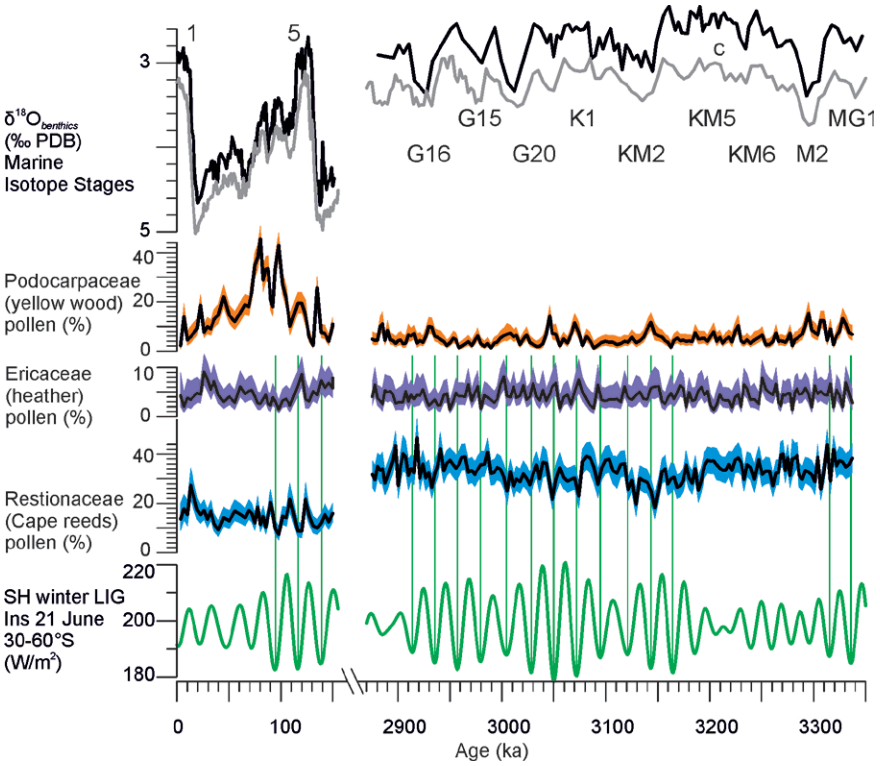


Fig. 1: From top to bottom: Stable oxygen isotopes of benthic foraminifera of U1479 (black) and the global stack (LR04. grey) (Liesiecki and raymo 2005); pollen percentages of the total of pollen and spores in U1479 of Podocarpus (orange), Ericaceae (peurple and Restionaceae (blue). Southern hemisphere winter latitudinal insoliation gradient (green).

pollen and spores reaching the ocean along south coast of South Africa.

Subtropical and Mediterranean regions are equatorward defined by the transition from subtropical to tropical (monsoonal) climates. The rainfall season changes from summer rains in the tropics to winter rains in the subtropics, which has a large impact on the vegetation. In South Africa, the subtropical winter rainfall zone (Chase and Meadows 2007) is nowadays restricted to the Western and Southern Cape Province. In South Africa, the subtropical winter rainfall zone is mainly vegetated by Fynbos (Linder 2003). Fynbos is a species-rich heathy vegetation, which established in South Africa during the late Miocene (Scott 1995, Dupont et al. 2011).

Maxima in the percentages and concentration of heather pollen and minima in the Restionaceae (Cape reeds) pollen percentages mostly coincide with minima in the latitudinal insolation gradient between 60 and 30°S of the southern hemisphere winter (21 June). According to Davis & Brewer (2009) this gradient is important in the forcing of the climate in the winter rainfall regions of the mid-latitudes. The insolation gradient influences the latitudinal temperature gradient whereby a weak southern hemisphere winter gradient would weaken the southern westerlies and winter precipitation. Conversely a strong gradient would strengthen the westerlies and associated rainfall. The pollen record suggests a response of the vegetation to fluctuations in winter precipitation by variations in the ericaceous component of the Fynbos. Compared to the Late Pleistocene pollen record of the same site, the variability is less in the mid-Piacenzian. Also the Late Pleistocene record shows a response of the vegetation to the glacial-interglacial cycle. Remarkable is the low relative abundance of Restionaceae pollen (under 27%) in the Late Pleistocene compared to the mid-Piacenzian and the high late Pleistocene percentages of Podocarpaceae pollen (up to 46%) between 110 and 80 ka (figure). Comparison with the Late Pleistocene record indicates that substantial changes in vegetation took place after the Piancenzian with likely a large reduction in the area of Fynbos vegetation and increase in millenial scale variability.

