UK-IODP ANNUAL MEETING 2025

Monday 15th December 2025

University of Southampton,
National Oceanography Centre Southampton
& Online

UK IODP3 INTERNATIONAL OCEAN DRILLING PROGRAMME

UKRI Natural Environment Research Council

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How to join the meeting online

Please click the link below to join the zoom call:

https://noc-ac-uk.zoom.us/j/85924195822?pwd=bFoPRpC48chVDj8IaKBhxjFdMJRGBV.1

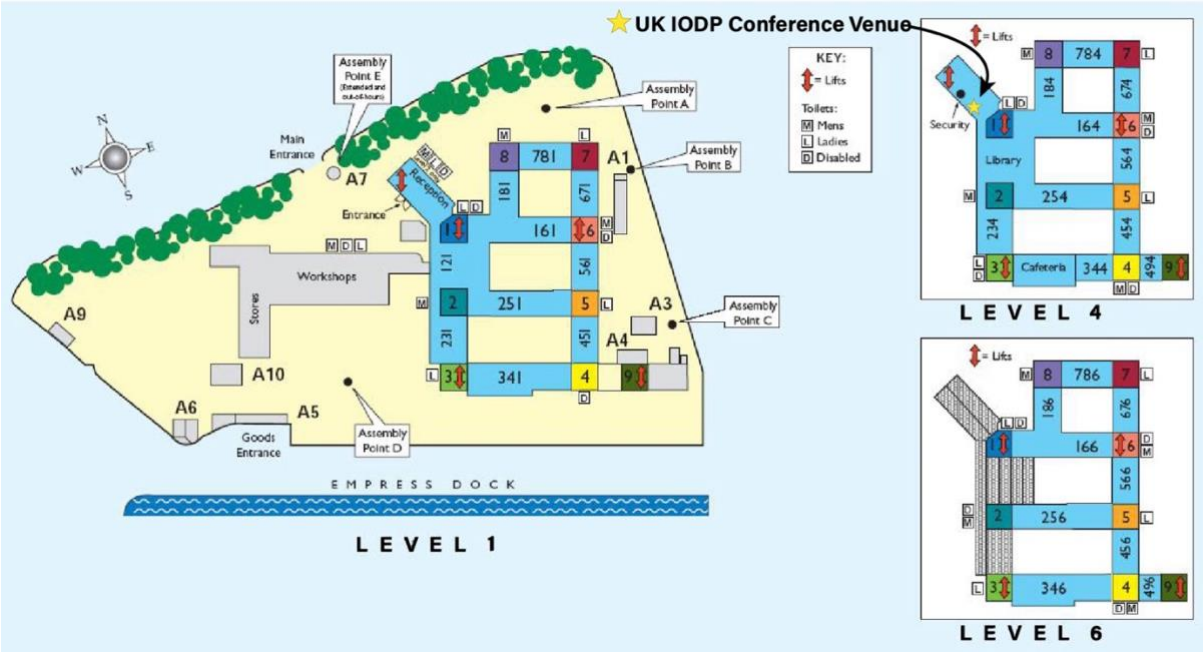
Meeting ID: 859 2419 5822

Passcode: 472460

Please mute your microphone and turn off your camera while presenters are giving their talks. Please do switch your camera (and microphone!) on when asking a question during the Q&A sessions.

Venue Map

Building plan, National Oceanography Centre Southampton



Enter the building via the main Reception area and make your way up to level 4 via the lift or stairs, where you will find the conference registration desk. Talks will be held in the Henry Charnock Lecture Theatre and posters and refreshments will be in the adjacent exhibition space outside the main doors to the lecture theatre.

Posters

Presenting Author	Affiliation	Poster Title
Tobias Agterhuis	University of Southampton	North Atlantic sea surface temperature evolution across the Oligocene-Miocene Transition based on TEX86 paleothermometry
Lottie Atton	University of Plymouth	High-resolution imaging spectroscopy as a tool for drill core mineral mapping
Lottie Atton	University of Plymouth	IODP3 Expedition 502: Impact of petit-spot magmatism on subduction zone seismicity and global geochemical cycles
Miros Stavros James Charidemou	National Oceanography Centre	Evaluation of the new Itrax FleXRay X-ray Fluorescence Core Scanner at the British Ocean Sediment Core Research Facility
Lingle Chen	University of Southampton	Covariant Dust Variability in the Mid-Latitude Japan Sea and Greenland During the Last Glacial
Lingle Chen	University of Southampton	Late Pleistocene Variability in Mediterranean Outflow Water Depth and Strength along the west Iberian Margin
Meriam Chouar	University of Portsmouth	Marine Isotope Stage 11 in the Southern Pacific Ocean: coccolithophore assemblages and calcification at IODP Site U1540
Marcelo A. De Lira Mota	University of Birmingham	Palynofacies evidence for Pliocene climate dynamics in the Amundsen Sea sector (IODP Site U1532, West Antarctica)
Mengyao Du	University of Cambridge	Re-evaluating the orbital pacing of glacial cycles across the Plio-Pleistocene Transition (3-2 Ma)
Kirsty Edgar	University of Birmingham	Hot Oceans, More Fish: Mesopelagic Fish Productivity across the Palaeocene–Eocene Thermal Maximum
Emma M. Hanson	University of Birmingham	A detailed coccolith assemblage analysis over the mid Pliocene Warm Period
Bernát Heszler	University of Bristol	Reconstructing Late Cretaceous Atmospheric CO_2 from DSDP Site 463, Mid-Pacific
Xinhui Huo	University of Leicester	Insights into North Atlantic Deep-water formation from Carbonate Deposition during the late Oligocene to Early Miocene
Chloe Jones	Queen Mary University of London	Reconstructing Pliocene SST Variability in the Western Indian Ocean from ODP Site 709

Catriona McCleery	University of Cambridge	Petrographic and mineral chemistry constraints on the interplay between deformation and fluid-rock interaction in the Atlantis Massif OCC
Becky McGanity-Smith	University College London	Sediment cycling on the Marion Plateau
Oskar Mitrovic	University of Portsmouth	Morphometrics of Reticulofenestra from Late Miocene to Pleistocene in the Pacific sector of the Southern Ocean
Hannah Nienhaus	University of Southampton	Imaging the magma storage region and hydrothermal system of an active arc volcano using the controlled-source electromagnetic method
Niall J. Quinn	University of Southampton	Resolving Discrepancies in the Geomagnetic Polarity Timescale: Astrochronological Constraints on the C3An Reversals from IODP Sites U1385 and U1587
Marisa Rydzy and Tayyaba Khurram	University of Leicester	Breaking New Ground: Technical Innovation and Operational Reliability in IODP³-NSF Expedition 501
Gowtham Sekar	University of Bristol	Investigating the trigger mechanisms for OAE1d using boron isotopes
Emaan Tungekar	University College London	Chemical Weathering Response of Northern New Guinea to Orbital-Scale Climate Variability
Bridget Warren	The Open University	Greenland Sea Surface Temperatures during the mid-Piacenzian Warm Period
Yiming Zhang	University College London	Reconstructing surface and deep ocean circulation changes in the Northwest Atlantic over the past 21,000 years
Fangjingcheng Zhu	University of Southampton	Isotopic Fingerprinting of Terrigenous Sediment Sources to the Southwest Iberian Margin Since the Late Miocene – Implications for the Messinian Salinity Crisis

IODP[3] SPARC Proposal 1108-S: ENIGMA – Exploration into a Global Early Miocene Anomaly

Adam Woodhouse*[1], Jennifer Kasbohm[2], Alex Auderset[3], Kenji Matsuzaki[4], Elizabeth Sibert[5], Gawain Antell[6], Imogen Browne[7], Jesse Farmer[8], Anya Hess[5], Adriane Lam[7], Anta-Clarisse Sarr[9], Jansen Smith[10], Anshuman Swain[11]

[1]*Cardiff University, UK*

[2]*Carnegie Science Institute, USA*

[3]*University of Southampton, UK*

[4]*The University of Tokyo, Japan*

[5]*Woods Hole Oceanographic Institution, USA*

[6]*University of California Los Angeles, USA*

[7]*Binghamton University, USA*

[8]*University of Massachusetts, Boston, USA*

[9]*University of Oregon, USA*

[10]*University of Minnesota at Duluth, USA*

[11]*University of Michigan, USA*

**Presenting Author, woodhousea2@cardiff.ac.uk*

The early Miocene is emerging as a potentially transformative time in marine ecosystem history. A lack of sampling in the early Miocene, relative stability in the genus-level richness of traditionally studied marine fossils (e.g. shallow water hard-shelled invertebrates), and a lack of perturbation in traditional climate proxies such as benthic foraminifera-derived carbon and oxygen isotopes has led to an assumption that the transition between Oligocene and Middle Miocene was gradual and uneventful. Growing evidence suggests this is very much not the case, where recent high-resolution marine microfossil, phylogenetic, and geochemical records have revealed that the early Miocene was far from stable, but rather was a time of significant ecological upheaval that led to permanent changes in marine ecosystem structure and function at a scale not observed since the Cretaceous-Paleogene Mass Extinction event.

Observed early Miocene biotic changes spanned trophic levels from primary producers to top predators, impacting diatoms, foraminifera, reef fish, and whales, alongside other marine taxa. Specifically, open ocean sharks were heavily impacted, suffering the largest extinction event known in their 400-million-year history, corresponding with a global disruptive event in planktic foraminifera community composition. Though a clear environmental driver for these ecological changes is not yet known, the upheaval observed in the marine biota corresponds with an abrupt shift in foraminiferal-bound nitrogen isotopes, signifying a change in deep ocean oxygenation or nutrient cycling. Compounded, these records suggest that the rapid changes in biodiversity and marine community structure during the Early Miocene were profound, laying the foundation for the ocean ecosystem structure observed from the later Miocene to present day.

In this IODP[3] SPARC Proposal, we seek to explore the biotic and environmental correlates to this critical and understudied interval in Earth's history. Spanning the entire Atlantic Ocean basin, we seek to employ a multi- and interdisciplinary approach, refining age models to ultimately assess the basin wide response across preserved trophic levels to Early Miocene ecosystem change. This synthesis will be the most spatiotemporally complete documentation of the ecological response of an entire ocean basin to better disentangle this enigmatic Earth system change.

Did deep-sea methane release contribute to the warm Miocene?

Alexandra Auderset[1,2*], Gordon N. Inglis[1], Jesse R. Farmer[3], Alfredo Martínez-García[2*]

[1]*School of Ocean and Earth Science, University of Southampton, Southampton SO14 3ZH, United Kingdom*

[2]*Climate Geochemistry Department, Max Planck Institute for Chemistry, Mainz, 55128, Germany*

[3]*School for the Environment, University of Massachusetts Boston, Boston MA 02125, USA*

**Presenting Author, a.auderset@soton.ac.uk*

The Miocene Climate Optimum (MCO) was an interval of elevated surface temperatures (~8-15°C higher than preindustrial) and atmospheric CO_2 concentrations (pCO_2 ~150-300 ppmv higher than preindustrial). However, global temperatures appear higher than expected based on pCO_2 estimates, and the drivers of elevated MCO CO_2 remain debated. Methane (CH_4) is a trace greenhouse gas that can enhance planetary warming both directly and indirectly via its oxidation to CO_2. Here, we use globally distributed archaeal biomarker records to quantify seafloor CH_4 release during the past 23 million years. Our data reveal persistently elevated deep-ocean CH_4 fluxes (~10 times higher than present) during the MCO, especially in core sites along active plate boundaries like (I)ODP Sites U1337, 1168, 704, 667 and 608. The close link observed between CH_4 fluxes and reconstructed oceanic crust production rates suggest that the deep-sea CH_4 release was driven by increased tectonic activity. Our results demonstrate that deep-sea CH_4 release could have directly or indirectly reinforced MCO greenhouse warmth, helping to explain its longevity as well as various hyperthermal events. Furthermore, the proposed enhanced CH_4 release could also resolve the apparent mismatch between global warming and modestly elevated CO_2 during the MCO.

Neogene Chemical Weathering of New Guinea and its Impact on Global Climate

Peter D. Clift[1]*, Yifan Du[2]

[1] *Department of Earth Sciences, University College London, 5 Gower Place, London WC1E 6BS, United Kingdom*

[2]*Institute of Marine and Environmental Sciences, University of Szczecin, 70-383 Szczecin, Poland*

**Presenting Author, peter.clift@ucl.ac.uk*

Chemical weathering of silicate rocks in low latitude, tectonically active arc and ophiolite settings has been recognized as potentially being an important sink of atmospheric CO_2 that may be as important or even more influential than silicate weathering in the Himalayas in controlling the long-term cooling of planet Earth during the Cenozoic (Clift and Jonell, 2021; Clift et al., 2024a). In this study we investigated the chemical weathering of New Guinea on tectonic and millennial timescales in order to understand how the uplift and erosion of this island may have impacted the global carbon cycle. DSDP Sites 210 and 287 in the Gulf of Papua have been used to reconstruct ~25 Ma of chemical weathering (Clift et al., 2024b). Weathering proxies show increasing alteration since 7 Ma and that because of the mafic character of the bedrock that the island around three times more efficient at consuming CO_2 compared to weathering of Himalayan bedrocks. Most of the change in the efficiency of CO_2 consumption is related to shifting patterns of erosion in the sources between more siliceous continental rocks offscraped from the colliding Australian continent and the mafic arc and ophiolite units that comprise much of the Highlands. It is not yet possible to calculate a total flux for New Guinea in the geological past because of a lack of matching seismic data that would allow estimate of the total amount of erosion. Data from modern river systems suggest that the eastern half of New Guinea may alone be consuming as much atmospheric CO_2 as the entire Himalaya and Tibetan Plateau reflecting the rapid erosion and the mafic source character.

