CLIMATE & BIOTA of the EARLY PALEOGENE

CBEP 2011

5[th] - 8[th] June, Salzburg/Austria

5 – 8 June 2011
Salzburg
Austria

CONFERENCE PROGRAM AND ABSTRACTS

Edited by: Hans Egger

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is held under the auspices of

The Austrian Federal Minister for Science and Research	**Dr. Karlheinz Töchterle**
The Governor of the State of Salzburg	**Mag. Gabriele Burgstaller**
The Mayor of the City of Salzburg	**Dr. Heinz Schaden**

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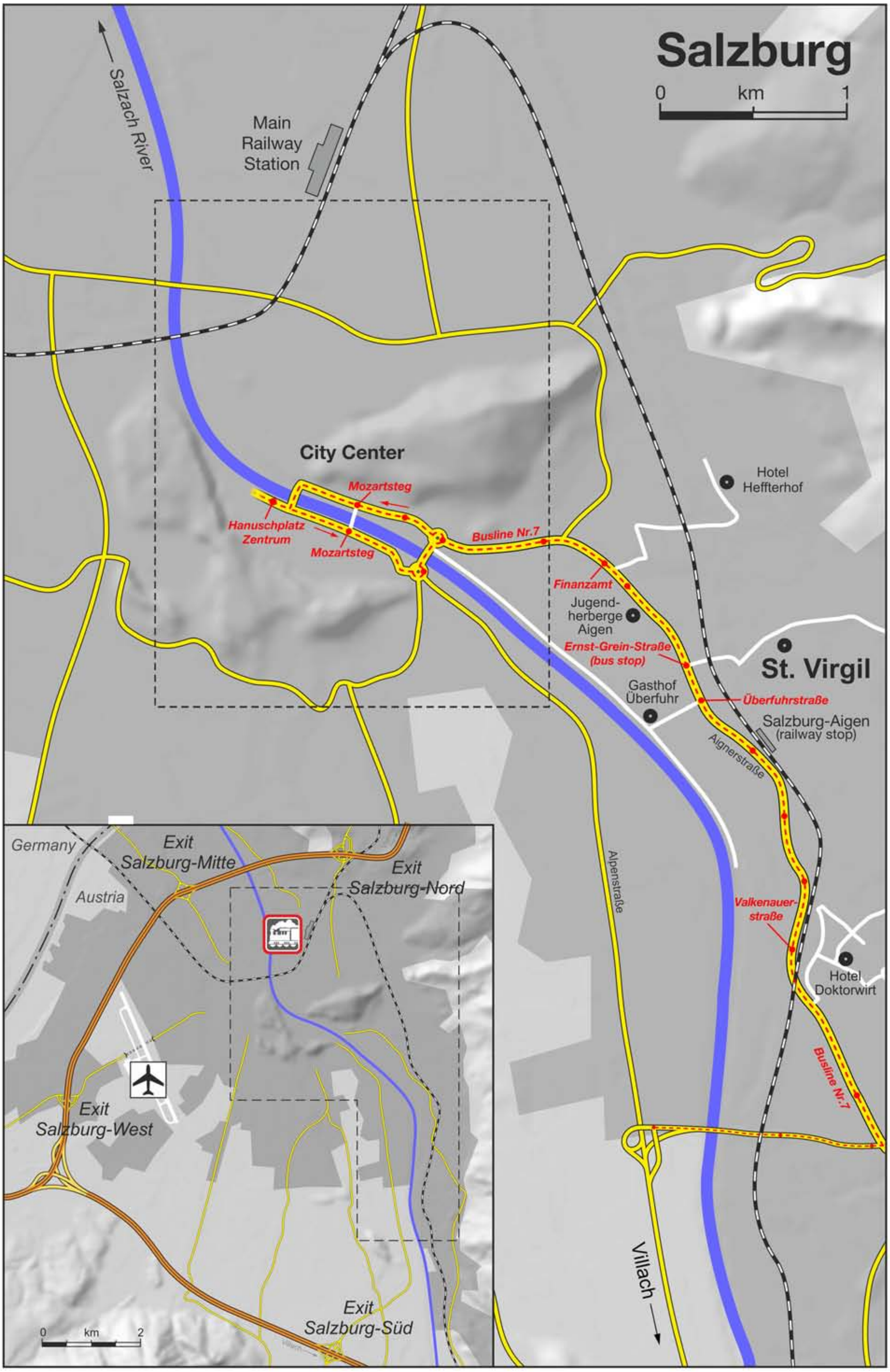

Salzburg
0 km 1
Salzach River
Main Railway Station
City Center
Mozartsteg
Hanuschplatz Zentrum
Mozartsteg
Busline Nr.7
Finanzamt
Jugend-herberge Aigen
Hotel Heffterhof
St. Virgil
Ernst-Grein-Straße (bus stop)
Gasthof Überfuhr
Überfuhrstraße
Salzburg-Aigen (railway stop)
Aignerstraße
Alpenstraße
Valkenauer-straße
Hotel Doktorwirt
Busline Nr.7
Villach
Germany
Austria
Exit Salzburg-Mitte
Exit Salzburg-Nord
Exit Salzburg-West
Exit Salzburg-Süd
0 km 2

The Salzburg city map will also be in your conference satchel.

GENERAL INFORMATION

CONTACT INFORMATION

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Email: Agnes.Spiessberger@sbg.ac.at

VENUE

St. Virgil Salzburg (Conference Centre and Hotel, Ernst-Grein-Strasse 14, 5026 Salzburg, Austria. Tel: +43/662/65901-0; Fax: +43/662/65901-509; Email: office@virgil.at; Webpage: www.virgil.at) is an international meeting place for seminars, conferences and congresses. The venue includes a restaurant for lunches and dinners. Located conveniently in the southern part of the city, it has good access by public transport and is also within walking distance (ca.40 min.) to the historical city centre.

REGISTRATION DESK

Registration will be possible before departure of the pre-conference field trips at St. Virgil. The registration desk will be open in the entrance hall of the conference centre on Saturday 4 June and Sunday 5 June (7.30 to 8.30 am). Sunday afternoon registration will be possible at St. Virgil between 3 pm and 5.30 pm. On Monday 6 June, the registration desk will be located at the entrance hall of St. Virgil from 7.30 am till 11.00 am. On Tuesday 7 June and Wednesday 8 June the registration desk will be open from 7.30 am to 8.30 am.

POSTERS

Posters can be placed on the boards from 3 pm on Sunday 5 June and from 7.30 am on Monday 6 June. All posters will be displayed for the duration of the conference and can be removed after the afternoon coffee break on Wednesday 8 June. Pins to attach the posters will be provided. Poster sessions are to be held on Monday, Tuesday and Wednesday. Coffee and tea will be served.

DOWNLOAD OF PRESENTATIONS

A PC laptop running Microsoft Windows 7 will be set-up near the registration desk on June 4 (7.30-8.30am) and June 5 (7.30-8.30 am; 3 pm-5.30 pm) to download presentations. On Monday and during the following days of the conference, the download area will be situated in the lecture hall from 7.30 am. Please assist the AV co-ordinator by reporting well in advance of your session with a copy of your presentation.

Presentations can be displayed using Microsoft Powerpoint (2007 or earlier versions) or as a PDF file using Adobe Acrobat Reader. When preparing and saving presentations please keep in mind that our computers run with Microsoft Windows 7. Apple (Mac) computer facilities will not be available. Due to format-compatibility please make sure that your Powerpoint-presentation uses standard fonts and colour-schemes. Prior to the conference, please let us know if you have any special requirements for your presentation. If you have a movie in your presentation, please check that it runs properly after downloading the presentation to the conference system.

LUNCHES

Buffet-style lunches with a selection of vegetarian and non-vegetarian food will be provided during the conference at the St. Virgil restaurant. The lunches are included in the conference fee. Drinking water will be on the tables; other drinks can be purchased from the restaurant. It will also be possible to have dinner (not included in the fees) at the St. Virgil restaurant but you must arrange this yourself each morning at the conference centre reception. The Gasthaus Überfuhr, beside the Salzach river (see map) is also a recommended restaurant near St. Virgil. This has a nice beer-garden but unfortunately is closed on Mondays.

FUNCTIONS

Ice-breaker party, 7.00-9.00 pm, Sunday 5 June

The Ice-Breaker party is an informal gathering that will be held in the premises of the "Haus der Natur" (Nature Museum and Competence Centre; www.hausdernatur.at; Museumsplatz 5, 5020 Salzburg) in the city center. During the Ice-Breaker, the participants will be able to make complimentary tours through part of the museum collection. To reach the "Haus der Natur" from St. Virgil, catch bus line 7 and get off at the "Hanuschplatz/Zentrum" stop, this is the first stop after crossing the bridge over the river Salzach. About 250 m ahead from the bus stop, take the first turn left to Museumsplatz. The museum entrance is on the right side of this square (see map).

Chamber Concert, 7.30-8.30 pm, Tuesday 7 June

The chamber concert, which will be held in the historical venues of the residence of the archbishop is an invitation by the state and town government of Salzburg. The "Residenz" building is located next to the cathedral. The entrance is at Residenzplatz.

INTERNET ACCESS

WLAN is provided in the entrance hall of St. Virgil.

SUPER MARKET

For buying food and drink, the closest supermarket to St. Virgil is "Billa" next to Salzburg-Aigen railway station. The supermarket is open between 8 am to 7 pm from Monday to Friday, and from 8 am to 6 pm on Saturday. It is closed on Sunday.

TRANSPORTATION

St. Virgil can be reached by public transport using **bus line 7**. Coming from the city take the bus in direction of Salzburg Süd and get off at the Ernst-Grein Strasse stop (see map). To go into the city take the bus towards Salzachsee at the Ernst-Grein Strasse stop. Tickets for the town busses can be purchased from the driver (€ 2.10 for a single ticket, valid for one hour in one direction even if you change bus) or as pre-paid tickets in newspaper shops (you have to buy at least 5 tickets, with each costing € 1.60). The closest newspaper vendor to St. Virgil is at Aigner Strasse, opposite the Überfuhrstrasse bus stop (see map).

If you arrive at Salzburg main railway station you can catch bus lines 3, 5 or 6 in front of the station building heading in direction city centre („Zentrum“). At the Mozartsteg stop change to bus line 7 to go towards Salzburg-Süd and get off at the Ernst-Grein Strasse stop.

Another way to reach St. Virgil using public transport is by train. For this, catch the suburban train line S3 in either Golling or Schwarzach-St.Veit. These trains depart from the Salzburg main railway station twice every hour (19 and 49 minutes after the full hour) and it takes 8 minutes to reach Salzburg-Aigen (the fourth stop after the main rail way station). Usually, there are 1 or 2 taxis waiting at this stop. St. Virgil is ca. 500 m from the Salzburg-Aigen station. It is not possible to buy tickets on the train; you have to buy them in advance at the ticket counter or from a ticket machines on the platform. A single ticket costs € 2,10.

Note that the main railway station at Salzburg is under construction at the moment. This causes long extra walks and unexpected staircases, which can be a problem with heavy luggage.
A taxi to St. Virgil will cost you approximately € 12 from Salzburg railway station and ca. € 18 from Salzburg airport. Taxi drivers in Austria expect a tip of about 10% of the fare (but this is not compulsory).
If you arrive at the airport in Munich, a convenient airport shuttle (one way fare ca. € 50) also takes passengers from Munich Airport to their accommodation at Salzburg. The shuttle has to be booked in advance (www.mietwagenservice.at).
Trains leave Munich main railway station for Salzburg every hour. The fare depends on the time of booking and the type of train. Slow trains (Regional-Express) need more than 2 hours for the trip, fast trains (Railjet, EC, IC) need about 1.5 hours. For the best option please ask at the ticket counter in Munich.
Time tables for train connections in Austria and neighbouring countries can be found in www.oebb.at.

CONTENTS

PREFACE

The warm early Paleogene was the most recent period in Earth history when large continental ice sheets were entirely absent. The period began with a regeneration of the fauna and flora after the catastrophic asteroid impact at the Cretaceous/Paleogene boundary (K/Pg: 66 Million years ago) and ended with the onset of global cooling during the middle Eocene (45 Million years ago). Superimposed on the generally warm climates during the early Paleogene, were multiple short-term extreme warming events (hyperthermals).

Most likely, the extreme paleoenvironmental changes in the early Paleogene were a response to high greenhouse gas concentrations. The atmospheric CO_2 concentrations predicted for the coming centuries have not been equaled since the early Paleogene. Thus an understanding of the impact of such greenhouse conditions on the global climate in the past is vital to identify and quantify present and future climate feedback-processes related to the current rising atmospheric carbon concentrations.

As in previous conferences of the working group on the early Paleogene (New Zealand 2009; Spain, 2006; Belgium 2003; Egypt, 2002; USA 2001; Sweden, 1999; France 1998; Spain, 1996), the overall goal of the Austrian meeting is to illustrate the current state of knowledge in understanding the causes and consequences of extreme climatic events in the greenhouse world of the early Paleogene. The conference draws together 168 participants from 27 countries and from most branches of Earth sciences, for the common purpose of utilizing the geological record of past global change as a model and predictor of future environmental changes in a warming world.

The organization of this conference would not have been possible without the help and contributions of many colleagues. I would like to express my gratitude to the members of the Organising and Scientific Committees; to the field trip leaders; to the staff of the Geological Survey of Austria, in particular to Monika Brüggemann-Ledolter, Elfriede Dörflinger and Sylvia Hable. I am indebted to Agnes Spiessberger, who did most of the organizing work at Salzburg and will take care of the registration desk, and, last but not least, to Markus Kogler, who did all the formatting work of the conference materials and will be responsible for the technical performance of the presentations during the conference.

The conference is supported by the State of Salzburg; by the municipal government of Salzburg; by the Geological Survey of Austria; by the Austrian Academy of Science; by the Commission for the Palaeontological and Stratigraphical Research of Austria; by the generosity of EOS-Elektronenoptik, Zeiss-Austria, Rohöl-Aufsuchungs GmbH and Adelholzener. All this support is gratefully acknowledged!

Hans Egger
Convenor of CBEP 2011

CONFERENCE PROGRAM

Sunday 5 June

19:00	***21:00***	***ICEBREAKER***

Monday 6 June

Start	End	Item	Chair	Speaker	Title
07:30	***08:30***	***REGISTRATION (coffee & tea)***			
08:30	***08:50***	***OPENING***			
08:50	09:10	General topics	Röhl	Westerhold Thomas	Age concern – testing the astronomical calibration of the early Paleogene and the K/Pg boundary
09:10	09:30			Dickens Gerald	A Recent Literature Cycle Mystery (And a Return to an Early Palaeogene World With a Large and Dynamic Organic Carbon Capacitor)
09:30	09:50			Schulte Peter	Black shales from the Latest Danian Event and the Paleocene-Eocene thermal maximum in central Egypt: Two of a kind?
09:50	10:10			Thomas Ellen	Life in the Deep-Sea during Eocene Hyperthermal Events
10:10	10:30			Hart Malcolm	The response of foraminifera to modern seawater acidification: A real-time proxy for Paleogene hypothermal events
10:30	***11:00***	***COFFEEBREAK***			
11:00	11:20	PETM	Schmitz	Penman Donald	Boron proxy evidence for surface ocean acidification & higher pCO_2 during the PETM
11:20	11:40			Hesse Reinhard	Appearance of gigantic biogenic magnetite during the PETM: A progress report
11:40	12:00			Khozyem Hassan	Climatic and environmental changes during the Paleocene-Eocene thermal maximum: Dababiya GSSP
12:00	12:20			Shcherbinina Ekaterina	High-resolution study of PETM record in the key section of NE Peri-Tethys
12:20	12:40			Dupuis Christian	Sea level changes in the Paleocene-Eocene interval in NW France Evidence of two major drops encompassing the PETM
12:40	13:00			Pujalte Victoriano	Sea-level changes across the PETM in the Pyrenees, part 1: evidence from coastal plain settings
13:00	***14:00***	***LUNCH***			
14:00	14:20	PETM	Speijer	Bornemann Andre	A complex history of the Paleocene–Eocene Thermal Maximum in the NE Atlantic
14:20	14:40			D´haenens Simon	Benthic foraminiferal assemblage fluctuations during early Eocene hyperthermals at DSDP Site 401, Bay of Biscay, North East Atlantic
14:40	15:00			Uchman Alfred	Ichnological record of macrobenthic community changes across the Paleocene-Eocene Thermal Maximum in the Zumaia section, northern Spain
15:00	15:20			Stassen Peter	Dissecting the PETM along the New Jersey Coastal Plain
15:20	15:40			Charles Adam	Dynamic oceanographic conditions in Arctic Spitsbergen during the Palaeocene-Eocene thermal maximum: new evidence from dinoflagellate cysts
15:40	***17:00***	***COFFEEBREAK, POSTERSESSION***			
17:00	17:20	PETM	Sluijs	Hollis Chris	An update on paleoclimate data-model comparisons for the Southwest Pacific
17:20	17:40			Krishnan Srinath	Hydrological Changes in the Southern Hemisphere during the Paleocene Eocene Thermal Maximum
17:40	18:00			Slotnick Benjamin	Large amplitude variations in carbon cycling and terrestrial weathering during the latest Paleocene and earliest Eocene
18:00	18:20			Gladenkov Yuri	New data on the upper Paleocene - lower Eocene stratigraphy of West Kamchatka region, the North Pacific

Tuesday 7 June

Start	End	Item	Chair	Speaker	Title
08:00	08:20	PETM	Gingerich	Quesnel Florence	Unravelling the PETM record in the “Sparnacian” of NW Europe: new data from Sinceny, Paris Basin, France
08:20	08:40			Hooker Jerry	Mammalian faunal change across the Paleocene-Eocene boundary in NW Europe: the roles of displacement, community evolution and ecology
08:40	09:00			Abels Hemmo	First high-resolution terrestrial record of Eocene Thermal Maximum 2 (ETM2 / H1) and H2 in the Bighorn Basin (USA)
09:00	09:20			Clyde William	Post-PETM Hyperthermals in the Bighorn Basin, WY
09:20	09:40			Foreman Brady	Characterization of Paleocene-Eocene Fluvial Deposition in the Piceance Creek Basin of western Colorado, USA
09:40	10:00			Baczynski Allison	Resolving discrepancies between bulk organic matter and *n*-alkane PETM carbon isotope records from the Bighorn Basin, Wyoming
10:00	***11:00***	***COFFEEBREAK, POSTERSESSION***			
11:00	11:20	Continental Ecosystems	Collinson	Jaramillo Carlos	PETM effects on Neotropical Vegetation
11:20	11:40			Feng Xinxin	Eocene fossil woods from South China and their paleoclimatic implication
11:40	12:00			Smith Thierry	Paleoenvironmental reconstruction of a lake deposit from the early Eocene Wutu coal mine, Shandong Province, East China
12:00	12:20			Archibald Bruce	Beta diversity, climate, and topography across an early Eocene landscape
12:20	12:40			Lenz Olaf	Lake Messel, a high resolution archive for early Middle Eocene climate variability
12:40	***13:40***	***LUNCH***			
13:40	14:00	Methods	Dickens	Sexton Philip	Deep ocean temperature response to astronomical forcing in the Eocene “greenhouse”
14:00	14:20			Vanhove Daan	Assessing the use of fish otolith stable O and C isotope geochemistry as a paleotemperature and seasonality proxy: results from the early Eocene climatic optimum (EECO) in Belgium
14:20	14:40			Grimes Steven	Coupling of marine and continental isotope records during the Eocene/Oligocene transition
14:40	15:00			Douglas Peter	Eocene sea surface temperature reconstructions from bivalve clumped isotope measurements
15:00	***16:00***	***COFFEEBREAK, POSTERSESSION***			
16:00	16:20	Polar regions	Hollis	Collinson Margaret	The Eocene Arctic Azolla phenomenon: species composition, temporal range and geographic extent.
16:20	16:40			Bijl Peter	Integrated stratigraphy of the Eocene Wilkes Land Margin, Antarctica; preliminary results from IODP Expedition 318: dinoflagellate cyst and TEX86 results
16:40	17:00			Contreras Lineth	Antarctic vegetation and climate dynamics during the Eocene: new data from the Wilkes Land margin
17:00	17:20			Houben Alexander	Oligocene environmental changes on the Wilkes Land margin in response to a developing East Antarctic ice sheet

19:30	***20:30***	***CHAMBER CONCERT***

Wednesday 8 June

Start	End	Item	Chair	Speaker	Title
08:00	08:20	K/Pg-boundary	Schulte	Gavrilov Yuri	Diagenetic nature of Ir-anomalies: an alternative of impact hypothesis?
08:20	08:40			Taylor Kyle	Reconstructing Post Cretaceous/Paleogene Boundary Climate and Ecology at Mid-Waipara River and Branch Stream, New Zealand
08:40	09:00			Alegret Laia	The Cretaceous/Paleogene (K/Pg) boundary impact event: no global collapse of export productivity
09:00	09:20			Birch Heather	carbon system Recovery and Planktonic foraminifera ecology after the end Cretaceous mass extinction
09:20	09:40			Mohamed Omar	A Model for Neritic and Bathyal Dinoflagellates around the K/Pg Boundary and their Paleoenvironmental Indicators in the eastern Alps
09:40	***10:40***	***COFFEEBREAK, POSTERSESSION***			
10:40	11:00	Marine Ecosystems	Aubry	Sessa Jocelyn	Climatic controls on Late Cretaceous through Paleogene ecosystems
11:00	11:20			Aubry Marie-Pierre	Abiotic forcing on the Paleogene evolution of the marine protists
11:20	11:40			Bown Paul	Plankton perturbations through the Eocene-Oligocene transition
11:40	12:00			Weinbaum-Hefetz M.	Diachronous turnover in calcareous nannofossils following the EECO in the Tethys; evidence from Avedat, southern Israel
12:00	12:20			Witkowski Jakub	Siliceous Plankton Response to the Southern Ocean Warming During the Late Middle Eocene: Results from ODP Site 748
12:20	12:40			Papazzoni Cesare	Playing with different rules: nummulite banks in a greenhouse world
12:40	***13:40***	***LUNCH***			
13:40	14:00	Stratigraphy	Thomas	Hilding-Kronforst Shari	Refining Middle Eocene Planktonic Biostratigraphy
14:00	14:20			Benyamovskiy Vladimir	Detailed planktonic foraminiferal zonation of Middle Eocene in Crimean-Caucasus Region of Northeastern Peritethys
14:20	14:40			Cotton Laura	Extinction of larger benthic foraminifera in the late middle Eocene and across the Eocene-Oligocene transition, Kilwa district, Tanzania
14:40	15:00			Less György	Bartonian–Priabonian larger foraminiferal events in the West Tethys
15:00	15:20			Öczan Ercan	First detailed analysis of early Bartonian orthophragmines from the northern margin of Africa (Damouss section, NE Tunisia) and their paleobiogeographic aspects in the Tethys
15:20	***15:40***	***COFFEEBREAK***			
15:40	16:00	Stratigraphy	Pujalte	Gingerich Philip	Projection stratigraphy of the upper Eocene Gehannam, Birket Qarun, and Qasr el-Sagha formations and their fossil whales at the Wadi Al Hitan World Heritage Site, western Fayum Province (Egypt)
16:00	16:20			King Christopher	Type section of the Thebes Formation (Lower Eocene, Egypt)
16:20	16:40			Dallanave Edoardo	Late Cretaceous–early Eocene magneto-biostratigraphy and rock-magnetism from the Belluno Basin (NE Italy)
16:40	***16:50***	***BREAK***			
16:50	***17:30***	***STUDENT AWARD PRESENTATION AND CLOSING CEREMONY***			

LIST OF ORALS AND POSTERS

ORAL SESSIONS (Presenter, if not first Author)

Author	Title	Time
Abels et al.	First high-resolution terrestrial record of Eocene Thermal Maximum 2 (ETM2 / H1) and H2 in the Bighorn Basin (USA)	Tu, 08:40
Alegret et al.	The Cretaceous/Paleogene (K/Pg) boundary impact event: no global collapse of export productivity	We, 08:40
Archibald et al.	Beta diversity, climate, and topography across an early Eocene landscape	Tu, 12:00
Aubry	Abiotic forcing on the Paleogene evolution of the marine protists	We, 11:00
Baczynski et al.	Resolving discrepancies between bulk organic matter and *n*-alkane PETM carbon isotope records from the Bighorn Basin, Wyoming	Tu, 09:40
Benyamovskiy	Detailed planktonic foraminiferal zonation of Middle Eocene in Crimean-Caucasus Region of Northeastern Peritethys	We, 14:00
Bijl et al.	Integrated stratigraphy of the Eocene Wilkes Land Margin, Antarctica; preliminary results from IODP Expedition 318: dinoflagellate cyst and TEX86 results	Tu, 16:20
Birch et al.	carbon system Recovery and Planktonic foraminifera ecology after the end Cretaceous mass extinction	We, 09:00
Bornemann et al.	A complex history of the Paleocene–Eocene Thermal Maximum in the NE Atlantic	Mo, 14:00
Bown et al.	Plankton perturbations through the Eocene-Oligocene transition	We, 11:20
Charles et al.	Dynamic oceanographic conditions in Arctic Spitsbergen during the Palaeocene-Eocene thermal maximum: new evidence from dinoflagellate cysts	Mo, 15:20
Clyde et al.	Post-PETM Hyperthermals in the Bighorn Basin, WY	Tu, 09:00
Collinson et al.	The Eocene Arctic Azolla phenomenon: species composition, temporal range and geographic extent.	Tu, 16:00
Contreras et al.	Antarctic vegetation and climate dynamics during the Eocene: new data from the Wilkes Land margin	Tu, 16:40
Cotton et al.	Extinction of larger benthic foraminifera in the late middle Eocene and across the Eocene-Oligocene transition, Kilwa district, Tanzania	We, 14:20
D´haenens et al.	Benthic foraminiferal assemblage fluctuations during early Eocene hyperthermals at DSDP Site 401, Bay of Biscay, North East Atlantic	Mo, 14:20
Dallanave et al.	Late Cretaceous–early Eocene magneto-biostratigraphy and rock-magnetism from the Belluno Basin (NE Italy)	We, 16:20
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Douglas et al.	Eocene sea surface temperature reconstructions from bivalve clumped isotope measurements	Tu, 14:40
Dupuis et al.	Sea level changes in the Paleocene-Eocene interval in NW France Evidence of two major drops encompassing the PETM	Mo, 12:20
Feng et al.	Eocene fossil woods from South China and their paleoclimatic implication	Tu, 11:20
Foreman et al.	Characterization of Paleocene-Eocene Fluvial Deposition in the Piceance Creek Basin of western Colorado, USA	Tu, 09:20
Gavrilov	Diagenetic nature of Ir-anomalies: an alternative of impact hypothesis?	We, 08:00
Gingerich et al.	Projection stratigraphy of the upper Eocene Gehannam, Birket Qarun, and Qasr el-Sagha formations and their fossil whales at the Wadi Al Hitan World Heritage Site, western Fayum Province (Egypt)	We, 15:40
Gladenkov Y.	New data on the upper Paleocene - lower Eocene stratigraphy of West Kamchatka region, the North Pacific	Mo, 18:00
Bugler, Grimes et al.	Coupling of marine and continental isotope records during the Eocene/Oligocene transition	Tu, 14:20
Hart et al.	The response of foraminifera to modern seawater acidification: A real-time proxy for Paleogene hypothermal events	Mo, 10:10
Schumann, Hesse et al.	Appearance of gigantic biogenic magnetite during the PETM: A progress report	Mo, 11:20
Hilding-Kronforst et al.	Vicissitudes of the Eocene: Radical Overturning of Middle Eocene Planktonic Biostratigraphy	We, 13:40
Hollis et al.	An update on paleoclimate data-model comparisons for the Southwest Pacific	Mo, 17:00
Hooker et al.	Mammalian faunal change across the Paleocene-Eocene boundary in NW Europe: the roles of displacement, community evolution and ecology	Tu, 08:20

Author	Title	Time
Houben et al.	Oligocene environmental changes on the Wilkes Land margin in response to a developing East Antarctic ice sheet	Tu, 17:00
Jaramillo	PETM effects on Neotropical Vegetation	Tu, 11:00
Khozyem et al.	Climatic and environmental changes during the Paleocene-Eocene thermal maximum: Dababiya GSSP	Mo, 11:40
King et al.	Type section of the Thebes Formation (Lower Eocene, Egypt)	We, 16:00
Krishnan et al.	Hydrological Changes in the Southern Hemisphere during the Paleocene Eocene Thermal Maximum	Mo, 17:20
Lenz et al.	Lake Messel, a high resolution archive for early Middle Eocene climate variability	Tu, 12:20
Less et al.	Bartonian–Priabonian larger foraminiferal events in the West Tethys	We, 14:40
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ORAL & POSTER ABSTRACTS

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A high-resolution terrestrial record of Eocene Thermal Maximum 2 (ETM2 / H1) and H2 in the Bighorn Basin (USA)

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Late Paleocene and early Eocene hyperthermal events are short-lived periods of rapid greenhouse warming related to massive increases in the concentration of atmospheric CO_2. Eocene Thermal Maximum 2 (ETM2; also known as the *Elmo* event or H1) is the second largest of these events (after the PETM) and followed after ~100 kyr by the smaller H2 event. ETM2 has only been documented in a few high-resolution marine successions and possibly one low-resolution terrestrial record. Thus the impact of ETM2 on continental climates and biotas remains largely unknown.