The mPWP encompasses six warm stages and the cold stage KM2. The model intercomparison project PlioMIP2 has been focussed on MIS KM5c (3.205 Ma) as the warmest phase of the mPWP (Haywood et al. 2020 submitted). First data-model comparisons, mainly concerning sea surface temperatures, have been carried out (McClymont et al. 2020 submitted). Earlier studies compared separately modelled interglacials within the mPWP (each with its individual orbital forcing) finding considerable differences between the warm stages (Prescott et al. 2014, 2018). There is generally good agreement between the sea surface temperature data and predictions of an ensemble of climate models of varying complexity with the focus on MIS KM5c encompassing the warmest phase of the mPWP. Notable differences are found for the Bengula region. Intensification of upwelling of colder waters in this region during the Pleistocene strongly lowered sea surface temperatures in the Benguela Upwelling region, which is not modelled by the relatively coarse resolution of global models (Haywood et al. 2020 submitted, McClymont et al. 2020 submitted). The warmer sea surface temperatures along the west coast of southern Africa would have influenced the vegtation on land. Our data indicate substantial more fynbos in the region suggesting a more winter precipitation where models predict less annual rainfall and also less winter rainfall for Pliocene South Africa (Hunter et al. 2019).

References

Burls, N.A. & Fedorov, A.V., 2017. Wetter subtropics in a warmer world: Contrasting past and future hydrological cycles. PNAS Early Edition, www.pnas.org/cgi/doi/10.1073/pnas.1703421114

Chase, B.M. & Meadows, M.E., 2007. Late Quaternary dynamics of southern Africa‘s winter rainfall zone. Earth-Science Reviews, 84: 103-138.

Davis, B.S. & Brewer, S., 2009. Orbital forcing and role of the latitudinal insolation/temperature gradient. Climate Dynamics, 32: 143-165.
Dupont, L.M., 2011. Orbital scale vegetation change in Africa. Quaternary Science Reviews, 30: 3589-3602.
Hall, I.R., Hemming, S.R., Levay, L.J. & Exp 361 Scientists, 2017. Site U1479. Proceedings of the International Ocean Discovery Program Volume 361. (International Ocean Discovery Program, College Station, TX.
Haywood, A.M., Hill, D.J., Dolan, A.M., et al., 2013. Large-scale features of Pliocene climate: results from the Pliocene Model Intercomparison Project. Climate of the Past, 9: 191-209.
Haywood, A.M., Tindall, J.C., Dolan, A.M., et al., 2020. A return to large-scale features of Pliocene climate: the Pliocene Model Intercomparison Project Phase 2. Climate of the Past Discussions. https://doi.org/10.5194/cp-2019-145.
Hunter, S.J., Haywood, A.M., Dolan, A.M. & Tindall, J.C., 2019. The HadCM3 contribution to PlioMIP phase 2. Climate of the Past, 15: 1691-1713.
Linder, H.P., 2003. The radiation of the Cape Flora, southern Africa. Biological Review, 78: 597-638.
McClymont; E.L., Ford, H.L., Ho, S.L., Tindall, J.C., Haywood, A.M., et al., 2020. Lessons from a high CO2 world: an ocean view from ~3 million years ago. Climate of the Past Discussions. https://doi.org/10.5194/cp-2019-161.
Prescott, C.L., Dolan, A.M., Haywood, A.M., Hunter, S.J. & Tindall, J.C., 2018. Regional climate and vegetation response to orbital forcing within the mid-Pliocene Warm Period: A study using HadCM3. Global and Planetary Change, 161: 231-243.
Prescott, C.L., Haywood, A.M., Dolan, A.M., Hunter, S.J., Pope, J.O. & Pickering, S.J., 2014. Assessing orbitally-forced interglacial climate variability during the mid-Pliocene Warm Period. Earth and Planetary Science Letters, 400: 261-271.
Salzmann, U., Dolan, A.M., Haywood, A.M., et al., 2013. Challenges in quantifying Pliocene terrestrial warming revealed by data model discord. Nature Climate Change, 3: 969-974.
Salzmann, U., Dolan, A.M., Haywood, A.M., et al., 2013. Challenges in quantifying Pliocene terrestrial warming revealed by data model discord. Nature Climate Change, 3: 969-974. Scott, L., 1995. Pollen evidence for vegetational and climatic change in southern Africa during the Neogene and Quaternary. E.S. Vrba, G.H. Denton, T.C. Partridge, L.H. Burckle (eds.). Paleoclimate and evolution, with emphasis on human origins. Yale University Press, New Haven: 65-76.