IODP Site U1485, located off the north coast of New Guinea, has also provided the opportunity to look at millennial scale variations modulated by orbital processes (Du et al., 2024). The weathering history shows a clear 100 ky cyclicity. Although the intensity of alteration doesn't change markedly through time, the style of weathering is linked to global climate variations and shows more seasonal weathering favouring smectite rather than kaolinite formation during cold/dry glacial times. Unlike the southern records the northern area shows more erosion of Australian continental rocks during warm interglacial phases. Since these consume less CO_2 when they undergo chemical weathering this means that there is greater CO_2 consumption during colder periods when the island is dry and rainfall does not intrude as far into the interior. As a result of this New Guinea exercises an amplifying effect on global climate by removing more CO_2 from the atmosphere when the climate is already colder. Ongoing work now examines the role of low latitude continental shelves as carbon sinks, particularly the Sunda continental shelf between Indochina and Borneo as being another important modulator of global climate.

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Isotopic Fingerprinting of Terrigenous Sediment Sources to the Southwest Iberian Margin Since the Late Miocene – Implications for the Messinian Salinity Crisis

Fangjingcheng Zhu[1]*, Anya J. Crocker[1,2], Chuang Xuan[1], Paul A. Wilson[1]

[1] *School of Ocean and Earth Science, University of Southampton, Waterfront Campus, National Oceanography Centre, Southampton, UK*

[2] *Present address: School of Earth Sciences and Earth Institute, University College Dublin, Dublin, Ireland*

**Presenting Author, F.Zhu@soton.ac.uk*

Ocean drill cores from the southwest Iberian Margin provide high quality archives of past climate variability with exceptional age control well suited to studying the linkages between ocean, ice and terrestrial climate systems. To a significant extent, this exceptional age control derives from very high fidelity downcore variability in sedimentary physical and geochemical properties tuned to astronomical targets. However, our understanding of many of the climate signals captured in these data series is undermined by uncertainty over the provenance of terrigenous sediment supply to the Iberian Margin. Not least among these uncertainties is the question of whether carbonate-rich or carbonate-poor horizons in the cores should be tuned to precession-paced insolation minima or maxima. Here we report radiogenic isotope data (strontium, Sr and neodymium, Nd), terrigenous grain size distributions and XRF-core scan derived elemental data in sediments of late Miocene to Holocene age from International Ocean Discovery Program (IODP) Site U1587 (37°34.87′N, 10°21.53′W, 3479 mbsf) to address this problem.

At astronomical timescales, our radiogenic isotope data for the >10 μm size fraction suggest binary mixing between sediments derived from Tagus River (radiogenic Sr & Nd isotope signatures) and North Africa (non-radiogenic Sr & unradiogenic Nd isotope signatures). We document a consistent relationship between lithology as traced by Ti/Ca and Nd isotope composition with higher Ti/Ca ratios corresponding to more unradiogenic Nd composition (enhanced sediment supply from North Africa). We also document amplification of this signal between ~7.2 and 5.5 Ma.

We interpret our results to reflect the following: (1) North African sediment supply to the Iberian Margin by Mediterranean Outflow Water (MOW) during insolation minima in response to weakened summer monsoon and/or reduced winter rainfall which promote drying in North Africa and Mediterranean regions and salinification of the Mediterranean Basin. (2) A progressively denser, stronger-flowing and deeper compensating Mediterranean Outflow Water (MOW) in response to the stepwise restriction of the Atlantic-Mediterranean gateways and culminating in the Messinian Salinity Crisis (through the Primary Lower Gypsum and the Halite stages) when massive evaporite deposits were laid down in the Mediterranean Sea.

IODP Expedition 403: Challenges and Achievements of the Final JOIDES Resolution Mission under the ODP/IODP Flag

Renata G. Lucchi, Kristen K. St John, Thomas A. Ronge, Maria Angeles Barcena, Stijn De Schepper, Lucinda Duxbury, Catalina Gebhardt, Alba Gonzalez-Lanchas, Gryphen Goss, Nicole Greco, Jens Gruetzner, Lauren Haygood, Katrine Husum, Mutsumi Iizuka, Isuri Kapuge, Adriane R. Lam, Olga Libman-Roshal, Yanguang Liu, Lindsey Monito, Brendan Reilly, Yair Rosenthal, Yuhi Sakai, Yusuke Suganuma, Sijinkumar A. Veedu, Yi Zhong, and the *JOIDES Resolution* Exp403 technical support team.

The Fram Strait gateway, linking the North Atlantic and Arctic Oceans, is a key region for understanding interactions between ocean circulation and ice sheet dynamics during past climatic transitions. Insights from this area are critical for improving predictive models of future global change. IODP Expedition 403 was designed to obtain continuous, high-resolution depositional sequences containing both the palaeoceanographic record of the northward-flowing West Spitsbergen Current (WSC) and the cryosphere evolution of the Svalbard–Barents Sea Ice Sheet (SBSIS).

During the expedition, more than 5.3 km of sediment cores were recovered from seven sites distributed along the WSC pathway (south to north) and across settings ranging from proximal to distal relative to the paleo-SBSIS terminus (east to west). Initial age models based on paleomagnetic reversals and microfossils reveal expanded Pleistocene and Pliocene sequences in the proximal SBSIS region, as well as distal sequences exceeding 600 m in length that extend back to the mid-Pliocene and early Pliocene/late Miocene.

Preliminary comparisons between site lithologies and established lithofacies from piston cores along the western Svalbard margin suggest that Expedition 403 records can constrain the history of shelf-edge glaciation, meltwater discharges, iceberg calving events, and warm intervals characterized by persistent contour currents. Supporting evidence from physical property measurements, indicates that orbital cycles and marine isotope stages (MIS) are recorded at all sites, despite diagenetic overprints that complicate recognition of primary depositional signals and stratigraphy.

We also report on the challenges encountered during Expedition 403, the final mission of the RV *JOIDES Resolution* conducted under the historic ODP/IODP international program.

New Pliocene sedimentary records of the sub-polar North Atlantic from IODP Expeditions 384, 395C and 395

Tom Dunkley Jones[1*], Ross E. Parnell-Turner[2], Anne Briais[3], Leah LeVay[4], Expedition 395 Scientists, Emma Hanson[1], Margaret Morris[2], Marcin Latas[1], Bridget Warren[5], Marcelo de Lira Mota[1,6], Gemma Baker[1] and James Bendle[1]

[1]*School of Geography, Earth and Environmental Sciences, University of Birmingham, UK*

[2]*Scripps Institution of Oceanography, University of California San Diego, USA.*

[3]*Geo-Ocean, Centre National de la Recherche Scientifique (CNRS), Institut Universitaire Européen de la Mer, France.*

[4]*International Ocean Discovery Program, Texas A&M University, USA.*

[5]*School of Environment, Earth and Ecosystem Sciences, The Open University*

[6]*Institute of Geosciences, University of São Paulo, Brazil*

** Presenting Author t.dunkleyjones@bham.ac.uk*

International Ocean Discovery Program (IODP) Expeditions 384 (2020), 395C (2021) and 395 (2023) targeted a set of sites on an east-west transect at ~60ºN in the Irminger and Iceland Basins of the sub-polar North Atlantic. Together these expeditions form a unified set of samples and observations that address the aims of IODP proposal 892-Full2: 1) the Neogene behaviour of the Iceland mantle plume; 2) ocean circulation in the sub-polar North Atlantic; 3) the hydrothermal alteration of oceanic crust. The recovery of extensive sedimentary records from three major contourite drifts (Björn and Gardar Drifts in the Iceland Basin, and Eirik Drift in the western Irminger Basin) extend the potential oceanographic and climate proxy archives of these basins back to the earliest Oligocene. Initial work has focused on a major change in sedimentation rates and character around the lower/upper Pliocene boundary, inferred to be driven by an increase in intensity of Iceland-Scotland Overflow Water (ISOW) at this time (Sinnesael et al. 2025). Conversely records from the Eirik Drift (Morris et al. *in review*) indicate more persistent southward flow of deep waters over the Denmark Strait through the late Miocene to Recent. Here we give an overview of the recovered sedimentary records, variability in sediment composition over time and initial results of organic biomarker and foraminiferal stable isotope analyses through the early/late Pliocene transition.

References

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Did the Indian Monsoon notice the intensification of Northern Hemisphere Glaciation?

Kate Littler[1*], Pallavi Anand[2], Yasmin Bokhari-Friberg[2,3], Jinrong Gan[1], Sev Kender[1], Marci Robinson[4], Oscar Romero[5], Masafumi Murayama[6,7], Philip Sexton[2], Melanie Leng[8], Shardul Pandit[2], Chaithanya Bhagavathi Parambu[1]

[1] Department of Earth and Environmental Sciences, University of Exeter, Penryn Campus, Cornwall, UK.

[2] School of Environment, Earth and Ecosystem Sciences, Open University, Milton Keynes, UK.

[3] School of Natural Sciences, Macquarie University, Sydney, NSW, Australia.

[4]Geology Department, College of William and Mary, Williamsburg, VA, USA.

[5] MARUM, Centre for Marine Environmental Sciences, University of Bremen, Bremen, Germany.

[6] Faculty of Agriculture and Marine Science, Kochi University, Kochi, Japan.

[7] Center for Advanced Marine Core Research, Kochi University, Kochi, Japan.

[8] National Environmental Isotope Facility, British Geological Survey, Nottingham, UK.

**Presenting Author, k.littler@exeter.ac.uk*

The Indian (South Asian) Monsoon is a critical component of modern tropical climate, bringing seasonal freshwater for agriculture, sanitation, and industry to over 1.6 billion people. Climate models predict that anthropogenic warming will increase monsoon-related rainfall and introduce greater variability in the timing of summer monsoon onset, while also potentially weakening the winds that drive the monsoon system. However, there is disagreement between different models and a lack of geological data to ground-truth these assertions from time periods with comparable pCO_2 levels (e.g., >400 ppmv). The Late Pliocene–Early Pleistocene (4–2 million years ago; Ma) was a time of revolution and reorganisation of the Earth system, and so is a good target to test the effects of changing boundary conditions on monsoon activity. Following the relative warmth and higher pCO_2 conditions of the mid Pliocene, the intensification of Northern Hemisphere Glaciation (iNHG) was marked by a pCO_2 fall and the establishment of quasi-permanent NH ice sheets from ~2.7 Ma onwards, although the overall transition was spatially and temporally heterogeneous. While this transition has been relatively well studied in the mid and high latitudes, the response of the low latitude monsoon systems is less well resolved. Here we present a selection of the latest geochemical and micropaleontological data we have gathered from the Bay of Bengal and Andaman Sea spanning this critical time period, based on sediment cores recovered during International Ocean Discovery Program (IODP) Expedition 353. We will showcase how our data addresses interesting research questions around: the Indian Monsoon response to iNHG; the links between local marine productivity and monsoon activity; and the underlying orbital heartbeat of the monsoon.

A stable greenhouse climate during the Early Cretaceous

Graham, O.A.[1], Witkowski C.R.[1], Littler K.[2], Steinig S.[3], Lunt D.J.[3], Huber B.T.[4], Robinson S.A.[5], and Naafs B.D.A.[1]*

[1]*Organic Geochemistry Unit, University of Bristol, UK*

[2]*Department of Earth and Environmental Sciences & Environment and Sustainability Institute, University of Exeter, UK*

[3]*School of Geographical Sciences, University of Bristol, UK*

[4]*Department of Paleobiology, Smithsonian Institution, USA*

[5]*Department of Earth Sciences, University of Oxford, UK*

**Presenting Author, david.naafs@bristol.ac.uk*

The Early Cretaceous (~94–145 Ma) was a critical interval in Earth's history, marked by profound evolutionary change within both the marine and terrestrial realms. On land, the rapid expansion of flowering plants facilitated the diversification of insects, birds, and mammals, while in the oceans, periods of widespread anoxia reshaped biogeochemical cycles and marine biodiversity. However, the evolution of climate during this critical interval remains poorly constrained, hindering the assessment of the role of climate in driving these evolutionary changes.

Here we present novel biomarker-based reconstruction of sea surface temperatures (SST) and atmospheric carbon dioxide concentrations (pCO_2) from DSDP Site 398 in the mid-latitude proto-North Atlantic Ocean spanning ~95–135 Ma. For this purpose, we use the established TEX_{86}-SST proxy and the stable carbon isotopic composition ($\delta^{13}C$) of phytane to provide the first long-term and continuous records of SSTs and *p*CO2 across the Early Cretaceous. Our data reveal consistently elevated SSTs (>30 °C) and high pCO_2 (>750 ppm), interrupted only by transient cooling following Ocean Anoxic Event 1a.

These findings challenge previous interpretations of a cooler and a temporally variable climate system during the Early Cretaceous. Our climate model simulations suggest that apparent temporal variability in published SST records largely reflects local paleogeographic changes, rather than true global-scale climatic oscillations, and are biased by the lack of continuous and global records. This revised view of Early Cretaceous greenhouse climate stability challenges the hypothesised role of pCO_2 change in driving the biotic turnover of the period, and invites a reassessment of the underlying evolutionary catalyst.