Recently, we located two successive negative carbon isotope excursions (CIEs) of ~3.75 and ~2.5 per mille in paleosol carbonate in the floodplain sedimentary record of the Bighorn Basin, Wyoming (USA). These are in the Upper Deer Creek section, in McCullough Peaks exposures of the lower Eocene Willwood Formation. The C24r/C24n magnetochron boundary is pinpointed above the base of the larger CIE in our preliminary paleomagnetic results (Fig. 1). This stratigraphic position and the pattern and magnitude of the events indicate that the CIEs are the ETM2/H1 and H2 events, respectively.

New finds of the mammalian genus *Bunophorus* in and slightly below the Upper Deer Creek section indicate that the Wa4-Wa5 biozone boundary occurs well below ETM2. The Wa4 mammals *Ectocion* and *Haplomylus* have not been found in large samples from and slightly below the section. If rapid faunal turnover at the Wa4-Wa5 boundary (‘biohorizon B’) involved extinction of *Ectocion* and *Haplomylus* and the first appearance of *Bunophorus*, as commonly assumed, then faunal turnover at biohorizon B cannot be explained by greenhouse warming at the ETM2 hyperthermal event.

Our new terrestrial carbon isotope record of ETM2/H1 and H2 reveals a very similar pattern to records recovered from marine successions. Preliminary cyclostratigraphic analysis corroborates a short eccentricity trigger behind both hyperthermal events, with additional precession-pacing of background climate variability. The magnitudes of the ongoing CIEs are similar to those found in a terrestrially-influenced record from the Arctic basin and to a low-resolution excursion found in western India that has been tentatively linked to ETM2.

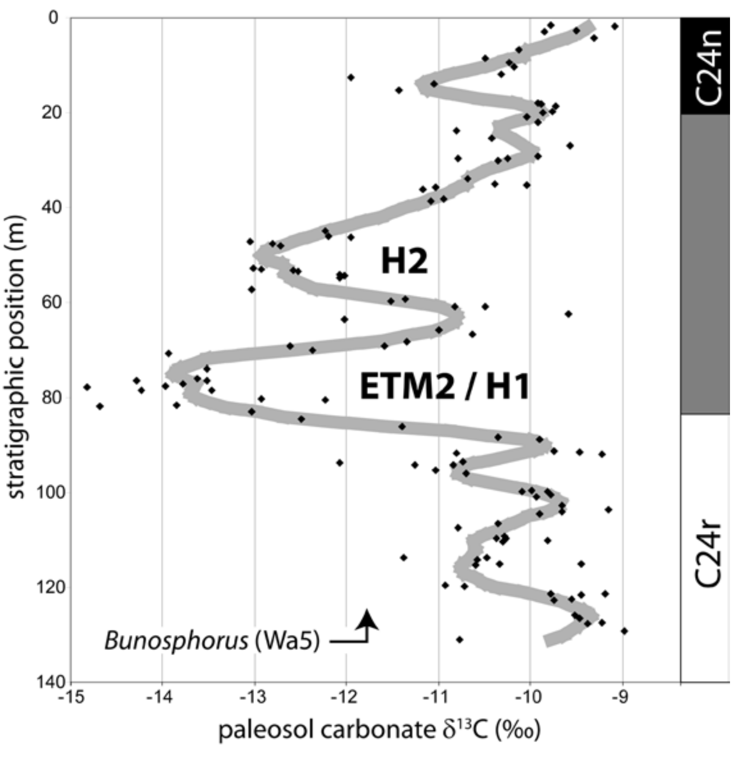

Figure: Paleosol-carbonate carbon isotope results from the Upper Deer Creek section in the Bighorn Basin, Wyoming (USA). Lowest finds of the mammalian genus *Bunophorus* in the section are indicated. To the right, the interpreted polarity from preliminary magnetostratigraphic results is shown. The two carbon isotope excursions are linked to the ETM2 / H1 and H2 hyperthermal events. Stratigraphic position (depth) is measured down from the top of the section.

The Cretaceous-Tertiary transition at Gams, Austria: a multiproxies approach

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The Cretaceous-Tertiary (K-T) transition in eastern Austria (Gams, Styria) was analyzed in terms of lithology, mineralogy (bulk and clay minerals), stable isotopes, major and traces elements and biostratigraphy (planktic foraminifera). The Gamsbach section is part of the Nierental Formation and comprises a 6.4 m thick deep-water sequence composed of marlstones, marly limestones interbedded with sandy to silty turbidites, which become more frequent above the KTB. Age control is based on a high-resolution planktic foraminiferal biozonation of which permits evaluation of the continuity of the sedimentary record across the KTB transition based on the presence of relatively short interval zones and subzones. Presence of P. hantkeninoides in the 1.75 m below the KTB at Gamsbach indicates sediment deposition occurred in zone CF1, or during the last 150 ky of the Maastrichtian. Just below the KTB, an irregular wavy surface at the top of the marly limestone marks an unconformity, which is strongly bioturbated (Chondrites-type burrows) coincident with a 2.5 permil drop in $\delta^{13}C$ values and low calcite content (< 2%). Most Maastrichtian species abruptly disappear at this level, except for survivor species that continue into the early Danian and a few reworked specimens. Above this surface, 0.2 to 0.4 cm of yellowish rusty clay marks the basal Danian overlain by 2 – 3 cm thick gray claystones both enriched in Ir, Co, Cr, Sc, Zn, Pb and Ni indicating an extraterrestrial source. Ten Danian species abruptly appear at that level, including P. longiapertura and P. eugubina the index species for zone P1a and abundant Eoglobigerina edita . The high species diversity and presence of Parasubbotina pseudobulloides 3 cm above marks subzone P1a(2). This indicates that zone P0 and subzone P1a(1) are mainly missing at this hiatus. Erosion of the top part of zone CF1 below the unconformity is also likely. Reworked Cretaceous species in Danian sediments are frequent in particular intervals and reflect downslope transport of eroded older sediments in upslope or shelf areas probably during times of intensified ocean circulation Two hiatuses can be therefore identified in the Gamsbach section: 1) at the KTB where the basal Danian zone P0 and subzone P1a(1) are mainly missing above an undulating erosion surface of Upper Maastrichtian marly limestone, and 2) in the lower Danian where most of zone P1b is missing. Bulk and clay minerals indicate reduced detrital input in the Upper Maastrichtian becoming more significant during the lower Danian reflecting increased turbidite activity linked to growing Austro-Alpine tectonic subsidence and erosion. Weathering Index of Parker (WIP) that shows higher values in the Lower Danian confirms this change in detrital inputs.

Absolute abundance, volume calculation and carbonate mass estimation of early Paleogene calcareous nannofossils

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Due to their large numbers, calcareous nannoplankton can be considered among the most important primary producers at the base of the marine food-chain. They are profoundly involved in the carbon cycle of the marine ecosystem, because they produce organic carbon and carbonate. They constitute a great part of the pelagic sediments produced for the last about 230 million years and thus can be used as a precious tool for palaeoecological and biogeochemical interpretations. During the past decades, volume calculation of extant calcareous nannoplankton has been performed in order to convert coccolith fluxes data into carbonate export productivity. Here, we present volume estimates of most abundant Paleocene calcareous nannofossil that are used to quantitatively evaluate the contribution of calcareous nannoplankton mass to the total carbonate production. Data come from several DSDP/ODP Sites located at different latitudes both in the Atlantic (DSDP 401 and ODP 690, 1051, 1260, 1263 Sites) and Pacific (ODP Site 1209). These results were applied to a specific case history in order to investigate the absolute abundance of coccolith, the coccolith carbonate mass per species and the total calcareous nannofossil contribution to carbonate production. For our exercise we have chosen one of the most prominent global warming episode occurred approximately 55.8 million years ago: the Paleocene Eocene Thermal Maximum (PETM). A dramatic decrease both in the number of specimens/mm^2 and in the carbonate production starts well before the onset of $\delta^{13}C$ negative shift and lasted for at least 100 Kyr, suggesting a gradual modification of pre-event conditions and a very perturbed paleoenviroment during the main phase of the event.

E/O biospheric crisis transition “warm” to “cold” biosphere of central part of extratropical Eurasia (stratigraphy, palaeogeography and palaeoclimatology)

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Biotic and abiotic events in the Middle Eocene and Oligocene (45 – 25 Ma) were studied for the period of transition from “warm” to “cold” biosphere in central Asia. The reference point was the beginning of elimination of direct marine communications between the Peri-Tethys and the Arctic Basin accompanied by reduction of silica deposition. The Late Oligocene stabilization of superregion, when the Turgayan mesophyllic flora had been set up, was regarded as termination of the transition period. The Late Eocene stage of “warm” biosphere was studied in reference sections of South Siberia, where paleontological research was conducted jointly with geochemical studies. The transitional stage was investigated in the Chelkar-Nury (Turgai) sections, where the Upper Eocene Chegan Formation gives way to Lower Oligocene sequence of avandelta sand of Urkimbai Formation and clay of the Chelkar-Nury Formation containing *Indricotherium*, was in the section of Borehole no. 8 south of Omsk-city. A special emphasis was laid on investigating *Azolla* beds, which developed in a semi-close marine basin with the estuary-type of sea water circulation, with a low level of the World Ocean. At that period the arrival of sea water from the Peri-Tethys was limited and inlet of fresh water prevailed. Along with water column differentiation, a freshened water stratum and anoxia of bottom water developed, being accompanied by appearance of suppressed benthos. At the period of the Late Tavdian transgression, the sea connection between the West-Siberian basin and the Peri-Tethys was restored, and the inner basin became saline again. The xerophilous palynological assemblage is located in the lower part of *Azolla* beds and in underlying Lower Tavdian Bartonian clays. Their age coincides with that of the xerophilous assemblage of microfossils situated at the northern coast of the Peri-Tethys; it extends from the South Urals towards the Pavlodar area (Irtysh River). Northward expansion of the arid zone in the Central Asia (up to Southern Siberia) coincided in time with the transformation of the West Siberian inland sea into a semi-closed basin. Simultaneously, a climatic belt of small-leaved flora developed in middle latitudes. It extended from Central Europe through Ukraine, Urals, and the southern part of the West Siberian plate into East Kazakhstan. The main rearrangement of marine biota in Central Asia at the Eocene-Oligocene boundary is described in a number of papers (Popov, Akhmetiev, et al., 2009; Akhmetiev et al., 2010). To submit the climatic curve for the Early Oligocene, in some parts of which xerophytes are alternated with hydrophytes, several sections were studied in North Ustyurt, north Aral, and Turgai districts in terminal sequences of the Chegan Formation (Priabonian) up to the roof of the Solyonovsky horizon (Late Rupelian). In the Early Oligocene, the humid and arid phases developed the general cooling tendency. That was confirmed by rhythmic alternation of palynospectra, dominated by the pollen of plants, which have different humidity characteristics: *Pinus*, xeromorfous *Quercus, Ephedra*, Chenopodiaceae, and others (xerothermal phase), Taxodiaceae, Mesophytic, and hydrophytic ferns, reduction of herbaceous pollen (humid phase). Five inversions of humid characteristics occurred during the Early Oligocene. Two sea ingressions were recorded from the Turanian basin to West Siberia through the Turgai Strait.

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Open and semi-closed Paleogene marine systems in northeastern Peri-Tethys: stable and transitional biostratigraphic, paleogeographic and paleoclimatological aspects

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Paleogene geological events, which occurred in middle latitudes of central Eurasia, have defined all natural conditions in extratropical Eurasia, except its Pacific margin. Three phases are distinguished in the development of the region in the Paleocene and Eocene: a) development of direct (through) meridional communications between Arctic and the Tethys (Paleocene-Early Eocene); b) their intermittent interruption, up to their complete termination (Lutetian); c) separation of the West Siberian marine basin from Arctic, maintaining connection only with Peri-Tethys (Bartonian-Priabonian). The climate of each stage was transformed correspondingly from paratropical (Paleocene-Early Eocene), through summer-wet monsoonal, subtropical (Latest Early Eocene-Lutetian) to the seasonal winterwet with semi-arid features, and, finally, to warm-temperate, up to subtropical with concurrent alternation of humid and arid phases (Priabonian).
The Early Paleogene phase was characterized by uniform composition of sediments in sedimentary basins, which were interconnected and occurred on both sides of the Alpian-Himalayan belt. While studying the Early Paleogene stage, the model of the palinspastic reconstruction (Scotese, 1998), was used. It was modified by Jan a. Harrison, (2003) for the International Tectonic Map, prepared under the head of International Union of Geological Sciences (http//jan.ucc.nau.edu/~rcb7/eocenasia.jpg). This model substantiates the independence of the north branch of the trade wind flow, which connects the Tethys with marginal basins of Peri-Tethys, extending further to the West Siberian basin. This branch is one of the sources that bring warmth to high latitudes.
Lockhartia Katinia, Rotalia, Rhanikotalia, Miscellania and other large foraminifera, typical of Pakistan and India, were found in the Shikergin Formation of the Peter the Great Ridge (Tadzhikistan). *Lockhartia luppovii* (Bugrova, 1980) was identified in southern Turkmenistan (Badkhyz, Kushka) and Uzbekistan.
Numerous dinocysts taxa have been identified in Upper Paleocene and Lower Eocene sections of the Tethys in India and Pakistan (Patala, Nammal, and Subathu sections of the Salt Range, Jammu and Kashmir, and other states), on the one hand, and in West Siberian and Turanian sections, on the other. Another sequence includes *Apectodinium augustum* (RETM episode).
The next phase in the West Siberian basin is characterized by recurrent loss and restoration of direct marine communications between Arctica and marginal basins of the Peri-Tethys. The phase ended in the ultimate loss of the connections in Late Lyulin time (Late Lutetian). The West Siberian basin became semi-close with circular water motion of an estuary type, open to the south to Pery-Tethys. Marine biota was reorganized being accompanied by the appearance of endemic dinocysts in the West Siberian basin (*Kisselovia ornata, Thalassiphora elongata, Wetzeliella irtyshensis* a. oth.). Xerophillous flora with *Arthotaxis,* xeromorphic *Quercus, Palibinia,* Myrtaceae and others were abundant along the entire coast of Northern Peritethys, from the Voronezh anteclise to Pavlodar area (Irtysh River). Pollen assemblages were dominated by xerophytes. The formation of *Azolla* beds started when the Arctic basin got completely isolated from the West Siberian inner sea (Tavda time, Late Bartonian). This occurred in periods of maximum lowering of the Ocean level, when the inflow of fresh water into the inner basin prevailed over supply of sea water from Peri-Tethys. This was accompanied by water column differentiation, desalination of surface water and bottom disoxia involving an assemblage of suppressed benthic foraminifera. Since the rise of sea level in the latest Late Eocene, the inlet of salty water from Peri-Tethys increased and the West Siberian basin became wholly salty. This was confirmed by rich plankton and benthic foraminifers in the Tavda Formation terminal strata.

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The Cretaceous/Paleogene (K/Pg) boundary impact event: no global collapse of export productivity

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The K/Pg impact event caused mass extinction of oceanic calcifying plankton, probably at least in part due to darkness. The extinction of calcifying photosynthesizers (calcareous nannoplankton) has been seen as indicative of a collapse of all oceanic primary productivity ('Strangelove Ocean' model), or of vertical transport of organic matter (i.e., the biological pump, 'Living Ocean' model), as reflected in the collapse of vertical carbon isotope gradients. Evidence from organic biomarkers, however, indicates a rapid recovery of primary productivity, and non-calcifying phytoplankton did not suffer extreme extinction. Populations of benthic foraminifera are strongly coupled to surface productivity in the modern oceans, but did not suffer significant extinction. There is thus considerable evidence that the K/Pg extinction did not result in global collapse of export productivity on time scales of 10^5 years.
In order to assess the evolution of export production across the K/Pg boundary, we analyzed stable isotopes and benthic foraminifera in the same samples from ODP and DSDP sites in the Pacific, SE Atlantic and Southern Oceans.

Benthic foraminiferal accumulation rates and species relative abundances indicate that directly after the impact organic matter export declined but persisted in the SE Atlantic and Southern Oceans, and temporarily increased in the Pacific, although the carbon isotope gradient in these same samples collapsed. A rapid recovery of marine productivity in terms of biomass is thus compatible with benthic foraminiferal proxies for export production, the lack of significant extinctions among benthic foraminifera, and evidence from organic biomarkers. We argue that the collapse of vertical $\delta^{13}C$ gradients should not be interpreted as reflecting collapse of global export productivity: the extinction of calcifying phytoplankton may have been, at least in part, caused by surface ocean acidification resulting from the impact, and is not indicative of overall phytoplankton extinction. The carbon isotope records may have been severely affected by the mass extinction of the surface-dwelling carriers of the isotope signal (nannoplankton and planktic foraminifers), the increased abundance of isotopically light calcareous dinocysts, and changes in relative strength of the biological and solubility pumps in the oceans. The recovery of oceanic productivity in terms of biomass thus may have occurred on the same time scale as terrestrial productivity.

Searching for Paleogene hyperthermals in the Betic External Zones, south Spain: preliminary results and perspectives

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The Betic External Zones constitute the westernmost segment of the Tethys Seaway northern margin, transformed into a thrust-and-fold belt during the Miocene. Two main domains, the Prebetic and Subbetic Zones, are classically recognized (Fig. 1), both containing extensive outcrops of Paleogene marine deposits (Vera, 2000, Revista de la Sociedad Geológica de España, 13, 345-373). Yet, to our knowledge, the PETM has been conclusively recognized only in two sections of the Subbetic Zone (Alamedilla and Caravaca, Fig. 1), and none of the remainder Paleogene hyperthermals have been reported so far. A research plan was consequently designed to improve this situation, in the assumption that a more extensive regional database would allow a better understanding of the effects of these thermal events. This contribution summarizes the current results of our research.

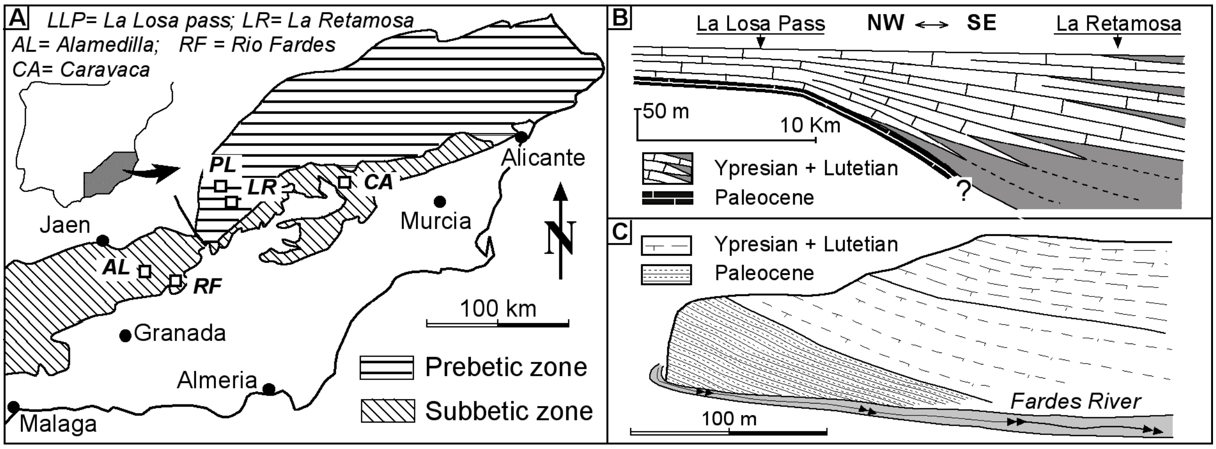

Figure 1 A): Location of the Prebetic and Subbetic zones and reference sections; **B)** Cross-section showing facies and thickness changes in the Prebetic zone; **C)** Sketch of the Fardes River section

Of several sections examined, four were selected for further study: La Losa Pass and La Retamosa in the Prebetic Zone, Alamedilla and Rio Fardes in the Subbetic Zone (Fig. 1). The former two are made up of carbonate ramp deposits (Fig. 1B), while Alamedilla and Rio Fardes contain deep marine hemipelagic and turbiditic deposits, thus representing a wide range of settings. The Paleocene is ca. 50 m thick in the Rio Fardes section, but is mostly made of calciturbidites, and due to a combination of low sedimentation rate and hiatuses, less than 20 m thick in the La Losa Pass and Alamedilla sections. The chances of finding Paleocene hyperthermals in these sections are therefore quite low. However, sedimentation rates increased in all sections during Ypresian and Lutetian times, and so do the possibilities of locating Eocene hyperthermals. Indeed, as mentioned above, the PETM was located long ago at Alamedilla and we have constrained its occurrence to a narrow interval at La Losa Pass. The planktic and benthic foraminiferal content of the Ypresian-Lutetian segment of La Retamosa, Alamedilla and Rio Fardes sections is currently being investigated, to establish their depth range and to pinpoint the position of the rest of the Eocene hyperthermals.

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Beta diversity, climate, and topography across an early Eocene landscape

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The Early Eocene Okanagan Highlands fossil sites of far-western North America present a unique opportunity to examine the effect of climate on diversity. Although it spans the height and decline of the Early Eocene Climatic Optimum – the warmest time of the Cenozoic – this was an upland of cool mean annual temperature (MAT) values, as in the modern temperate zone; however, multiple biotic indicators suggest that climate was equable (low temperature seasonality), as in the modern tropics, a combination of factors contrary to the usual pattern in the modern world. Here, we examine insect beta diversity across this region. Just over four decades ago, Janzen hypothesized a relationship in the modern world between dispersal, topography, climate, and latitude. He proposed that while warm valleys and cool mountain passes in seasonal temperate regions have a temperature overlap at least part of the year allowing dispersal of organisms adapted to valley climates, the same elevation difference in the equable tropics shares no common temperatures, and so constitutes a physiological dispersal barrier resulting in higher overturn of species across the landscape, i.e., increased beta diversity. Montane regions in the globally less seasonal Eocene should then show such high beta diversity even in higher latitudes, which we test in six localities representing a thousand kilometer transect of the early Eocene Okanagan Highlands of southern British Columbia, Canada and northern Washington, USA. Here, we present our analyses of insect beta diversity among these communities in a variety of taxa that includes herbivores, active predators, parasitoids, fungivores, and detritivores. We find that beta diversity was indeed high. This supports the idea that overall global diversity was elevated in the Eocene relative to the modern world, as suggested by a recent study of mid-latitude Eocene alpha diversity.

Intercontinental dispersal of giant thermophilic ants across the Arctic during early Eocene hyperthermals

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Early Eocene land bridges allowed numerous plant and animal species to cross between Europe and North America via the Arctic. While many that were suited to prevailing cool Arctic climates would have been able to cross throughout much of this period, others would have found dispersal opportunities only during limited intervals when their requirements for higher temperatures were met. Here we present a new giant (> 5cm long) formiciine ant from the early Eocene (~49.5 Ma) Green River Formation of Wyoming, USA. We show that the extinct ant subfamily Formiciinae is only known from localities with estimated mean annual temperature of about 20°C or greater, consistent with the tropical ranges of almost all of the largest living ant species. This is the first known formiciine of gigantic size in the Western Hemisphere and the first reported case of cross-Arctic dispersal by a thermophilic insect group. This implies dispersal across the Arctic during brief high temperature episodes (hyperthermals), representing brief, episodic openings of a climate-controlled physiological gate during the interval between the late Paleocene establishment of intercontinental land bridge connections and the presence of giant formiciines in Europe and North America by the early middle Eocene.

Cenozoic climates and the evolution of green lacewings (Neuroptera: Chrysopidae)

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Green lacewings are familiar insects today, well known by gardeners for controlling aphids and other plant pests. The great majority of its 1200 species belong to the subfamily Chrysopinae, which appeared in the late Eocene; the relictual subfamily Nothochrysinae, however, dominated the family in the early Paleogene. This turnover in subfamily dominance in these nocturnal insects may be explained in part by the Eocene appearance of bats and the evolution of auditory organs in the Chrysopinae that detect bat echolocation sounds, lacking in the Nothochrysinae. We find that climate, however, may also have been a major factor. We examined the climates of their modern and Eocene habitats, which suggest that the Nothochrysinae now occupies a conservative climate type resembling that of those Eocene regions where their fossils have been recovered, but Chrysopinae appears to have been able to expand and flourish in a wide variety of more modern climate types across much the globe since the Eocene, from the hot tropics to cold regions above the Arctic tree line.

Abiotic forcing on the Paleogene evolution of the marine protists

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The coccolithophores (calcareous nannoplankton) are marine unicellular protists, which secrete a complex, piece meal exoskeleton surrounding the cell. They are characterized by a complex life cycle in which the haploid and diploid stages represent distinct life strategies, including motile/non-motile capabilities and the production of utterly different coccoliths. The biology and ecology of the living coccolithophores remain poorly known, and the biological/physiological and/or ecological role of the coccoliths has not been resolved, which hampers a comprehensive interpretation of evolutionary dynamics of the group as a whole, and of its discrete lineages. A careful analysis of the structure of coccoliths in some living species has led to the hypothesis that coccoliths may be useful for collecting nutrients and preys, including bacteria and species of the eukaryotic picoplankton.

The role of coccoliths is even more difficult to determine in extinct species for which the coccosphere itself is rarely known. However, temporal analysis of the changes in shape in morphologically convergent lineages allows determination of significant physiological and ecological novelties in these lineages. For instance, it is possible to determine that high productivity associated with the earliest Oligocene ice-build up resulted in the appearance of lineages characterized by flagellate cells bearing hydro-dynamically shaped coccoliths, arising from ancestral lineages of non motile taxa. This strongly indicates the introduction or enhancement of mixotrophic physiology in these lineages. Morphostructural analysis strongly suggests that among the several roles that coccoliths may play, adaptation to food collecting/active hunting may be prominent. In any case, strong morphological convergence implies major forcing on evolution.

Ecological models are based on the categorization of the coccolithophores as primary producers. On the other hand, the planktonic foraminifera, another prominent group of oceanic calcifiers, are classified as low-level consumers. Yet, inferences from structural and isotopic analysis of tests indicate that the physiology has changed during the Paleocene, from carnivory in all Danian taxa to mixotrophy in the shallow dwelling Thanetian taxa. Capable of harboring photosymbionts, the planktonic foraminifera behave as primary producers, at least temporally, whereas adapted to mixotrophy the coccolithophores behave as low-level consumers. Determination of the forcing agent on the evolutionary dynamics in these two groups must take into account their physiological requirements.

Paleocene evolution of the Order Discoasterales (Coccolithophore): biostratigraphic and paleoceanographic implications

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We have investigated the nannofossil- and stable isotope (δ^{13}Corg, δ^{13}Ccarb, δ^{18}Obulk) stratigraphy of the Qreiya section (Eastern Desert, Egypt) across the Danian-Selandian (Middle Paleocene) interval. The 20 m thick section consists for the most part of homogeneous grey mudstones, and spans upper Zone NP4 and lowermost Zone NP5. A 31 cm thick interval of claystone and organic-rich shale constitutes a typical succession that can be traced regionally and is known as the Neo-Duwi Event. We document the appearance ~2 m below the base of the the Neo Duwi record of the hitherto undescribed calcareous nannplankton genus *Diantholitha* Aubry and Rodriguez, and its diversification (3 species) in a 3 m interval. This taxon, clearly related to the first true Cenozoic genus *Biantholithus*, illuminates the evolution of the Paleocene genera of the Order Discoasterales Hay emend Aubry, and leads us to reconsider the taxonomy of the fasciculiths, which we interpret as representing three evolutionary events, each originating from *Biantholithus*. These are the rise of *Gomphiolithus* Aubry and Rodriguez(e.g., *G. magnus*), *Lithoptychius* Aubry and Rodriguez (e.g., *L. ulii*) and *Fasciculithus* emended Aubry and Rodriguez (e.g., *F. tympaniformis*). These events, which occur, respectively, ~3 m below, 2 m below and 9 m above it, are not related to the Neo-Duwi event. The latter is marked by pronounced positive (~2‰) excursions of the δ^{13}C of bulk organic matter and δ^{13}C of the bulk carbonates. The former is indicative of high productivity, the latter of reservoir effect as a result of high productivity. Poor preservation (dissolution) and low abundance of coccoliths in this interval hampers satisfactory documentation of the remarkable radiation of *Lithoptychius* (often referred to as the second radiation of the fasciculiths). There are no other isotopic signatures in the vicinity of the evolutionary events. Our study shows that the establishment of major lineages of Paleocene coccolithophores was not directly related to the Neo-Duwi event. In addition, the introduction of new taxa helps improve the stratigraphy of the Danian-Selandian interval.