ICDP

Experimental studies on formation and thermal history of Surtsey

B. Zimanowski[1], R. Büttner[1], T. Dürig[2], J. D.L. White[3], M. T. Gudmundsson[2]

[1] Physikalisch Vulkanologisches Labor, Universität Würzburg, Pleicherwall 1, D-97070 Würzburg, Germany
[2] Institute of Earth Sciences, University of Iceland, IS-101 Reykjavik, Iceland
[3] Department of Geology, University of Otago, Dunedin 9054, New Zealand

With the aim to provide constraints for a better understanding of the Surtsey eruptions 56 years ago and to find answers to still open questions about the eruption mechanisms, the energetics, and the production of volcanic ash by subaerial and submarine processes, experiments were conducted using representative basaltic melt at magmatic temperatures: Experiments using expanding argon-gas or pressurized dry steam as driving media to stress and fragment the experimental melt, as well as standardized MFCI-experiments in entrapment (coolant entrapped in melt) and stratification (water superimposed on melt) configuration have been performed, thus covering explosive magmatic and phreatomagmatic eruption mechanisms.

Samples from all experiments that produced ash-sized particles typus particles have been compared to their natural analogues and the major eruptive mechanism could be identified.

Thermal granulation experiments by non-explosive interaction of melt and watery coolants have been performed in a calorimeter, thus we have information on the thermal history of these products.

In cooperation with the working group of PI Bach (Univ. Bremen) a hydrothermal long-term experiment using fresh, experimentally produced glass particles was conducted in a calorimeter with a duration of 18 months to investigate the syneruptive and early post eruptive thermal history. Data processing is in progress, but the observation of cementation processes and decreasing permeability may point to the onset of palagonitisation.

ICDP

Multi-scale 2D/3D images in carbonate cores: integrating sedimentary fabrics and petrophysics for upscaling permeability heterogeneities

S. Maerz[1], G. Winterleitner[1], M. Mutti[1]

[1] Institut für Geowissenschaften (Uni Potsdam), Potsdam

The accurate prediction of porosity and permeability heterogeneity in uncored and inter-well intervals is yet an unresolved challenge in subsurface reservoir characterisation. Core and plug samples provide the sole hard data source, guiding subsequent integration of wireline logs and seismic data to assess the permeability field between wells. It is thus of paramount importance to evaluate core porosity and permeability in detail in order to provide representative petrophysical reservoir properties based on samples representing an infinitesimal volume of a given reservoir. In particular carbonate cores may pose a problem, owing to the fact that several porosity systems, encompassing dual or triple permeability characteristics can be present in one standard 2" core plug. Carbonate depositional fabrics and subsequent phases of diagenetic overprint cause large heterogeneities in textural and pore systems properties. This can be assigned to the mostly biogenic character of carbonate deposition and their high chemical reactivity. Depending on the extent, magnitude and scale of these textural variations, the heterogeneity of the pore system and its petrophysical response acts at variable scales. By linking gas-injection porosity and permeability measurements with quantitative pore structure information from 2D image analyse and micro computed tomographic (CT-) scans, the nature of such variations can be assessed more rigorously.