IODP[3] SPARC Expedition 506S: SIGNALS (Stratigraphic InteGration of North Atlantic Legacy Sites)

David Hodell[1]* and Arisa Seki[2]

[1]*Department of Earth Sciences, University of Cambridge, Cambridge CB2 3EQ, United Kingdom*

[2] *Fukada Geological Institute, Tokyo, 113-0021, Japan*

**Presenting Author, dah73@cam.ac.uk*

The North Atlantic plays a crucial role in regulating global climate due to its proximity to major ice sheets and sensitivity to changes in the Atlantic Meridional Overturning Circulation (AMOC). Over millennial and orbital timescales, the region has experienced abrupt climate shifts with significant global implications. Despite the wealth of sediment cores recovered from North Atlantic legacy sites through IODP and predecessor programs, many remain underutilized due to challenges in stratigraphic correlation and integration. The **SIGNALS** (Stratigraphic InteGration of North Atlantic Legacy Sites) project aims to synthesize and integrate these legacy records into a coherent, four-dimensional stratigraphic framework to provide a regional reconstruction of past climate variability on millennial to orbital timescales since the late Miocene.

SIGNALS will enhance stratigraphic correlation, refine age models, and synchronize proxy datasets for multiple legacy sites across the North Atlantic spanning a wide range of climatic and bathymetric gradients. The project will capitalize on advanced methods, including machine learning and signal correlation algorithms, to rapidly produce high-resolution data by automated processing of core images, point counting, and precise stratigraphic correlation. The **SIGNALS** Expedition Science Team will work collaboratively to produce training datasets to refine AI models, stratigraphic correlation methods, and age models.

SIGNALS will address methodological issues associated with estimating uncertainty in stratigraphic correlations and the limits of temporal resolution at each site given varying sedimentation rates, bioturbation, and sampling frequency. Furthermore, we will develop process models to understand how orbitally-driven climatic changes are expressed as cycles in the stratigraphic record of each site. By analyzing high-resolution geochemical and sedimentological proxies in a robust stratigraphic framework, the project will reconstruct climate evolution and ocean circulation changes across the North Atlantic since the late Miocene. The project will focus on major climatic transitions and provide robust regional paleoclimate data for numerical modeling and assimilation studies.

Beyond research advancements, SIGNALS will foster collaboration by developing user-friendly computational tools, training early-career researchers, and making data publicly accessible through open repositories. The project will contribute to other programs, such as PAGES PMIP, TIMES, Beyond-EPICA Oldest Ice, by providing robust paleoclimatic information for assimilation and comparison. SIGNALS aligns with key objectives of the IODP 2050 Science Framework, including: Earth's Climate System, Feedbacks in the Earth System, Tipping Points in Earth History, and Global Cycles of Energy and Matter. Additionally, it addresses the themes of Technology Development and Big Data Analytics through machine learning applications and automated data collection.

A New Estimate of the B and Sr Isotopic Systematics of Subducting Serpentinized Oceanic Mantle

William Osborne[1*], Ivan Savov[1,2], Samuele Agostini[2], Andrew McCaig[1], Marguerite Godard[3]

[1]*Institute of Geodynamics and Tectonics, School of Earth and Environment, University of Leeds, Leeds, United Kingdom*

[2]*Istituto di Geoscienze e Georisorse - Consiglio Nazionale delle Ricerche, Pisa, Italy*

[3]*Géosciences Montpellier, CNRS, Université de Montpellier, France*

**Presenting Author, eewjo@leeds.ac.uk*

Volatile element exchange between Earth's oceans and interior is dominated by the subduction and subsequent devolatilization of altered oceanic crust and serpentinized mantle lithosphere. Fluid mobile elements including B and Sr are often employed to constrain the volume and source of water entering subduction zones, but existing estimates of the geochemical makeup of oceanic serpentinite are based on ophiolitic analogues, dredge samples, and shallow (<200m) drill cores which may not be representative of the bulk serpentinized slab mantle.

Here we present the first whole rock B, Sr and O isotopic measurements on a deep (1268m) core in abyssal serpentinite and subordinate gabbroic rocks drilled at the Atlantis Massif oceanic core complex (30°N, Mid-Atlantic Ridge); U1601C, 800m from the Lost City hydrothermal field.

Serpentinite B contents decrease by an order of magnitude downcore (from around 35µg/g to <3µg/g), which we interpret as reflecting distillation of alteration fluid and/or lower integrated flux away from a crustal-scale detachment fault. Substantial variation in serpentinite B isotopic values (+12‰< $\delta^{11}B$ <+40‰) indicates spatial and temporal variability in temperature and pH conditions during alteration that we suggest are common to the actively-metamorphosing deep substrate of Lost City.

Sr concentrations in several deep serpentinites (<0.04 µg/g) are considerably lower than primary mantle values suggesting that serpentinization is not uniformly accompanied by Sr incorporation. Leaching experiments indicate that the Sr isotopic compositions of serpentinites reflect interaction with isotopically evolved fluids resembling Lost City vent fluid.

We argue that the serpentinized lithospheric mantle supplies significantly less B to subduction zones than previously assumed, and does not contribute significant Sr to slab-derived subduction zone fluids compared to mafic and sedimentary crustal components. Whilst B and Sr isotopic systematics are commonly used to assess the source of water derived from subducting slab material and the tectonic settings for serpentinization in ophiolite terranes, we propose that the geochemical signature of oceanic serpentinization in most cases reflects the composition of chemically evolved vent fluids rather than unmodified seawater.

This research used data and samples provided by the International Ocean Discovery Program (IODP). We thank the Expedition 399 scientists, the JRSO technical staff, and the Siem Offshore crew of the JOIDES Resolution for making this study possible. Funding for this research was provided by NSF-OCE 1326927: Management and Operations of the JOIDES Resolution as a Facility for the International Ocean Discovery Program.

Lithological controls of high-temperature ductile strain localization in the lithospheric roots of the Atlantis Massif OCC

Andrew J. Parsons[1]*, Catriona McCleery[2], Rebecca Kuehn[3], Barbara E. John[4], Jeremy R. Deans[5], Ethan L. Lopes[6], Kuan-Yu Lin, C[7]. Johan Lissenberg[8], Carlotta Ferrando[9], and the Expedition 399 Scientists

[1] School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth UK.

[2]Department of Earth Sciences, University of Cambridge, Cambridge, UK.

[3] Institute of Geosciences and Geography, Martin-Luther-University Halle-Wittenberg, Halle, Germany.

[4] Department of Geology and Geophysics, University of Wyoming; Laramie WY, USA

[5] School of Biological, Environmental, and Earth Sciences, Univ. Southern Mississippi, MS, USA.

[6] Department of Geophysics, Stanford University; Stanford CA, USA

[7]National Museum of Natural History, Smithsonian Institution; Washington, DC, USA.

[8]School of Earth and Environmental Sciences, Cardiff University; Cardiff, UK

[9]Department of Earth, Environmental and Life Sciences, University of Genova; Genova, Italy

**Presenting Author, andy.parsons@plymouth.ac.uk*

Oceanic core complexes (OCCs) are a key structural feature of slow- to ultraslow-spreading mid-ocean ridges. Along these ridges, OCCs accommodate plate spreading through detachment faulting and a subordinate component of magmatic accretion, resulting in the uplift and exhumation of peridotite and gabbroic intrusions to the seafloor. This study presents on-going analyses of rock core recovered from the Atlantis Massif OCC (30°N, Mid-Atlantic Ridge) during IODP Expedition 399 (Lissenberg et al., 2024; McCaig et al., 2025), with the aim of understanding the processes which control formation and evolution of OCCs. Expedition 399 recovered 1268 m of drill core from Hole U1601C, comprising ~70% serpentinized peridotite and ~30% mafic intrusions. High-temperature ductile deformation of gabbroic intrusions is observed throughout the core and forms the focus of our study.

Integration of macro- and micro-structural observations reveal that high-temperature (>800°C) ductile deformation is strongly localized in zones of lithologic heterogeneity created by meter- to submeter-scale gabbroic intrusions within peridotite. High-temperature ductile deformation is found in all gabbroic rock types, but preferentially localized within intervals of Fe-Ti oxide-bearing gabbros. Our observations suggest that Fe-Ti-oxides crystalized during melt-reactive porous flow of evolved melt through a gabbroic crystal mush. Cross-cutting relationships suggest that evolved melt infiltration followed and enhanced ductile deformation, especially along or close to the margins of gabbroic intrusions. In most cases, these gabbroic contacts are overprinted by an early amphibole alteration assemblage, which continued to localize ductile deformation as the OCC cooled to lower temperatures (~700-500°C).

Collectively, our observations highlight important spatially controlled relationships between magmatic architecture, ductile deformation, and fluid-rock interaction within the lithospheric roots of the Atlantis Massif OCC. We argue this controlling relationship may be significant for similar “moderately-magmatic OCCs”, described along the Mid-Atlantic Ridge and other slow-spreading ridges.

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Much Ado About Cracking: Ocean crustal veins record dynamic plate cooling and seawater chemistry

Aled D. Evans* [1], Rosalind M. Coggon [1], Michelle Harris [2], Elliot J. Carter [3], Elmar Albers [4], Gilles M. Guérin [5], Thomas M. Belgrano [6], Mallika Jonnalagadda [7], Lewis J.C. Grant [1], Pamela D. Kempton [8], David J. Sanderson [1], James A. Milton [1], Timothy J. Henstock [1], Jeff C. Alt [9], Damon A.H. Teagle [1]

[1] *University of Southampton, UK*

[2] *University of Plymouth, UK*

[3] *Keele University, UK*

[4] *Woods Hole Oceanographic Institution, USA*

[5] *Columbia University, USA*

[6] *University College Dublin, IRE*

[7] *Savitribai Phule Pune University, IND*

[8] *Kansas State University, USA*

[9] *University of Michigan, USA*

**Presenting Author, A.Evans@soton.ac.uk*

As ocean crust traverses away from spreading ridges, low-temperature hydrothermal minerals fill cracks to form veins, transforming the physical and chemical properties of ocean crust whilst also modifying seawater chemistry. This mechanism is proposed to explain why seismic velocities in ocean crust mature within 8 million years of crustal formation. However, heat flow studies indicate that advective heat loss and thus chemical exchange endures on average for 65 million years in oceanic crust.

Here I will present (Evans et al., 2025) new observations from recent and previous scientific ocean drilling sites that show vein widths broaden and strain accumulates with crustal age, whereas vein densities remain approximately constant. Together with in situ elemental and isotopic mapping, these data reveal multiple precipitation-fracturing episodes. This challenges the existing notion that ocean crustal veins are passively filled; rather, they are dynamic features of ocean crust aging. Combined with thermal strain modelling, these data indicate a positive feedback mechanism where cooling of the ocean plate induces cracking and the reactivation of pre-existing veins, ultimately resulting in further cooling. This proposed model reconciles the disagreement between contrasting geophysical datasets and demonstrates that ocean crust endures as an active geochemical reservoir for tens of millions of years after formation.

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Nadir Crater: from discovery to drilling proposal (and expedition?)

Uisdean Nicholson[1]*, IODP 1004 proponents[2],

[1] *Heriot-Watt University, Riccarton Campus, Edinburgh, Eh14 4AS*

[2] *https://iodp3.org/proposals/active-proposals/1004/*

**Presenting Author, u.nicholson@hw.ac.uk*

The Nadir Crater is an exceptionally well-preserved impact structure situated ~400 km offshore Guinea, West Africa. Buried ~300 m below the seafloor in 900 m water depth, well within the operational range of mission-specific platforms (MSPs). This presentation traces the journey from the crater's serendipitous discovery in 2020 to its current status as a tentatively scheduled IODP expedition.

The crater was identified initially from a single 2D seismic profile across the Guinea Plateau that was being evaluated for a possible IODP drilling proposal on the opening of the Equatorial Atlantic Gateway The profile revealed a concave-up crater floor, a distinct central uplift and annular moat surrounded by normal faults, all consistent with a complex crater. Intriguingly, the crater floor was interpreted to be near K-Pg in age, leading to the possibility that this could be genetically related to the Chicxulub impact event (Nicholson et al., 2022).

Serendipity struck again in 2022, when we found out that a seismic company had acquired a new 3D seismic survey directly across the structure. These data (Nicholson et al., 2024) revealed the crater architecture in unprecedented detail, allowing us to reconstruct crater kinematics during the crater modification stage, and to observe evidence of the cascade of environmental consequences that ensued, including liquefaction, tsunami resurge and landslides. The 3D seismic also serves as critical site survey data for locating drilling sites and assessing site safety.

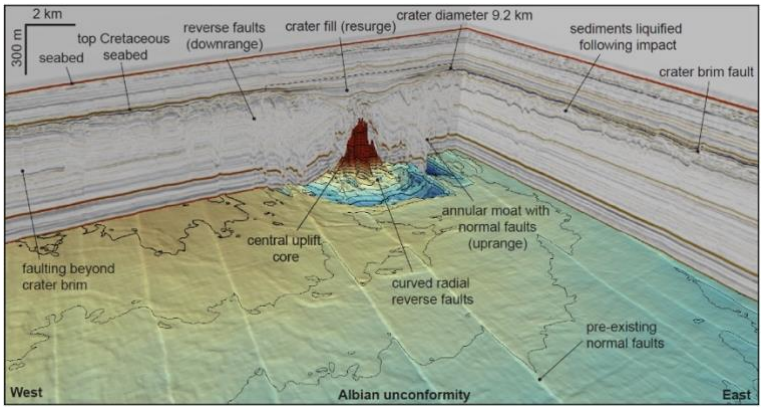

Figure 1. Nadir Crater on 3D seismic (Nicholson et al., 2024)

The discovery of the Nadir Crater fundamentally reshaped our scientific drilling plans. Having re-focused the proposal on testing the K-Pg impact hypothesis, this was submitted as a *Joides Resolution* Auxiliary Drilling Project (ADP) proposal in 2021, and finally approved by the Science Evaluation Panel in 2023. However, the landscape for scientific ocean drilling was changing rapidly. With the end of *JR* operations and IODP(2) in 2024, this proposal was modified and transferred to the new IODP[3] programme. At the time of writing, and pending final approvals and permitting, Nadir is tentatively scheduled as a full IODP expedition in 2027 – only ~7 years after it was originally discovered, and 6 years after the initial proposal was submitted.