Resolving discrepancies between bulk organic matter and *n*-alkane PETM carbon isotope records from the Bighorn Basin, Wyoming

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The Paleocene-Eocene Thermal Maximum (PETM), a period of abrupt, short-term, and large-scale global warming fueled by a large release of isotopically light carbon, is a relevant analogue for episodes of rapid global warming and recovery. This event is recorded in pedogenic carbonate, bulk organic matter, and long-chain *n*-alkanes as a prominent negative carbon isotope excursion (CIE) in paleosols exposed in the Bighorn Basin, Wyoming.

Here we present a high-resolution composite stable carbon isotope record from *n*-alkanes and four bulk soil organic matter carbon isotope records from individual sections spanning the PETM interval in the Cabin Fork area of the southeastern Bighorn Basin. The *n*-alkane curve shows an abrupt, negative shift in $\delta^{13}C$ values, an extended CIE body, and a rapid recovery to more positive $\delta^{13}C$ values. The shape of this high-resolution *n*-alkane curve, with a prolonged and sustained core of the CIE followed by a rapid initial recovery, is similar to the newest ^{3}He-based timescale for the PETM using data from Walvis Ridge, IODP site 1266 (Murphy *et al*., 2010). In contrast, although the bulk organic carbon records show similarly abrupt negative shifts in $\delta^{13}C$ values, the CIE appears to be compressed as well as smaller in magnitude, and the return to more positive $\delta^{13}C$ values is often more gradual. Furthermore, the stratigraphic thickness of the most negative CIE values and the pattern of the recovery phase are not consistent among the four bulk organic carbon records.

Why do we observe such discrepancies between the bulk organic matter $\delta^{13}C$ records and the *n*-alkane composite stable carbon isotope record? Bulk soil organic matter $\delta^{13}C$ values can be influenced by degradation and selective preservation whereas *n*-alkanes are resistant to diagenesis and isotopic exchange. *n*-Alkane stability suggests that they offer a more reliable record of the PETM CIE. To explore why the bulk organic matter $\delta^{13}C$ records fail to capture the full duration of the CIE, we calculate predicted bulk organic matter $\delta^{13}C$ values from the *n*-alkane record by applying an enrichment factor (approximated as the difference between δ_{lipid} and $\delta_{total\ plant\ tissue}$) to the $\delta^{13}C$ values of the *n*-alkanes, assuming $\delta^{13}C_{total\ plant\ tissue}$ approximates soil organic matter $\delta^{13}C$ values. The anomaly, or the difference between the expected and observed bulk organic matter $\delta^{13}C$ values, is calculated for each of the four PETM records. The anomaly is then compared to various soil characteristics (weight percent carbon and grain size) and the possibility of contamination of older transported (Jurassic-Cretaceous) marine organic matter is considered to evaluate potential reasons for the disparities between the bulk soil organic matter and *n*-alkane carbon isotopes.

Detailed planktonic foraminiferal zonation of Middle Eocene in Crimean-Caucasus Region of Northeastern Peritethys

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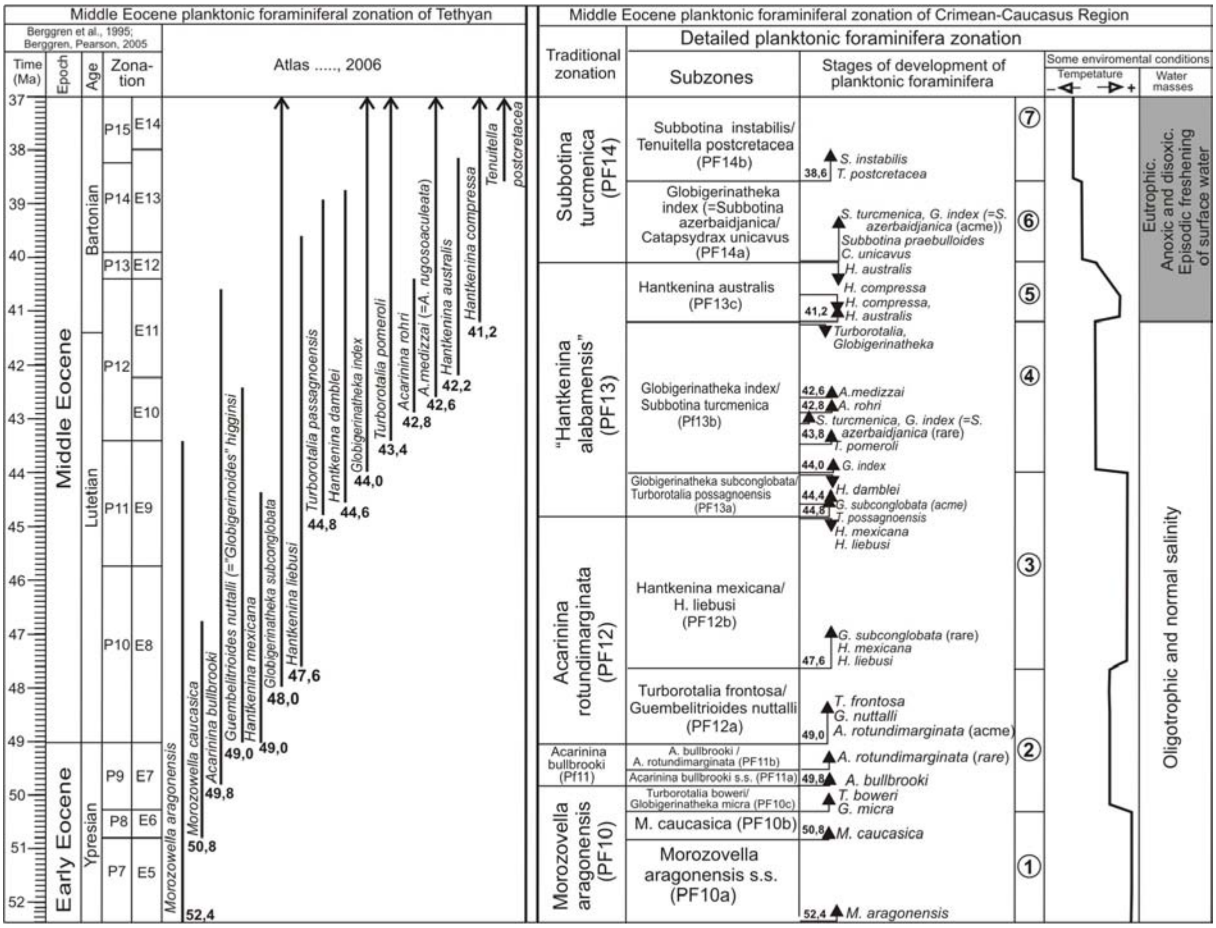
The traditional Middle Eocene zonation in the Crimean-Caucasus Region contains 4 zones (Resolutions.., 1989; Akhmetiev, Benyamovskiy, 2003). The new detailed zonation contains 9 subdivisions ranked as subzones (table). The lower boundaries of the zones are defined on first or last appearances of important for stratigraphy species. In evolution of the planktonic foraminifers in the region 7 stages are recognized. The stages are marked by evolutionary and ecological processes. The similarity, unidirectional evolution and close change of species of fast evolving and dominated planktonic genera in the Crimean-Caucasus Region and Tethys are firm basis for correlation of regional Crimean-Caucasus and international (standard) Tethyan foraminiferal Paleogene zonations. The proposed version of the detailed zonation is result of continuous studies of author on this topic (Benyamovskiy, 2001; Akhmetiev, Benyamovskiy, 2006; Beniamovski, 2006; Benyamovskiy, 2009; Zakrevskaya et al., 2011, in press).



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The Dababiya Corehole, Upper Nile Valley, Egypt: Litho-bio-chemostratigraphy and geophysical logging

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The 140 m long Dababiya corehole, located ~200 m east of the DBH section (25° 30' 09.9" N, 32° 31' 27.1" E; GSSP of the Eocene) was spudded in the El Mahmaiya Member of the Esna Shale Formation (Zone E2), ~9.5 m above the Dababiya Quarry Member, and penetrated downward to a total depth of ~140.2 m in ammonite-baculitid-nuculid–bearing Maastrichtian phosphatic shales. The Dababiya Quarry Member (Zone E1) was encountered down to 11.75 m, the Hanadi Member (Subzone P4c and Zone P5) down to 21.15 m, the Tarawan Chalk Formation (Subzone P4a-b) down to 39 m, and the Dakhla Formation below (Zones Pa to P$) down to ~80 m. The Paleocene/Eocene and Cretaceous/Paleocene (K/P) boundaries are located at 11.75 m, and ~80 m, respectively.

Benthic foraminiferal assemblages are dominated by taxa typical of the Midway-type fauna, and of outer shelf environments; diversity decreases and relative abundance of infaunal morphogroups increasesfrom Cretaceous to Late Paleocene. Differences include assemblages characteristic of low-oxygen environments in the Cretaceous Dakhla Formation, dominance of Paleocene Midway type fauna in the Dakhla Shale and Tarawan Chalk Formations and latest Paleocene buliminids-dominated assemblages in the Hanadi Member.

Geophysical logs exhibit sharp peaks at the P/E and K/P boundaries, particularly the Natural Gamma Ray and Single Point Resistivity log, as well as magnetic susceptibility.

Geochemical analysis of the Dababiya Quarry Member indicates very high productivity during the PETM. Elevated nutrients may be due to upwelling or to an enhanced hydrological cycle.

Integrated stratigraphy of the Eocene Wilkes Land Margin, Antarctica; preliminary results from IODP Expedition 318: dinoflagellate cyst and TEX_{86} results

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IODP Leg 318 recovered sediment cores from the Antarctic Wilkes Land Margin dating back into the early Eocene, the warmest time interval of the Cenozoic era. These cores provide an insight into environmental dynamics of an ice-free Antarctica. The onboard and postcruise studies have resulted in a well-constrained age model, and the multidisciplinary biogeochemical and micropaleontological data allows detailed paleoecological interpretations.

Here we present the results of a high resolution TEX_{86} and dinocyst study on the Eocene recovered at IODP Site U1356. We evaluate sea level, sea surface temperature and productivity fluctuations and put the record of dinocyst endemism in the context of the regional tectonic evolution of the Australo-Antarctic continental breakup.

Carbon system recovery and planktonic foraminifera ecology after the end Cretaceous mass extinction

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The end Cretaceous mass extinction profoundly affected the marine ecosystem. Surface-to-deep-ocean carbon isotope ($\delta^{13}C$) gradients and carbonate accumulation records suggest that pelagic extinctions coincided with a breakdown in marine biological pumping, which was followed by a long (3Myr) delay in recovery, but the apparent lack of response by benthic foraminifera has questioned the extent of this perturbation. Existing reconstructions of K/Pg carbon pumping are based on the difference between $\delta^{13}C$ in the calcitic tests of benthic and surface living foraminifera. One problem with this however, is our limited understanding of $\delta^{13}C$ disequilibrium effects in fast evolving early Paleocene planktonic foraminifera that diversified rapidly after decimation (~90 % extinction) of late Cretaceous stocks at the K/Pg. Positive or negative $\delta^{13}C$ disequilibrium effects that are a known feature of fossil and planktonic foraminifera could significantly over or underestimate the measured planktonic-benthic $\delta^{13}C$ gradient.

To help address this problem we present new multispecies foraminiferal stable isotope data size trends from ODP Site 1262. Our results suggest that all small specimens < 150 µm, which includes typical post-K/Pg Danian opportunists and extinction survivors, as well as small/pre-adult forms of other species, likely underestimate water column DIC $\delta^{13}C$ by 0.3 – 0.5 ‰ because of a pronounced metabolic vital effect. Our results also lend support to the hypothesis that foraminiferal photosymbiosis evolved in the *Praemurica* lineage but the new data provide further constraints on the timing of development of this ecology, which is associated with a positive disequilibrium $\delta^{13}C$ effect, pin-pointing its appearance to the *Pr. pseudoinconstans- Pr. inconstans* morphogroup by 63.5 Ma. All photosymbiotic species should, therefore, be expected to have artificially enriched $\delta^{13}C$ (by up to 1.0 ‰), especially species above 200 µm. By applying these new constraints to our down core records we are able to produce revised estimates of K/Pg changes in surface-to-deep $\delta^{13}C$ gradients and carbon cycling.

Punctuated gradualism in the earliest Eocene species *Helio-discoaster mahmoudii*

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The mode and tempo of evolution of species have not yet been resolved using the fossil record. Despite their continuous record and remarkable abundance, only a few studies have used microfossils to test the models of gradual evolution (Darwin, 1859) and punctuated equilibrium (Eldredge and Gould, 1972).

We have conducted a morphometric analysis on the distinctive, short-ranged calcareous nannoplankton species *Helio-discoaster mahmoudii* that is essentially restricted to the earliest Eocene (Biochron NP9b). This is small discoaster with 5 to 7 rays that possesses two knobs, one on the proximal (concave) and one the distal (convex) face. Each knob is lobate, the number of lobes corresponding to the number of rays. The shape of the proximal knob shows a remarkable variability in the lower part of the range of the species and then stabilizes. We have conducted a morphometric analysis to describe this morphological change using specimens collected from the El Mahmiya Member of the Esna Shale Formation, exposed in the Dababiya Quarry located 35 km south of Luxor. There, *H. mahmoudii* occurs over an 18 m thick interval. Because the species is very rare in the upper part of its range, we have studied only the lower 13 m part of the range (level DBH 5.4 to DBD 9.5).

The mean diameter of the proximal knob fluctuates between 3 and 7 µm in the lower three meters of the range of the species, and then stabilizes at ~5 µm for the next 10 meters. The coefficient of variation for this knob varies between 30 – 50 % in the lower two meters of the range of the species, and then it decreases to ~15% in the next meter. From there it increases and stabilizes at ~20%. The coefficient of variation is the ratio (mean/standard deviation) representing the amount of change around the mean diameter of the proximal knob. We interpret these data as indicating high variability in the lower range of the species followed by the fixation of a morphotype. The ancestor of *H. mahmoudii* is unknown at this time but this suggests an evolutionary modality similar to that found by Malmgren et al. (1983) in the Neogene planktonic foraminiferal species *Globorotalia tumida*, a mechanism to which they referred as punctuated gradualism. The evolutionary mode of *H. mahmoudii* may reflect ecological stability following the rise of the species immediately after the environmental disruptions associated with the Paleocene/ Eocene boundary.

References:
Darwin, C. R., 1859, On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life., London: John Murray. , p. 1-516.
Eldredge, N., and Gould, S., 1972, Punctuated equilibria: an alternative to phyletic gradualism: Models in paleobiology, v. 82, p. 115.
Malmgren, B., Berggren, W., and Lohmann, G., 1983, Evidence for punctuated gradualism in the Late Neogene *Globorotalia tumida* lineage of planktonic foraminifera: Paleobiology, v. 9, no. 4, p. 377-389.

New insights into long-term paleoceanographic changes during the late Paleocene to middle Eocene interval from the NE Atlantic

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The early Paleogene is characterized by a greenhouse climate punctuated by at least two transient hyperthermal events (< 200 ky) introducing the longer lasting Early Eocene Climatic Optimum (EECO, 52 – 54 Ma). This episode of warmth is subsequently followed by a general long-term cooling trend culminating in the Eocene-Oligocene glaciation. A number of more or less detailed foraminiferal $\delta^{18}O$ and $\delta^{13}C$ long-term records for the late Paleocene to middle Eocene interval have been published during the last two decades, yet most of them are from the Southern and Pacific oceans.
Here we present new detailed planktic and benthic foraminiferal isotope records from DSDP Site 401, which is situated on the North Biscay margin and represents thereby one of the most northern scientific drill sites providing pelagic carbonates of Paleocene to middle Eocene age. The study interval has been investigated with respect to the $\delta^{18}O$ and $\delta^{13}C$ composition of planktic (*Acarinina*, *Hantkenina*, *Morozovella*, *Morozovelloides* and *Subbotina*) and epibenthic foraminifera (*Cibicidoides* and *Nuttallides truempyi*). A fairly good core recovery in combination with well preserved foraminiferal calcite makes this site suitable for correlations and comparison with previously published long-term records from the Pacific Ocean (e.g., Allison Guyot, Shatsky Rise) and the Southern Ocean (Maud Rise). Benthic foraminiferal data of both $\delta^{18}O$ and $\delta^{13}C$ are well in line with the multi-site compilation of Zachos et al. (2008, Nature) showing the well know long-term shift towards heavier $\delta^{18}O$ values. By contrast, surface dwelling planktic foraminifera don't show any indication for a middle Eocene cooling, while subsurface dwelling taxa display a minor increase in $\delta^{18}O$. This again raises doubt about a general surface water cooling as already proposed by Pearson et al. (2007, Geology) based on data from Tanzania.

A complex history of the Paleocene–Eocene Thermal Maximum in the NE Atlantic

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The Paleocene–Eocene Thermal Maximum (PETM; 55.8 Ma) is the most prominent of a number of global transient warming events during the Paleocene and Eocene epochs. This so-called hyperthermal has been studied in numerous deep and shallow marine sediments as well as in terrestrial archives. Nearly all of them show indications of substantial warming and a pronounced negative $\delta^{13}C$ excursion. However, only few detailed deep-sea records exist from the North Atlantic region. In the Bay of Biscay at DSDP Site 401 a fairly thick sequence of clay-rich PETM-related sediments have been recovered providing a well preserved planktic and benthic foraminiferal fauna.

Geochemical studies of foraminiferal test carbonate reveal a complex history for the PETM in the NE Atlantic region. All studied taxa (benthic *N. truempyi*, thermocline dwelling subbotinids and surface dwelling morozovellids) display a discrete negative $\delta^{13}C$ excursion (CIE) followed by a synchronous recovery phase. By contrast, the $\delta^{18}O$ data of planktic and benthic foraminifera are decoupled during the recovery phase. This suggests different temperature histories for the different water-masses with a post-CIE cooling for bottom waters while surface waters remained warm, or alternatively, changes in the deep-water source. Mg/Ca data of these taxa show a different picture. All three records show the PETM warming at the base of the CIE, but the benthic foraminiferal record does not recover as expected by the $\delta^{18}O$ data suggesting no major change in bottom water temperature. Planktic foraminifera show a decline in Mg/Ca indicating a decrease in water temperature, while $\delta^{18}O$ values stay low. This suggests that the $\delta^{18}O$ anomalies during the PETM recovery phase likely represent a geochemical change characterizing different water masses rather than a predominant temperature signal.
In addition, He isotope data suggest a major input of terrestrial material and an increase in sedimentation rate starting with the onset of the CIE. These changes are in agreement with the clay-rich, extended sequence representing the PETM at DSDP Site 401. An increase in terrestrial ^{3}He is subsequently followed by a pronounced pulse of kaolinite deposition, which persists for several hundred thousand years after the termination of the CIE. The prolonged period of clay deposition implies that the PETM fundamentally altered both weathering conditions and sediment supply long after the end of the climatic transient.

Ecological response of Tethyan benthic foraminifera to the Middle Eocene Climatic Optimum (MECO) from the Alano section (NE Italy)

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The Middle Eocene Climatic Optimum (MECO) is a prominent and transient (~500 Kyr) warming episode that, at 40 Ma, interrupted the overall cooling trend of the middle Eocene (Bohaty & Zachos, 2003; Tripati et al., 2005; Sexton et al., 2006; Edgar et al., 2007a). MECO is recorded worldwide by pronounced changes of the $\delta^{13}C$ and $\delta^{18}O$ values and coeval oscillations in global CCD (Bohaty et al., 2009).

The expanded and continuous Alano di Piave section (northeastern Italy), located in a marginal basin of the central-western Tethys, provides an excellent record of the MECO, offering the opportunity to investigate this event in detail with multi-proxy, high-resolution approaches (Spofforth et al., 2010). At Alano a peculiar sapropelic interval, characterized by excursions in both the carbon and oxygen bulk-carbonate isotope records, represents the lithological expression of the post-MECO event. Such organic-enriched interval follows the $\delta^{18}O$ negative shift, interpreted as the peak of MECO warming (Spofforth et al., 2010). Previous studies on the Alano section, indicate profound changes in calcareous nannofossil and planktonic foraminiferal assemblages during the MECO and post-MECO intervals and highlight a marked increase in eutrophic, opportunist, low-oxygen tolerant taxa and a decrease in oligotrophic and specialized ones (Luciani et al., 2010; Toffanin et al., 2010). These biotic modifications suggest increased nutrient input and surface ocean water productivity in response to the environmental perturbation associated with the MECO.

In order to improve our knowledge about the marine ecosystem response to the MECO, we investigated benthic foraminiferal fauna of the middle bathyal Alano di Piave section through the analysis of the ≥ 63 µm fraction. Here we present a detailed, high-resolution, quantitative analysis of benthic foraminiferal assemblage with the aim to reconstruct the modifications of the sea-floor conditions during the environmental perturbations of the MECO and post MECO intervals. Our preliminary results show, in the sapropelic intervals, increased abundance of *Uvigerina*, a taxon common in oxygen-depleted, organically enriched settings, together with other bi-triserial taxa (bolivinids and buliminids) and *Hanzawaia ammophila* (another indicator of dysoxic conditions). These faunal modifications are interpreted as a result of deeply perturbed/stressed environmental conditions and in particular: a) a remarkable food transfer to the sea-bottom and b) development of dysoxic waters at the sea-floor, but no total anoxia as also indicated by geochemical proxies (Spofforth et al., 2010). Such conditions were an effect of eutrophication of surface waters, because of the modified, enhanced hydrological cycle in response to the MECO warming.

Plankton perturbations through the Eocene/Oligocene transition

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The Eocene-Oligocene transition (E/OT) was arguably the most significant period of climatic change in the Cenozoic and a major step in the development of modern glacial climates. Records from the equatorial Pacific show rapid and highly correlated increases in deep-ocean oxygen and carbon isotopes and a drop in the Calcium Carbonate Compensation Depth (CCD) of over a kilometer (Coxall et al. 2005). However, the role of surface ocean productivity changes, especially at low latitudes, within this carbon cycle perturbation remains open to question. Here we present high-resolution calcareous phytoplankton records from the Pacific, Atlantic and Indian ocean basins that reveal significant reorganization of planktonic niches coincident with the E/OT. These include a series of nannoplankton extinction events and major assemblage shifts that are closely coupled to the isotopic excursions. The assemblage shifts are not always expressed in the same taxa at the different locations but in all cases they indicate a coherent transition from broadly oligotrophic to eutrophic taxa through the E/OT. The onset of this transition precedes the start of the E/OT and $\delta^{18}O$ shift with the most important changes in assemblage compositions occurring before the E/OT at around ~34.6 Ma and at the second step in $\delta^{18}O$ at ~33.7 Ma. That similar changes are documented in planktic foraminferal records and far more profound shifts are seen in the siliceous plankton, suggests that significant reorganisation occurred in the global surface ocean during the E/OT.

Reference:
Coxall, H. K., Wilson, P. A., Palike, H., Lear, C. H. & Backman, J. 2005. Rapid stepwise onset of Antarctic glaciation and deeper calcite compensation in the Pacific Ocean. *Nature* 433: 53-57.

Bioevents at the Paleocene-Eocene boundary in flysch sediments of the Outer Western Carpathians, Czech Republic.

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Paleocene-Eocene boundary (PEB) in the flysch sediments of the Bílé Karpaty Unit, Magura group of nappes, was found at the Blatnička section (Bubík et al. 2001). Thin to thick turbidites in the 17 m thick section consist of 2 to 14 cm thick fine-grained calcareous sandstones (mostly Tc turbidite members), brown grey siltstones (Td) and prevailing 6 to 200 cm thick grey, brown grey, rarely green grey calcareous clays/claystones (Te). Hemipelagites are 0.5 to 7 cm thick mottled grey green non-calcareous clays. Turbidite clays/claystones bear calcareous nannofossils and planktonic foraminifers while the hemipelagite clays contain autochthonous agglutinated foraminifers, poorly preserved radiolarians and fish teeth.

The P/E boundary interval has nannofossil record. *Discoaster multiradiatus, Rhomboaster cuspis* and rare specimens of genus *Fasciculithus* (*F. schaubii, F. thomasii, F. tympaniformis*) occur in the uppermost Paleocene zone NP9. Transitional forms *Rhomboastrer-Tribrachiatus, T. contortus* and *T.* cf. “*digitalis*” sensu Egger (1997) indicate the Eocene zone NP10, while the genus *Fasciculithus* is missing. Assemblages may be compared with the lower part of P/E BI sensu Aubry (1999).

Low-diversity communities of agglutinated foraminifers (surface-dwelling detritus feeders) can be compared with “low-oxygen” biofacies of various authors. In the Blatnička section, diversity of agglutinated foraminifers and their feeding strategies increase from the upper part of NP10 zone. The bioevents at the PEB may be influenced by high productivity of phytoplankton connected with decrease in oxygen content. The stratigraphically important
taxa of agglutinated foraminifers within the Upper Senonian-Paleocene interval (rzehakinids, some hormosinids, *Glomospirella grzybowskii*, etc.) disappear in the NP9 zone and marker Eocene taxa such as *Pseudonodosinella nodulosa, P. elongata* appear in the upper NP10 zone. The lack of these species in the interval close to the PEB was probably caused by restricted conditions in the bottom waters.

At the Paleocene-Eocene transition, different fossil groups underwent major faunal turnover. Global changes in deep-sea agglutinated foraminifer assemblages are especially prominent. Many agglutinated taxa became extinct (some hormosinids, rzehakinids, *Annectina grzybowskii, Praesphaerammina gerochi,* etc.) and other taxa appeared *(Saccamminoides carpathicus, Pseudonodosinella nodulosa, P. elongata*).

References:

Aubry M.P. (1998): Early Paleogene Calcareous Nannoplankton Evolution: A Tale of Climatic Amelioration. In: Aubry M.P., Lucas S., Berggren W.A. (eds.): Late Paleocene-Early Eocene Climatic and Biotic Events in the Marine and Terrestrial Records. *Columbia University Press*, pp. 158-203.

Bubík M., Švábenická L., Uchmann A. (2001): B.10. Blatnička. In: Bubík M.: Fossil record of agglutinated rhizopods (foraminifers, testaceans) on the territory of the Czech Republic. *Field trip guide of the 6th IWAF, Prague,* 78-79.

Egger H., Bichler M., Draxler I., Homayoun M., Huber H.J., Kirchner E. Ch., Klein P., Surenian R. (1997): Mudturbidites, Black Shales and Bentonites from the Paleocene/Eocene Boundary: The Anthering Formation of the Rhenodanubian Flysch (Austria). *Jb.Geol.B.-A..,* 140, 29-45.

Coupling of marine and continental isotope records during the Eocene/Oligocene transition

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During the Cenozoic, conditions existed that allowed for the formation of permanent continental-scale ice caps on Antarctica (Miller *et al*., 1991; Zachos *et al*., 2001). Long-term cooling commenced after the Early Eocene Climatic Optimum (52 to 50 Ma), culminating in the Oi-1 glacial maximum (~33.65 Ma) (Miller *et al*., 1991; Zachos *et al.,* 2001; Bohaty and Zachos, 2003). This event reflects a transition from a greenhouse to an icehouse world and is recorded in the marine realm as a stepped positive $\delta^{18}O$ shift in benthic and planktonic foraminifera (Coxall *et al*., 2005; Katz *et al*., 2008; Pearson *et al*., 2008; Lear *et al*., 2008).

Reported here is a $\delta^{18}O$ record across the continental Eocene/Oligocene transition (EOT). The record derived from *V. lentus* displays 3 cycles followed by a positive $\delta^{18}O$ shift across Oi-1 with subsequent recovery to pre-Oi-1 values. Within these cycles, plus across the isotope shift and recovery, $\delta^{18}O$ values change in magnitude between 1.4 – 1.8‰. If entirely due to temperature this would equate to a 6 – 13°C (depending on calibration) temperature variation, which according to its high magnitude, implies a contribution from another factor, such as changes in the isotopic composition of the host water in which *V. lentus* grew. The ultimate control on this is likely to be related to changes in global ice volume. The *V. lentus* $\delta^{18}O$ Oi-1 shift and recovery are comparable to that seen in the marine record. Furthermore, in cycle 1 the most positive $\delta^{18}O$ value corresponds with the Late Eocene Event as observed in the marine record. Cycles 2 and 3 together occupy the same time interval, recording successive positive $\delta^{18}O$ shifts in the marine realm. Moreover, the negative $\delta^{18}O$ peak between cycles 1 and 2, associated with biotic and isotopic evidence for warming, matches a marine calcite compensation depth shoaling event. Although the cycle 2 positive $\delta^{18}O$ peak has no equivalent in the marine realm, fluctuations within cycle 3 appear synchronous with the named events EOT1/Step 1 and EOT2 (Coxall *et al*., 2005; Katz *et al*., 2008; Pearson *et al*., 2008; Lear *et al*., 2008). Therefore, the $\delta^{18}O$ record from *V. lentus* in a coastal floodplain environment shows substantial similarities with those from benthic foraminifera in the marine realm across the EOT and Oi-1 in timing and trajectory. Combined with multiproxy isotope derived summer temperatures, sea-level change and biotic data, some patterns of climate change with respect to the relative roles of temperature and ice-volume in this continental record are also comparable with those documented in the marine record. This suggests that when sampling resolution allows, a coupling of the marine and continental isotope records through the EOT can be observed.