In this study we test the reliability of plug-derived data versus core scale information in order to obtain reliable porosity and permeability estimates. The lower Muschelkalk has recently gained renewed interest in geothermal exploration in the greater Berlin area due to its productive aquifer systems for potential geothermal production and storage. We used analogue outcrop data from the Rüdersdorf Muschelkalk quarry, SW Berlin to analyse the petrophysical properties of the main aquifer unit to guide future exploration. By generating a high-resolution nitrogen-injection permeability map of a core-seized slab, representing an ooidal grainstone with inversed texture and abundant oomoldic pores, the heterogeneity of porosity-permeability distribution is captured. Subsequently, pore structure geometry is quantified in 2D with image analysis and combined with the permeability map. The variations in porosity and permeability properties/distribution are further tested by using the 3D CT-scan model of a cylindrical plug from the core slab. Comparison of the gas-injection measurements and 2D and 3D modelling results indicate a high scale dependency of the permeability variation due to a complex pore structure. The latter changes with the degree of modelling resolution (micro vs. full slap image analyses) and permeability measurements (full plug flow vs. point gas injection). It is thus necessary to analyse the permeability at several scale levels to ensure the optimal upscaling strategy to full core permeability values for input into subsequent reservoir models.

IODP

Deoxygenation of the Pacific during the Pliocene (DePac)

J. Groeneveld[1,2,3]

[1] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
[2] MARUM-Center for Marine and Environmental Sciences and Department of Geosciences, University of Bremen, Bremen, Germany
[3] Institute of Geology, Hamburg University, Hamburg, Germany

The oxygen content of the world's oceans is essential for the survival of most organisms and therefore has severe economic impact when conditions deteriorate. With ongoing global climate change, the oceans are warming and therefore less oxygen can be dissolved into the sea water. In addition, increasing pollutants are flushed into the oceans such that coastal areas are also becoming starved of oxygen and thus life. To understand the impact of decreasing oxygen content on the marine ecosystem, the history of changing oxygen content can teach us what to expect in the future. Foraminifera are the ultimate tool to study these changes, as they have been shown to not only survive but also calcify, which is essential for using their geochemistry, under low-oxygen conditions. During calcification they are incorporating redox-sensitive elements like manganese indicative of the dissolved oxygen content of the water at time of calcification into their shells. With this project I will use foraminiferal Mn/Ca to show how the Pacific gained its present day state of low oxygen content during the final stages of the Pliocene. I will test the hypotheses that firstly the Pacific rapidly lost its oxygen after onset of the Northern Hemisphere Glaciation (NHG; ~2.7 Ma) due to water column stratification in the North-Pacific; secondly that short-term North Pacific stratification during Marine Isotope Stage (MIS) M2 (~3.3 Ma) decreased Pacific oxygen content; and thirdly that oxygen content in the Pacific temporarily recovered during the first warm interglacials (~2.5 Ma) after the onset of NHG. Analyses will be performed on deeper-dwelling planktonic foraminifera, i.e. that spend part of their life cycle in lower-oxygen water masses, on samples from (I)ODP Sites 1012, 1236, 1241, and U1338.

IODP

Late Quaternary vegetation, climate and ocean dynamics in southeastern South America and the adjacent Atlantic inferred from marine sediment cores

F. Gu[1], K. A. F. Zonneveld[2], C. M. Chiessi[3], H. Behling[1]

[1] University of Göttingen, Department of Palynology and Climate Dynamics, Untere Karspüle 2, 37073 Göttingen, Germany
[2] University of Bremen, MARUM – Center for Marine Environmental Sciences, Leobener Str. 8, 28359 Bremen, Germany
[3] University of São Paulo, School of Arts, Sciences and Humanities, Rua Arlindo Bettio, 1000, CEP03828-000 São Paulo, SP, Brazil

Southeastern South America harbours highly diverse ecosystems, such as the Atlantic rainforest, *Araucaria* forest and grasslands. These ecosystems are highly sensitive to changes in climate which in turn is influenced by a complex interaction between atmospheric and oceanographic features. In the study area, different climatic features, such as the South Atlantic Convergence Zone, cold polar fronts and El Niño Southern Oscillation can play a role. Furthermore, the Brazil Current from the north as well as the Malvinas Current (MC) and Brazilian Coastal Current (BCC) from the south not only control the major hydrological patterns in the western South Atlantic, but also influence the climate on land.

To reconstruct vegetation, climate and ocean dynamics over long time periods, three marine sediment cores located on a 1400 km-long latitudinal transect (Figure 1) from ca. 27 to 38°S off southeastern South America have been studied for its pollen, spore, dinoflagellate cysts and freshwater algae content.