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Enabling IODP^3-NSF Expedition 501 science through novel downhole logging operations

Andrew J. McIntyre[1]*, Erwan Le Ber [1,2], Brandon Dugan[3], Rebecca S. Robinson[3], Jeremy Everest[4], IODP^3-NSF Expedition 501 Science Team[3] and the ECORD Science Operator

[1]*School of Geography, Geology and the Environment, University of Leicester, UK*

[2]*CNRS, Géosciences Montpellier, University of Montpellier, Montpellier, France*

[3]*Affiliations at https://www.ecord.org/expedition501/*

[4]*British Geological Survey, Lyell Centre, Edinburgh*

**Presenting Author, am1422@leicester.ac.uk*

International Ocean Drilling Programme and National Science Foundation (IODP^3-NSF) Expedition 501: New England Shelf Hydrogeology sailed 19th May-1st August 2025. The expedition aimed to provide direct evidence of freshened groundwater extending offshore the North American Atlantic margin (Dugan et al., 2025) as previously hypothesised following prior drilling efforts, including findings from IODP Expedition 313 New Jersey Margin, and paleohydrological modelling (e.g. Lofi et al., 2013 and Person et al., 2003). Core, borehole, and fluid samples obtained during Expedition 501 from three Sites (M0111-M0113) will provide necessary constraints on the distribution, age, origin and emplacement of the freshened water, and provide insight into the stratigraphy, geochemical evolution, and microbiological ecosystems within offshore aquifer systems.

On Mission Specific Platform (MSP) Expeditions, the ECORD Science Operator (ESO) uses a suite of slimline tools (typically <60mm in diameter) to broadly characterise in-situ subsurface properties and contribute to meeting the expedition-specific scientific objectives. Poorly consolidated shelf sediments, as exist on the New England continental shelf, provide the challenge of post-coring formation instability and the risk of borehole collapse. During Expedition 313, mitigations for logging in unstable formations included logging in stages and running a gamma-ray tool through metal casing (Mountain et al., 2009). During Expedition 501, a different approach was implemented. Prior to downhole logging, polyvinyl chloride (PVC) casing was temporarily installed in place of the drill string to enable safe passage of tools within the borehole. This was the first use of a PVC casing during any DSDP/ODP/IODP expedition and enabled the collection of continuous records of spectral and total gamma ray, formation conductivity and magnetic susceptibility in non-consolidated siliciclastic sediments. Without the PVC casing in this setting, logging data, let alone a continuous characterisation of the lithologies, the magnetic mineralogy and formation fluid properties may not have been possible or restricted solely to gamma-ray measurements through drill string.

Expedition 501 was the first MSP expedition to deploy a slimline Borehole Nuclear Magnetic Resonance (NMR) logging tool in order to determine porosity and volume of fluids within clay-bound, capillary-bound and free-fluid components. NMR-based permeability models will be calibrated as part of post-expedition activities. The NMR-derived porosity, fluid volumes and permeability data will build a crucial understanding of the distribution, dynamics and mobility of the freshened water sampled within this offshore hydrological system. Furthermore, the logging data will provide foundation for interdisciplinary work on hydrogeological–microbiological studies and model simulations of continental shelf systems.

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21st Century Drilling Project - Building capacity in the digital domain using scientific ocean drilling legacy material

Anna Joy Drury[1,2], Gerald Auer[3], Beth Christensen[4], Junichiro Kuroda[5], Yusuke Kubo[6], David De Vleeschouwer[7], Thomas Westerhold[8], Ursula Röhl[8], Laurel Childress[9], Minoru Ikehara[10], and the 21st Century Drilling Project Team Members*

[1]School of Geography, Geology and the Environment, University of Leicester, UK

[2]Department of Earth Sciences, University College London, UK

[3]Department of Earth Sciences, NAWI Graz Geocenter, University of Graz, Austria

[4]Department of Environmental Science, School of Earth and Environment, Rowan University, USA

[5]Atmosphere and Ocean Research Institute, The University of Tokyo, Japan

[6]Kochi Institute for Core Sample Research, JAMSTEC, Kochi, Japan

[7]University of Munster, Germany

[7]MARUM, University of Bremen, Germany

[8]Texas A&M University; USA

[9]Kochi University, Japan

**Presenting Author, a.j.drury@leicester.ac.uk*

The success of 55+ years of scientific ocean drilling through the International Ocean Discovery Program (IODP) and its predecessors has provided the international scientific ocean drilling community with a wealth of legacy archives, stored in three IODP core repositories and several databases. Greater utilisation of legacy archives is anticipated in the International Ocean Drilling Programme (IODP[3]), especially as it now possible to generate digital cores to use as a primary data source (e.g., through packages like Code for Ocean Drilling Data, or CODD; Wilkens et al., 2017). There is significant scope for integrating these “virtual CODD cores” with data derived from re-analysis of physical legacy core stored in IODP3s core repositories. This integration offers a future pathway to increase capacity and utilisation of legacy material.

The 21st Century Drilling Project aimed to test best practices for the re-analysis and integration of physical and digital IODP/ODP/DSDP legacy material through four global workshops hosted at all three core repositories. These workshops aimed to test best practices for training of early career scientists in hands-on core analysis and address the scientific objectives to trace changes in ice-rafted debris (IRD) and biological responses to shifting Antarctic fronts in the Southern Ocean due to Miocene ice volume variability. To achieve this, the four linked workshops targeted five sites spread across the Indian, Atlantic and Pacific sectors of the Southern Ocean.

The first workshop was hosted as part of J-DESC’s RECORD ReC23-01 at the Kochi Core Centre (KCC, Japan) in August 2023 and investigated DSDP Site 266 (Indian Ocean Sector). Two ECORD MagellanPlus 21st Century Drilling Workshops were held at the Bremen Core Repository (BCR, Germany) in April and November 2024, investigating respectively ODP Site 704 and ODP Sites 1090 and 1092 (Atlantic Ocean Sector). The final USSSP 21st Century Drilling workshop was held in February 2025 at the Gulf Coast Repository (GCR, USA), focussing on ODP Sites 1095 and 1096 (Pacific Ocean Sector). The target sites were carefully chosen to address the scientific objectives while ensuring coverage of sites spanning IODP’s entire history. This approach enabled the workshops to identify potential differences in the analytical requirements of legacy material depending on the age of the cores.

Through the four workshops, we have brought together 68 early-career to experienced researchers from a wide range of IODP and non-IODP countries. Though linked by common

goals, each workshop had its own specific focus and developed a path tailored toward participant needs and site-specific requirements. By conducting the workshops sequentially, we had the opportunity to evaluate our approaches and adapt them as appropriate. Here, we will illustrate initial highlights of best practice approaches for investigating digital and physical legacy material to provide powerful research and training opportunities for the next generation researchers engaged with the international scientific ocean drilling community.

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*21st Century Drilling Project Team Members: Anna Joy Drury, Gerald Auer, Beth Christensen, Junichiro Kuroda, Yusuke Kubo, David De Vleeschouwer, Thomas Westerhold, Ulla Röhl, Laurel Childress, Minoru Ikehara, Gary Acton, Anna Arrigoni, Gracie Babineaux, Disha Baidya, Sebastian Beil, Christina Belanger, Or Bialik, Samantha Bombard, Alianna Bronstein, Anson Cheung, Ann Cook, Deepa Dwyer, Sara Emanuel, Cécile Figus, Jodi Fox, Mukhtiar Ghani, Juliette Girard, Monica Alejandra Gomes Correa, Hongcheng Guo, Julia Hagemann, Emma Hanson, Tamara Hechemer, Jess Hillman, Claire Jasper, Heather Jones, Boris Karatsolis, David King, Ravi Kiran Koorapati, Olivia Laub, An-Sheng Lee, Christopher Lepre, Diederik Liebrand, Jiarui Liu, Vikki Lowe, Jing Lyu, Margaret Morris, Theresa Nohl, Natsumi Okutsu, Tina Palme, Renjie Pei, Werner E Piller , Xabier Puentes Jorge, Christina Riesselman, Gerald Rustic, Rohit Samant, Arisa Seki, Torben Struve, Haley Svadlenak, Deborah Tangunan, Victoria Taylor, Emily Tibbett, Muhammad Usman, Jamal Wadood, Roy Wilkens, Jumpei Yoshioka, Jeremy Young, Yan Zhang, Yunlang Zhan

North Atlantic sea surface temperature evolution across the Oligocene-Miocene Transition based on TEX_{86} paleothermometry

Tobias Agterhuis[1*], Heather M. Stoll[2], Thomas Tanner[2], Emily H. Hollingsworth[1], Gavin L. Foster[1], Bridget S. Wade[3], and Gordon N. Inglis[1]

[1]*School of Ocean and Earth Science, University of Southampton, Southampton, United Kingdom*

[2]*Department of Earth Sciences, ETH Zürich, Zürich, Switzerland*

[3]*Department of Earth Sciences, University College London, London, United Kingdom*

**Presenting Author, t.agterhuis@soton.ac.uk*

The Oligocene-Miocene Transition (OMT) is marked by a prominent ~1‰ positive excursion in benthic oxygen isotope records ($\delta^{18}O_{benthic}$), the so-called Mi-1 glaciation, which reflects expansion of the Antarctic ice sheet and/or deep ocean cooling. At present, limited reconstructions of sea surface temperature (SST) evolution across the OMT have been published. Consequently, it remains uncertain how much global cooling was associated with the Mi-event. Here we present high-resolution (~10 kyr) SST reconstructions across this interval from IODP Site U1406 on the Newfoundland Margin (North Atlantic) using the lipid biomarker TEX_{86} proxy (isoGDGT distributions).

Our record shows TEX_{86} values ranging from 0.64 to 0.76, with a drop of ~0.04 units across the Mi-1 event. To assess potential non-thermal overprints on the TEX_{86} data, we calculated GDGT-based indices, including the Branched-to-Isoprenoid Tetraether (BIT) index. BIT values are high (0.4–0.8), suggesting input of additional GDGTs from terrestrial sources that could potentially bias the TEX_{86} (and therefore the reconstructed SST) signal. However, our preliminary data do not show a strong correlation between TEX_{86} and BIT values (R^2 value of 0.124). Furthermore, a ternary plot of brGDGT distributions reveals that the brGDGTs in the Newfoundland samples have a distinct composition compared to modern soils and peats. These observations suggest that the brGDGTs were likely produced in the marine realm, and that the TEX_{86} record is not influenced by terrestrial GDGT contributions, reliably reflecting SST. Translating TEX_{86} into temperature, our record indicates warm SSTs ranging from 26 to 30°C, with a cooling of ~2°C during the Mi-1 event. These TEX_{86}-based SST estimates show excellent agreement with published low-resolution alkenone-derived ($U^{K'}_{37}$) SSTs from the same site (Guitián et al., 2019), both in terms of absolute temperatures and relative changes.

Assuming the ~2 °C cooling in the North Atlantic across Mi-1 reflects a global temperature signal implies that the positive $\delta^{18}O_{benthic}$ excursion in the deep ocean is driven by roughly equal contributions from global cooling and Antarctic ice sheet expansion (~60 m sea level drop). However, SSTs near Newfoundland are also sensitive to changes in ocean circulation. The region currently experiences a strong SST gradient due to the interaction of warm, saline waters from the Gulf Stream and much colder, fresher waters from the Labrador Sea Current. In addition to global temperature changes, latitudinal shifts in the position of this front would also affect the SST evolution at Site U1406. Future work combining TEX_{86}-based SST estimates with planktic foraminiferal $\delta^{18}O$ (and Mg/Ca) measurements will allow estimation of the isotope composition of the surface waters ($\delta^{18}O_{sw}$). Potential changes in $\delta^{18}O_{sw}$ can be used to track shifts in the relative contributions of Gulf Stream and Labrador Sea Current waters (higher and lower $\delta^{18}O_{sw}$, respectively), offering a tool to infer changes in the position of the front and ocean circulation during the OMT.

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High-resolution imaging spectroscopy as a tool for drill core mineral mapping

Lottie Atton[1]*, Dr. Michelle Harris[1], Dr. Andrew Parsons[1], Dr. Rebecca Greenberger[2], Prof. Tony Morris[1]

[1] *University of Plymouth, Plymouth, PL4 8AA, United Kingdom*

[2] *Caltech, Pasadena, CA 91125, United States*

**Presenting Author, lottie.atton@plymouth.ac.uk*

Imaging spectroscopy is a powerful analytical technique that enables the identification and mapping of geological material through infrared wavelengths, capturing mineral-specific spectral fingerprints. While widely applied at airborne and outcrop scales in mining, its use at sub-millimetre (~250 µm) resolution remains underexplored (Greenberger *et al.,* 2015; Greenberger *et al.,* 2021). This approach may bridge the gap between discrete sample analyses and core-scale observations, generating a continuous record that provides unprecedented insights into alteration processes beyond traditional core description. Demonstrating the effectiveness and value of imaging spectroscopy at this scale requires careful integration with more traditional approaches (e.g. core description, thin sections, mineral and bulk rock geochemical analyses) to understand how it can be leveraged to improve our geological interpretations. Our study will apply the novel microimaging technique to drill core samples from modern mid-ocean ridge and the Oman ophiolite, to assess the distribution, timing and magnitude of hydrothermal alteration in the ocean crust (Harris *et al.,* 2017), whilst assessing the advantages and limitations of high-resolution imaging spectroscopy as a tool in characterising fluid/rock reactions. The methodology also holds significant potential for the mining industry as a rapid, scalable, and non-destructive alternative to conventional techniques for identifying mineralisation patterns, such as alteration halos (Mathieu *et al.,* 2018). As mining operations seek to optimise resource assessment strategies, integrating imaging spectroscopy presents a promising advancement.