References:

Bohaty, S. M. & Zachos, J. C., 2003. *Geology* 31, 1017-1020. Coxall, H. K., *et al*., 2005. *Nature* 433, 53-57. Hooker, J.J. et al., 2009. Chapter 12: In *The Late Eocene Earth—Hothouse, Icehouse, and Impacts* (eds. Koeberland, C. & Montanari, A). The Geological Society of America Special Paper, 452. Katz, M. E., *et al*., 2008. *Nature Geoscience* 1, 329-334. Lear, C. H., *et al*., 2008. *Geology* 36, 251-254. Miller, K. G., *et al*., 1991. *Journal of Geophysical Research-Solid Earth and Planets* 96, 6829-6848. Pearson, P. N., *et al*., 2008. *Geology* 36, 179-182. Zachos, J., *et al*., 2001. *Science* 292, 686-693.

Composition of *n*-Alkanes in Individual Fossil Leaves from the Paleocene-Eocene Boundary

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Long-chain *n*-alkanes (C_{21} to C_{35}) are distinctive plant lipid biomarkers that are not only remarkably ubiquitous across many terrestrial and marine environments but also can survive for millions of years in the geologic record. Their molecular and stable isotopic compositions can provide records of ancient environments. Most fossil *n*-alkanes are extracted from paleosols and bulk sediments, and therefore can be considered as mixtures of inputs from local plants. *n*-Alkanes from fluvial sediments in the Bighorn Basin, Wyoming, USA, have been examined across the Paleocene-Eocene boundary, including the Paleocene-Eocene Thermal Maximum (PETM) carbon isotope excursion. To date, interpretations of *n*-alkanes from these rocks have depended on comparison with modern plant *n*-alkanes, which are isolated from the leaves of individual plants. In order to avoid this mismatch between lipids from individual modern plants and bulk lipids from ancient sediments, we have examined the *n*-alkane compositions of individual fossilized leaves from fluvial channel fill deposits within the same Bighorn Basin stratigraphic sections where sedimentary *n*-alkane and bulk carbon isotope records have been measured. Initial comparisons of compression fossils with the directly adjacent sediment matrix for multiple fossil leaves show the lipids are much more concentrated in the fossil leaves than the surrounding matrix, and this suggests the lipids come from the leaf rather than being dispersed in the sediment.

Analysis of the lipid signatures of individual leaf morphotypes, as well as comparison of those fossil morphotypes with one another and with modern species lipid data, further our understanding of the relationship between paleosol *n*-alkanes and the source plant community. Changes in both the molecular and carbon isotopic compositions of sedimentary *n*-alkanes across the PETM have been previously ascribed to changes in the local plant community, where deciduous gymnosperms were a large component before and after, but not during, the PETM. By focusing on leaf fossils such as *Ginkgo* as well as locally abundant angiosperms, we can assess the relative importance of different plant lipid sources – most importantly, distinguishing between gymnosperms, angiosperms, and deciduous and evergreen plants. The relationship between carbon isotopic content and *n*-alkane chain length can be assessed for fossil species and then compared with the same data in modern species. Analysis of fossil leaves builds on previous modern plant data demonstrating that deciduous gymnosperms show a trend of increasingly negative carbon isotope values with increasing *n*-alkane chain length similar to that observed in deciduous angiosperms. This modern data is in contrast to the hypothesis that gymnosperms and angiosperms can be distinguished from one another based on the relationship between carbon isotope value and *n*-alkane chain length. *n*-Alkane molecular distributions appear similar between paired fossil and modern leaves, and carbon isotope values from the fossil leaves will further illuminate the nature of this relationship and its preservation in the fossil record.

Dynamic oceanographic conditions in Arctic Spitsbergen during the Palaeocene-Eocene thermal maximum: new evidence from dinoflagellate cysts

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The Palaeocene-Eocene thermal maximum (PETM) ~56 Ma, provides an opportunity to study the response of the Arctic ecosystem to transient global warming. Previously published dinocyst data from Spitsbergen (Longyearbyen section) suggest maximum flooding and salinity changes around the peak of the PETM in the Arctic. However, these changes cannot currently be assessed on a regional (Arctic) basis due to coring gaps through the only other PETM succession known in any detail from the region, IODP Site 302-4A. Thus to provide a wider geographical overview of Arctic palaeoceanography (i.e. across the Spitsbergen Central Basin) we compare published results from Longyearbyen with data from two additional successions. Changes in dinocyst assemblages from core BH9/05 near Sveagruva and a new outcrop section at Bergmanfjellet demonstrate local and basin-scale acmes in dinocyst taxa, which imply pronounced spatial and temporal variability in palaeoceanographic conditions. Peak abundances of fully marine taxa coincide with maximum dinocyst diversities, confirming the presence of a maximum flooding surface at the peak of the PETM. Later influxes of the low salinity proxy *Senegalinium* indicate the presence of a surficial freshwater lens which decreased in influence from northeast to southwest across the Central Basin. This fresh water influx, combined with indicators of lowered oxygen conditions, confirm the establishment of salinity-driven water column stratification. Fluctuations in *Senegalinium* abundance indicate pronounced temporal variability in the intensity of terrestrial runoff and thus the hydrological cycle, and that maximum intensity was reached ~30 kyr after the onset of the carbon isotope excursion.

The calcareous nannofossils across the Cretaceous-Paleogene boundary in northern Romania (Bucovina and Maramureş)

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Three sections from north-eastern Romania (Bucovina), within the Vrancea Nappe (Cuejdiu – Runcu Valley), Tarcău Nappe (Putna – Putna Valley section), and from northern Romania (Maramureş), from Poiana Botizei (Botiza Valley) were compared. These sections were studied in order to establish the Cretaceous-Paleogene boundary.

The lithostratigraphic context that provided the study of the Cretaceous/Paleogene boundary in the Moldavidic flysch is the one belonging to Tarcău and Vrancea Nappes.

The section from Runcu Valley, near Cuejdiu, contains a lithological succession characteristic to the central-eastern part of the Moldavidic flysch (Lepşa and Runcu formations). The delineation of the K/Pg boundary based on calcareous nannoplankton provides the premises for the correlation with the western part of the Moldavidic basin and for better outlining the bioevents and tectogenetic events that have influenced the Moldavidic flysch basin. At the base of the section, rich Upper Cretaceous calcareous nannofossils appear, with: *Arkhangelskiella cymbiformis, Broinsonia* ssp., *Micula* ssp., a.o. An interval that contain, besides Cretaceous, also Paleogene taxa follow. Upper Cretaceous calcareous nannofossils, with *Nephrolithus frequens,* a.o., but also Paleogene taxa: *Biantolithus sparsus, Cyclagelosphaera alta, Cruciplacolithus tenuis, Podorhabdus elkefensis*, are present. The K/Pg boundary is probably located in this interval. The next interval contain rare Paleogene and rare reworked Cretaceous taxa.

Calcareous nannofossils from the turbidites of the Putna Valley section (Hangu and Izvor formations) (Tarcău Nappe) were investigated in order to identify the Cretaceous/Paleogene boundary. The abundant late Cretaceous and Paleogene calcareous nannofossil assemblages along the first part of the section are followed by a barren interval in nannofossils, then, again the Paleogene forms and sometimes reworked late Cretaceous taxa. The Cretaceous biozones with *Micula prinsii, M. murus* and *Nephrolithus frequens* are present. The first part of the Paleogene contains frequent calcispheres - especially *Opercudinella operculata* and *Markalius inversus, Ericsonia* ssp., *Cruciplacolithus primus*.

The section from Maramureş area, from Poiana Botizei, belong to the Poiana Botizei Klippen Zone (Red Marls) (Puchov Marls) (Cenomanian–Paleocene). In the Poiana Botizei section, the calcareous nannofossil assemblages at the base of the section, with *Micula staurophora, Ceratholithoides kamptneri, Broinsonia verecundia* point to the presence of Upper Cretaceous deposits. This assemblage is followed by *Micula murus, Arkhangelskiella maastrichtiana, Nephrolithus frequens*, a.o. An interval with few Lower Paleogene nannofossils of small sizes and reworked Upper Cretaceous taxa was also identified, followed by an interval barren in calcareous nannofossils. The Lower Paleocene calcareous nannofossil assemblage contains: *Cruciplacolithus primus, Biantholithus sparsus, Markalius inversus, Biscutum melaniae, Neocrepidolithus* cf. *cohenii*, and relatively frequent thoracospheres.

Lower Eocene flysch deposits with horizon of bentonitized tuffites in the Subsilesian Nappe (Outer Carpathians, Poland)

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In the Outer Carpathians the Subsilesian Nappe is overthrust by the Silesian Nappe. In the western sector of Polish Carpathians both these units northwardly thrust over the Miocene deposits filling the Carpathian Foredeep, and in the eastern sector both thrust over the Skole Nappe. Cretaceous and Palaeogene Deposits of the Silesian Nappe crop out on the surface at front of the Silesian Thrust as well as in numerous tectonic windows formed in the Silesian Nappe. Lastly in the Subsilesian Nappe was found sedimentary complex with numerous thin layers of bentonitized tuffites (Cieszkowski at al. 2008, *Ann. Soc. Geol. Pol. 76, 2: 197-214*). They occur in the upper part of green shales and in the lower part of the Lipowa beds that consist mainly of muddy turbidites represented by green or green-brownish shales with rare intercalations of sandstones. The bentonitized tuffites, composed of almost pure dioctahedral motmorillonite, form numerous thin layers and laminae, only occasionally exceeding 5 cm. Tuffite bearing complex, Lower Eocene in age was called by authors the Glichów Tuffite Horizon. Outcrops of the green shales and Lipowa Beds with the Glichów Tuffite Hrizon are known from the Żywiec Tectonic Window as well as from several tectonic windows of the Lanckorona-Żegocina Structural Zone.

The age of the tuffite bearibg deposits was estimated as the Early Eocene (*Glomospira* div. sp. and *Saccamminoides carpathicus* zones) on the base of micropaleontological investigations. Three groups of foraminiferal saaemblages have been divided here. <u>The first group</u> includes assemblages typical for the Zone *Glomospira* div. sp. with numerous specimens of *Glomospira. Glomospira* genus is represented by 5 species. The most frequent species *Glomospira charoides* (Jones et Parker) and *Glomospira gordilais* (Jones et Parker) compose together about 70% of every assemblage. There occasionally arrive also typical Eocene species e.g. *Saccamminoides carpathicus* Geroch. In <u>the second group</u> the assemblages of *Glomospira* div. sp. Zone occur together with Paleocene foraminifera. These assemblages are almost the same like in the first group, but include also separate examples of Paleocene taxons characteristic for older Zone *Rzehakina fissistomata*. In <u>the third group</u> occur assemblages represented the *Saccamminoides carpathicus* Zone with numerous index taxon. Here the specimens of *Glomospira*, *Paratrochamminoides* and *Recurvoides* genus are not so numerous like in assemblages typical for the *Glomospira* div. sp. Zone.

It is possible that the Glichów Tuffite Horizon could be correlate with deposits of similar age containing tuffites which are known from the Silesian, Magura and Skole nappes. The Lipowa Beds show lithological similarities to the Early Eocene deposits with intercalations of bentonitized volcanic ashes from the Antherin section (Egger et al., 1997, 2000) located in the Eastern Alps in Austria close to Salzburg. It is very probable that both these positions could be equvalents. Anyway it is worth to conclude that there exist significant similarities between the Upper Cretaceous, Paleogene and Lower Eocene deposits of Ultrahelvetic Unit of Eastern Alps and the Subsilesian Unit of the Outer Carpathians.

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Upper Cretaceous-Paleocene Mutne Sandstone Mb. with olistholites of carbonate rocks (Magura Nappe, Outer Carpathians, Poland)

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The Mutne Sandstone (Cieszkowski *et al.*, 2007. *Ann. Soc. Geol. Pol.* 77,3: 269-290) is a lithostratigraphic member of the Jaworzynka Formation. This formation, traditionally called Inoceramus beds (biotitic facies), is widespread in the northern zone of the Magura Nappe in the West Outer Carpathians. It is equivalent of the Solan Formation divided in Czech and Slovak republics but exerts also significant similarities with the Altlenkbach Formation from the Rhenodanubian Flysch in the Easten Alps. The Mutne Sadndstone Member consists of the thick-bedded sandstones up to 2,0 m. They are medium- and coarse-grained, occasionally with layers of conglomerates. Massive sandstones pass up the top of the layer to pralell, ripple cross- or convolute lamination. In some cases large-scale cross-bedding, load-casts and flame-structures can be observed. The grain composition of sandstones consist mainly of quartz, with admixture of feldspar, clasts of metamorphic rocks, phyllites as well as shales, marls and limestones. In conglomerates clasts of carbonate rocks are more frequent. Limestomes from pebbles are massive, but also display parallel- or/and cross lamination. In some of them assemblages of planctonic foraminifers including *Globotruncanidae* and radiolarians were noticed. In some layers the numerous of limestone clasts arranged paralelly to the bedding form a kind of sedimentary breccia. The large olistolite of the marly limestones up to dozen or so meters in size occur within the sandstones outcroped in Mutne.

The micropaleontological analysis of the deep-water agglutinated foraminiferal assemblages documents the Late Mastrichtian age of the lower part of Mutne Sandstone Member in its type locality in Mutne village. Between others the several taxa e.g. *Gerochammina lenis* (Grzybowski) and *Caudammina gigantea* (Geroch) from examined assemblages are characteristic for Late Cretaceous. Occurrence of *Rzehakina inclusa* (Grzybowski) determine the Late Cretaceous age of the studied deposits. Beside of this several forms in the investigated assemblages are typical for latest Cretaceous – Paleocene. Assemblages from others localities of the Mutne Sandstone Member exert similar taxonomical character as in Mutne village and include specimens of *Rzehakina inclusa* (Grzybowski) and *Remesella varians* (Glaessner). The variegated shales of the Łabowa Shale Formation normally overlied the Mutne Sandstones in the lithostatigraphic section contain in its lower part the Late Paleocene assemblage of agglutinated forams. Between others assemblages include typical Paleocene species *Rzehakina fissistomata* (Grzybowski) and *Haplophragmoides* cf. *mjatliukae* Maslakova. The *Hormosina velascoensis* (Cushman) was also encountered there. So the age of the Mutne Sandstone Member was estimated as Mastrichtian-Paleocene. Probable Paleocene age of uppermost part of this division results from its position in the lithostratigraphic section of the Magura Series in the Siary Subunit beneath of the Łabowa Shale Formation, dated in its lower part as the Late Paleocene.

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Bryozoan-lithothamnium Szydłowiec Sandstones from the Subsilesian Nappe (Outer Carpathians, Poland)

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Bryozoan-lithothamnium Szydłowiec Sandstones were described by Książkiewicz (1951) as a sandstone complex belonged to the Subsilesian Nappe that builds the Szydłowiec hill (recently named Goryczkowiec hill). The hill is locacted in southern part of Wadowice town, notherly of Gorzeń Dolny village. Szydłowiec Sandstones, Paleocene in age, are a lithostratigrafic division of the Subsilesian Series. They are overlied by the Paleocene Gorzeń Sanstones and presumably underlied by the Cretaceous variegated marls. The Szydłowiec Sandstones are predominate by thick-bedded coarse grained and conglomeratic sandstones. Occasionally conglomerates occur there. The sandstone complexes are intercalated by not numerous thin layers of shales or thin- and medium-bedded shally-sandstone flysch. The sandstones are usually cemented by carbonate matrix. In the grain composition of sandstones quartz predominate, others are represented by metamorphic and magmatic rocks, as well as sedimentary rocks, mainly organodetritic limestones. The limestones often are rich of *Lithothamnium* and *Briozoa* remnants, as well as occasionally oyster scarps and echinoid prickles. The age of the Szydłowiec Sandstones have been previously estimated as the Maastrichtian.

The Paleocene age of the Szydłowiec Sandstones was definitively estimated on the base of the last micropaleontological investigations of foraminiferal assemblages performed by Waśkowska. These assemblages include mainly aglutinated forms of foraminifera known from deep sea flysch deposits. Admixtures of calcareous forms in different samples are various. Foraminiferal assemblages from the stratotype section of the Szydłowiec Sandstones represent the Paleocene Rzehakina fissistomata biozone with the typical Palecene taxon *Rzehakina fissistomata* (Grzybowski) occasionally accompanied by *Haplophragmoides mjatliukae* (Maslakova) - species also indicating the Paleocene age. Besides of these in the assbemblages occure cosmopolitan Maastrichtian-Paleocene as well as Senonian-Eocene forms.

Up to now geological interpretations included the Szydłowiec and Gorzeń sandstones to the individual thrust-sheet, differed as tectonic element of the Subsilesian Nappe. In Wadowice this structure should thrust northward over the next tectonic element of the Subsilesian Nappe. In Gorzeń village it is thrust over by the Silesian Nappe. Actual authors' discernment not excludes dissimilar interpretation. It let suppose that the Szydłowiec and Gorzeń sandstone body don't build an independent thrust-sheet, but represent large olistholit within Early Miocene olistostome that form here the highest lithostratigrphic level of the Subsilesian Series. The olistostrome developed in the lithostratigraphic section above the Oligocene-Early Miocene Krosno beds was emerged since tectonic movements that formed the Outer Carpathian acretionary prism. Discussed olistostrome take here geological position analogical to the Andrychów Klippes, also emerged as chaotic deposits.

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Post-PETM Hyperthermals in the Bighorn Basin, WY

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Recent focus on deep marine records of the early Paleogene has established the existence of smaller amplitude geochemical anomalies that mimic those found at the PETM. For example, Eocene Thermal Maximum 2 (ETM2, also known as H1 and Elmo) is associated with the second largest CIE identified in the early Paleogene record thus far and corresponds to even greater high-latitude temperatures than the PETM. ETM2 is followed closely in time by another event known as “H2”. Unlike the PETM, however, these other hyperthermals are not well documented from continental settings. Continental records of these smaller events are important to confirm their global nature, compare their biotic and hydrologic effects to those found at the PETM, and to help resolve the total amount of carbon released during these events.

We carried out meter-scale sampling of paleosol carbonate nodules for geochemical analysis from an ~160 meter interval surrounding the Chron C24r-24n polarity reversal in the McCullough Peaks section of the Bighorn Basin. The McCullough Peaks section has a relatively continuous and well-documented early Eocene stratigraphic record with good magnetostratigraphic control and abundant fossil mammals. Previous low-resolution isotopic results from this section indicated high variability near this polarity reversal and marine stratigraphic records exhibit several CIEs from this same interval, including the CIEs associated with the ETM2 and H2 events.

Results show two distinct negative $\delta^{13}C$ isotopic excursions in the interval surrounding the C24r-24n reversal. A -2‰ shift in average $\delta^{13}C$ of paleosol carbonates occurs ~110 meters below the base of Chron C24n (~800 meters above the PETM) and a second, well-defined, excursion of -2.7‰ occurs ~2.5 meters above the base of Chron C24n. Assuming uniform sediment accumulation rates for the 2 million year interval between the PETM and the base of Chron C24n, the lower excursion occurred ~240 ky before the polarity reversal and the upper excursion peaked ~5 ky after the reversal. Detailed marine cyclostratigraphic records indicate that the ETM2 CIE occurred between 126 – 315 ky before the Chron 24r – 24n reversal and the H2 CIE occurred almost coincident with the reversal. Given their close temporal association, we interpret the lower CIE in our section as ETM2 and the upper CIE as H2.

Our results indicate that CIEs recorded in paleosol carbonate are variably amplified compared to coincident marine CIEs suggesting the later are more reliable for estimating the total mass of carbon released during these events. In addition, ETM2 in the McCullough Peaks section coincides precisely with Biohorizon B (= Wa-4/Wa-5 biozone boundary) which represents the largest early Eocene mammalian turnover in the Bighorn Basin. ETM2 also coincides with an increase in the size and frequency of channel sandstone complexes throughout the basin, signifying regional hydroclimatic changes. In contrast, H2 does not correspond to any obvious biotic or sedimentological changes. These results show that hyperthermals smaller than the PETM can still, but do not necessarily, cause first order hydrologic and biotic changes in continental environments, highlighting the sensitivity and unpredictability of the earth system to transient changes in the carbon cycle.

The Eocene Arctic *Azolla* phenomenon: species composition, temporal range and geographic extent.

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Azolla is one of the world's fastest growing aquatic macrophytes renowned for its rapid vegetative spread and invasive biology. Using samples from IODP cores from the Lomonosov Ridge (Arctic) and from outcrops in Denmark (Collinson et al 2009 a,b *Review Palaeobotany and Palynology* 155,1-14; & doi:10.1016/j.revpalbo.2009.12.001) we have shown that two species of this freshwater floating plant bloomed and reproduced in enormous numbers in the latest Early to earliest Middle Eocene of the Arctic Ocean and in the area of present day Denmark. To expand our knowledge of the spatial distribution of these species we have now completed a study of samples from 15 additional sites. The sites range from the Sub-Arctic (Northern Alaska and Canadian Beaufort Mackenzie Basin) to the Nordic Seas (Norwegian-Greenland Sea and North Sea Basin) and the material comes from ODP cores and commercial exploration wells. The study included palynological slides and mesofossils.

The new data show that the *Azolla* phenomenon involved five species, in some sites more than one species co-existed. Species can be distinguished from one another by characters of the megaspore apparatus (e.g. megaspore wall, floats, filosum) and the microspore massulae (e.g. glochidia hairs and fluke tips). The attachment to one another and the co-occurrence of megaspore apparatus and microspore massulae, combined with evidence that these spores were shed at the fully mature stage of their life cycle, shows that the *Azolla* remains were not transported over long distances, a fact which could not be inferred from isolated massula fragments or glochidia alone. However, glochidia characters are particularly useful as they provide the future potential to identify the different species when only palynological preparations are available. Our evidence shows that the *Azolla* phenomenon affected the area from the western Arctic, through the North Sea and south as far as Denmark for a maximum duration of 1.2 million years (from c. 49.3 to c. 48.1 Ma). In some areas the *Azolla* grew on the ocean surfaces and in others on adjacent land. Apparently, co-incident with the termination of the EECO, Northern Hemisphere middle and high latitude environmental conditions were suitable for simultaneous widespread proliferation of several *Azolla* species. High precipitation conditions invoked (e.g. by climate models) for the EECO might have aided in the onset of massive *Azolla* proliferation in the Northern Hemisphere. The *Azolla* phenomenon is an unexpected and unpredictable consequence of Paleogene warm climate conditions.

Antarctic vegetation and climate dynamics during the Eocene: new data from the Wilkes Land margin

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During IODP Expedition 318 (January–March 2010, Wellington to Hobart), ~2000 m of Eocene to Quaternary sediments were recovered from the Antarctic (Wilkes Land) margin, documenting the evolution of this margin from an ice-free “greenhouse Antarctica” to the present-day icehouse environment. Based on a bio- and magnetostratigraphically dated, late early to early middle Eocene record recovered at Site U1356, we have carried out palynological and organic geochemical analyses in order to gain insights into the terrestrial environmental dynamics on Antarctica under peak greenhouse conditions.

Our preliminary palynological indicate that the vegetation along the Wilkes Land margin was highly diverse and contains thermophilous elements that today are widely distributed in the subtropics; along with our organic geochemical results, their presence suggests warm conditions at least in the coastal lowlands of the Wilkes Land margin. At the same time, taxa that today are typical for cool temperate settings are consistently present.

An age model for the Lutetian to Priabonian beds of Adelholzen (Helvetic Unit, Bavaria, Germany)

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The 18 m thick Adelholzen Section, located southwest of Siegsdorf in southern Bavaria, Germany is part of the Helvetic (tectonic) Unit and comprises six lithologic units: 1) marly, glauconitic sands with predominantly *Assilina*, 2) marly bioclastic sands with predominantly *Nummulites*, 3) glauconitic sands, 4) marls with *Discocyclina*, 5) marly brown sand (units 1-5 “Adelholzener Schichten” or Kressenberg Formation), and 6) Stockletten (marls without established formal name). The Adelholzen-Section is rich in planktic foraminifera. Reworked specimens from older deposits commonly occur, whereas most zonal markers were not found within the investigated samples; other potential index species show a rather sporadic occurrence instead of a continuous record. Consequently, our age model is based mainly on calcareous nannofossils and nummulitids and one zonal boundary only is based on planktic foraminifera. All investigated sediments contain very rich and well preserved calcareous nannoplankton assemblages, dominated by reticulofenestrids. All samples are characterized by low percentages of reworked taxa. Quantitative analyses were used to refine our age model.

Unit 1 (*Assilina*-sand) contains the transition from the uppermost Shallow Benthic Zone (SBZ) 13 (late early Lutetian) to SBZ 14. Accordingly, calcareous Nannoplankton Zone NP15 is indicated by the nannofossils assemblages and the investigated planktonic foraminifera point to zones P10 (E8) to P11 (E9). The micro- and nannofossil assemblages as well as the larger benthic foraminifera fauna of units 2 (*Nummulites*-sand) and 3 (glauconitic sand) indicate a middle Lutetian age (NP15, P11 (E9), and SBZ 14 and 15 p.p.). Unit 4 (*Discocyclina*-marls) is of late Lutetian age, indicated by SBZ 15, NP15, and P12. The planktic foraminifera boundary E10 to E11 was found in the uppermost part of this unit. Unit 5 (brown sand) also belongs to the late Lutetian (SBZ15, NP16, P12 (E11). The Stockletten (unit 6) did not yield larger foraminifera anymore and spans a wider biostratigraphic range (NP16 to NP20, corresponding to upper P12 (E11) to P15/16 (E15)). However, Zone NP 17 is missing and we therefore assume a stratigraphic gap (at least 3 Ma) in the lower part of the exposed Stockletten. This assumption is supported by the almost complete disappearance of acarinids (planktic foraminifera) in the overlying strata, pointing to a strong change in paleoceanography. A prominent decrease in bulk rock $\delta^{18}O$-values indicates the Mid-Eocene Climatic Optimum-Event around the brown sand (unit 5) and confirms our biostratigraphic zonation. The $\delta^{13}C$-curve shows characteristic patterns, which could be directly related to the global carbon isotope record and helped to refine our age model. The overall sediment-accumulation rate was at least 1.8 mm/Ky.

Lack of first and last occurrences, evidence of stratigraphic gaps, and reworked planktic foraminifera specimens complicate the construction of a consistent biostratigraphic framework. As reported from other sections elsewhere, planktic foraminifera, calcareous nannoplankton and larger benthic zonations did not always correlate well with established zonal schemes. Application of independent approaches however enabled us to overcome these difficulties.

Extinction of larger benthic foraminifera in the late middle Eocene and across the Eocene-Oligocene transition, Kilwa district, Tanzania.

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It has long been known that a number of widespread and long-ranging genera of larger benthic foraminifera undergo extinction events in the late middle Eocene and across the Eocene-Oligocene transition. Larger benthic foraminifera peak in size within the middle Eocene, but large sized species of *Nummulites*, along with *Assilina* and *Alveolina* become extinct during the late middle Eocene, closely linked with muricate planktonic foraminiferal extinctions. Larger benthic foraminifera then suffer a second dramatic, rapid, extinction during the Eocene-Oligocene transition, with the last global occurrences of families such as Asterocyclinidae, Discocyclinidae, Pellatispiridae and a number of species belonging to the genus *Nummulites*.

However, questions remain about the exact timing of events and correlation with global stratigraphy, largely due to the mutually exclusive environments of larger benthic and planktonic foraminifera, and species endemism preventing exact correlation between provinces. Additionally the global regression associated with the transition means many shallow water carbonate successions are incomplete across the boundary itself. Adams *et al.* (1986) suggested the extinction of larger benthic foraminfera was a mass extinction caused by the drop in sea level, however data from new and recently discovered sections from Tanzania suggest this is not the case.

We have studied these larger benthic foraminiferal events in detail, using recently drilled cores from the Pande formation of southern coastal, (Kilwa District) of Tanzania. Within the Pande formation limestones rich in larger benthic foraminifera occur as secondary gravity flow deposits and as isolated specimens within the clays, allowing for a detailed study of larger benthic foraminifera events. These secondary limestone beds, along with clay specimens and numerous field samples (collected in 2009) have been used to construct an overview of the larger benthic foraminiferal ranges through the Eocene to Early Oligocene with particular emphasis on the two extinction events. This larger foraminferal stratigraphy is calibrated by stable isotope, planktonic foraminiferal and nanno-fossil studies of the clays bounding the limestones, allowing for accurate integration with global stratigraphy.

Three of the TDP cores (drilled 2004-5) continuously span the Eocene/Oligocene boundary and have been used in a high resolution study of the larger benthic foraminiferal extinction. Extensive previous work on the planktonic foraminifera, nanno-fossils and stable isotopes ($\delta^{18}O$, $\delta^{13}C$) of the Tanzanian record has enabled detailed correlation with plankton stratigraphy and the global isotope curve and therefore precise extinction levels to be determined.

The results of this correlation have proved surprising.