The northernmost core GeoB2107-3 (27.18°S) indicates cool but wet climatic conditions that probably produced an extensive coverage of *Araucaria* forest from 73.5 to 65 cal kyr BP. Colder and drier climatic conditions prevailed between 38.5 and 13.0 cal kyr BP, and were probably related to an enhanced transport of cold water masses from the south, evidenced by the occurrence of long distance transport of *Nothofagus* pollen. Multiple proxy records indicate that orbital obliquity is one of the most important factors controlling marine and continental environmental changes during the last 73.5 cal kyr BP.

Core GeoB6211-2 (32.50°S) recorded environmental changes since the Last Glacial Maximum (LGM). The results indicate cold and dry climate during the LGM when grasslands dominated the landscape over the studied area. Gallery forests expanded slightly during Heinrich Stadial 1. The Atlantic rainforest expansion to the south was only recorded after 5.5 cal kyr BP. The MC and BCC had a stronger influence to the coring site during the LGM and HS1.

The southernmost core GeoB13862-1 (38.01°S) provides ocean dynamics of the upper water column in the Brazil Malvinas Confluence region since 12.6 cal kyr BP. The palynological records suggest an increase in precipitation since 5.7 cal kyr BP, which probably related to higher frequency and stronger El Niño events. The highest eutrophication of the ocean surface occurred during the last ca. 100 years, which was most probably due to stronger human impact in the drainage basin of the Rio de la Plata.

Our transect records contributes to a better understanding of past vegetation and climate dynamics in southeastern South America, as well as of surface ocean conditions in the western South Atlantic over long time periods. It also provides an insight into how long-term sea level changes affect coastal ecosystems in southeastern South America.

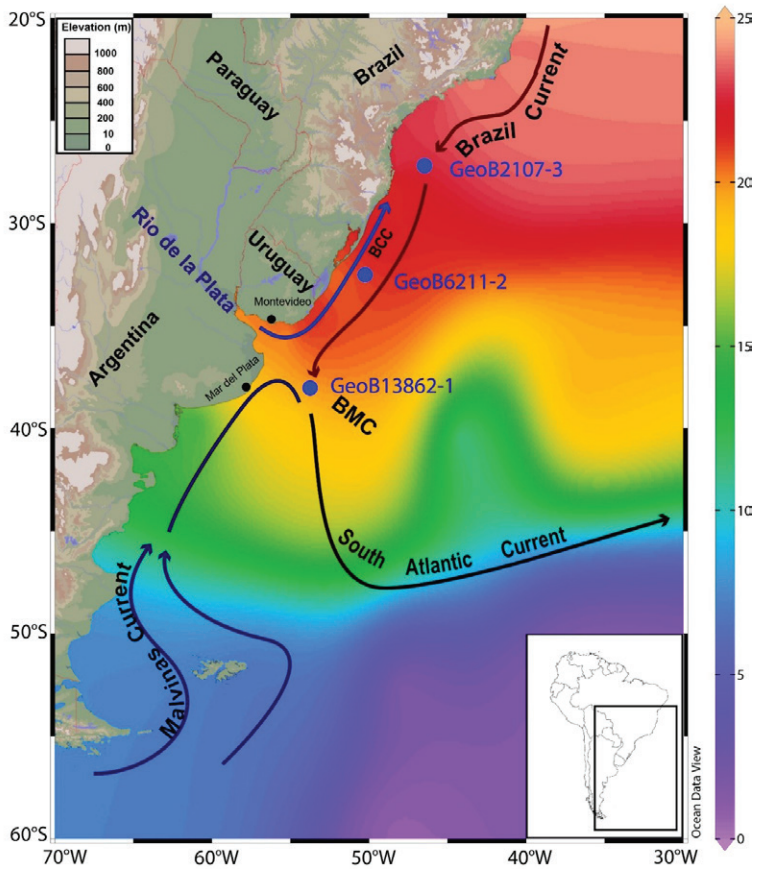


Fig. 1: Coring sites and schematic surface oceanic currents in the study area. Colour shading shows mean annual sea-surface temperatures (°C). BCC: Brazilian Coastal Current; BMC: Brazil-Malvinas Confluence.