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IODP[3] Expedition 502: Impact of petit-spot magmatism on subduction zone seismicity and global geochemical cycles

Lottie Atton[1]*, Hiroko Kitajima[2], Asuka Yamaguchi[3], Natsumi Okutsu[4], and the IODP[3] Expedition 502 Science Team

[1] *School of Geography, Earth & Environmental Sciences, University of Plymouth, United Kingdom*

[2] *Center for Tectonophysics, Texas A&M University, United States of America*

[3] *Department of Ocean Floor Geoscience, The University of Tokyo, Japan*

[4] *Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan*

**Presenting Author, lottie.atton@plymouth.ac.uk*

Petit-spot volcanism is a distinct style of small-volume (0.005–1 km^3) intraplate eruption that occurs on the down-going oceanic plate at subduction zones (Hirano *et al.,* 2006). Flexure of the lithosphere prior to subduction facilitates extraction of pre-existing melt from the upper asthenosphere and focuses magma ascent to the surface along fractures in the bending plate. These eruptions produce young, highly alkaline, CO_2-rich basalts that host mantle xenoliths and have isotopic compositions similar to MORB (Machida *et al.,* 2017; Okumura and Hirano, 2013; Yamamoto *et al.,* 2014). Since the initial discovery of petit-spot volcanism near the Japan Trench on the northwest Pacific plate, similar fields have been documented at the Java, Chile and Mariana trenches, suggesting that the process may be ubiquitous in regions of plate flexure (Fujiwara *et al.,* 2007; Hirano and Machida, 2022). However, the deep-marine setting makes detection and sampling challenging, so both the distribution and subsurface structure of petit-spots remain poorly constrained.

International Ocean Drilling Programme (IODP[3]) Expedition 502 (31st October – 24th November 2025) cored a petit-spot region on the outer rise of the Japan Trench (NW Pacific plate), recovering a continuous succession from pelagic sediments to petit-spot basalts and providing the first subsurface record of these systems. The expedition will test the hypothesis that petit-spot volcanism is more widely distributed than previously recognised, with key objectives to: (a) characterise the nature of the acoustic basement, (b) assess the impact of petit-spot activity on the composition and physical properties of plate-boundary materials, and (c) quantify associated geochemical fluxes. These findings will enhance understanding of submarine volcanism and how petit-spot activity modifies subduction inputs, with implications for earthquake nucleation and slip, arc magmatism, and global geochemical cycles.

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Evaluation of the new Itrax FleXRay X-ray Fluorescence Core Scanner at the British Ocean Sediment Core Research Facility

Miros Charidemou[1]*, James Hunt[1], Cían McGuire[1], Suzanne Maclachlan[1], Edward Doherty[1]

National Oceanography Centre, Southampton, UK

**Presenting Author, mirosc@noc.ac.uk*

The first Itrax XRF core scanner, developed by COX Analytical Systems, was installed at the British Ocean Sediment Core Research Facility (BOSCORF) in 2003. Since that time, XRF core scanning (XRF-CS) has become a cornerstone of geological core analysis workflows for the study of marine and lake sediment cores (Rothwell & Croudace, 2015; Croudace et al., 2019) and is a technique used extensively within scientific ocean drilling (e.g., Abrantes et al., 2025). Despite its widespread use, XRF-CS data are typically treated as semi-quantitative, providing relative changes in elemental concentrations rather than absolute values. While various calibration strategies have been proposed, a universal approach remains elusive (Bertrand et al., 2023).

In 2024—two decades after the first Itrax—BOSCORF commissioned the Itrax FleXRay, the latest generation XRF core scanner from COX Analytical Systems. Here, we evaluate the FleXRay's performance through comparative analyses of Standard Reference Materials (SRMs) and a sediment core from offshore northwest Africa, using both the legacy Itrax and the FleXRay systems. SRM measurements enable assessment against known elemental compositions, while downcore comparisons highlight differences in elemental intensities and ratios.

Our results show strong correlations between XRF intensities and elemental concentrations for both scanners across elements from aluminium to zirconium, with some differences between systems. Downcore comparisons reveal variations in relative elemental intensities measured on the core sample but good agreement in elemental ratios, consistent with previous inter-system studies (e.g., Dunlea et al., 2020).

We conclude that the Itrax FleXRay provides reliable semi-quantitative compositional data for geomaterial characterisation, including sediment cores. Ongoing work aims to develop a systematic, scalable calibration protocol to convert XRF-CS outputs from the Itrax FleXRay into fully quantitative datasets.

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Covariant Dust Variability in the Mid-Latitude Japan Sea and Greenland During the Last Glacial

Lingle Chen[1]*, Chuang Xuan[1], Celeste Pallone[2], Anya J. Crocker[1], Peter O. Hopcroft[3], David McGee[2], Paul A. Wilson[1]

[1] *School of Ocean and Earth Science, University of Southampton, Waterfront Campus, National Oceanography Centre, Southampton, UK*

[2] *Massachusetts Institute of Technology, Department of Earth Atmospheric and Planetary Sciences, Cambridge, MA, United States*

[3] *School of Geography, Earth & Environmental Sciences, University of Birmingham, Birmingham, UK*

** Presenting Author, lingle.chen@soton.ac.uk*

The deserts of East Asia inject over 700 million tons of mineral dust into Earth's atmosphere annually, creating airborne particulate plumes visible from space and affecting the health of hundreds of millions of people in Asia. Many plumes are transported thousands of kilometres eastward over the Pacific Ocean and Greenland ice cap where dust deposition creates geological archives that inform us of past changes in continental aridity and atmospheric circulation on geological and human timescales. However, two challenges impede our interpretation of these records. First, windblown dust records from sites distal to desert sources come with an attribution problem (i.e., the provenance of the accumulated dust provenance is debated) and this is especially true of the Greenland records. Second, in the deep North Pacific Ocean which lies downwind of Asia and en route to Greenland, marine biogenic sediments accumulate slowly, if at all, so dust records from these sites are of uncertain age control and too coarsely resolved to help shed light on the cause of the abrupt changes in dust flux of 1–2 orders of magnitude observed in the Greenland records. Here we report new dust provenance and flux records covering about 200 thousand years ago (ka) to present from the Japan Sea, a marginal basin situated between East Asia and the Pacific Ocean where sedimentation rates are very high. Our provenance record, benefits from rigorous removal of marine contaminants and strong age control through correlation to the Greenland ice-core records and reveals remarkable systematic changes in source and flux on different climatic timescales. During the warm conditions of the Holocene and last interglacial, dust export is dominated by the two main East Asian dust sources, the Gobi and Taklimakan deserts. During glacial conditions, including both stadials and interstadials, dust export from the higher latitude Gobi source weakens and the lower latitude Taklimakan desert becomes the overwhelming source of dust transported eastwards. Dust fluxes in the Japan Sea and Greenland covary closely, implying a common response to climate change. Paleoclimate model results suggest that these findings are explained by intense cooling during glacial conditions which induced two-way land surface-atmosphere interactions that resulted in southwards expansion of permafrost, supressing dust activation over the Gobi desert. Yet dust flux from East Asia towards Greenland increased because of drying and increased wind speeds at lower latitudes caused by intensification of the Siberian High Pressure Cell system which displaced the extratropical cyclone belt and East Asian monsoon southwards.

Late Pleistocene Variability in Mediterranean Outflow Water Depth and Strength along the west Iberian Margin

Lingle Chen[1]*, Matthew D. Nichols[1], Anya J. Crocker[1], Jiawang Wu[2], Paul A. Wilson[1], Chuang Xuan[1]

[1] *School of Ocean and Earth Science, University of Southampton, Waterfront Campus, National Oceanography Centre, Southampton, UK*

[2] *Sun Yat Sen University and Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai), Zhuhai, China,*

** Presenting Author, lingle.chen@soton.ac.uk*

Ocean bottom currents transport heat, salt, energy, and nutrients across the globe and play a crucial role in regulating climate variability, yet their past dynamics remain poorly resolved due to the scarcity of robust and high-resolution proxies. Although Mediterranean Outflow Water (MOW) variability has been studied using cores from Integrated Ocean Drilling Program (IODP) Expedition 339 and International Ocean Discovery Program (IODP) Expedition 397, existing reconstructions rely mainly on grain-size proxies for current strength and on indirect, low-resolution geochemical indicators for depth, leaving key aspects, particularly depth changes, poorly constrained. Here, we present an integrated framework that combines anisotropy of magnetic susceptibility (AMS) as a proxy for paleo–flow direction with sortable silt (SS) as a proxy for flow strength to reconstruct past MOW depth and strength changes in the North Atlantic along the West Iberian Margin. Using rapid, non-destructive AMS measurements, we generate a ~0.5-kyr resolution record of paleo–flow direction at Site U1588 spanning the past 400 kyr. Comparison of AMS and SS data from IODP Sites U1588 (water depth 1339 m) and U1391 (water depth 1085 m) allows a continuous reconstruction of MOW shoaling and deepening history throughout the late Pleistocene. Our results show that MOW depth varied systematically with sea-level changes across glacial–interglacial and precession cycles, with a long-term deepening trend since Marine Isotope Stage (MIS) 5. Together, AMS and SS provide a transferable approach for quantifying both the direction and strength of paleo-bottom currents, offering new insights into MOW evolution and the dynamics of deep-water masses globally.

Marine Isotope Stage 11 in the Southern Pacific Ocean: coccolithophore assemblages and calcification at IODP Site U1540

Meriam Chouar[1]*, Mariem Saavedra-Pellitero[1,], Craig Storey[1,], Tom Dunkley Jones[2]

[1] *University of Portsmouth, School of the Environment and Life Sciences University of Portsmouth Burnaby Building, Burnaby Road, Portsmouth, PO1 3QL, UK*

[2] *University of Birmigham, School of Geography, Earth and Environmental Sciences University of Birmingham Edgbaston Birmingham B15 2TT UK*

**Meriam Chouar, meriam.chouar@port.ac.uk*

Marine Isotope Stage 11 (MIS 11; ~424-374 ka) was one of the warmest and longest interglacials of the past 800,000 years, with higher-than-present sea levels and significant carbon cycle feedbacks. Its Holocene-like orbital configuration makes MIS 11 an important natural analogue for studying long-term climate dynamics. Coccolithophores were particularly abundant during this time period, with *Gephyrocapsa caribbeanica* dominating the assemblage. This study uses data from IODP Expedition 383, Site U1540, in the Southern Pacific Ocean, to look at how coccolithophore assemblages and calcification patterns responded to warm conditions, as well as their potential role in carbon export. The findings will provide new insights into high-latitude ecosystem dynamics during MIS 11 and their implications for future climate change.

Palynofacies evidence for Pliocene climate dynamics in the Amundsen Sea sector (IODP Site U1532, West Antarctica)

Marcelo A. De Lira Mota[1,2]*, Daniel B. Chabu[2], Lilian M. Leandro[3]

[1] *School of Geography, Earth and Environmental Sciences, University of Birmingham, B15 2TT, Birmingham, UK*

[2] *Institute of Geosciences, University of São Paulo, R. do Lago, 562 - Butantã, São Paulo - SP, 05508-080, Brasil*

[3] *Technological Institute of Paleoceanography and Climate Change, Unisinos University, Av. Unisinos, 950 - C11 - Cristo Rei, São Leopoldo - RS, 93022-750, Brasil*

**Presenting Author, marcelomota@usp.br*

The mid-Pliocene Warm Period (mPWP; ~3.3–3.0 Ma) represents the most recent interval of sustained global warmth comparable to present-day CO_2 levels. Understanding the response of the West Antarctic Ice Sheet (WAIS) to such conditions is critical to constrain thresholds for future marine ice-sheet retreat. Here we present new palynofacies data from IODP Site U1532, located on the Amundsen Sea continental rise, aimed at reconstructing variations in organic matter composition and depositional conditions across the mid- to late Pliocene. Quantitative counts of amorphous organic matter (AOM), phytoclasts, and palynomorphs, combined with phytoclast morphometrics, reveal three main stages in the WAIS evolution between ~3.32 and 2.88 Ma. A pre-mPWP interval (~3.32–3.25 Ma) is characterised by high AOM (>50%) and moderate phytoclast input (~40%), indicating dysoxic bottom waters and reduced ice-sheet influence. During the mPWP (~3.25–3.07 Ma), AOM collapses to ~10% while phytoclasts increase to >80%, reflecting enhanced ventilation, strong terrigenous flux, and intensified glacial erosion consistent with renewed grounding-line advances reported from seismic and provenance records (Gohl et al., 2021; Gille-Petzoldt et al., 2022; Rahaman et al., 2025). After 3.07 Ma, partial recovery of AOM (~40%) and reduced but persistent phytoclast input suggest episodic WAIS readvances superimposed on a longer-term cooling trend. These results provide a process-based link between marine palynofacies variations and WAIS dynamics, demonstrating that transitions from retreating to readvancing states were accompanied by shifts from dysoxic to ventilated bottom-water regimes and from marine to terrigenous organic matter dominance. The study highlights the potential of palynofacies analyses to refine stratigraphic and palaeoenvironmental interpretations of IODP cores from polar margins.