The extinction of the majority of larger benthic foraminifera in the Tanzanian sections occurs at the Eocene-Oligocene boundary, as recognized by the extinction of the planktonic foraminiferal Family Hantkeninidae, rather than as Adams predicted at the oxygen isotope excursion associated with the main phase of Antarctic ice growth and eustatic regression. This correlates both the top of letter stage Tb and shallow benthic foraminiferal zone 20 with the Eocene-Oligocene boundary (top of planktonic foraminifer Zone E16) in the stratotype section at Massignano, Italy. It also raises the question of what process could have caused the simultaneous extinction of planktonic foraminifera in the open ocean and larger benthic foraminifera on the carbonate platforms.

Glassy foram stable isotope records of Eocene-Oligocene climate change from two latitudinal extremes: The high north Atlantic and the Indo-Pacific warm Pool

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The quality of foraminiferal calcite preservation plays a crucial role in our ability to produce accurate palaeoclimate reconstructions. This is especially true for reconstructions of Palaeogene surface ocean properties because planktonic foraminifera proxy tools that are used as tracers are highly susceptible to post burial diagenetic alteration under the influence of subsurface and pore waters that overprint a cool, deep water temperature signal on planktonic foraminiferal $\delta^{18}O$. This has set the challenge to seek exceptionally well-preserved “glassy” microfossil material preserved in impermeable hemipelagic clay sequences, which is thought to preserve unaltered isotopic compositions. Here we present new geochemical records of Eocene-Oligocene (E-O) climate change based on glassy planktonic and benthic foraminifera from two climatically extreme regions of the Earth; 1) the high North Atlantic (ODP Site 647) and 2) the Indo-Pacific warm pool (Central Java, Nanggulan Bore Hole). These regions are currently under sampled for E-O time. The Site 647 E-O section comprises small but exceptionally well-preserved foraminifera preserved in a sequence of hemipelagic clay south of Greenland (palaeolatitude ~54°N). It remains the northernmost carbonate-bearing sequence known. Available core material suggests that the E-O interval is complete at this site. The sequence recovered in the new Indonesian Nanggulan bore hole records deposition in a shallow low latitude margin setting (200 – 300 m depth, palaeolatitude ~2°N) in one of the warmest regions of the Earth. Isotope records derived from the typically tropical Nanggulan assemblages were measured on whole unfilled specimens, supplemented with samples based on isolated shell fragments where infilling occurred. Our new $\delta^{18}O$ data record the large (> 1.0 ‰) positive shift in foraminiferal $\delta^{18}O$ at both sites that is the signature of E-O glacial expansion. Consistent with previous E-O stable isotope studies using glassy foraminifera from Tanzania and the US Gulf Coast, our planktonic records show lower $\delta^{18}O$ than similar records based on deep sea ooze material, i.e. approximately - 4 ‰ and - 3 ‰ in the Eocene and early Oligocene respectively for Java and - 2 ‰ increasing to ~ -1 ‰ in the Oligocene at Site 647. These results suggest late Eocene sea surface temperatures of ca. 34°C in Java, compared to 28°C today, and 25°C in the southern Labrador Sea, compared to 8°C modern. Our data provide rare insight into ocean and climate responses to E-O climate change in high northern latitudes, as well as new constraints on E-O latitudinal thermal gradients.

Paleogene insect herbivory as a proxy for pCO_2 and ecosystem stress in the Bighorn Basin, Wyoming, USA

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The early Paleogene rock record of the Bighorn Basin, Wyoming, USA, preserves both long- and short-term environmental changes. In this study, we compare the response of insect herbivores to the abrupt, CO_2-driven Paleocene-Eocene Thermal Maximum (PETM, 55.8 Ma) and the gradual Early Eocene Climatic Optimum (EECO, ~53 – 51 Ma). A Bighorn Basin paleotemperature record for the late Paleocene through early Eocene has already been constructed (*1, 2*), and paleobotanical estimates are 20.1 ± 2.8°C for the PETM and 22.2 ± 2°C for the EECO. Although temperature changes during the PETM and EECO are well constrained, variations in pCO_2 remain poorly understood. Studies of pCO_2 during the PETM conclude that more than 2,000 Gt of carbon were released in the atmosphere (*3*), but because pCO_2 of the late Paleocene is unknown, it is impossible to compare the PETM to other time intervals. Carbon dioxide levels during the EECO have been calculated using a variety of proxies; however, estimates range from 100 to 3500 ppm (as compiled in *4*).

Comparing insect herbivory during the PETM and EECO both documents biotic response to different scales of environmental perturbation and also provides insight into the nature of these perturbations. Temperature and carbon dioxide affect insect herbivores differently. Warming speeds up insect metabolic rates, which decreases larval development time and reduces susceptibility to predators and parasitoids. Therefore, insect herbivore population densities are often higher during warming events. Temperature also impacts insect diversity because of its effect on insect geographic ranges. Carbon dioxide indirectly affects insects through a decrease in food quality. Plants grown in elevated pCO_2 tend to accumulate more carbon and have a lower nitrogen : carbon ratio. Insects must compensate for this decrease in nutrient concentration by increasing consumption.

We studied insect herbivory on one PETM flora and one EECO flora from the Bighorn Basin. In order to establish background values of insect herbivory, we analyzed seven additional Bighorn Basin Paleogene floras that are not from intervals of high temperature or carbon cycle perturbations. We conducted insect damage censuses to measure insect damage diversity (number of damage morphotypes, standardized by sample size) and frequency (the proportion of leaves with insect herbivore damage). Leaf area removed or damaged by insect herbivores was measured on a subset of the censused leaves using Image J.

Damage diversity is highest in the EECO and then the PETM, and both are significantly more diverse than the other sites. This is unsurprising due to the strong, positive correlation between damage diversity and temperature, and likely represents the northward migration of diverse insect populations from lower latitudes. Furthermore, the PETM and EECO are marked by significantly elevated damage frequency, which likely indicates high insect population densities. Leaf area removed/damaged by insect herbivores is significantly greater during the PETM than during the EECO, and this has two possible interpretations. First, it could signify that pCO_2 was significantly higher in the PETM than in the EECO. An alternate explanation is that the abruptness of temperature and pCO_2 change during the PETM destabilized terrestrial ecosystems. PETM forests were highly stressed ecosystems that lacked a tight coevolution of plants and insect herbivores.

References:

1. S. L. Wing, H. Bao, P. L. Koch, in *Warm climates in earth history,* B. T. Huber, K. G. MacLeod, S. L. Wing, Eds. (Oxford U P, Cambridge, 2000), pp. 197-237.
2. E. D. Currano, C. C. Labandeira, P. Wilf, *Ecological Monographs* **80**, 547 (2010).
3. J. C. Zachos, G. R. Dickens, R. E. Zeebe, *Nature* **451**, 279 (2008).
4. D. L. Royer, *P Natl Acad Sci USA* **107**, 517 (2010).

Benthic foraminiferal assemblage fluctuations during early Eocene hyperthermals at DSDP Site 401, Bay of Biscay, North East Atlantic

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Contrary to the Paleocene Eocene thermal maximum (PETM; ~55.5 Ma), which is well-known for its benthic foraminiferal extinction (BFE; e.g. Thomas, 2007), foraminiferal records of early Eocene hyperthermals are scarce and incomplete (e.g. Lourens *et al*., 2005), limiting our understanding of these global warming events and the early Paleogene climate system as a whole.

Here, we present geochemical and quantitative benthic foraminiferal records from the early Eocene of Deep Sea Drilling Project Site 401 (Bay of Biscay, North East Atlantic). The pelagic sediments at this site (paleodepth ~2000 m) show a well-developed cyclicity. Throughout Biozone NP11, several thin marly levels stand out in the otherwise grayish-brown calcareous chalks. The $\delta^{13}C$ and $\delta^{18}O$ records (*Nuttallides truempyi*, *Oridorsalis umbonatus* and bulk material) clearly show five transient negative excursions of up to ~ 0.80 ‰ associated with these dark marly levels. These values are comparable to the observed values of the isotopic H1 and K excursions - which are linked to hyperthermals - even more so when compared with localities from the Northern Hemisphere.

Although the smaller isotope excursions are not correlated with any significant faunal perturbations, the larger isotope excursions display strong benthic foraminiferal assemblage changes, suggesting the existence of certain paleoceanographic thresholds. During the largest negative excursion, an incursion of abyssal-related taxa (e.g. *Nuttallides umbonifera*, *Globocassidulina subglobosa*, *Gyroidinoides* spp., *Stilosomella* spp. and *Cibicidoides ungerianus*) takes place, followed by a recovery composed mainly of lower-middle bathyal taxa (e.g. *Cibicidoides eocaenus*, *Brizalina carinata*, *Angulogerina muralis, Bulimina virginiana*, *Pseudoparrella minuta*,). A detailed statistical and ecological study reveals that the assemblage changes are mainly due to fluctuations in the C_{org} flux to the seafloor, with oligotrophic and oxic conditions prevailing during the isotopic excursions. Furthermore, the assemblage changes appear to be tracking lysocline shoaling and subsequent overdeepening (e.g. Leon-Rodriguez and Dickens, 2010) as well. The aftermath of this intense event includes a pronounced and seemingly permanent shift in benthic foraminiferal composition at this site. This implies that hyperthermal events have the potential to disrupt and reshape the benthic deep-sea communities on both short and longer time scales. We conclude that the regional faunal patterns of the hyperthermals observed at Site 401 strongly resemble those observed in many deep-sea PETM deposits worldwide. As such, this may support the hypothesis that early Eocene hyperthermals are very similar to the PETM and are causally linked.

References:

Leon-Rodriguez, L., Dickens, G.R. (2010) Constraints on ocean acidification associated with rapid and massive carbon injections: The early Paleogene record at ocean drilling program site 1215, equatorial Pacific Ocean. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **298**(3-4), 409-420

Lourens, L.J., Sluijs, A., Kroon, D., Zachos, J.C., Thomas, E., Röhl, U., Bowles, J., Raffi.I.(2005) Astronomical pacing of late Palaeocene to early Eocene global warming events. *Nature Letters* **435**, 1083-1087.

Thomas, E. (2007) Cenozoic mass extinctions: What perturbs the largest habitat on Earth? 1-23, In: Monechi, S., Coccioni, R., Rampino, M.R. (Eds.), Large Ecosystem Perturbations: Causes and Consequences, *Geological Society of America Special Paper*, **424**.

Late Cretaceous–early Eocene magneto-biostratigraphy and rock-magnetism from the Belluno Basin (NE Italy).

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The magnetostratigraphy and the rock-magnetism of the upper Cretaceous – lower Eocene Tethyan marine Ardo and Cicogna composite section (Belluno Basin, NE Italy) are presented. The paleomagnetic results have been integrated with calcareous nannofossil biostratigraphy, indicating that the composite section extends from Chron C29r to Chron C23r, encompassing nannofossil Zones *Micula prinsii* – NP12 (Maastrichtian–Ypresian). We determined the sediment accumulation rates by means of correlation with the CK95 geomagnetic polarity time scale; they vary from ~3 m/Myr in the Danian part of the section, up to ~18 m/Myr stratigraphically upward. As indicated by the rock-magnetic data, the magnetic mineralogy of the sediments generally consists of variable proportions of magnetite–maghemite–hematite, which are iron oxides characterized by different oxidation states and structures. We placed the rock-magnetic variability on a temporal reference frame using the CK95-based age-depth function. Data indicate that relatively warmer climate periods (i.e. the Paleocene-Eocene thermal maximum and the early Eocene warming trend leading to the Early Eocene climatic optimum) are associated with high relative content of detrital hematite with respect to magnetite-maghemite, while relatively cooler climates (i.e. the Paleocene) are associated with a relative increase of magnetite-maghemite. We speculate that the relative increase of detrital hematite observed during global warming periods is associated with intensified chemical weathering conditions. This scenario is supported by the fact that hematite is one of the most abundant iron oxide phase produced on land during the chemical weathering of Fe-bearing silicates under warm and humid climates. Our hypothesis is confirmed by a correlation between rock-magnetic properties and global climate as revealed by a standard benthic oxygen isotopes record from the literature. This approach confirms the existence during the latest Cretaceous–early Eocene interval of the silicate weathering negative feedback mechanism to eventually stabilize long-term Earth's surface temperature.

Vegetation types of Europe and North America across the Paleocene/Eocene transition

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The impacts of the Paleocene-Eocene Thermal Maximum (PETM) on plants and vegetation types are poorly known in comparison to mammal communities and oceanic plankton. In an effort to better understand the transition, geographic interaction and modification of floras from the Late Paleocene into the Early Eocene we have assembled a dataset of European and North American palynofloras to characterize the differences between different holarctic continents and between different vegetation types. This dataset from localities that are dated to late Thanetian and Ypresian contains approximately 1000 taxa from c. 80 localities from the North America (USA) and Europe (Austria, Belgium, Germany, France, Romania, UK, Spain, and Slovak Republic) that collapse into about 400 angiosperm taxa once synonyms and singletons are removed from the data matrix. Preliminary results show significant differences between both continents in pollen records although families tend to be geographically widespread: e.g. Bombacaceae are more widespread during the Paleocene of North America than in Europe, Burseraceae is common in Europe but not in North America, Sapotaceae occurred on both continents during Paleocene but their abundance increases in North America during the Eocene. Palms are more significant in number of form-taxa in Europe than in North America. Geographic differences between fern spores are not significant because they are highly facies dependant. The Paleocene/Eocene boundary is associated with limited exchange between continents with little immigration into Europe that can be tied to the PETM. The significance of the turnover pattern will be tested with further work to build a null model of change to identify areas and vegetation types that change in the Eocene significantly beyond the expected pattern.

A Recent Literature Cycle Mystery (And a Return to an Early Palaeogene World With a Large and Dynamic Organic Carbon Capacitor)

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An interval of the early Palaeogene (~58-51 Ma), including brief events within, has become a magnet for examining past climate change. The underlying primary reasons – extremes in global temperature, environmental change, and carbon input – have been known for over 10 years. Oddly, with the escalation of people attracted to this time interval, and the ensuing scientific output, key concepts have become blurred rather than clarified. For example, and in contrast to suggestions in high-profile papers over the last 5 years, there never have been good arguments to suggest that, during the PETM, the carbon isotope composition of the ocean and atmosphere shifted by more than 3.5 per mil, the carbon input associated with this excursion drove all associated warming, the global CCD rose by 2 km, sea-level dropped and exposed epeiric seas, volcanism increased tremendously, seafloor methane was minimal, terrestrial biomass disappeared, etc. The emphasis on setting stratigraphic points without deep rationale, the focusing on mean annual temperature rather than seasonal temperature (especially at high latitudes), and the finding and naming of multiple hyperthermal events without definition has muddled studies further. Despite the obfuscation, the most fundamental aspects concerning early Palaeogene global climate change and carbon cycling have not only remained but have become amplified. Between about 58 and 51 Ma, Earth's surface warmed by about 6°C, and carbon fluxes to the ocean and atmosphere increased. Superimposed on these changes were a series of events marked by rapid global warming and massive carbon injection. For both the long-term and short-term intervals, warming led carbon input, and the carbon input was depleted in 13C; moreover, successive carbon inputs decreased in magnitude. All indications still point to an early Paleogene world with at least one large and dynamic (and probably microbially mediated) "carbon capacitor" that operated as a positive feedback to changes in temperature. Once this framework is appreciated, testable hypotheses emerge and widespread (often disparate) records of environmental change can be understood and linked at a basic level. The capacitor could have been methane in marine sediment, solid organic carbon in terrestrial sediment, or both; each has merits and demerits.

Eocene sea surface temperature reconstructions from bivalve clumped isotope measurements

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Reconstructing meridional temperature gradients remains a critical problem in understanding Eocene climate. Recent reconstructions of peak Eocene sea surface temperatures have revised estimates towards warmer values in both the tropics and high latitudes. However, uncertainty due to proxy biases remains a concern, particularly regarding empirically calibrated organic paleothermometers. Carbonate clumped isotope paleothermometry offers a novel approach for reconstructing temperature from biogenic carbonates that does not require assumptions regarding the isotopic composition of seawater. Previous data (Came et al., 2007) and our preliminary measurements of modern bivalve carbonates suggest that clumped isotope paleothermometry records growing-season temperature in both aragonitic and calcitic bivalves.

We have applied clumped isotope paleothermometry to Eocene bivalves from Seymour Island, Antarctica (paleolatitude ~65°S) and from the U.S. Gulf Coastal Plain (~28°N). Peak early Eocene sea surface temperatures at Seymour Island are approximately 18°C, and decline to 13 to 14°C by the middle to late Eocene. Paired clumped isotope analyses of primary shell aragonite and secondary calcite cement suggests that clumped isotope measurements record shell growth temperatures and are not overprinted during burial. Reconstructed temperatures from Seymour Island are generally consistent with bivalve $\delta^{18}O$ derived temperatures based on a seawater $\delta^{18}O$ value of -1 ‰. However, these temperatures are as much as 14°C cooler than TEX_{86} derived temperatures from the East Tasman Rise at a similar paleolatitude. This discrepancy suggests either major zonal temperature heterogeneity at high latitudes, or unresolved biases affecting TEX_{86} paleothermometry in Eocene subpolar environments

Early Eocene bivalve clumped isotope temperatures from the U.S. Gulf Coast (Hatchetigbee Formation, Alabama) average 27 ± 2°C, a value that is corroborated by similar temperatures derived from bivalve $\delta^{18}O$ and MBT/CBT analyses. TEX_{86} analyses indicate slightly warmer temperatures averaging 28 ± 0.3°C using the reciprocal calibration of Liu et al. (2009). Clumped isotope measurements of seasonally-specific growth bands within bivalve shells indicate a small seasonal temperature range of 2 ± 2°C, whereas the large variability observed in $\delta^{18}O$ values indicates seasonal variation in precipitation and/or continental runoff. Our multiproxy temperature estimates from the Gulf Coast are cooler than other early Eocene reconstructions at both lower and higher latitudes.

Viewed together, Eocene clumped isotope paleotemperature estimates from Seymour Island and the U.S. Gulf Coast suggest a reduced temperature gradient between subtropical and subpolar regions relative to modern conditions, consistent with other studies. However, temperatures from both sites are cooler than recent paleotemperature estimates from similar latitudes, particularly compared to temperatures inferred from TEX_{86} measurements. These discrepancies point to either a large-scale zonal temperature variability in the Eocene, to significant differences between sea-surface and shallow benthic temperatures, or to unconstrained inter-proxy biases. Further multi-proxy studies involving clumped isotope measurements will help to resolve this question.

The Paleocene/Eocene transition in the NW part of the Paleogene Adriatic carbonate platform and the adjacent basin

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From the Late Cretaceous to the end of Early Eocene the NW margin of the Paleogene Adriatic Carbonate Platform bordered on a deeper sedimentary basin characterized by clasitic sedimentation.
The present study concerns two sections of the Upper Paleocene/Eocene sediments: Nanos section (S slope of Mt. Nanos) with clastic basin sedimentation and, Sopada section (Trieste-Komen Karst) with sediments deposited in the shallow-water carbonate platform. The Nanos section was studied for planktonic foraminifera, calcareous nannoplankton, and ostracods. The Sopada section was studied for stable carbon isotopes. Larger benthic foraminifera were studied in both sections.
The age attribution of the Sopada sediments was done based on larger foraminifera. The presence of *Assilina azilensis* and *Glomalveolina levis* point out to SBZ 4, while Lower Eocene age (SBZ 5) was proven by occurrences of the index species *Alveolina aramaea* and *A. latior. Thomasella labyrinthica*, *Lacazina blumenthalii*, *Pseudolacazina donatae*, as well as ranikothalids, nummulitids and rotaliids were found in samples assigned to both biozones. CIE with pronounced negative $\delta^{13}C$ values was detected in the upper part of the Paleocene corresponding to the extinction of some foraminiferal species. The assemblages found are comparable to those described from the Eastern Neotethys (*e. g.*, Turkey and Egypt).
The occurrences of planktonic foraminifera *Morozovella aequa*, *M. acuta*, and *M. velascoensis* indicate P5 biozone (the uppermost Paleocene and the lowermost part of the Eocene) for the sediments from Nanos section. Calcareous nannoplankton assemblage studied from the same samples contains *Discoaster multiradiatus*, *D. lenticularis*, *D. mohleri* and several species of the genus *Fasciculithu*s. Listed species along with complete absence of *Rhomboaster* spp., are characteristic for NP9 biozone or the uppermost Paleocene. While the deep-sea ostracod species *Cytherella* sp. is considered as autochthonous, the larger benthic foraminifers were transported into the basin from the shallower parts. The findings of spherical foraminiferal form were of particular interest, because of its similarity to species known from the Megathaya region (NE India) (Tewari, Drobne, Pugliese, Melis, unpublished data). The identification was a challenge for us – we presumed that forms belong to the genus *Aberisphaera.* Mt. Nanos probably was the easternmost end of geographic range of the genus. The presence of the species supports the hypothesis of a possible connection between these geographically remote areas, the Paleogene Adriatic Carbonate Platform and Megathaya region.

Sea level changes in the Paleocene-Eocene interval in NW France Evidence of two major drops encompassing the PETM

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Terrestrial and lagoonal to shallow marine paleoenvironments are preserved in the Lower Paleogene outliers scattered along the eastern English Channel coast (Dieppe-Hampshire Basin). Stratigraphic studies in this Paleocene-Eocene (P-E) interval reference area (Dupuis *et al.*, 1998; Aubry *et al.,* 2005) are especially useful in reconstructing sea level changes. Nine regional units can be delineated and traced along the coast transect. They are separated by eight hiatuses of diverse durations and variable lateral continuity and structured in three transgressive sets of units. The lower one belongs to the Thanetian (NP7 to NP9a). The two others encompass the “Sparnacian” and the Early Ypresian (*s.s.*) (NP10-NP11). The second set comprises the successive Mortemer Fm, Ailly Mb and Craquelins Mb.

The first Major Sea Level Drop (MSLD1) resulted in the erosion of large channels filled up by the fluviatile-palustrine Mortemer Fm. The upper bed of this later Fm bears the CIE onset pointing to the P-E boundary. The transgression continued with the lagoonal-shallow marine Ailly Mb yielding the *Apectodinium* acme. The overlying Craquelins Mb is a glauconitic clay only recognized along the Varengeville outlier and in the Sotteville-sur-Mer and Eu sections; it coincides with the end of the *Apectodinium* acme and marks a maximum flooding of the transgression. The third set starts after the MSLD2 which formed a regional erosional surface. On it lays a complex unit of very shallow marine sands often rich in “avelannes”, very well rounded small flint pebbles, appearing for the first time in the stratigraphic record (“Sables Fauves”, Blackheath Beds, Oldhaven Mb, etc.). Of variable thickness, this unit marks the base of the marine Ypresian (*s.s*) (Varangeville Fm, London Clay Fm, etc.).

The two MSLDs are of different natures. MSLD1 is widely reported in the studied area where the uppermost Paleocene fluvial channels can be observed (Cap d’Ailly, Newhaven, Dormaal, Erquelinnes, Flines-les-Râches, Therdonne, Le Quesnoy-Rivecourt, etc.). The regular size of the channels and their rather uniform distribution suggest that the incision of fluvial networks was dependent to a broad uplift due to the magmatic activity of the NAIP (North Atlantic Igneous Province). The subsequent cooling of the intrusion caused the thermal subsidence controlling the transgressive trend of the succession (Knox, 1996) later perturbed by the MSLD2. Of independent (?) origin, MSLD2 is related to a sea shore abrasion surface the effects of which vary from almost no erosion to large denudations resulting in unconformities over rejuvenated (?) tectonic structures (Bray anticline, etc.).

The MSLD1 context suggests a scenario for some global events around the P-E boundary. The NAIP driven uplift emerged a large area around the hot spot. This may have triggered both the organic matter oxidation of those regions and the destabilization of the sea slopes clathrates, adding a contribution to the release of thermogenic methane from the intrusions in the Norvegian Sea (Svensen et al, 2004). This interpretation may also explain the position of the CIE shortly after the incision of the channels and the beginning of the transgression.

Transient symbiont bleaching of planktonic foraminifera during the Middle Eocene Climatic Optimum

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The short-term or permanent loss or inhibition of photosymbionts – '*bleaching*' – has recently been reported in many modern organisms including corals and benthic foraminifera in response to environmental stress. However, bleaching events in the fossil record and their impacts are relatively unknown. During the early and middle Eocene (~36-60 Ma), low and mid-latitude planktonic foraminiferal assemblages were dominated by surface-dwelling, symbiont-bearing genera including *Acarinina, Morozovelloides* and *Globigerinatheka.* A transient global warming event at ~40 Ma, the Middle Eocene Climatic Optimum (MECO), provides an opportunity to assess biotic impacts on these taxa in response to sea-surface temperatures and other transient environmental changes. We use size-restricted $\delta^{13}C$ analysis of planktonic foraminifera to investigate symbiont activity across the MECO event at Ocean Drilling Program (ODP) Sites 1051 and 748 (NW Atlantic and Southern Ocean, respectively). Our new records indicate large changes in the ecology of the surface-dwelling foraminiferal groups, specifically the acarininids and globigerinathekids, which experienced bleaching, during the MECO. Close coincidence between minimum $\delta^{18}O$ values and a loss or reduction in the test size- $\delta^{13}C$ gradient may imply a link between short-term loss of photosymbionts and increased sea surface temperatures (SSTs) during the MECO. We evaluate the viability of potential bleaching mechanisms including: 1) a direct impact from increased SSTs, 2) a shift to deeper in the water column in response to warming, 3) a restriction of depth habitat and 4) a response to pH decrease in surface waters. Following the MECO, photosymbiotic activity in surface-dwelling taxa at both study sites rapidly returned to pre-event levels.

The Middle Eocene Transgression on the southern European Shelf (Adelholzen Beds, Eastern Alps, Bavaria)

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The shallow water sedimentary record of the Helvetic shelf of the southern European Plate (northwestern Tethyan margin) is punctuated by a number of stratigraphic gaps, which become more pronounced northwards, in direction to the continent. In the North-Helvetic realm, Paleocene deposits are absent because there the Middle Eocene (Adelholzen beds) rests with an erosional unconformity on the Upper Cretaceous. The Wimmern section near Teisendorf (Bavaria) is the only known outcrop where this transgressional contact is exposed. There, dark grey claystone of the Gerhardtsreith Formation (Maastrichtian) is overlain by 4 m thick glauconite rich sand of the lower Adelholzen beds. Poorly preserved calcareous nannoplankton assemblages from the basal 50 cm of the sand contain *Chiasmolithus grandis*, *Chiasmolithus solitus*, *Cyclicargolithus floridanus*, *Nannotetrina cristata*, and *Sphenolithus spiniger*, indicating calcareous nannoplankton Sub-Zone NP14b.

The poor preserved planktonic foraminifera assemblage from the glauconitic sand at the base of the section yields *Acarinina coalingensis*, *A. esnehensis*, *A. interposita*, *Igorina broedermanni*, and *Pseudohastigerina wilcoxensis*. Fifty centimetres above the transgression *Acarinina bullbrooki*, *A. cuneicamerata*, and *Pseudohastigerina micra* have their first occurrences. The assemblage suggests an assignment to planktonic foraminiferal Zone E7 in the zonation scheme of Wade et al. (2011).

Three samples from the Adelholzen beds were processed for palynology and contained abundant organic-walled dinoflagellate cysts (dinocysts), and few terrestrial palynomorphs (pollen and spores). Dinocyst assemblages were dominated by near-shore, lagoonal species, such as *Cleistosphaeridium* and *Homotryblium*, but also species characteristic for transgressive facies such as *Glaphyrocysta* and *Areoligera*. Age-diagnostic species include *Areoligera sentosa* and *A. tauloma*, *Areosphaeridium diktyoplokus* and *Achilleodinium biformoides*, the co-occurence of which suggests a Lutetian age for the sequence (based on correlation to Southern England (Eaton 1976).

The age of the transgression of the Adelholzen beds (which is called Bürgen Formation in Switzerland) is equivalent to the age of the transgression of the Lutetian at the Lutetian stratotype (St. Leu d´Esserent in the Paris Basin) where Aubry (1991) attributed the base of the type Lutetian to calcareous nannoplankton Subzone NP14b.

References:

Aubry, M.-P., 1991. Sequence stratigraphy: Eustasy or tectonic imprint?: Journal of Geophysical Research, v. 96, p. 6641-6679.

Eaton, G. L., 1976. "Dinoflagellate cysts from the Bracklesham Beds (Eocene) of the Isle of Wight, Southern England." Bulletin of the British Museum (National History) geology 26: 227-332.

Wade, B. S. et al., 2010. Review and revision of Cenozoic tropical planktonic foraminiferal biostratigraphy and calibration to the geomagnetic polarity and astronomical time scale. Earth-Science Reviews, doi: 10.1016/j.earscirev.2010.09.003

Seasonally-resolved Eocene surface ocean temperatures from large benthic foraminifera – implications for a tropical thermostat

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The existence of a tropical thermostat – one or more physical processes regulating tropical surface ocean temperatures – is a hypothesis without current consensus. The Eocene provides a good thermostat test case because global mean temperature was higher relative to today. Recent arguments against a thermostat based on computer models and the tetraether index (TEX_{86}) proxy appear to be at odds with most 'traditional' proxy evidence suggesting tropical sea surface temperatures (SST) only slightly higher than present. We have extended the Mg/Ca temperature proxy to the large benthic foraminifera (LBF) family Nummulitidae in order to provide evidence independent of previous methods. Our results – calibrated using recent samples – suggest that Eocene tropical surface ocean temperatures were in fact only slightly higher compared to present day. We chose LBF over their more routinely studied planktic relatives because LBF are longer lived, enabling the reconstruction of seasonally-resolved temperature profiles. This is important given that it is now becoming apparent that seasonality is a key component of climate change *[1]* and therefore an understanding of both mean annual temperature and the seasonal temperature range of relevant palaeoclimates is crucial.