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Western Pacific Warm Pool perspective of prolonged El Niño-like conditions during the Late Miocene

Anna Joy Drury[1,2,3], Thomas Westerhold[2], Nina Rohlfs[2], Ze Tao[1], Ana-Christina Ravelo[4], Bridget Wade[1]

[1]*Department of Earth Sciences, University College London, UK*

[2]*MARUM, University of Bremen, Germany*

[3]*School of Geography, Geology and the Environment, University of Leicester, UK*

[4]*Ocean Sciences Department, University of California, USA*

**Presenting Author, a.j.drury@leicester.ac.uk*

The Late Miocene is characterised by warmer-than-present conditions with temperatures comparable to those predicted for the year 2100. It is important to understand how equatorial Pacific climate systems such as the El Niño Southern Oscillation (ENSO) were impacted during interval of past global warmth, such as the Late Miocene. The presence of Late Miocene permanent El Niño-like conditions in the equatorial Pacific remains ambiguous, with several studies proposing either 1) a permanent Late Miocene El Niño-like state (e.g., Ravelo et al., 2014), 2) alternating El Niño-like (9.6-6.5 Ma) and La Niña-like (6.5-6.1 Ma) conditions (e.g., Nathan and Leckie, 2009; Drury et al., 2018), or 3) modern thermal gradients since ~12 Ma (e.g., Zhang et al., 2014). As the modern ENSO system causes significant precipitation and temperature anomalies around the globe, reconciling these disparate views of prolonged El Niño-like conditions during the Late Miocene is a key step towards understanding the potential global impacts of long-term warming in the equatorial Pacific.

Clarification of the status of permanent El Niño-like conditions in the Late Miocene was hindered by low-resolution data in the Western Pacific Warm Pool (WPWP), exacerbated by the scarcity of archives suitable for high-resolution work in the WPWP region. The recovery of International Ocean Discovery Program (IODP) Site U1488 during IODP Expedition 363 to the WPWP provided the key sedimentary sequences needed to resolve this issue. We generated high-resolution (2.5 kyr) mixed layer, thermocline and benthic foraminiferal stable oxygen (δ18O) and carbon (δ13C) isotope stratigraphies to reconstruct the evolution of water column structure in the WPWP between ~10 and 6 Ma. We integrate our new WPWP records with high-resolution foraminiferal data from the eastern equatorial Pacific (Drury et al., 2018). Our initial findings provide insight into the extent of prolonged El Niño-like conditions during the Late Miocene, and how these conditions may have impacted heat transport and carbon cycling in the equatorial Pacific Ocean.

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Re-evaluating the orbital pacing of glacial cycles across the Plio-Pleistocene Transition (3-2 Ma)

Mengyao Du[1]*, Simon Crowhurst[1], Maryline Mleneck-Vautravers[1], James Rolfe[1], David Hodell[1]

[1]*Godwin Laboratory for Palaeoclimate Research, Department of Earth Sciences, University of Cambridge*

**Presenting Author, md970@cam.ac.uk*

Milankovitch (1941) predicts that the growth and decay of the Northern Hemisphere ice sheets is driven by changes in caloric summer half-year insolation at the periods of precession and obliquity. The “41 kyr world” provides a valuable test bed for this hypothesis due to its smaller ice sheets and a presumed more linear climate response to orbital forcing than the “100 kyr world”. Yet, there is still no comprehensive theory linking orbital parameters to glacial-interglacial cycles, and the presence of precession power in benthic d18O records remains elusive in this interval.

Here, we present a new high resolution benthic $\delta^{18}O$ record from IODP Site U1385 (Exp 397, Iberian Margin), covering the Plio-Pleistocene Transition (3-2 Ma). Based on a precession-tuned age model, our analyses show that obliquity strongly governs the timing of glacial terminations and inceptions. However, we find no evidence that precession determines the timing of glacial-interglacial transitions, despite the age model favouring its detection.

The resemblance between our benthic $\delta^{18}O$ record and caloric summer half-year insolation further motivated us to assess the combined contribution of obliquity and precession in pacing glacial cycles. We applied Empirical Nonlinear Orbital Fitting (ENOF) (Eq. 1) (Liautaud et al. 2020) to the first derivative of benthic $\delta^{18}O$ ($d\delta^{18}O/dt$), revealing a precession-to-obliquity amplitude ratio of 0.42 on the precession-tuned age model and 0.33 on the LR04 timescale. This suggests a modest yet detectable contribution from precession.

$$d\delta^{18}O/dt = A_o(t)\varepsilon(t - \Delta t_o) + A_p(t)esin(\varpi(t - \Delta t_p)) + \eta(t) \text{ (Eq. 1)},$$

Where $d\delta^{18}O/dt$ is modelled as a linear combination of obliquity (ε) and climatic precession ($e \cdot \sin(\varpi)$), with time varying amplitudes (A_o, A_p) and time offsets (Δt_o and Δt_p). The residual term $\eta(t)$ represents noise and non-linearities not captured by the linear orbital model.

We further observe an abrupt increase in the residual noise at the MIS 100 deglaciation, which persists through subsequent glacial cycles, suggesting enhanced non-linearity in ice volume changes. This raises a key question: can glacial cycle asymmetry be explained by orbital forcing?

To assess this, we ran the coupled Northern Hemisphere ice sheet and energy balance model (Huybers and Tziperman 2008), driven by the full seasonal cycles of insolation and modified to include long-term cooling and a superimposed CO_2 drop between 2.9-2.7 Ma (Martínez-Botíet al. 2015). The modelled ice volume captures many features of the benthic $\delta^{18}O$ waveform (i.e. the shape of glacial cycles), suggesting both obliquity and precession modulate the rate of ice volume changes. However, we note that additional processes, including interactions between millennial- and orbital-scale climate variability, likely contribute to explaining the non-linearities in ice sheet response to orbital forcing.

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Hot Oceans, More Fish: Mesopelagic Fish Productivity across the Palaeocene-Eocene Thermal Maximum

Kirsty M. Edgar[1]*, Elizabeth C. Sibert[2], Morgan Gall[1], Jacob Godfrey[1], Haf Nawsath[1], Samuel Flinders[1], Hannah Bird[1], Daniel Gaskell[3], Douglas Tomczik[4] and Richard D. Norris[4]

[1] *School of Geography, Earth and Environmental Sciences, University of Birmingham, UK*

[2] *Department of Geology and Geophysics, Woods Hole Oceanographic Institution, USA*

[3] *Department of Earth and Planetary Sciences, University of California, USA*

[4] *Geosciences Research Division, Scripps Institution of Oceanography, USA*

**Kirsty Edgar, k.m.edgar@bham.ac.uk*

Marine ecosystem models predict variable changes in the direction and magnitude of pelagic fish production under anthropogenic warming. Long-term, low-resolution data records suggest elevated pelagic fish productivity in the Pacific Ocean during the early Eocene Climatic Optimum, ~49-53 million years ago (Ma), the peak of the Cenozoic greenhouse. However, pelagic fish responses to shorter-term warming remain unclear. We present new ichthyolith accumulation rates (IARs), a proxy for productivity, along with diversity records to reconstruct pelagic fish community dynamics across the Palaeocene-Eocene Thermal Maximum (PETM), ~56 Ma—a major global warming event, often regarded, though imperfect, as an analogue for anthropogenic warming. Records are derived from three deep-sea sites: IODP Site U1514 (mid to high-latitude Indian Ocean), ODP Site 1260 (equatorial Atlantic Ocean), and ODP Site 1209 (equatorial Pacific Ocean). Preliminary results show transient elevated IARs during the peak of the PETM that cannot be accounted for by changing sedimentation rates or dissolution alone, indicating increased fish productivity associated with the warmest temperatures with little or no change in community composition. This suggests that, regardless of warming rate or duration, mesopelagic fish production is higher globally in warmer oceans.

A detailed coccolith assemblage analysis over the mid Pliocene Warm Period

Emma M. Hanson[1]*, Tom Dunkley Jones[1], Kirsty M. Edgar[1], Marcin Latas[1], Morgan Gall[1], Marcus Badger[2], Bridget Warren[2],

[1] *School of Geography, Earth & Environmental Sciences, University of Birmingham, Birmingham, UK*

[2] *School of Environment, Earth & Ecosystem Sciences, The Open University, Milton Keynes, UK*

**Presenting Author, e.hanson.1@bham.ac.uk*

Coccolithophores, a marine haptophyte algae, intracellularly create calcite plates called coccoliths, which are often abundant in marine sediments and are excellent recorders of surface ocean environmental change through time. Detailed assemblage analysis using the automated image recognition system SYRACO allows an in depth look at how communities are affected by intense climatic changes, such as during the mid-Pliocene Warm Period (mPWP, 3.3-3.0 million years ago). The mPWP is a key period of study, as its atmospheric CO_2 was close to modern levels and temperatures were warmer than present. It is the closest 'future analogue' for the climate of the future according to the International Panel for Climate Change (IPCC). Here we present high resolution coccolith assemblage data for three high latitude ocean drilling sites; DSDP Site 594 to the east of New Zealand, ODP Site 982 in the North Atlantic Ocean, and ODP Site 1090 in the southeastern Atlantic Ocean. Changes in community are present at all three sites over the mPWP, as well as variations in size and thickness, but the nature of response is site-specific, indicating a stronger role for climate-controlled local-to-regional changes in oceanography rather than a uniform response to global atmospheric CO_2.

Reconstructing Late Cretaceous Atmospheric CO_2 from DSDP Site 463, Mid-Pacific

Bernát Heszler[1]*, Markus Adloff[1], Ross D. M. Whiteford[2], Caitlyn R. Witkowski[3], David Naafs[3], Maria Rose Petrizzo[4], Brian T. Huber[5], Michael J. Henehan[1]

[1]*School of Earth Sciences, University of Bristol, UK*

[2]*Department of Earth Sciences, Queen's Building, Royal Holloway University of London, UK*

[3]*Organic Geochemistry Unit, School of Chemistry and School of Earth Science, University of Bristol, UK*

[4]*Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Milano, Italy*

[5]*National Museum of Natural History, Smithsonian Institution, Washington, DC, USA*

**Presenting Author, bernat.heszler@bristol.ac.uk*

The extreme warmth of the Late Cretaceous hothouse offers a critical perspective on Earth's tipping points in the face of today's rapidly changing climate (Tierney et al., 2020). This epoch experienced some of the highest temperatures of the past 250 million years, characterized by episodic global carbon cycle perturbations, often coupled with ocean anoxia and global ecosystem upheaval. However, the evolution of atmospheric CO_2 during the Cretaceous is less well-documented than in the Cenozoic. Here, we apply the boron isotope-pH proxy ($\delta^{11}B$) on planktic foraminifera samples from the low-palaeolatitudinal site, DSDP Site 463, drilled on the Western Mid-Pacific Mountains. We present a new $^{87}Sr/^{86}Sr$ record and a new derivation of $[Ca]_{sw}$ from foraminiferal Mg/Ca ratios. We integrate $\delta^{11}B$ with a geochemical model and cGENIE Earth system simulations to constrain $\delta^{11}B_{sw}$ and the carbon cycle. Our findings indicate that elevated CO_2 levels were reached during the peak warmth of the Turonian, followed by a steady decline into the early Maastrichtian. We explore the implications of climate sensitivity during this hothouse interval and find that Earth System Sensitivity was comparable to Cenozoic estimates, implying that the Earth system response to CO_2 forcing remained relatively constant even under hothouse conditions.

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Insights into North Atlantic Deep-water formation from Carbonate Deposition during the late Oligocene to Early Miocene

Xinhui Huo[1]*, Anna Joy Drury[1], Tim van Peer[1], Sarah Davies[1]

[1] *University of Leicester, Leicester LE1 7RH, UK*

**Presenting Author, xh178@leicester.ac.uk*

Earth's climate evolution throughout the Cenozoic has profoundly influenced global carbon cycling and marine carbonate sedimentation (Westerhold et al., 2020). The late Oligocene to Early Miocene (~27.3-15.97 Ma) marks a key interval of climatic and oceanographic reorganization, characterized by Antarctic ice sheet expansion and shifts in deep-water circulation. However, regional variability in orbital forcing and oceanographic conditions complicates the interpretation of carbonate records. While previous studies have demonstrated the influence of orbital parameters on carbonate sedimentation in the Atlantic Ocean (Drury et al., 2021; van Peer et al., 2024), their interactions with deep-water circulation and biological productivity remain unresolved.

The International Ocean Drilling Programme (IODP[3]) and its predecessors provide an extensive database of thousands of globally-distributed drill sites. Here, we integrate high-resolution carbonate records, spectral analysis of astronomical cycles, and palaeoceanographic reconstructions from selected sites in the Atlantic to systematically investigate the controls on carbonate sedimentation in the late Oligocene-Early Miocene. Recent work has shown that there is a distinct difference in orbital pacing of carbonate sedimentation between sites in the North versus South Atlantic. Spectral analysis indicate that Site U1406 was predominantly influenced by obliquity cycles (~43 kyr; van Peer et al., 2024), where Site 1264 responded primarily to short eccentricity cycles (~91 kyr; Drury et al., 2021). These differences suggest that oceanographic conditions, including sedimentation rates and carbonate accumulation, modulated astronomical forcing at regional scales. We show initial compilations of available datasets from a latitudinal distribution of Atlantic drilling sites (Sites 366, 667, 699, 926, and 929) to construct preliminary age models calibrated to GTS2020 and establish preliminary constraints on Atlantic carbonate deposition patterns. This data synthesis will enable comparative evaluation and allow a more detailed investigation of how ocean circulation influenced sedimentation patterns, including through generating additional data (e.g., carbonate coulometry, ICP-MS, grain size).

The initial results from this study already highlight the complexity of astronomical forcing on carbonate sedimentation, demonstrating its dependence on a number of factors, including latitude, water depth, sedimentation rate, and carbonate accumulation. Extending this approach to additional Atlantic sites will refine the understanding of orbital controls and improve constraints on past climate variability.