We present seasonally-resolved temperature profiles of Eocene *Nummulites* measured by laser-ablation inductively-coupled-plasma mass-spectrometry (LA-ICPMS). Analysis using the laser-ablation facility at RHUL *[2]* enables simultaneous multi-element measurement, essential for the identification of µm-scale diagenesis that appears to affect even exceptionally-well preserved samples. Eocene samples were collected from Nanggulan, Central Java (with a low palaeolatitude) and the Hampshire Basin, UK (with a mid-palaeolatitude). Reconstructed low-latitude temperatures from Nanggulan suggest that the Eocene tropical Pacific was only slightly warmer than today (28.6 ± 1.1°C) with a seasonal temperature variation of 4.0 ± 0.7°C. We use this evidence to infer that a tropical thermostat does exist. Preliminary comparative analysis of samples from higher-palaeolatitudes suggests significantly higher temperatures in comparison to equivalent present day locations, confirming other recent high latitude proxy work *[3]*. This demonstrates that reduced oceanic latitudinal temperature gradients were also a feature of globally warmer periods.

References:
[1] Eldrett *et al.* (2009) *Nature* **459**, 969-74.
[2] Muller *et al*. (2009) *JAAS* **24,** 209-214.
[3] Eberle *et al.* (2010) *EPSL* **296,** 481-6.

Eocene fossil woods from South China and their paleoclimatic implication

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Two new Eocene dicotyledonous wood species, *Paraphyllanthoxylon hainnaensis* sp. nov. and *Paraphyllanthoxylon maomingensis* sp. nov. are described from Changchang Basin and Maoming Basin, South China respectively. The genus *Paraphyllanthoxylon* was first established by Bailey (1924) to describe angiosperm fossil woods from the Upper Cretaceous of Arizona, USA. Bailey selected *Paraphyllanthoxylon* as the genus name to indicate its affinity to genera *Bridelia* and *Phyllanthus* of the section Phyllanthoideae of Euphorbiaceae. Bailey's diagnosis of this genus included a distinct combination of anatomical characters: indistinct well-defined growth rings, diffuse-porous wood, solitary or radially grouped vessels, simple perforation plates, abundant tyloses, septate fibers, and heterocellular multiseriate rays. As the two types of fossil woods under study show the complete suite of those diagnostic characters, they are assigned to *Paraphyllanthoxylon.* Nevertheless, they are similar but not identical to any *Paraphyllanthoxylon* species described previously and hence, two new species are established. Not only does this discovery provide important fossil evidence for research on the phytogeographic history of this genus, but also contributes to our scant knowledge of Palaeogene wood in China.

Great similarity exists between *P. hainanensis* and the woods of some genera in the *Glochidion* group of the Euphorbiaceae, subfamily Phyllanthoideae, such as subtribe *Flueggeinae*, *Antidesma*, *Bischofia*, *Bridelia*, *Hymenocardia*, *Neowawrea*, *Spondiathus*, and *Uapaca*. *P. hainanensis* also resembles Neogene wood *Bischofia.javanice* discovered in Hubei, China and Neogene wood *Bischofia palaeojavanica* collected in India. Extant *Bischofia* species are universally distributed in South and South-East Asia, Australia and Polynesia. They exist mainly in South-West, Central, East and West of China as well as Hainan Island. The species of *Bischofia*, the main species of tropical and sub-tropical evergreen rainforest, grow in humid gully of low latitude mountain and sapling is hydrophytic with good shade tolerance. *P. hainanensis* was collected in the coal-bearing series of the Changchang Formation, in which abundant aquatic plants such as *Nelumbo* and *Salvinia natans* L. are also discovered. Thereby, we deduce that the climate of Changchang Basin is warm and humid during Eocene and the Euphorbiaceae trees grow in the lowland rain forest near lake basin.

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Marine diatoms in the Paleocene of the SW – Pacific

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Quantitative analysis of the acid-insoluble residue of the late Paleocene sediments of ODP Site 1121B, located at the foot of the Campbell Plateau in the SW-Pacific, reveals a 30 m long interval, in which siliceous microfossils are relatively well preserved.

Correlation with results from analysis of the stable carbon- and oxygen isotopes from the same site shows that this abundance maximum in siliceous microfossils and the interval, in which they are best preserved, coincides with the late Paleocene productivity maximum.

Taxonomic analysis of the diatoms suggests dominance a) of species indicating high productivity and b) of heavily silicified neritic species, but an absence of freshwater species and benthic species. The abundance of neritic species in these deep sea sediments makes it highly probable that west-wind driven currents across a broad shelf on Campbell Plateau displaced these diatoms into the depo-center at the eastern foot of the plateau.

The implications of these findings are discussed.

Characterization of Paleocene-Eocene Fluvial Deposition in the Piceance Creek Basin of western Colorado, USA

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More than 175 fluvial sand-bodes from the Wasatch Formation exposed across a broad (40 x 30 km) area of west-central Colorado, near the town of DeBeque, demonstrate secular changes in sand-body thickness and lateral extent, alluvial architecture, paleo-flow depths, prevalence of different lithofacies, and paleodrainage characteristics spanning the Paleocene-Eocene boundary. The formation is traditionally divided into three distinct members based upon the relative abundance (%) of fluvial sandstones versus floodplain deposits. The lowermost Atwell Gulch Member is dominated brown, gray, purple, and red mudstones and carbonaceous shales with relatively few, thin fluvial sandstones (~25%). In contrast, the overlying Molina Member is dominated by thick, laterally-extensive fluvial sandstones (~60%), and fine-grained facies that are dominated by gray and purple siltstones and mudstones. In the Shire Member fine-grained facies again become dominant, though pink and red in coloration, and fluvial sandstones are thinner and more laterally restricted (<10%). Ages of the three members are constrained by mammalian and plant fossils, which indicate a mid-Tiffanian (late Paleocene) through late Wasatchian (early Eocene) age for the formation. To date, no fossils have been found in the Molina Member for pinpointing its age, though preliminary carbon isotopic results from this study and others suggest the P-E boundary exists near its base.

Field measurements indicate that average sand-body thickness doubles between the Atwell Gulch and Molina Members from 3.4 m to 6.9 m, and decreases to 5.4 m in the Shire Member. Many Molina sand-bodies are laterally continuous (>1.5 km), whereas Atwell Gulch and Shire bodies range from 1.5 m to 182.0 m in width (average of ~30 m). In many cases Molina Member sand-bodies are clearly amalgamations of sand-bodies of slightly larger dimensions (3.0 m thicker and 10.0 m wider) to those observed in the Atwell Gulch and Shire members. Flow depths, taken from the relief along bar clinoforms and mud-plug thicknesses, are 50% greater and display twice the range in the Molina Member as compared to the other members. In addition, 100% of Molina sand-bodies were underlain by intervals of crevasse splay deposits, whereas only ~5% of Atwell Gulch and ~12% of Shire sand-bodies rest upon splay sequences. The Atwell Gulch and Shire sand-bodies are also commonly associated with well-developed levee deposits, which are absent among Molina sand-bodies. Furthermore, Molina sand-bodies are dominated by subhorizontal planar bedding (occasionally with mudcracks on parting planes), soft-sediment deformation, and minor amounts of small-scale trough cross-bedding. In contrast, Atwell Gulch and Shire sand-bodies are dominated by small- and large-scale trough cross-bedding and ripple laminations; planar bedding is rare. Paleocurrent directions show no significant variation among the three members and show a consistent drainage to the northwest (~345°).

These patterns indicate a transitory shift in river behavior and floodplain dynamics in the study area, potentially related to climate change associated with the Paleocene-Eocene Thermal Maximum. Upper flow regime sedimentary structures and more variable flow depths suggest greater seasonality of precipitation and peaked hydrograph during Molina Member deposition. The alternation between well-developed levee deposits and prevalence of crevasse splay deposits indicates weakened banks and more frequent flooding, and the more highly amalgamated and thicker nature of sand-bodies suggests a higher avulsion rate during Molina deposition. Overall these patterns are consistent with increased seasonality of precipitation and aridity in the mid-latitudes during the PETM hypothesized by previous studies.

Tropical climate, ecology and hydrology during the Paleocene-Eocene Thermal Maximum

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The Paleocene-Eocene Thermal Maximum (PETM) plays a key role in the paleoclimate research, as it represents an imperfect analogue to future warming. The PETM was a geologically brief (~170 kyr) episode of extreme global warming. A pronounced negative carbon isotope excursion (CIE) in sedimentary components and deep sea carbonate dissolution reflect massive and rapid carbon input at that time. Documentation of this period is extensive for the high and mid latitudes, but the tropics remain virtually untouched. However, for the full understanding of PETM climates the tropical end member needs to be quantified in terms of temperature and hydrology. We have studied an Upper Paleocene – Lower Eocene shelf section from Nigeria deposited at equatorial latitudes. Carbon isotope analysis and palynological analysis in the form of dinoflagellate cyst assemblages have been conducted and biomarker analysis has been started. Carbon isotope analysis on total organic carbon (TOC) revealed an excursion of ~-6‰. Dinoflagellate cyst biostratigraphy confirms that this CIE represents the PETM. Shifts in species composition in the preliminary dinocyst assemblage data set are interpreted in terms of temperature, salinity, sea level, eutrophication and stratification. Representatives of the dinocyst genus *Apectodinium* are present throughout the section and abundant before the CIE. However, during the CIE this genus is surprisingly absent, while it dominates all other PETM assemblages studied so far. Its absence may be due to extreme fresh water input or extreme tropical temperatures. Finally, we will present preliminary organic biomarker analysis, including TEX_{86} paleothermometry.

Dissolved Oxygen across the Paleocene/Eocene Boundary at the Paleocene/Eocene global standard Stratotype-Section and Point

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Dissolved oxygen at the Paleocene/Eocene Global Standard Stratotype-section and Point, Luxor, Egypt are calculated based on quantitative analysis of the recorded calcareous benthic foraminiferal dysoxic, suboxic, and oxic indicators, in order to investigate the cause of the benthic foraminiferal turnover and extinction across the Paleocene/Eocene Thermal Maximum (PETM) interval. The studied interval comprises the El-Hanadi, Dababiya Quarry (DQBs 1–5), and the El Mahmiya Members of the Esna Formation. Ninety two calcareous benthic foraminiferal species (2 porcellaneous and 90 hyaline) are identified and classified into 46 genera (31 infaunal and 15 epifaunal microhabitats), 24 families, 15 superfamilies and 3 suborders. These 92 species are found within the size fractions 63 – 500 µm and concentrated within the size fractions 63 – 350 µm (High rate of calcium carbonate dissolution).

Taxonomic and quantitative analyses of the recorded calcareous benthic foraminifers reflect stressful environmental conditions at the seafloor across the DQBs, which are characterized by: 1) Low oxic condition (1.5009 ml/l O_2) at the uppermost 7 cm of the El-Hanadi Member, which is decreased upward into anoxic condition (0.0 ml/l O_2: Dissolved Oxygen Excursion Event) within DQB 1. These conditions may be caused by gradually increasing in temperature, which terminated within DQB 1 (PETM: > 50ºC) and in salinity (up to > 50‰: high rate of calcium carbonate dissolution), and by breathing of bacteria during decomposition of organic matter (DQB 1 is rich in organic matter). Accordingly, benthic foraminiferal species of relatively shorter oxygen, temperature, and salinity ranges of tolerance for survival were gradually move out or die and replaced by species of relatively longer oxygen, temperature, and salinity ranges of tolerance for survival until completely disappear within DQB 1 (Benthic Foraminiferal Extinction Bioevent). And 2) Dysoxic condition (0.0592 ml/l O_2) at the base of DQB 2, which increasing upward into suboxic condition within the DQB 5 (0.7180 – 0.9174 ml/l O_2) and at the basal part of the El Mahmiya Member (1.0918 ml/l O_2). These conditions may be caused by gradual decreasing upward of temperature and salinity and by aquatic plant and algae photosynthesis.

Paleocene-Eocene Thermal Maximum consequences on terrestrial environments. Insights from the evolution of organic matter in the Vasterival section (Dieppe-Hampshire Basin, France)

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The Paleocene-Eocene Thermal Maximum (PETM, 55.8 Ma, Aubry et al, 2007) is regarded as one of the most rapid global warming of the Cenozoic era, with temperature increase of 4 – 8°C in about 10 – 20 ka. Thus, it is often proposed as a potential analogue of future climatic conditions expected in the screenplays provided by the International Panel on Climate Change (IPCC). The PETM is recorded in both marine and continental deposits by an abrupt negative Carbon Isotope Excursion (CIE) associated with other sedimentary and biological anomalies. The consequences of the PETM in terrestrial environments are less documented than in marine ones. This limits our regional- and global-scale understanding of the impact of such a climate change on continents and the ecosystems response.

This study focuses on the Vasterival section (Seine-Maritime, Upper Normandy) located in the southern part of the Dieppe-Hampshire Basin, in which the PETM is recorded in the organic matter (OM) by the negative shift in $\delta^{13}C_{org}$ of the CIE, and confirmed by the stratigraphic record in this locality belonging to the Cap d'Ailly composite section (Dupuis et al., 1998). The 2 m thick section, which presents a notably well preserved OM, is mainly constituted by terrestrial sediments from lacustrine to coastal swamp environments and in which OM-poor clays are followed by OM-rich clays, centimetric lignite beds and clays with roots evidences. The uppermost part of the section is constituted by 50 cm thick lagoonal clay with shell debris that records the *Apectodinium* acme.

Global organic geochemical, palynofacies and isotopic analyses were performed on thirty samples. The total organic carbon of this section is ranging from 0.5% for OM-poor-clays to 45% for lignite levels. Lipid biomarkers extracted from twenty five samples were quantified and their hydrogen and carbon isotopic composition were determined by GC-irMS. Important changes in palynofacies, biomarker assemblages and compound-specific isotopic data are coincident with the CIE onset interval. This is consistent with an important environmental modification in the Vasterival area during the Early Eocene that could be linked to the PETM climatic change.

The Cretaceous-Paleogene boundary in turbiditic deposits of the Skole Nappe, Polish Carpathians

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In the turbiditic sequences of the deep Alpine basins, the K-T boundary is very difficult to identification due to the rare occurrence of index planktonic foraminiferids and strong redeposition causing the occurrence of mixed foraminiferal assemblages. Only in a few cases, the identification was narrowed to some relatively thin intervals. The boundary occurs within about a metre thick interval in the Magura Unit in Moravia, Czech Republic, based on dinocyst assemblages (Bubík et al. 2002). In the Romanian Carpathians, it was identified within tens of meters by means of the calcareous nannoplankton and foraminiferids (Melinte 1999; Chira et al. 2009). Recent studies of the Ropianka Formation in the Skole Unit (Husów area, Bąkowiec section) of Polish Carpathians (Gasiński & Uchman, *in review*), based on 58 samples, allowed recognition the Gansserina gansseri and Abathomphalus mayaroenesis standard biozones. Also the intermediate Racemiguembelina fructicosa Zone is distinguished. Moreover, the appearance of Paleocene foraminiferids *Subbotina cancellata* Blow, *Subbotina triangularis* (White), *Eoglobigerina* cf. *edita* (Subbotina) point to the earliest Paleocene zone (P1 Zone sensu Olsson et al. 1999). The latest Maastrichtian (*A. mayaroensis*) and the lowest Paleocene foraminifers occur within a 15 cm thick interval limited to the top of one depositional turbiditic-hemipelagic rhythm and the lower part of the next one. Thus, this is the most precisely determined K-T boundary in turbiditic sediments in the Carpathians. A rapid decrease in abundance and diversity of planktonic foraminifers in noted above the boundary. Qualitative analysis of the studied foraminiferal assemblages has been performed. The correlation of quantitative charts of composition of foraminiferal assemblages between the studied samples and those collected from the Gaj section (next thrust sheet Ropianka Formation, Skole Unit; Gasiński & Uchman, 2009) points to their close similarity, especially in the part dated as the latest Maastrichtian. This suggests that the similar factors influenced boundary section environment in this part of the Skole Basin.

Conclusions: 1. The K-T boundary was identified in the turbiditic sediments with the accuracy of 15 cm for the first time. 2. The Gansserina gansseri, Abathomphalus mayaroensis (Late Maastrichtian) and P1 (Early Paleocene) standard biozones were recognized in the studied section on the basis of planktonic foraminiferids. 3. The Racemiguembelina fructicosa Zone as the Partial Range Zone within the lower part of A. mayaroensis Zone has been determined for the first time in the Carpathians and the flysch sediments. 4. Qualitative and quantitative significant fluctuations among the studied foraminiferal assemblages were recognized around the K-T boundary similarly to those indicated in the Gaj section (Skole Nappe, next thrust sheet).

References:
Bubík et al. 2002. *Geol. výzkumy na Moravě a ve Slezsku v roce 2001*, 18-22.
Chira et al. 2009. *Berichte Geol. Bundestanst.* 78, 8.
Gasiński M.A. & Uchman A. 2009.*Geol. Carpathica* 60, 4, 283-294.
Melinte M.C. 1999. *Acta Paleont. Romaniae* **2**, 269–273.
Olsson et al. 1999. *Smithsonian Contr. Paleobiol.* 85, 1-252.

Diagenetic nature of Ir-anomalies: an alternative of impact hypothesis?

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At the different stratigraphic intervals of Phanerozoic sedimentary record of many areas, there are levels enriched by chemical elements, specifically iridium. The most interesting and intricate problem is the occurrence of Ir-anomaly at the K/T boundary. As it is widely known, this and Ir-anomalies at some other stratigraphic levels are mostly considered as a result of meteorite impact. Difficulty of its nature revelation is caused by low iridium concentrations in both embedded sediments and Ir-rich layer. We consider here possible causes of the formation of geochemical anomalies by the example of more large-scale processes where maturation of Ir-anomalies is a particular case.

In the Phanerozoic sedimentary record, there are prominent boundaries between TOC-rich sediments, most commonly clayey, and sediments lack in TOC, mainly sandstones, limestones, cherty rocks. In many cases, sulfide-rich beds correspond to these interfaces. Their thickness ranges from few cm to few dm and spatial extension reaches up to many tens or even hundreds km. Initially, sulfides in form of hydrotroilite $FeS{\cdot}nH_2O$, as well as Fe^{2+} and H_2S occurred in the strongly reduced conditions of TOC-rich clayey sediments. Later, they could penetrate into the near-contact zone under the influence of different factors (diffusion, transfer by interstitial water as a result of sediment compaction, gravitational, and electrochemical effects) where they precipitated forming a bed rich in disulfides (pyrite, a.o.). The cause of monosulfide to disulfide transformation is the higher oxygenation level of sulfur from pyrite than of sulfur from hydrotroilite. In other words, oxidizing agent, specifically oxygen, should be involved into the process of pyrite generation. That is why capable to migration jellous hydrotroilite turned into stable pyrite at the oxygen-bearing contact zone. Different elements including platinoids could be concentrated within formed by such a way sulfide-bearing beds.

A spectrum of conditions (Eh, pH, a.o.), which could promote migration of sulfides from reduced sediments and their precipitation at the geochemically contrasting boundaries, is rather wide. This process can occur at relatively low sediment enrichment in TOC. In this case, concentration of sulfides at the interface boundary is low also. Nevertheless, thin layers rich in a number of elements including iridium can be formed following this scenario.

This suggested mechanism of Ir-anomalies formation as a result of diagenetic processes allows the explanation of some their peculiarities which are inexplicable by impact hypothesis. I suggest that diagenetic sulfide migration and formation of geochemical anomalies of different scale are widely distributed at many stratigraphic levels, specifically, at the K/T boundary.

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Changing paleo-environments of the Lutetian to Priabonian beds of Adelholzen (Helvetic Unit, Bavaria, Germany)

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The Adelholzen Section is located southwest of Siegsdorf in southern Bavaria, Germany. The section covers almost the entire Lutetian and ranges into the Priabonian. It is part of the Helvetic (tectonic) Unit and represents the sedimentary processes that took place on the southern shelf to upper bathyal of the European platform at that time. Six lithologic units occur in the Adelholzen-Section: 1) marly, glauconitic sands with predominantly *Assilina,* 2) marly bioclastic sands with predominantly *Nummulites*, 3) glauconitic sands, 4) marls with *Discocyclina*, 5) marly brown sand. These units were combined as “Adelholzener Schichten” and can be allocated to the Kressenberg Formation. For the sixth unit, Stockletten, no formal name has been established. The total thickness of all units exposed is about 18 m.

The Adelholzen-Section is rich in planktic and benthic foraminifera. Planktic foraminifera form up to 80% of the total foraminiferal assemblages in the Stockletten, but also the basal nummulitic marls contain about 20% of planktic species. The ratio of planktic to benthic foraminifera is considered to be a good estimator also for paleo-water depth estimations at least during the Cenozoic. The percentage of planktic foraminifera in the assemblages points to depth ranges from 50 m (inner shelf) at the base of the section to a maximum of c. 600 m (upper bathyal) in the Stockletten. Nummulitids and macrofossil assemblages (oysters, spondylids, sea urchins, serpulids, crabs, bryozoans, shark teeth) however point to shallower paleo-water depths, in particular for the basal and middle lithologic units. The succession shows two distinct increases in paleo-water depth (transgressive phases): a first step at the beginning of the *Discocyclina*-marl sedimentation and a second, more pronounced step at the base of the Stockletten.

The number of heterotrophic planktic and benthic foraminifera is largely coupled to primary surface productivity as these groups either feed directly on diatoms, coccolithophores or other algae (planktic foraminifera) or depend on the organic rain that reaches the seafloor (benthic foraminifera). Foraminiferal abundance is therefore a good estimator for paleo-productivity of ancient eco-systems. The rather parallel curves for planktic and benthic foraminiferal abundance are both pointing to at least two transgressive phases that resulted in increased nutrient mobilization and subsequent increased numbers of foraminifera. The second one coincides with the Mid-Eocene Climatic Optimum. The benthic foraminiferal assemblages are dominated by rather large planoconvex or lenticular species (*Cibicidoides, Gavelinella, Lenticulina* etc.), pointing to oxic conditions at the seafloor.

All samples from the section contain very rich calcareous nannoplankton with the dominance of small reticulofenestrids, *Reticulofenestra dictyoda* and *Cyclicargolithus floridanus.* Small reticulofenestrids generally dominate nannoplankton assemblages along continental margin. High amounts of *Reticulofenestra minuta* can be interpreted as indicator of warm, well stratified water column. Low percentages of *Coccolithus pelagicus* point to oligotrophic paleo-environments and is in good agreement with the foraminiferal interpretations.

Scaled marine plankton disruption through early Paleogene transient global warming events

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The Paleocene-Eocene Thermal Maximum (PETM, ~56 Ma) is global warming event associated with the injection of carbon into the ocean-atmosphere system, with analogies to current anthropogenic climate change. However, the PETM was not a singular event, but rather the most extreme of a series of inferred transient warming events in the Paleogene known as ‘hyperthermals’. These events provide enormous potential for testing for biotic response across a range of carbon cycle perturbations that are relatively closely spaced in time. We present and apply a novel metric to quantify the marine biotic disruption associated with the PETM and several smaller hyperthermal events including Eocene Thermal Maximum 2 (ETM2), H2, I1 and I2. Summed standard deviation analysis of calcareous nannoplankton records show a linear relationship between assemblage variability and magnitude of the carbon isotopic excursions (CIEs) that mark the hyperthermals. CIEs smaller than the PETM, ETM2 and I1 show no significant biotic variance implying an environmental threshold equivalent to approximately 2°C warming for this particular biotic response in the Eocene. Our analysis also provides comparable results from the foraminifera and dinoflagellate data, demonstrating the enormous potential this approach has for enabling fully integrated biotic comparisons, even between biologically unrelated groups.

Projection stratigraphy of the upper Eocene Gehannam, Birket Qarun, and Qasr el-Sagha formations and their fossil whales at the Wadi Al Hitan World Heritage Site, western Fayum Province (Egypt)

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Wadi Al Hitan or 'Valley of Whales' is a 17 x 17 km UNESCO World Heritage Site in the Western Desert of Egypt. It has a thick sequence of middle and late Eocene shallow marine strata overlain by continental lower Oligocene beds. The marine strata are richly fossiliferous, with more than a thousand skeletons and partial skeletons of fossil whales, sea cows, and other vertebrates mapped to date. Some are exceptionally complete and well preserved. All accumulated in or near the Tethys Sea on a passively subsiding African continental margin. The Gehannam Formation is glauconite-rich with fine-grained carbonate-cemented sandstones at the top. The Birket Qarun and Qasr el-Sagha formations are complexes of fine-grained sandstones, siltstones, and mudstones, with sandy shell beds marking the tops of parasequence in the latter.

The onshore-offshore geometry of Wadi Al Hitan strata is complicated, and lithologies are repeated, making visual correlation unreliable. We are improving the sea level sequence interpretation of Gingerich (1992) by 3D GPS mapping of formation boundaries and key marker beds. Bed traces can then be projected down-dip and/or along-strike to show onlap-offlap geometry. Two macroscale 'deltas' of incised valley fill (IVF) emerge clearly in down-dip projection (Fig. 1). These include numerous transported land-mammal specimens, indicating a fluvial origin. The incised valleys correspond to 3rd-order sequence boundaries Pr-2 and Pr-3 (Peters et al., 2009, 2010; we disavow claims to the contrary by lead authors of Underwood et al., 2011, based on their brief visits to relevant sites). Our study complements Abdel-Fattah et al. (2010) by connecting the lower and upper parts of the sections they studied, but sequence boundary Pr-2 clearly belongs in the lower Qasr el-Sagha Formation in a part of the section not studied by Abdel-Fattah and co-authors.

The lower Gehannam, upper Gehannam through lower Qasr el-Sagha, and upper Qasr el-Sagha formations each have a distinctive archaeocete whale fauna, with *Dorudon atrox* (Uhen, 2004) and *Basilosaurus isis* from the Birket Qarun Formation being the best studied.

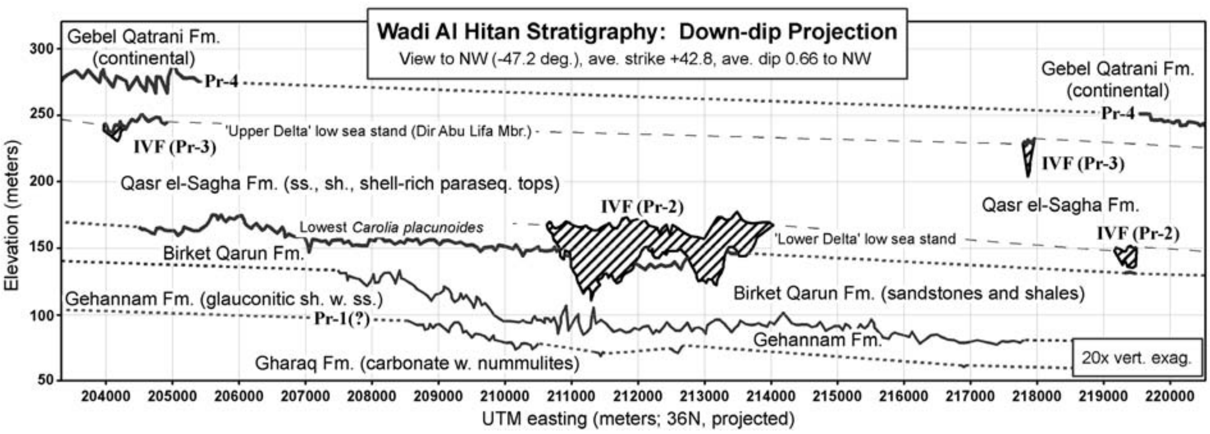

Figure 1. Projection stratigraphy of Wadi Al-Hitan, here projected down the computed dip. Panel shown is 17 km wide and ca. 250 m high (vertical exaggeration x20). Note that there are two intervals with incised valley fill deposits (IVF; hatched), that represent sequence boundaries Priabonian Pr-2 and Pr-3. The position of Pr-1 is at or near the base of the Gehannam Formation. Pr-4 is on top of the 'Bare Limestone' (carbonate-cemented sandstone) capping the Qasr el-Sagha Formation.

First data on the Eocene diatoms from the marine Paleogene stratigraphic key section of northeast Kamchatka, Russia

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The stratigraphic section on the Il'pinsky Peninsula, northeast Kamchatka, is a unique key section for the marine Paleogene with a practically continuous sequence composed of a 2500 m thick Paleocene through Oligocene sediments. It is one of the northernmost known places in the Pacific region where planktic foraminifera and nannofossils of Paleocene and Eocene have been documented and studied from different stratigraphic levels. The assemblages of calcareous microfossils correlative with their analogues from standard Paleogene zones have been used to subdivide the sedimentary succession and determine age of stratigraphic units. However, until recently the section has been considered to be barren of marine diatoms.

Additional sampling for diatom analysis was done during recent field work at the Il'pinskii Peninsula. A number of samples collected throughout the section yield fossil marine diatoms. Study of their assemblages allowed distinguishing the "beds with diatoms" for different stratigraphic intervals of the Oligocene and infers their age (Gladenkov, 2008, 2009). Furthermore, diatoms are also documented from the older than the Oligocene part of the section. These diatom-bearing sediments are determined at the uppermost part of the Kylanskaya Formation having the Eocene age. *Stephanopyxis grunowii*, Genus et sp. indet., *Pyxilla gracilis*, *Hemiaulus* sp., *Triceratium* (*Lisitzinia*) *inconspicuum*, *Riedelia borealis*, *Coscinodiscus decrescens*, *Azpeitia* cf. *tuberculata* var. *atlantica*, *Goniothecium rogersii*, *Arachnoidiscus ehrenbergii*, *Stictodiscus kittonianus*, *Distephanosira architecturalis* are typical of the marine diatom assemblage studied from this stratigraphic level. The Eocene assemblages of nannofossils and planktic foraminifera (correlative with the zones P10 to P12 of standard Paleogene scale) documented from this part of section have an age within the Lutetian Stage. Thus, it indicates the middle Eocene (Lutetian) age of diatom flora. These are the first finds of the Eocene diatoms in the Northwest Pacific region having such correlation with assemblages of carbonate plankton.

The obtained data is quite important for an elaboration of detailed biostratigraphic subdivisions based on siliceous microfossils because finds of the Eocene diatoms are very rare the in Northwest Pacific and known only from few localities lacking direct correlation with carbonate plankton or magnetostratigraphic record.

References:

Gladenkov, A.Yu. (2008). The North Pacific advanced Oligocene to lower Miocene diatom stratigraphy. *Bull. Geol. Surv. Japan* 59: 309-318.
Gladenkov, A.Yu. (2009). Fossil diatom flora from the marine Paleogene stratigraphic key section of northeast Kamchatka, Russia. *Acta Botanica Croatica* 68: 199-209.

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New data on the upper Paleocene - lower Eocene stratigraphy of West Kamchatka region, the North Pacific

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In West Kamchatka there are some excellent sequences of marine Paleogene and Neogene, which were described many times in literature. However up to recently the important part of the Paleogene, i.e., upper Paleocene – lower Eocene, remained unstudied. Deposits of this age are missing in the region because of tectogenesis. Lately V.I. Volobueva discovered them in northwestern Kamchatka and referred them to the Unel and Ommai formations (sandstones, siltstones, up to 3000 m thick). Previously, in the 1950s, these formations were considered as the upper Eocene and Oligocene.

V.I. Volobueva passed her paleontological materials to the Geological Institute of Russian Academy of Sciences in Moscow. Their examination yielded the following results. In the sequences 7 local beds with mollusks (more than 70 identified species), 6 beds with benthic foraminifers, and 8 levels with planktonic foraminifers were established. Mollusks were studied by V.N. Sinelnikova and the author and foraminifers by V.N. Benyamovsky and N.A. Fregatova. The benthic assemblages show a great similarity with (appeared to be very similar to) the Zelandian-Thanetian and Ypresian associations of adjacent regions (including California). In particular, 50 – 57% of molluscan species are identical with the California forms. They are mostly warm-water species (“moderate” or “paratropical” forms). The planktonic foraminifers discovered only in the Ommai Formation clearly indicate its Ypresian (*Acarinina*, *Morozovella*, *Subbotina* and others) and possibly early Lutetian (*Turborotalia* and others) ages. The Ypresian planktonic foraminifers have been found in West Kamchatka for the first time. At this time interval there was no connection between the Pacific and Arctic basins (the first opening of the Bering Strait took place only in the latest Miocene - early Pliocene). Shelf basins of the Asiatic and American provinces of the North Pacific were intimately related and characterized by similar relatively warm-water conditions. Biota of the basins was not “boreal” from the present-day standpoint.

The formation of the marine Thanetian and Ypresian sequences in northwestern Kamchatka was due to the appearance of a basin connected by straits with the North Pacific water areas. Thus, in Kamchatka the molluscan and foraminiferal assemblages that mark the most significant warming event of the Cenozoic (Thanetian-Ypresian) have been identified for the first time. This makes us to introduce some corrections into the regional Paleogene stratigraphic schemes and paleogeographic reconstructions for Kamchatka.

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Organic walled dinoflagellate cysts from the Tarim Basin, western China: Implications for the retreat of the Paratethys Sea.

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Paleogene sediments of the Tarim basin in western China hold the easternmost extent of the Paratethys Sea, an epicontinental sea that covered a large part of Eurasia and probably extended to the Mediterranean Tethys in the west. The late Cretaceous and Paleogene sedimentary record of the Tarim basin is characterized by several trans- and regressions before the sea finally retreated.
The final regression has been suggested to be associated with the Indo-Asia collision and with eustatic sea level fall during the initiation of Antarctic glaciation at the Eocene-Oligocene transition (EOT, ~34 million years ago). However, the timing, cause and consequences of Paratethys Sea retreat are largely unknown.

In 2010, a field campaign to the Tarim Basin was organized during which five sections were sampled, from west to east respectively: Mine, Kansu, Kezi, Aertashi & Keliyang. We investigated the organic walled remains of surface dwelling dinoflagellates (dinocysts), that allow for biostratigraphic correlation between the sections and distant locations elsewhere. In addition, ensuing paleomagnetic studies, aid towards constraining the timing of these sea-level cycles. Furthermore, dinocyst assemblages sensitively record environmental change, this provides the opportunity to reconstruct the paleo-environment in the Tarim Basin and to elucidate on the magnitude of sea-level variation.

The response of foraminifera to modern seawater acidification: A real-time proxy for Paleogene hypothermal events

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The seas around the island of Ischia (Italy) have a variable and, on average, lowered pH as a result of volcanic gas vents that emit carbon dioxide from the sea floor at ambient seawater temperatures. These areas of acidified seawater provide natural laboratories in which to study the long-term biological response to rising CO_2 levels. Benthic foraminifera are routinely used to interpret the effects of climate change as they have short life histories, are environmentally sensitive and have an excellent fossil record. Here, we examined changes in foraminiferal assemblages along gradients in pH at CO_2 vents on the coast of Ischia as they may provide a useful model on which to base future predictions of the consequences of ocean acidification (Dias *et al*., 2010). We show that foraminiferal abundance, diversity and ability to calcify decreased markedly in living and dead assemblages as pH decreases, the result of CO_2 percolating through the seawater. Recent work by de Nooijer *et al*. (2009) has shown that foraminifera increase their internal pH to ~9.0 in the area of chamber calcification. If the ambient pH in the enclosing seawater is reduced to 7.8 (or below) the foraminifera with calcareous tests appear to be unable to complete the test construction process. These results are in accord with the responses recorded by coralline algae, corals, molluscs, barnacles and echinoderms at the same sites (Hall-Spencer *et al*., 2008).

Samples from the normal (pH8.17) environments around Ischia contain a diverse fauna dominated by miliolid foraminifera (e.g., *Peneroplis planatus*, *P. pertusus*, *Quinqueloculina* spp.) while those from areas with reduced pH (7.8 to 7.6) have faunas that are progressively less diverse and composed of <100% agglutinated taxa (e.g., *Ammoglobigerina globigeriniformis*, *Miliammina fusca*, *Trochammina inflata*, *Textularia* sp. cf. *T. bocki*). The changes in the benthic foraminifera are quite dramatic for only a slight reduction in pH and confirm the possibility that events, such as the PETM, could quite easily record a widespread loss of diversity or extinction as a result of ocean acidification.

Work on Ischia is on-going and there is a comparable site being investigated in the Gulf of California. A site on the south-east coast of the island of Vulcano (Mediterranean Sea) is also being considered.

References:

Dias, B.D., Hart, M.B., Smart, C.W. & Hall-Spencer, J.M. 2010. Modern seawater acidification: the response of foraminifera to high-CO_2 conditions in the Mediterranean Sea. *Journal of the Geological Society, London*, **167**, 843-846.

Hall-Spencer, J.M., Rodolfo-Metalpa, R., Martin, S. et al., 2008. Volcanic carbon dioxide vents show ecosystem effects of ocean acidification. *Nature*, **454**, 96-99, doi:10.1038/nature07051.

De Nooijer, L.J., Toyofuku, T. & Kitazato, H. 2009. Foraminifera promote calcification by elevating their intracellular pH. *Proceedings of the National Academy of Sciences*, **106**, 15374-15378.

Paleobiogeography and completeness of the Early Eocene through Early Oligocene molluscan fossil record

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Incomplete and inconsistent data are among the most significant challenges for paleontologists undertaking the kinds of global analyses necessary for testing and developing concepts of paleobiogeography. Such analyses require adequate sampling of globally distributed fossil assemblages and an internally consistent and systematic source of data; the *Paleobiology Database* (www.paleodb.org) provides such a resource. The database presently comprises over 11,000 occurrences of Early Eocene-Early Oligocene molluscs, derived from nearly 3,000 faunal assemblages. While the database is now fairly comprehensive with regards to geographic coverage (so far as published data exists), significant effort has focused on the development of a sound taxonomic framework. This resource now permits adequate analyses of spatial relationships between faunal assemblages throughout the middle and late Paleogene.

This investigation demonstrates the utility of the database for analyzing patterns of distribution among marine invertebrate taxa. Specifically, these data are used to quantify changes in provincialism during the Eocene and Early Oligocene. Biogeographic units (realms and provinces), defined with both genus- and species-resolution data in the context of tectonic reconstructions, are shown for four geologic intervals across the Paleogene using consistent quantitative protocols. The faunal rosters of paleogeographic areas (5° paleolatitudinal and paleolongitudinal grid cells) are compared using standard biogeographic similarity measures and with endemism metrics for each time interval. A quantitative assessment is also made of the completeness of the reported molluscan fauna across the paleogeographic landscape in each geologic interval through analysis of sampled paleoenvironments and a comparison of body size distributions captured by the fossil record against modern baseline data.

The study succeeds in recognizing key features of previously published analyses of Cretaceous-Cenozic faunal provincialism, such as tethyan, neotropical, and southern hemisphere temperate realms. Biogeographic provinces (geographically and taxonomically distinct faunas) are also illustrated for each interval and indicate areas of high species-level endemism within each realm. Regions prone to active tectonics (resulting in accelerated burial and/or uplift and weathering) are susceptible to lithification and dissolution and often host a depauperate fossil record relative to areas along passive margins. However, active margins often preserve a broader range of paleoenvironments (shallow- and deep-water) than regions with passive tectonism. These data contribute to a greater understanding of the role that biogeographic gradients (beta diversity) play in varying biodiversity during the Paleogene, and provide insight into how geographically expressed preservational biases might be mitigated.

Exploratory paleontology of Paleogene marine molluscan faunas in the neotropics

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The Paleogene marine fossil record of the neotropics is widely regarded as being poorly preserved and under sampled, relative to contemporaneous, adjacent temperate regions, or the Neogene. Compared with the Gulf Coastal and Atlantic Coastal Plains of North America and classic Western European successions the Paleogene outcrops of Central America and northern South America are patchier in distribution, with lithified siliciclastic or carbonate facies, and are often more inaccessible or ephemeral in exposure. Recent research has focused on revisiting known Eocene fossil localities in Panama (Gatuncillo and Tonosí formations) to augment existing knowledge of the local faunas, and to make new collections that permit modern paleobiological analyses. These localities are being studied in a way will enable more meaningful comparison with the better-known faunas of contemporaneous temperate regions.

1) The Gatuncillo Formation, distributed within the Canal Basin of central Panama, was fairly well documented by Wendell Woodring during his authoritative studies of Panamanian Cenozoic molluscs. The formation ranges in age from the Middle through Late Eocene, as determined through large foraminiferal biostratigraphy and Sr isotopes. As many as 80 taxa are known from the formation, including 18 endemic species, although over 30 taxa have not been named to species-level because of their poor preservation. The formation preserves a diverse array of paleoenvironments, from marginal marine to mid-shelf depths, and includes both siliciclastic and carbonate facies.

2) The Tonosí Formation, on Panama's Azuero Peninsula, has been relatively ignored by paleontologists despite early reports of the presence of abundant fossils. The fauna is quite diverse, although to date no tabulations have been made of its apparent richness. Only three species appears to have been recorded in the literature from the formation, including a notable occurrence of abundant *Aturia* (Nautilida). The formation is Middle Eocene at its base but is thought to include rocks that range into the Miocene as dated through nanoplankton biostratigraphy. The Eocene portion of the formation comprises siliciclastic facies that accumulated in nearshore to mid-shelf depths while the overlying shallow marine carbonate succession probably accumulated during the Oligocene.

New collections from these units are being obtained from carefully measured stratigraphic sections, and are providing material suitable for taxonomic description as well as bulk samples appropriate for quantitative paleoecologic and diversity analysis. Stable isotope analysis will be carried out on suitably preserved material to understand local paleoceanographic conditions. Multiple dating techniques (Sr isotopes, molluscan, foraminiferal and nanoplankton biostratigraphy) are being utilized to produce an integrated chronostratigraphic framework for these formations and correlative stratigraphic units in Panama and Colombia.

Refining Middle Eocene Planktonic Biostratigraphy

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The Eocene cyclostratigraphic gap (53 to 42 Ma) has so far prevented extension of the astronomical time scale through the lower Paleogene. This study examines planktonic foraminiferal assemblages from Ocean Drilling Project (ODP) Leg 171B, Site 1051, Blake Nose in the western North Atlantic Ocean. Planktonic foraminifera are studied from 119 to 280 meters below seafloor at Site 1051A, corresponding to magnetochrons C21r to C18r of the Middle Eocene. All planktonic foraminifera are well preserved (although recrystallized) and assemblages are diverse with common *Acarinina*, *Globigerinatheka*, *Subbotina,* and *Turborotalia* genera*.*

Quantitative biostratigraphy reveals highest and lowest occurrences of *Turborotalia frontosa, Guembilitrioides nuttalli, Morozovelloides aragonensis, Globigerinatheka kugleri, Morozovelloides lehneri,* and allows for significant revision and recalibration of planktonic foraminifera zones E7b through E11.

As the foraminiferal biostratigraphy provides an important tool for unraveling dynamic changes through the middle Eocene, correlation with stable isotopic records will provide chronostratigraphic control and enhance our understanding of the middle Eocene. This study provides an important tool for unraveling dynamic changes resulting in a biostratigraphic and climatic record for the middle Eocene.

Pollen grains of Picrodendraceae, Phyllanthaceae, Euphorbiaceae (former Euphorbiaceae) from Palaeogene strata of Central Europe and South China.

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Fossil pollen grains assigned to Picrodendraceae, Phyllanthaceae and Euphorbiaceae have been encountered from sedimentary rocks of Palaeocene and Eocene ages. Fossil stephanoporate, echinate pollen of the *Aristogeitonia*-type (Picrodendraceae), that have been formerly described as *Malvacipollis* or *Longetia* are present in hyperthermal microfloras of Germany (mid-Eocene Stolzenbach) and Austria (lower Eocene Krappfeld, Carinthia) and from the Palaeocene/Eocene boundary rocks of Austria (Salzburg). Mostly all modern similar looking taxa of the Picrodendraceae do occur in the palaeotropics and only very few in the new world. Two fossil stephanoporate, reticulate pollen types that have been formerly described as *Retimultiporopollenites* spp. occur frequently in mid-Eocene sedimentary rocks of the Changchang Formation (Hainan, South China). They can be affiliated with the extant pantropical genus *Phyllanthus* (Phyllanthaceae, tribe Phyllantheae), in particular with the taxa P. ruber, P. hainanensis, *and* P. leptocladus, and might evidence a palaeotropical origin of the Phyllanthaceae. Fossil wood associated with *Phyllanthus* (*Paraphyllanthoxylon hainanensis*) from the Changchang basin corroborate the pollen data. A presumable Phyllanthaceae pollen from rocks of Palaeocene/Eocene age is compared with the genus *Richeriella,* which today has two species growing in Asia (China and Malaysia). Three fossil tricolporate, microreticulate pollen affiliated to the Euphorbiaceae, particularly to *Euphorbia, Stillingia* and *Leucroton* are present in the sedimentary rocks at the Palaeocene/Eocene boundary (Salzburg) and the Lower Eocene (Krappfeld, Carinthia) of Austria. Whereas *Euphorbia* today is a cosmopolitan genus *Leucroton* today occurs in the Caribbean region and extant *Stillingia,* a tropical genus, is distributed in the Americas, Madagascar and Malaysia.

The Krappfeld microflora, Carinthia (Austria): A presumable ETM-2 flora, SEM investigation of palynomorphs.

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Six samples of the Holzer Formation from a short time outcrop in a now refilled quarry near Pemberg (Krappfeld area, NNE of Klagenfurt, Carinthia) have been examined for palynomorphs using LM and SEM. The stratigraphic age of the section is indirectly indicated as Ypresian, because of the mass occurrence of the dinoflagellate genus *Apectodinium*, that is absent in younger strata. Despite the fact that nannoplankton is not preserved, the overlying nummulitic limestones of the Sittenberg Formation are correlative with the NP12.The terrestrial palynomorph assemblages are characterized by the bulk of Myricaeae, Juglandaceae (*Normapolles*-, post-*Normapolles, Engelhardia-, Platycarya*-types), and Fagaceae and to lesser extant by megathermal elements, of which some are quite common, whilst others occur only accessorial. Of particular interest are the frequently encountered monocots such as Araceae, Arecaceae, and Restionaceae. Further, eudicot taxa that can be assigned to the Alangiaceae, Anacardiaceae, Avicenniaceae, Calycanthaceae, Chloranthaceae, former Euphorbiaceae, Hamamelidaceae, Malvaceae Mastixiaceae, Olacaceae, Sapotaceae, ?Simaroubaceae, Styracaceae, Theaceae, Thymelaceae and many other families occur in smaller numbers.

An update on paleoclimate data-model comparisons for the Southwest Pacific

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New multi-proxy records of sea and land temperature variation from late Paleocene to early Eocene, eastern South Island, New Zealand indicate that both sea floor and sea surface temperatures (SFTs and SSTs) increased by ~10°C from late Paleocene to early Eocene times. Late Paleocene (58 – 59 Ma) TEX_{86}-derived SSTs for Canterbury Basin and Campbell Plateau range from 18 to 23°C, consistent with coeval TEX_{86} records from the south Tasman Sea, and indicative of a warm temperate climate for the region at this time. Campbell Plateau SFTs of 7 – 9°C are deduced from benthic foraminiferal Mg/Ca ratios. At this upper bathyal site, this temperature range is equivalent to the present-day Deep Western Boundary Current, and suggests that an equivalent southern-sourced cool water flow existed in the Paleocene, prior to the development of a circumpolar current.

In contrast to this temperate Paleocene climate, our multi-proxy studies (TEX_{86}, Mg/Ca, $\delta^{18}O$) indicate that the early Eocene of southeast New Zealand experienced truly tropical conditions. SST peaked at ~30°C during the Paleocene Eocene Thermal Maximum and the Early Eocene Climatic Optimum, decreasing only by ~2°C in the later early Eocene (48 – 46 Ma). SFT peaked at 17 – 20°C at 50 Ma and declined to 13 – 16°C by 48 Ma. A cooling step at 48.5 Ma corresponds to intensification in corrosive bottom water flow over the Campbell Plateau, as evident from the disappearance of the planktic-benthic $\delta^{18}O$ offset at DSDP site 277. The SST estimates are consistent with coeval TEX_{86}-derived SSTs from the southwest Tasman Sea.

Both global and regional climate models under high CO_2 conditions (2240 ppm CO_2, NCAR CCSM3; 1200 ppm CO_2, HadRM3p) suggest warm temperate conditions for New Zealand (SSTs of 15 – 20°C), which is consistent with Paleocene and later Eocene temperature estimates but not with early Eocene SST estimates. These models are also consistent with the results of physiognomic analysis (CLAMP) of leaf fossil assemblages from eastern South Island, which indicate cool temperate conditions for the Paleocene (mean annual air temperature [MAAT] of 10 – 12°C) and marginally subtropical conditions for the early Eocene (MAAT of 18 – 22°C). Other paleontological data, such as occurrences of the mangrove palm *Nypa* and the larger benthic foraminifera *Asteroclina* are consistent with warm subtropical conditions (but not warm tropical) in the early Eocene.

We suggest that the combined effects of salinity, seasonality and stratification result in a warm bias in the SST and SFT estimates derived from $\delta^{18}O$, Mg/Ca and TEX_{86} in these southwest Pacific records. We outline some ways to correct for this bias.

Mammalian faunal change across the Paleocene-Eocene boundary in NW Europe: the roles of displacement, community evolution and ecology

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The succession of mammal faunas across the Paleocene-Eocene (P-E) transition in Europe is best represented in the north west of the continent in the Anglo-Franco-Belgian Basin area. Here the P-E boundary is marked by a major turnover, the Mammalian Dispersal Event, and a change in the pattern of ecological diversity. Recently described taxa from the earliest Eocene and new taxa under study from the latest Paleocene show that the turnover was more major than previously recorded. Of 45 species in the latest Paleocene Paris Basin sites of Cernay, Berru and Montchenot, only five survived unchanged, whilst a further five appear to have given rise to slightly modified species. An eleventh species belongs to a clade that reappeared late in the PETM. Extinction at the end of the Paleocene therefore totals 76%. Most of the species and clades surviving the P-E boundary in NW Europe scarcely survived the PETM, with the notable exception of the plesiadapiform families Toliapinidae and Plesiadapidae, the latter surviving till the end of the Early Eocene. 76% of the 42 species occurring in the first mammal zone (PE I) of the Eocene have no close relatives in the Paleocene of NW Europe and are judged to have dispersed there, the majority from North America.

Recently improved knowledge of the postcranial skeleton of various extinct groups of small mammals (multituberculates, nyctitheriids, adapisoriculids and louisinines) allows more accurate recording of their locomotor adaptations in ecological diversity studies (Kielan-Jaworowska & Gambaryan 1994; Hooker 2001; Smith *et al.* 2009; Zack *et al*. 2005). Early Eocene faunas are similar to those of modern tropical forests in terms of their proportions and ranges of size, locomotor adaptation and diet. In contrast, latest Paleocene faunas differ somewhat from this habitat type in their size and locomotion categories. They differ in that there are no mammals larger than 45 kg, the terrestrial percentage is high and there are no arboreal types. Also most of the fruit consumers in the latest Paleocene were terrestrial or semiterrestrial, whereas in the Early Eocene far more were tree-dwelling. The restricted size might suggest denser forest in the latest Paleocene, whilst the importance of ground-dwelling frugivores at that time might suggest less diverse or less abundant tree fruits than in the Early Eocene. Currently, this habitat change hypothesis cannot be tested independently since contemporaneous fossil floras are either small or in need of revision. The absence of arboreal and aerial mammals in these Paleocene faunas is indicative of a widespread constraint in mammalian community evolution at this time, Early Eocene faunas showing distinct modernisation in respect of these locomotor strategies. Competitive exclusion and predation by the incoming fauna at the P-E boundary is strongly indicated by the large scale and high rate of the turnover. The large scale of the displacement and community evolution factors may be obscuring patterns of ecological change.

References:

Hooker, J.J. 2001. Tarsals of the extinct insectivoran family Nyctitheriidae (Mammalia): evidence for archontan relationships. *Zoological Journal of the Linnean Society*, **132**, 501-529. Kielan-Jaworowska, Z. & Gambaryan, P. P. 1994. Postcranial anatomy and habits of Asian multituberculate mammals. *Fossils and Strata*, **36**, 1-92. Smith, T., De Bast, E. & Sigé, B. 2009. Adapisoriculid mammals from the Paleocene of Hainin (Belgium) shed light on the phylogenetic affinities of the enigmatic arboreal Cretaceous *Deccanolestes* from the Deccan Traps of India. *JVP Program & Abstracts*, **29**, 183A. Zack, S.P., Penkrot, T.A., Bloch, J.I. & Rose, K.D. 2005. Affinities of 'hyopsodontids' to elephant shrews and a holarctic origin of Afrotheria. *Nature* **434,** 497-501.

Oligocene environmental changes on the Wilkes Land margin in response to a developing East Antarctic ice sheet.

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IODP Expedition 318 drilled several sites on the Wilkes Land margin of East Antarctica in Jan. – Feb. 2010. The principle objective of the cruise was to obtain a better understanding of the Cenozoic cryospheric evolution of Antarctica, in conjunction with the dating of major regional seismic unconformities WL-U3 thru U8. Unconformity WL-U3 was suggested to be related to the inception of Antarctic glaciation during the Eocene-Oligocene Transition (~34 Ma).

Changes in biotic assemblages distinctly denote an ecological transition from warm, Eocene ice-free ‘greenhouse’ conditions to colder, highly productive, Oligocene ‘icehouse’ conditions, more akin to the modern shelf environment of Antarctica. Preliminary dinoflagellate, and TEX_{86} results will be discussed. In addition, our paleoecological interpretations provide constraints for on-going geophysical studies aimed at modelling changes in relative sea level in response to East Antarctic glaciation and ice-sheet arrival at the Wilkes Land margin.

Hypothesis testing with sediment mixing models: preliminary results from 'unmixing' the Cretaceous-Paleogene boundary

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Improved age models, sampling resolution, and analytical techniques provide powerful approaches for increasing the resolution – and our understanding – of past climatic and biotic events. The interpretation of the fossil record is limited by sediment mixing, which spreads the record of a stratigraphically constrained event into overlying and underlying strata, and is a pervasive feature of most sedimentary environments. The relative timing, duration, and magnitude of events in Earth's history are thus obscured by sediment mixing. While many studies regularly incorporate methodologies to improve age models, sampling, and analytical resolution, few attempt to quantify and account for the effect of sediment mixing. In this study, we showcase the potential utility of sediment mixing models for hypothesis testing in deep time.

In previous work, we found that high-resolution iridium anomalies can be used to parameterize sediment mixing models across the Cretaceous-Paleogene boundary. Here we use iridium-parameterized sediment mixing models at pelagic sites in the Pacific, Indian, and Atlantic Ocean (DSDP Sites 577, 465, 527, and ODP Sites 738 and 690) to estimate the magnitude and duration of a boundary-related $\delta^{13}C$ excursion. We use these estimates of magnitude, duration, and occurrence to improve our tests of possible mechanisms underlying this pattern.

A new high resolution palynological and geochemical study of the Paleocene-Eocene Thermal Maximum from eastern Peri-Tethys

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A new high resolution palynological and geochemical data from a 6.5 m thick interval spanning the Paleocene/Eocene transition including PETM-interval is made in the marine key-section from eastern Peri-Tethys: the Kheu River outcrops (Kabardino-Balkar Republic, central Northern Caucasus, Russia). The uppermost Paleocene is composed of soft greenish marls, while sediments corresponding to the PETM interval are represented by 0.5 m thick sapropelite layer and ~1.5 m thick greenish calcareous clays.

Short-lived geologically extremely warm episode- the PETM-event is confirmed in the Kheu River section by coupled evidence of negative (~2 – 3.5‰) excursion in stable carbon isotopes (CIE), occurrence of dinocyst key-species *Apectodinium augustum* and *Wilsonidium pechoricum*, as well as the appearance of calcareous nannofossils *Rhomboaster* spp. (NP10 nannofossil zone) (see Shcherbinina et al., this Volume).

A high resolution quantitative analysis of dinocyst associations of the sapropelite layer corresponding to the maximum of $\delta^{13}C$ excursion shows an increase in abundance (acme) of tolerant to low salinity gonyaulacoids (*Polysphaeridium* spp., *Homotryblium* spp.) and peridinoids (*Apectodinium*/*Wilsonidium*), while dinocyst associations of the sediments overlying the sapropelite bed (with less pronounced $\delta^{13}C$ excursion) are characterized by significant decline of *Apectodinium*-abundance and dominance of open-marine *Spiniferites*-group.

Variations in dinocyst abundance combined with lithological and geochemical data enabled us to propose a possible pattern of environment dynamics during the PETM in considered area of eastern Peri-Tethys, which we will present in our talk.

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PETM effects on Neotropical Vegetation

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During the onset of the Palaeocene Eocene Thermal Maximum worldwide temperature increased by at least 5°C in ~10 to 20 thousand years returning to pre-PETM temperatures over the next 100 - 200 kyr. Temperatures in tropical regions are estimated to have increased by 3 – 5°C. For this study, we investigated the tropical forest response to this rapid warming by evaluating the palynological record of three stratigraphic sections in eastern Colombia and western Venezuela. This analysis included 357 pollen samples, 1104 morphospecies, and 37,952 individual occurrences together with 489 carbon isotopes samples, 21 plant biomarker samples, 17 TEX_{86} samples, and one radiometric age from a tuff deposited within the PETM itself. Contrary to expectations, plant extinction did not increase during the intense warming of the PETM. Instead, we observe a rapid and distinct increase in plant diversity and origination rates, with a set of new taxa, mostly angiosperms, added to the existing stock of low-diversity Palaeocene flora. Plant water use efficiency increased, and aridity did not increase in the northern Neotropics and the tropical rainforest was able to thrive under elevated temperatures and high levels of atmospheric CO_2, in contrast to speculations that the health of tropical ecosystems were catastrophically compromised by heat stress.