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Reconstructing Pliocene SST Variability in the Western Indian Ocean from ODP Site 709

Chloe Jones*[1], Heather Ford[1], *Kaustubh Thirumalai[2], Ryan Glaubke[2]*

[1] Queen Mary University of London, London UK

[2] University of Arizona, Tucson, Arizona, USA

**Presenting Author, chloe.jones@qmul.ac.uk*

The Indian Ocean plays a vital role in global climate, particularly in influencing rainfall patterns and monsoonal systems that affect over a billion people across Africa, Asia, and Australasia. The Indian Ocean Dipole (IOD), a coupled ocean-atmosphere phenomenon, can trigger extreme weather events such as floods, droughts, and wildfires. However, projections of future IOD behaviour remain highly uncertain due to divergent model responses to greenhouse warming. To better constrain this uncertainty, we look to the geological past, where intervals such as the mid-Pliocene Warm Period (mPWP; ~3.2–3.0 Ma) provide a valuable analogue for Earth's future climate.

This study focuses on reconstructing sea surface temperatures (SSTs) from Ocean Drilling Program (ODP) Site 709A, located in the western equatorial Indian Ocean, to better understand ocean-atmosphere variability under warm climate conditions. We use paired Mg/Ca and $\delta^{18}O$ measurements from mixed-layer and thermocline-dwelling foraminifera to reconstruct mean SSTs and vertical thermal structure. These reconstructions will be compared with outputs from the Pliocene Model Intercomparison Project Phase 2 (PlioMIP2) to evaluate model performance and to explore the potential operation of IOD-like or equatorial Niño-like variability during the mPWP.

By characterising the thermal structure of the Indian Ocean during this key interval, we aim to provide essential observational constraints on the mechanisms governing tropical climate variability. This research will improve our understanding of how the Indian Ocean climate system may evolve under continued anthropogenic warming and enhance the reliability of future climate projections.

Petrographic and mineral chemistry constraints on the interplay between deformation and fluid-rock interaction in the Atlantis Massif OCC

Catriona McCleery[1]*, Andrew J. Parsons[2], Michelle Harris[2], Jessica Berry[2,3]

[1] *Department of Earth Sciences, University of Cambridge, Cambridge, UK.*

[2] *School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth UK.*

[3] *Plymouth Electron Microscopy Centre (University of Plymouth)*

**Presenting Author, cam256@cam.ac.uk*

Oceanic core complexes (OCCs) at slow- and ultraslow-spreading ridges exhume mantle and lower crustal rocks to the seafloor, and form ideal locations for analysing fluid-rock interactions during deformation. The Atlantis Massif OCC, located adjacent to the Mid-Atlantic ridge at 30ºN, was sampled by IODP Expedition 399. High recovery of drill core from Hole U1601C provides an extensive record of the complex structure and character of the lithospheric root of the OCC. This record allows us to investigate the processes responsible for the formation of OCCs, as we can use it to understand how the interplay between deformation and fluid-rock interaction evolves, and what this means for strain localisation.

Using optical and scanning electron microscopy, we characterised the deformation history of a set of mylonitised gabbros from high-strain intervals of Hole U1601C. We identified mineral assemblages indicative of three distinct stages of deformation and/or alteration, each represented by a different amphibole population. Quantitative EDS, deformation microstructures, and element-exchange geothermometry was used to constrain the temperatures of each stage. Stage 1 is represented by dynamically recrystallised pyroxene and interstitial Ti-rich calcic amphibole, and is indicative of ductile deformation at temperatures of > 900ºC. This assemblage was overprinted, as demonstrated by tremolite overgrowths on the interstitial amphiboles which are calculated to have formed at ~700ºC (stage 2), and a pervasive overprint of green/colourless amphibole (stage 3). These assemblages both have largely static microstructures, suggesting that distributed high intensity ductile deformation was restricted to relatively high temperatures. These results provide important constraints for unravelling the multistage history of deformation and fluid-rock interaction in the Atlantis Massif OCC, which we consider further in our presentation.

Sediment cycling on the Marion Plateau since the Miocene

Becky McGanity-Smith[1]*, Peter Clift[1,2], Benjamin Petrick[1]

[1] *UCL Earth Sciences, University College London, United Kingdom*

[2] *Institute of Marine and Environmental Sciences, University of Szczecin, Poland*

**Presenting Author, becky.mcganity-smith.23@ucl.ac.uk*

Since the Miocene, the Australian climate has undergone significant shifts driven by the northward drift of the continent, its collision with Asia, and the resulting changes in circulation patterns surrounding the Maritime Continent. The northern tropical region of Australia experiences a monsoon, which is a part of the Asian Monsoon. However, unlike the Asian Monsoon, which has been extensively studied, the Australian Monsoon, including the onset, is poorly understood. Understanding the monsoon dynamics in this region across different climate states will provide insight into how weather patterns may vary under anthropogenic climate change. Additionally, understanding chemical weathering dynamics and ocean circulation changes can provide insight into past climatic changes.

Due to extremely arid climatic conditions that have prevented the preservation of fluvial and lacustrine activity, there is very little evidence of paleoclimatic changes on the continent. Therefore, this study considers two marine cores, Ocean Drilling Project (ODP) Site 1195B on the Marion Plateau and ODP Site 820 from the Townsville Trough. Site 1195B will provide a record of ~21 Ma, and ODP Site 820 a shorter record of ~ 300 ka. Additionally, river sediment samples were collected in Queensland opposite both sites. This study aims to explore the relationship between climate and weathering over three different periods: the Neogene, the Mid-Late Pleistocene, and the modern day.

Preliminary results were obtained from XRF core scanning, spectral reflectance data, and GDGTs at ODP Site 1195B. Fe/Ca has been used as a proxy for clastic flux, showing the highest delivery of clastic material to the area during the Miocene Climatic Optimum (MCO), at the same time as our highest SSTs. This input of clastic sediment then declined until 10 Ma, with short periods of higher fluxes in the more recent geologic past. There is then a sharp drop in clay abundance after 9 Ma, possibly linked to the onset of the Eastern Australian Current system. Likewise, K/Al is also seen to drop sharply at this time, implying delivery of more weathered material. However, this may reflect a change in provenance also associated with the onset of the Eastern Australian Current. Finally, the GDGT data shows a drop in SST at the same time as the sedimentary changes. Around 6.5 Ma, increasing aridity in the region is indicated by the ratio of 565/435 (haematite/goethite) and a*, which serves as a red-green proxy. The two spectral proxies show great similarity and generally an increase in aridity. A relative low around 4 Ma is seen in the 565/435 and a* proxy may reflect a humid interval followed by a peak between 2 and 3 Ma, which is potentially reflective of the onset of the Australian Monsoon.

Elemental analysis has been carried out on ODP Sites 1195B and 820. For Site 1195B, this data will be used to validate the XRF core scanning and consider changes in sediment input to this site since the Miocene. Elemental analysis of Site 820B will be used to examine a shorter time scale, and, as it is closer to the coast than 1195B, it may provide a better indication of how sediment fluxes and weathering rates have changed within the Pleistocene.

Morphometrics of *Reticulofenestra* from Late Miocene to Pleistocene in the Pacific sector of the Southern Ocean

Oskar Mitrovic[1]*, Dr Mariem Saavedra-Pellitero[1], Dr Karl-Heinz Baumann[2], Dr Elisa Malinverno[3]

[1] *School of Environmental and Life Sciences, University of Portsmouth, United Kingdom*

[2] *Department of Geosciences, University of Bremen, Germany*

[3] *Department of Earth and Environmental Sciences, University of Milano-Bicocca, Italy*

**Presenting Author, oskarmitrovic97@gmail.com*

There is considerable interest in reconstructing changes in biodiversity over time as an indicator of evolutionary changes, particularly as these often show clear correlations with important trends in global climate change. Coccolithophores are a group of eukaryotic single-celled flagellate phytoplankton species that are abundant in today's oceans and belong to the phylum Haptophyta. They are known to have a significant influence on both oceanic biogeochemistry and the global carbon cycle and are also used extensively for palaeoclimatic reconstructions (Rost & Riebesell, 2004; Guitián *et al.,* 2022.) *Reticulofenestra* is a widespread and diagenetically resistant coccolithophore that is useful in biostratigraphic studies due to its size variations and resistance to diagenesis (Young, 1990; Hendericks and Pagani, 2008). This study uses samples collected from the Pacific Sector of the Southern Ocean (at IODP Site U1541) to investigate the relationship between the morphometrics of the coccolithophore *Reticulofenestra* in the Pacific Sector of the Southern Ocean and recorded environmental factors from the Late Miocene through to Early Pleistocene, such as benthic foraminiferal isotopes δ in SSTs. The aim of this study is to analyse the strength of correlation between the morphometrics of *Reticulofenestra* and changes in the global climate, in an attempt to establish this taxon as a practical environmental proxy.

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Imaging the magma storage region and hydrothermal system of an active arc volcano using the controlled-source electromagnetic method

Nienhaus, H.[1], Minshull. T.A.[1], Henstock, T.[1], de Ronde, C.E.J.[2] and Evans, R.[3]

[1] *University of Southampton, United Kingdom*

[2] *Earth Sciences New Zealand, New Zealand*

[3] *Woods Hall Oceanographic Institution, United States*

**Presenting Author, h.nienhaus@soton.ac.uk*

The Brothers volcano, located 400 km NE of New Zealand, has been the focus of many international studies over the past ~25 years, including IODP drilling up to a depth of ~450 m below seafloor and seismic and shallower drilling experiments in 2025. While surface processes and the shallow subsurface have been well investigated, information on the magma storage region and the hydrothermal system's deep flow pathways is missing. Hydrothermal circulation is an important driver for the chemical and thermal interaction between solid Earth and ocean, such as the formation of mineral deposits on the seafloor. Geophysical methods can be used to image the geometry of these pathways, the magma storage region, as well as mineral deposits, providing a deeper understanding of hydrothermal circulation. The controlled-source electromagnetic (CSEM) method is sensitive to electrical conductivity in the subsurface, and thus to the presence of highly conductive materials such as fluids, partial melts, and metals.

Our CSEM method employs a long electrical dipole transmitter, towed by a vessel to emit electromagnetic waves that induce electric currents in the Earth. Secondary electromagnetic fields are measured by receivers either at the ocean bottom or towed behind the transmitter to gather information about the conductivity distribution beneath the seafloor. During a cruise scheduled for February-March 2026, we aim to measure data at the same locations and along some of the same survey lines used in the recent seismic study. The CSEM technique is sensitive to conductive structures up to several km deep. We aim to determine the size and shape of the magma storage and fluid pathways at Brothers volcano, and by extension, to estimate the temperatures and melt fractions present, using high-resolution 3-D images of the electrical resistivity generated from the results of our experiment. Furthermore, we seek to demonstrate the capabilities of the CSEM method for investigating hydrothermal systems of other volcanoes.

Resolving Discrepancies in the Geomagnetic Polarity Timescale: Astrochronological Constraints on the C3An Reversals from IODP Sites U1385 and U1587

Niall J. Quinn[1]*, Chuang Xuan[1], Wout Krijgsman[2], Trevor Williams[3], Timothy D. Herbert[4], Yuxi Jin[1], Expedition 397 and 401 Scientists

[1] *School of Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, Waterfront Campus, European Way, Southampton, SO14 3ZH, UK*

[2] *Department of Earth Sciences, Utrecht University, Utrecht, HD 3584, The Netherlands*

[3]*College of Marine Science, University of South Florida, St. Petersburg, FL 33701, USA*

[4]*Department of Geological Sciences, Brown University, USA*

**Presenting Author, n.j.quinn@soton.ac.uk*

The geomagnetic polarity timescale (GPTS) represents a calibrated record of the ages of geomagnetic reversals through geolgoical time. An accurately constrained GPTS provides a fundamental chronostratigraphic framework for dating and correlating worldwide sedimentary and volcanic sequences. It is also essential for determining seafloor spreading rates and the timing of tectonic events which underpin our understanding of Earth's geodynamic evolution. Yet, persistent discrepancies remain for many reversals among successive versions of the GPTS. In particular, ages of reversals within the C3An Chron (~6-7 Ma, Late Miocene) differ by up to ~50 kyr between GPTS 2012 (Hilgen et al, 2012) and GPTS 2020 (Raffi et al, 2020). These discrepacies led to uncertainties in models of plate motion and using polarity stratigraphy as a global dating and correlation tool. Primary sources of reversal age discrepancies include inaccurate determination of the reversal horizons due to weak/noisy or low-resolution palaeomagnetic records, and/or uncertainties in dating the reversal horizons (Drury et al, 2017).

New sediment archives recovered during International Ocean Discovery Program (IODP) Expeditions 397 and 401 to the west Iberian Margin offer an exciting opportunity to recalibrate the C3An reversal ages and revise the GPTS. Palaeomagnetic and physical property analyses of the sediments show exceptionally well-preserved orbital cyclicity and strong and high-fidelity palaeomagnetic signals. A total of 254 and 199 palaeomagnetic cube samples were analysed to build robust polarity stratigraphies for Sites U1385 and U1587, respectively, covering the four C3An reversals. High-resolution astronomical age controls for sediments of the two sites were established by independently tuning orbitally paced Natural Gamma Radiation (NGR) and X-Ray Fluorescence (XRF) records from the two sites to solar insolation or mixed orbital solution curves. Calibrated ages of the four C3An reversals are highly consistent between results from Sites U1385 and U1587 (typically within ~2-10 kyr) but show significant (up to 64 kyr) discrepancies compared with ages from the GPTS 2020, which were primarily based on weakly magnetised sediments from an equatorial Pacific site. Our revised C3An reversal ages also eliminate the anomalous acceleration in plate spreading rates observed when applying GPTS 2020 ages, thereby reconciling a long-standing irregularity in tectonic reconstructions.

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Breaking New Ground: Technical Innovation and Operational Reliability in IODP³-NSF Expedition 501

Marisa Rydzy[1]*, Tayyaba Khurram[1]*, Brandon Dugan[2], Rebecca S. Robinson[2], Jeremy Everest[3], IODP³-NSF Expedition 501 Science Team[2] and the ECORD Science Operator

[1] ESO and University of Leicester, School of Geography, Geology and the Environment, University of Leicester, Leicester, LE1 7RH, UK

[2]Affiliations found at https://www.ecord.org/expedition501/

[3]British Geological Survey, Lyell Centre, Edinburgh,

**Presenting ESO Authors, mbr8@leicester.ac.uk and tk335@leicester.ac.uk*

IODP³–NSF Expedition 501, "New England Shelf Hydrogeology" (Dugan et al. 2025) marked a breakthrough in offshore groundwater research by successfully sampling freshened groundwater beneath the New England Shelf for the first time. During the 74 days aboard the lift boat Robert, an international team of 41 scientists recovered 718 sediment cores totalling 871.83 meters and conducted 9 pumping tests, extracting nearly 50,000 litres of water from depths up to 393 metres below the seafloor. The expedition findings will provide critical insights into the age, origin, and geochemical evolution of offshore aquifers, their microbial ecosystems, and their role in nutrient and carbon cycling, advancing our understanding of coastal water resources and paleoclimate history.

Expedition 501 used new technical approaches to overcome operational challenges exacerbated by sandy intervals, abrasive sands, artesian flow introducing suspended sand, and formation instability. The offshore phase of the mission-specific platform (MSP) expedition was, in many ways, one of firsts: 1) the first to be implemented under the new IODP³ program, 2) the first MSP to include downhole pumping tests and large-volume fluid sampling, 3) the first MSP to install a borehole observatory, 4) the first MSP to deploy a slim-line Nuclear Magnetic Resonance (NMR) logging tool, and 5) the first to use temporary polyvinyl chloride (PVC) casing for improved borehole stability during logging.

As with all expeditions the success of the offshore operations for Expedition 501, was driven by the close collaboration between the ECORD Science Operator (ESO), the drilling crew, and the Science Team in achieving the expedition's research objectives and vision. Additionally, new contributors, such as the hydrogeologists from the British Geological Survey, brought specialized expertise, while JAMSTEC and SODCO supplied valued personnel and equipment—upholding the longstanding ethos of international cooperation in ocean drilling.

The collaboration between the IODP³ operational and scientific teams, the adaptation of strategies, and the resulting acquisition of high-quality data and samples will advance global knowledge of offshore groundwater systems and has set a new benchmark for mission-specific drilling in dynamic coastal environments.

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The ECORD Science Operator (ESO) undertakes mission-specific platform (MSP) operations for ECORD on behalf of IODP³. ESO is a consortium involving British Geological Survey (lead), Marum, University of Bremen, and the European Petrophysics Consortium (University of Leicester with University of Montpellier).

Investigating the trigger mechanisms for OAE1d using boron isotopes

Gowtham Sekar[1]*, Markus Adloff[1], Brian T Huber[3], Rich Pancost[1], Fanny Monteiro[2], Michael J. Henehan[1],

[1] *School of Earth Sciences, University of Bristol, Bristol, UK*

[2] *School of Geographical Sciences, University of Bristol, Bristol, UK*

[3] *Department of Paleobiology, MRC-121, Smithsonian Institution, Washington DC, USA*

**Presenting Author, gowtham.sekar@bristol.ac.uk*

The need to understand Cretaceous Oceanic Anoxic Events (OAEs) and the driving mechanisms behind them has become increasingly important with the ongoing expansion of oxygen-minimum zones (OMZs). Increased nutrient delivery – particularly phosphorus (P) – due to volcanic CO_2 emissions has been postulated as a key trigger (Monteiro et al., 2012), with P regeneration from anoxic sediments sustaining them (Beil et al., 2020). Intriguingly, several Cretaceous OAEs are associated with a decline in either the abundance, diversity or absolute flux of pelagic marine calcifiers (Jones et al., 2023), which could decrease the efficiency of the biological pump via a reduction in $CaCO_3$ mineral ballast (Henehan et al., 2019). Conversely, elevated nutrient concentrations during the Cretaceous OAEs would increase the strength of the biological pump. As the strength and the efficiency of the biological pump control the intensity and position of the OMZ (Meyer et al., 2016), understanding their variation might provide better insights into the trigger mechanisms behind the OAEs.

Here, we present new boron isotope-derived via MC-ICP-MS analysis of planktic and benthic foraminifera across OAE 1d, a relatively poorly-studied event, whose cause remain ambiguous. Our new multispecies timeslices provide insights into surface pH and vertical water column pH gradients across OAE 1d, helping detangle changes in atmospheric CO_2 and biological pump efficiency across this enigmatic event.

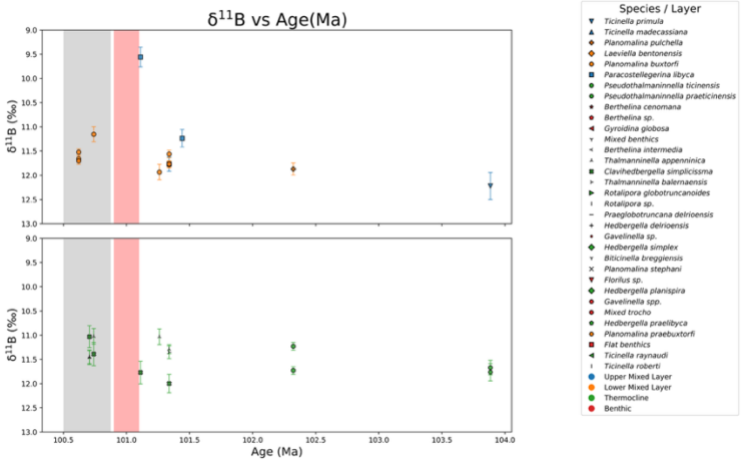

Fig 1: Variation in $\delta^{11}B$ of mixed-layer species (blue and orange) and thermocline species (green) across OAE1d. The red zone and the grey zone mark the no recovery zone and the main event (OAE1d), respectively.

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Chemical Weathering Response of Northern New Guinea to Orbital-Scale Climate Variability

Yifan Du[1], Peter D. Clift[1,2], Emaan Tungekar[1]*

[1] *Department of Earth Sciences, University College London, London, UK*

[2] *Department of Geology and Geophysics, Louisiana State University, Baton Rouge,USA*

**Presenting Author, ucfbetu@ucl.ac.uk*

Silicate weathering is recognised as a key long-term regulator of atmospheric CO_2. The chemical breakdown of silicate minerals removes CO_2 from the atmosphere, influencing Earth's climate over orbital to millennial timescales. While much attention has been focussed on continental-scale weathering in regions such as the Himalaya and Tibetan Plateau, the contribution of tropical, mafic-dominated islands has been less explored.

New Guinea is dominated by mafic arc-ophiolite complexes, which are highly susceptible to chemical weathering. Its role in modulating climate was investigated by reconstructing its provenance, weathering intensity and CO_2 consumption history over the last ~330 kyr. A total of 246 siltstone samples were analysed from marine cores recovered during the International Ocean Discovery Program (IODP) Expedition 363, Site U1485, located offshore the northern coast of Papua New Guinea, with sediment here largely delivered by the Sepik River (Du, Clift & Carter, 2025).

Analysis included grain size, major and trace element geochemistry, Nd and Sr isotope composition and clay mineralogy to characterise the provenance and chemical alteration. Age control was established based on nannofossil and foraminifera assemblages. Chemical weathering intensity and bedrock contributions were quantified using proxies such as the Chemical Index of Alteration (CIA), Chemical Index of Exchange (CIX) and smectite/kaolinite ratios. Rates of CO_2 consumption and organic carbon burial were also estimated to assess the effectiveness of weathering in modulating atmospheric CO_2.

Results indicate that CO_2 was consumed more rapidly during glacial periods, reflecting more seasonal chemical weathering targeted at mafic rocks. In contrast, interglacial periods were characterised by more extensive tropical weathering. Overall, New Guinea's weathering fluxes are respond strongly to orbital-driven climate variability, suggesting that tropical mafic islands can amplify global climate changes by modulating atmospheric CO_2 on glacial–interglacial timescales.

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Greenland Sea Surface Temperatures during the mid-Piacenzian Warm Period

Bridget Warren[1*], Emma Hanson[2], Marcelo de Lira Mota[2,3], Gemma Baker[2], James Bendle[2], Tom Dunkley Jones[2]

[1]*School of Environment, Earth and Ecosystem Sciences, The Open University*

[2]*School of Geography, Earth and Environmental Sciences, University of Birmingham*

[3]*Institute of Geosciences, University of São Paulo*

** Presenting Author, bridget.warren@open.ac.uk*

The mid-Piacenzian Warm Period (mPWP; 3.3-3.0 Ma) is a key interval for understanding the behaviour of the Earth's climate as it was the last time interval where atmospheric CO_2 was similar to modern levels. However, the mid-to-high latitude North Atlantic during the mPWP presents an enigma for the understanding of the Earth's sea surface temperatures (SST): modelled temperatures are consistently lower than proxy reconstructions, the majority of which use alkenones and the associated $U^{K'}_{37}$ index to reconstruct temperature.

In order to test whether $U^{K'}_{37}$ temperatures match an alternate temperature reconstruction within the same core, we produced sea surface temperature estimates for the mPWP from Site U1602, just south-east of Greenland, using the $U^{K'}_{37}$ and GDGT-based indices, derived from the relative abundances of alkenones and glycerol dialkyl glycerol tetraethers (GDGTs) respectively. Both GDGTs and alkenones reproduce the same relative trends in temperature throughout the interval, including a ~100 Kyr dip in temperatures immediately following the M2 glaciation. However, we find that the two proxies produce divergent temperature estimates: alkenone – based proxies suggest temperatures around 15 °C throughout the interval, whereas GDGT proxies suggest temperatures at least 10 °C colder than this. Furthermore, we show that GDGT-based temperature reconstructions depend heavily on the calibration method, with a 10 °C difference just between calibrations of the same GDGT distributions.

We suggest that the $U^{K'}_{37}$ temperatures are more likely to be accurate than GDGT-based proxies. Even the warmest GDGT-based estimates are significantly colder than the present, and a substantial difference in surface currents in the Nordic Seas compared to modern conditions would be necessary to explain this. Furthermore, we find no evidence for sea ice markers (IP_{25} and $\%C_{37:4}$ alkenone) that would independently corroborate very cold temperatures in the region. The lack of agreement between different GDGT SST calibrations further suggests that the region's GDGT producers are responding to temperature in ways that the current calibrations cannot account for, and that further work is needed to robustly apply GDGT-based SST proxies in this region of the sub-polar North Atlantic.

Reconstructing surface and deep ocean circulation changes in the Northwest Atlantic over the past 21,000 years

Yiming Zhang[1]*, Alice Carter-Champion[1,2], Jack H. Wharton[1], Philippa Goh[1]& David J.R. Thornalley[1,3]

[1] *Department of Geography, University College London, London, UK*

[2] *Centre for Quaternary Research, Department of Geography, School of Environmental and Life Sciences, Royal Holloway, University of London*

[3]*Woods Hole Oceanographic Institution, Woods Hole, MA, USA*

**Presenting Author, martina.zhang.23@ucl.ac.uk*

The Atlantic Meridional Overturning Circulation (AMOC) not only influences the distribution of ocean carbon and heat, but also interacts with variations in the Earth's system (Caesar et al., 2021). It carries warm, saline surface waters northward into the North Atlantic region, and returns cold, fresh deep waters southward (Buckley and Marshall, 2016), affecting Northwest Europe and further global climate dynamics. Modern AMOC variability is considered a major source of uncertainty in driving future global climate change (Pontes and Menviel, 2024), with both modelling-based and proxy-based studies arguing for an anomalously modern, weakened AMOC under the influence of anthropogenic impacts (Rahmstorf et al., 2015; Thornalley et al., 2018). The timing and driving mechanism behind this slowdown is currently debated, which indicates the significance of using multi-proxy methods in examining the past AMOC position to further understand the controls on AMOC strength and implications for weakening.

This study focuses on a depth transect of new sediment cores along Line W, in the Northwest Atlantic, where the surface is mainly bathed by the northward-travelling Gulf Stream together with other regional ocean currents, while the southward-flowing Deep Western Boundary Current dominates the intermediate and deep ocean. Due to the limited palaeo-investigations of both surface and deep ocean circulation variability and their linkages to broader AMOC changes at this site, this study aims to generate a multi-proxy paleoceanographic reconstruction of ocean circulation dynamics and regional environmental changes in the Cape Cod region over the last 21,000 years. This study presents new chronologies for three records by first combining radiocarbon dating and benthic foraminifera $\delta^{18}O$ signals, and then further transferring the nearby existing age model from Zhao et al. (2019) to create a robust and consistent regional chronology. By conducting planktic foraminifera assemblages, IRD and tephra counts, as well as sortable silt grain size analyses, we examine surface and deep ocean variability at Cape Cod over the last 21,000 years, with a particular focus on the Last deglacial and Holocene. This research will contribute to the understanding of local ocean circulation variations and provide evidence for future studies of AMOC weakening under human-driven climate change, supporting modern climate research and policy development.

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