Diversity and abundance patterns of marine primary producers across the Paleocene – Eocene boundary

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The composition of calcareous nannofossils across the Paleocene – Eocene Thermal Maximum (PETM) has been investigated at an equatorial site (Demerara Rise; ODP Site 1258C). The onset of the PETM is defined by a distinctive negative carbon isotope anomaly, carbonate dissolution and specific nannofossil events; the top of the PETM is gradual and therefore less accurately defined. The PETM interval is 1.47 m thick, including a 57 cm thick basal clay layer. Calcareous nannofossils were studied in high-resolution intervals of 5 cm and 2 cm by using smear and settling slides.

In the pre–PETM interval the species richness ranges from 20 to 32. The lowermost 22 cm of the PETM interval yield assemblages of low abundance and low diversity, in the upper 1.25 m of the PETM species richness increases to 19 species and remains high thereafter. Absolute abundances have a maximum of 2.3×10^9 specimens/g sediment in the pre-PETM interval. At the base of the PETM abundances drop to values slightly above zero, they stay below $2{,}5 \times 10^6$ specimens/g sediment during the event, before they increase slowly. Abundances are below $1{,}0 \times 10^9$ specimens/g sediment for the rest of the succession. Calcareous nannofossils show marked changes in the assemblage composition: Increased abundances of *Campylosphaera* sp. and *Chiasmolithus* sp. precede the onset of the PETM and may indicate eutrophic conditions. The nannofossil record during the PETM onset is obscured by carbonate dissolution, causing low total abundances in the lowermost 35cm of the PETM. Smaller taxa, like *Coronocyclus bramlettei* and *Coccolithus minimus* seem to have favoured the conditions prevailing during the early phase of the PETM, an interval perhaps affected by surface-water acidification. In the later stage of the PETM the large sized species *Coccolithus bownii* appears with high percentages and remains highly abundant throughout the interval. Discoasterids indicating warm surface-waters become more frequent and diversify concomitant to the PETM onset. *Discoaster araneus* is characterized by a reduction of its rays from a maximum of 9 in the lowermost part of the PETM to a minimum of 5 – 6 rays in the later stage. Deformed discoasterids are common throughout the entire PETM interval, paralleled by *C. bownii* and *Rhomboaster cuspis*. *R. cuspis* and *Rhomboaster bramlettei* are the only coccoliths, showing a distinctive variability of size, without changing their shape during the event.

Oceanographic, vegetation and climatic change at the Palaeocene–Eocene boundary in the North Sea region

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We present stable isotopic and micropalaeontological data across the Palaeocene–Eocene boundary from North Sea core 22/10a-4. The core was recovered from the central North Sea ~200 km from land, and the section investigated spans ~26 m of predominantly shale with occasional thin turbiditic sand beds. This expanded succession is thought to have been deposited in an estimated palaeo-water depth of ~500 m, with no major hiatuses. High resolution bulk rock total organic carbon isotopes ($\delta^{13}C_{TOC}$) reveal a negative carbon isotope excursion (CIE) of ~5‰, which takes ~2 m to reach the most negative values of the core of the CIE. The onset of the CIE, identified by the first shift towards more negative values, occurs close to the first appearance of *Apectodinium augustum* along with high abundances of other *Apectodinium* species, and defines the onset of the Palaeocene–Eocene Thermal Maximum (PETM). The $\delta^{13}C_{TOC}$ of the CIE shows no substantial recovery, indicating at most 3 precession cycles of the CIE may be preserved. The dark shale becomes laminated during the CIE, suggesting a temporary period of bottom water anoxia supported by the disappearance of benthic foraminifera. A large increase in the proportion of amorphous organic matter (AOM) occurs around the same time as the first *Apectodinium* and the CIE onset, and probably indicates an increase in the preservation of marine organic matter perhaps due to anoxia and lack of scavenging benthos. However, as AOM occurs both within and outside of the laminations, its occurrence may more likely indicate higher primary productivity within the CIE. Associated with these changes is a shift in the dinoflagellate assemblages. Open marine / neritic *Spiniferites*, *Glaphyrocysta* and various chorate cysts below the CIE are replaced by *Cerodinium*, *Lejeunia* and other peridinoid cysts leading up to and within the CIE suggestive of elevated nutrients and lower salinity. These records are therefore consistent with an increase in regional precipitation and oceanic nutrient supply. Furthermore, terrestrial spores and pollen show a significant shift away from abundant *Inapertuapollenites hiatus*, bisaccate pollen and *Caryapollenites* before the CIE, to abundant *Alnipollenites*, *Laevigatosporites* and *Plicapollis pseudoexcelsus* within the CIE, suggesting that a significant shift in vegetation occurred in Northwest Europe in concert with the CIE onset and appearance of *Apectodinium*.

Sea-level changes and lithological architecture of the Paleocene-early Eocene sediments of the western Crimean basin, Ukraine

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During the Paleogene time, sedimentary basin of the western Crimea, Ukraine was bordered by land of coarse topography, which occupied the territory of modern first range of the Crimean Mountains, on the south and by Simferopol uplift on the north and displays a wide spectrum of shallow water marine facies. Paleocene to early Eocene marine deposits are well preserved and can be studied in a number of exposures. Correlated by standard nannofossil scale, five exposures present a ~17 Ma record of sea-level fluctuations.

Danian, Selandian-Thanetian and Ypresian transgressive-regressive cycles are recognized in the sections studied. Major sea-level falls corresponding to hiatuses at the Danian/Selandian and Thanetian/Ypresian boundaries appear as hard-ground surfaces. Stratigraphic range of the first hiatus is poorly understood because Danian shallow carbonates are lack in nannofossils while accumulation of Selandian marl begins at the NP6. The second hiatus ranges NP9 - NP10 nannofossil zones.

The Danian cycle is built up of rudstones and shows minimal depth of the Paleocene basin. Second cycle is composed of Selandian packstone and wacke-packstone, Thanetian mud-wackestone, mudstone, wackestone, packstone, wacke-packstone and corresponds to maximal deepening related to a new transgression during which the sea depth evidently exceeded a hundred meters in the middle Thanetian. Ypresian cycle made up of floatstone, mudstone, wackestone, pack-wackestone, mud-wackestone displays relatively lower depth and tends to be shallower upsection culminating by nummulitic limestone.

Analyses of the lithological features, $CaCO_3$ content, siliciclastic compound and variations in calcareous nannofossil abundance give an opportunity to reconstruct sea-level fluctuations of lower (4^{th}) order for the Paleocene-Early Eocene interval. Selandian-Thanetian cycle displays two peaks of major sea-level highs in the upper part of NP6 zone (mudstone) and in the middle NP8 zone (pack-wackestone, wackestone) inferred from higher $CaCO_3$ concentrations, higher abundance of nannofossils and lower amount of siliciclastic material. Maximal depth of the basin was reached during this last short transgression (NP8 nannofossil zone).

In the lower part of the Ypresian cycle, $CaCO_3$ increase related to high nannofossil abundance is observed coherently with reduced amount of siliciclastic compound that marks transgressive pulse culminated in the upper NP12 zone (mudstone) and followed by long-termed slow regression. Frequent sea-level fluctuations of the fourth order which minima are marked by rhythmic intercalations of nummulite-bearing layers complicate this regressive trend during Ypresian cycle.

Such a lithological record of sea-level fluctuations in the western Crimean basin generally is in good agreement with the sea-level trend in the whole area of northeastern Peri-Tethys, the occurrence of thick upper Ypresian nummulitic limestone related to long-termed sea-level lowstand is the only specificity of early Paleogene Crimean basin.

Climatic and environmental changes during the Paleocene-Eocene thermal maximum: Dababiya GSSP.

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The Paleocene Eocene thermal maximum (55.8 million years) shows an extraordinary drop in the ratio of both $\delta^{13}C_{carb}$ and $\delta^{13}C_{org}$, suggesting that a massive amount of "light" carbon was released into the atmosphere in a very short time (few hundred ky). The most likely source would have been methane from ocean sediments or continental paralic areas. The emitted CO_2 is removed from the atmosphere by silicate rock weathering reactions and organic carbon burial. This balance is thought to have stabilized greenhouse conditions. The Dababiya GSSP (Luxor, Egypt) is thought to be the most complete known PETM section. Detailed geochemical and mineralogical studies have been achieved on 125 samples spanning the PETM interval to evaluate the rate of weathering and it's feedback. The base of the Eocene is marked by a sequence boundary overlain by silty clays deposited during low sea level (Bed 1) and followed by marly shales reflecting a progressive sea-level rise (Beds 2-5). Both organic and carbonate isotopes shows a long-term decrease starting 0.5 m below the P-E boundary. The persistent shift in $\delta^{15}N$ to nearly zero reflects the gradual increased in bacterial activity. Increased Ti, K and Zr and decreased Si contents at the P/E boundary indicate high weathering index (CIA) which coincides with significant kaolinite input and suggest intense chemical weathering under humid conditions at the beginning of the PETM. Above, the presence of two negative Ce/Ce* anomalies intervals reflects anoxic conditions which prevailed during the middle PETM (Bed 2). Anoxic to euxinic conditions are also revealed by increasing U, Mo, V Fe and the presence of small size pyrite framboids (2 – 5 µm). At the same interval, productivity sensitive elements (Cu, Ni, and Cd) show maximum concentration ratios suggesting high productivity in surface water. Above, phosphorus and barium tend to precipitate as oxic conditions were re-installed (upper PETM, Bed 3). These data highlight that intense weathering is one of the crucial parameter in the chain of the PETM events, especially for the recovery phase.

Type section of the Thebes Formation (Lower Eocene, Egypt)

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The Thebes Formation forms an extensive carbonate platform on the southern margin of Tethys, outcropping along the Nile Valley and over large areas of the Western Desert of Upper Egypt. It has an extensive literature, but its biostratigraphy, depositional environments and sequence stratigraphy are still not well integrated on a regional scale.

The type section of the Thebes Formation is Gebel Gurnah, on the west bank of the Nile opposite Luxor. The current study, in progress, is part of the TIGA (Thebes International GeoArchaeology) project, with authorisation from the Supreme Council of Antiquities, participation of Assiut University, and funding from the National Geographic Society. It was primarily intended to provide a detailed stratigraphic context for the West Bank Pharaonic tombs and other antiquities, but also documents a key Lower Eocene section.

The Thebes Formation in Gebel Gurnah forms a succession of stepped escarpments. The maximum thickness is preserved in the area of the high peak El Qurn, which overlooks the Valley of the Kings. A 350 m section was logged in this area; samples were collected for XRD analysis, microfauna and nannofossils. The Thebes Formation comprises mainly chalk and chalkstone (chalk with secondary interstitial cement). Layers of chert nodules are common, and siliceous limestones become increasingly common in the upper part. Lithofacies range from calcareous and dolomitic claystone through chalk to nodular limestone. These largely reflect relative water depths. Thin bioclastic limestones with larger foraminiferids represent episodes of reduced sedimentation.

Three levels of cyclicity can be identified: submetric chalk/chert or chalk/chalkstone interbedding, representing probable Milankovitch-scale cycles; decimetric parasequences based by bioclastic units; and 100 m-scale shallowing-upwards sequences. The base of the second sequence at 93 metres is a prominent burrowed omission surface, overlain by a thin bed of phosphatic pebbles. The third sequence is abruptly terminated at a thick sharp-based oyster coquina. This contact is interpreted as a major sequence boundary.

Calcareous nannofossil assemblages are considerably impoverished at most levels, but a few levels have yielded common, well preserved, highly diversified assemblages that confer an NP12 zonal age to the bulk of the formation.

This study has shown that a detailed record of Ypresian depositional history is preserved in the El Qurn section. We anticipate that it will be the basis for further regional study, and that it should serve as an international reference section for Ypresian sequence stratigraphy.

Isotope geochemistry of early Paleogene fossils and sediments from phosphate rich deposits of the Gafsa Basin, Tunisia

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In Tunisia widespread late Cretaceous-early Paleogene marine sediments occur indicating that most of the Tunisian landmass was covered by the southern part of the Tethys Ocean. Only some areas like the Djeffara and Kasserine islands emerged, between which the Gafsa Basin was located. Here the sedimentation took place under semi-closed condition and it was often influenced by sea-level fluctuation. Three main phosphate rich deposits appear in the region: the first is at the base of the El Haria Formation with an early Maastrichtian age, the second and economically most important the Thanetian-early Ypresian Chouabine Formation, while the youngest one is inter-bedded in the carbonate series of the Métlaoui Formation which correspond to Ypresian–Lutetian (Chaabani, 1995, Zaïer et al., 1998).

Our first attempt constraining paleo-environmental and paleo-depositional conditions during sedimentation of these phosphate beds, included rare earth element and stable isotope chemistry of shark teeth and coprolites, yielded very interesting results among them a pronounced negative carbon isotope excursion (CIE) of 3 – 4‰ in the upper part of the Chouabine Formation (Ounis et al., 2008). The observed CIE was proposed to mark the Paleocene-Eocene boundary in the Gafsa Basin. However the $\delta^{13}C$ values are extremely low maybe due to the local condition and it could relate to phosphatization processes. Hence further investigation is necessary focusing on the connection of the Gafsa Basin with the global ocean and the possible effects of diagenetical processes.

The here presented data include Sr and Nd isotope ratios of samples previously investigated and of phosphatic fossils newly collected from different phosphate layers of the Chouabine and Métlaoui Formations. The ε_{Nd} values are low and they vary between -8.8 and -10.7. The $^{87}Sr/^{86}Sr$ ratios are widely in the expected range of the late Cretaceous and early Paleogene open seawater however the younger samples show more pronounced deviations from the global ocean. This later result indicate either enhanced continental reworking or increased influence of early diagenetic fluid on the samples which is most possibly relating to the gradual closuring of the basin during the Paleogene.

Additionally in the Kef Eddour region sediments and microfossils of a detailed new section of the Chouabine Formation is under investigation especially across the supposed P/E boundary. Some archives show very homogenous distribution along the series, others mimic minor negative CIE. Biostratigraphy is attempted to be improved as well, although the preservation state of the carbonaceous microfossils are very poor making difficult any accurate dating. Preliminary data indicates that the large part of the Chouabine Formation was deposited during the late Paleocene.

References:

1) Chaabani, F. 1995: Dynamique de la partie orientale du bassin de Gafsa au Crétacé et au Paléogène: Etude minéralogique et géochimique de la série phosphatée Eocène, Tunisie méridionale. Thèse Doc. Etat. Univ. Tunis II. Tunisie;
2) Ounis, A., Kocsis, L., Chaabani, F. & Pfeifer, H.-R. 2008: Rare earth element and stable isotope geochemistry $\delta^{13}C$ and $\delta^{18}O$) of phosphorite deposits in the Gafsa Basin, Tunisia. Palaeogeogr. Palaeoclimatol. Palaeoecol., 268, 1-18;
3) Zaïer, A., Beji-Sassi, A., Sassi, S. & Moody, R.T.J. 1998: Basin evolution and deposition during the Early Paleocene in Tunisia. In: Macgregor, D.S., Moody, R.T.J. & Clark-Lowes, D.D. (eds): Petroleum Geology of North Africa. Geol. Soc. London Spec. Publ., 132, 375-393.

Facies of Paleogene deep-water deposits of the Gams basin (Styria, Austria)

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The sedimentary succession of the Gosau Group of Gams comprises deposits of Late Turonian to Ypresian age of the Northern Calcareous Alps (Wagreich et al., 2009a). In the Gams area, Cretaceous/Paleogene-boundary intervals (K/Pg) as well as Paleocene/Eocene-boundary intervals (P/E) are exposed (Egger et al., 2004). Detailed sedimentological studies within the Upper Gosau Subgroup above the K/Pg-boundary are done, and a comparison of the Gams slope basin with already published models of turbidite basins.

The Nierental Formation and the Zwieselalm Formation in the eastern outcrop area (Upper Gosau Subgroup, Campanian – Ypresian) are composed of deep-water deposits, mainly turbidites and hemipelagites (Egger et al., 2004, Wagreich et al., 2009a, b). There are several outcrops of the Gosau deep-water succession along the Gamsbach creek and tributary creeks at Krautgraben- and Gamsforst area, near the village Gams, but no continuously exposed section.

The Danian section of the Nierental Formation (calcareous nannoplankton zone NP1 – NP4) consists of hemipelagic to pelagic red and grey marls and marly limestones (carbonate contents range from 27 – 61 wt%) intercalated with some thin sandstone turbidite beds as well as slump layers and debris flow deposits. The turbidite sandstones are rich in carbonate and include redeposited material from the Northern Calcareous Alps, biogenetic components (foraminifera, corallinacea) are common. The debris flow deposits comprise miscellaneous components, including reworked Lower Gosau Subgroup and shallow-marine, Paleocene Kambühel limestones.

The basal part of the Zwieselalm Formation is marked by the first thick (>1 m) turbidite sandstone bed (NP5). Sandstones, grey marls and marly claystones are deposited on top of the Nierental Formation (NP5 – NP9), changing into a largely carbonate-free succession composed of turbidites and dark claystones (carbonate contents 2 – 6 wt%). The turbidites display only weak cementation, due to a very low carbonate content. Turbiditic shales are dark grey, mainly only a few centimetres thick and largely devoid of carbonate. A sedimentation depth below CCD is supposed.

The P/E-boundary interval is characterized by red to brown claystone and marly claystone layers. Occasionally, concretions consisting essentially of early diagenetic siderite occur. The largely carbonate-free turbiditic succession of the P/E-transition grades into a succession dominated by carbonate turbidites (NP10 – NP11), intercalated with hemipelagic marl layers (carbonate contents 3 – 29 wt%). Within the lower part of this succession (subzone NP10a) four 3 – 9cm thick yellowish to light-grey montmorillonite layers, which are interpreted as volcanic ashes, are exposed. The top of the Zwieselalm Formation (NP12) comprises a succession of marls and thin-bedded, fine-grained sandstone turbidites. Breccia layers at the basal part of the turbidites and slump beds are characteristic for the Zwieselalm Formation (Egger 2004, Wagreich 2009a, b).

References:

Egger, H., Rögl, F. & Wagreich, M. (2004). Biostratigraphy and facies of Paleogene deep-water deposits at Gams (Gosau Group, Austria). Ann. Naturhist. Mus. Wien, 106A: 281-307.

Wagreich, M., Kollmann, H.A., Summesberger, H., Egger, H., Sanders, D., Hobiger, G., Mohamed, O. & Priewalder, H. (2009a). Stratigraphie der Gosau-Gruppe von Gams bei Hieflau (Oberkreide-Paläogen, Österreich). Arbeitstagung ’09. Geol. B.-A., 81-105.

Wagreich, M. (Ed.) (2009b). Rapid Environmental/Climate Changes and Catastrophic Events in Late Cretaceous and Early Paleogene, RECCCE Workshop Abstracts and Excursion Guide. Ber. Geol. B.-A., 78, 74pp.

Hydrological Changes in the Southern Hemisphere during the Paleocene Eocene Thermal Maximum

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Understanding changes in the hydrological cycle with warming in the Southern Hemisphere is essential for making zonal predictions of precipitation changes with anthropogenic warming. In this study, we evaluate hydrological changes associated with global warming of the Paleocene-Eocene Thermal Maximum (PETM) using carbon and hydrogen isotopic compositions of terrestrial biomarkers (*n*-alkanes) derived from leaf waxes in Tawanui, New Zealand. These records have the unique advantage of recording atmospheric CO_2 (modified by plant fractionation) and precipitation (modified by plant fractionation and evapotranspiration), allowing for an evaluation of the relative timing of carbon and hydrogen isotopic (i.e., climate) shifts during the PETM.
The PETM represents a period of rapid, greenhouse-gas induced global warming ~55 Ma years ago, characterized by a negative $\delta^{13}C$ excursion in $\delta^{13}C$ and a pervasive marine carbonate dissolution.Previous work at the Tawanui site have established changes in *n*-alkane $\delta^{13}C$ trends, with a peak negative $\delta^{13}C$ shift of ~2 – 3%. Our preliminary results for terrestrially derived *n*-alkane dD compositions indicate similar temporal trends among a range of chain lengths (*n*-alkanes C25, C27, C29, and C31), but with varying magnitudes of change. Differences are emerging between Northern and Southern Hemisphere sites. In general, *n*-alkane dD trends observed in the Northern Hemisphere include a “pre-event” D-enrichment followed by D-depletion during the body of the PETM. While D-enrichment is not observed prior to the PETM at Tawanui, the most positive dD values are observed before the peak of the carbon isotopic excursion. No significant D/H changes are observed during the peak excursion itself with the values returning to pre-PETM values. These records will be presented and comparisons will be made with other sites globally.

Lake Messel, a high resolution archive for early Middle Eocene climate variability

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The Middle Eocene oil shale of the Messel pit near Darmstadt (Hesse, Germany) is worldwide known for an exceptionally well preserved fossil assemblage. A continuous core from the center of the basin proved that the oil shale was deposited in a meromictic maar lake which formed due to a phreatomagmatic eruption 47.8 ± 0.2 Ma ago. The core included a complete reference section of the Middle Eocene lake deposits (Messel Formation) thus representing a unique climate archive for the early Middle Eocene in Central Europe.

The classical “Messel oil-shale” of the Middle Messel Formation is characterized by a continuous succession of finely laminated bituminous claystones, representing long-term stable meromictic conditions. They show a very fine light and dark lamination, which was caused by annual algal blooms of the coccal green alga *Tetraedron minimum* forming light spring and summer layers that were superimposed on the terrigenous background sedimentation, as represented by the dark autumn and winter layers. An average sedimentation rate of 0.14 mm/yr has been calculated from the lamination, but there are short-term fluctuations in varve thickness which can be attributed to an “Eocene ENSO”.

High resolution palynological analysis of the oil shale of the Middle Messel Formation in the core, which represents a time interval of about 640 kyr, now provides an insight into the dynamics of a paratropical climax vegetation during the Middle Eocene greenhouse climate. Pollen and spores show that the vegetation surrounding Lake Messel did not change substantially in qualitative composition, but a change from a more humid climate with relatively high water levels in the lake to less humid conditions and lower water levels may be reflected by changes in the quantitative composition of the assemblage towards the top of the section. In addition to these long-term changes in the vegetation, short-term fluctuations in the frequency of individual taxa and certain clusters of taxa are recognizable.

Accepting an annual lamination, time series analyses of palynological data suggest that pollen assemblages reflect periodicities within the range of eccentricity, obliquity, long precession and short precession. This implies that orbital control of climate change was sufficient to impose quantitative changes in the composition of the terrestrial vegetation in the area though no taxonomic turnover occurred.

According to the cyclicity of the palynological data and with the availability of the astronomical solutions of La2004 and Va2003, it is now possible to implement an astronomical tuning to the 640 kyr record of the Middle Messel Formation. When tuning the pollen data to the La2004 Earth’s orbital solution, the age of the Middle Messel Formation can be astronomically fixed between 46.6 and 47.3 Ma.

Bartonian–Priabonian larger foraminiferal events in the West Tethys

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Having reflected the general cooling of the Earth, the composition of West Tethyan larger foraminifera (LF) significantly changed in the late Bartonian and Priabonian. It is characterized by the disappearance of *Alveolina*, giant *Nummulites* and *Assilina* and also of some orthophragminid phyla. Simultaneously, radiate and especially reticulate *Nummulites* (the *N. fabianii* lineage) and nummulitids with secondary chamberlets (*Heterostegina* and *Spiroclypeus*) emerged. Based on the evolution of these forms and also on other data (field observations, other LF and planktic data), a high-resolution stratigraphy of the Bartonian and Priabonian could be established in the frame of the Tethyan shallow benthic zonation (with SBZ zones and newly erected subzones for SBZ 18 and 19 based on the exceptionally rapid evolution of *Heterostegina armenica* and *H*. *reticulata*). The updated time-table of LF events for this period mainly based on first/last occurrence (FO/LO) data of the phyla is presented below (morphometrically undefined changes within lineages are not considered):

1. The base of the Bartonian (the SBZ 16/17 boundary) is tentatively defined by the FO of the *Operculina gomezi* group.

2. The base of the late Bartonian (the SBZ 17/18 boundary) is marked by the FO of genus *Heterostegina* (represented by *H. armenica*), *Chapmanina*, *Silvestriella* and of *Nummulites hormoensis*. The boundary of OZ 13/14 orthophragminid zones (the extinction level of the *Orbitoclypeus douvillei* lineage) roughly corresponds to this event, as well as the LO of the *Nummulites brongniarti*, *N. lorioli–ptukhiani* and *Assilina exponens* lineages.

3. The base of the latest Bartonian (the SBZ 18A/B boundary) is defined by the FO of the *Heterostegina reticulata* lineage. The FO of genus *Pellatispira* is close to this event.

4. The LO of the most widespread giant *Nummulites* (i.e. the *N. perforatus–biedai*, *N. millecaput–maximus* and *N. gizehensis–lyelli* groups) during the latest Bartonian seems to have been migrated eastward as reconstructed by the rapid evolution of the *H. reticulata* lineage subdivided into five subspecies in this interval. The LO of *Alveolina* s.s. is largely uncertain but might also have happened in this time.

5. The SBZ 18/19 boundary is marked by the FO of genus *Spiroclypeus* and by the intraphyletic change of *Heterostegina reticulata reticulata* to *H*. *r*. *mossanensis* and *Nummulites hormoensis* to *N. fabianii*. *Discocyclina discus* with giant embryon does not cross this boundary, which falls within the P 15 and NP 18 zones, and is being therefore slightly younger than the Bartonian/Priabonian boundary placed at the boundary of NP 17/18 zones by planktic experts.

6. The base of the late Priabonian (the SBZ 19/20 boundary) is defined by the FO of granular *Heterostegina* (*H. gracilis*), by the intraphyletic change of *Spiroclypeus sirottii* to *S*. *carpaticus* and by the boundary of OZ 15/16 orthophragminid zones. This event is preceded by the SBZ 19A/B boundary defined by the change between *H. reticulata mossanensis* and *H. r. italica* and by the OZ 14/15 boundary (the extinction level of genus *Nemkovella*, *Asterocyclina kecskemetii* and of the *Discocyclina pratti* and *A. alticostata* lineages).

7. The Priabonian/Rupelian (SBZ 20/21) boundary is marked by the LO of most LF including all orthophragmines, genus *Assilina*, all Eocene nummulitids with secondary chamberlets and most radiate *Nummulites*. The reticulate *N. fabianii* lineage survived the global boundary event, however it is reflected in the decrease of the embryon size. The change in the surface ornamentation between *N. fabianii* and *N. fichteli* cannot definitely be tied to this event.

Palynological reconstructions of early Eocene environmental and biotic perturbations in the Wind River Basin, Wyoming, USA

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The effect of early Cenozoic geologic perturbations on evolutionary trajectories in the sedimentary basins of Wyoming can be extensively studied using palynomorphs. During the late Jurassic, a large foreland basin, extending from the Arctic Ocean to the Gulf of Mexico, was forming as a result of crustal shortening associated with the Sevier Orogeny. From the end of Cretaceous through the early Eocene, this large basin was dissected into a series of well-established smaller basins as a consequence of the Laramide Orogeny. Superimposed on these Laramide geologic changes are previously documented climatic changes. Studies of late Paleocene through early Eocene (~58 – 50 Ma) climate record warming to a sustained Cenozoic maximum called the Early Eocene Climatic Optimum (EECO). With the onset of North American Land Mammal Zone Bridgerian 1b (Br1b, ~51 – 48.5 Ma), the climate became very cool and arid.

This study focuses on ecological trends in the Wind River Basin during the early Eocene. As this location has not been systematically studied paleobotanically, we will examine the pollen-rich lithofacies found widespread throughout the area. With this information, it will be possible to contrast biotic changes in the Wind River Basin to those previously documented in the Bighorn and Green River Basins, to the north and south, respectively. Pollen is very responsive to climatic and environmental changes, which makes it ideal to answer the following questions: (1) How do palynofloral changes in diversity and composition reflect large and small-scale changes, both geographically and stratigraphically? (2) Did Laramide geologic and environmental perturbations affect plant diversity and evolutionary trajectories?

It can be hypothesized that pollen taxonomic and ecological diversity should increase with warming through the early Eocene until the end of the EECO, as seen in plant and mammal communities in the adjacent basins. We predict a major decline in ecological diversity during the Br1b cooling, parallel to that observed in Wind River Basin mammal faunas. It can also be postulated that as Laramide deformation continued to disturb the environment, ecological communities and evolutionary paths will be altered.

Pollen samples were collected from varying lateral and stratigraphical sections of Wasatchian 6 (53 Ma) through Br1b (48.5 Ma). Thus far, 32 samples from the Wind River Formation have been processed. At least 300 pollen grains per sample were indentified, noting where geographically, temporally, and depositionally different genera are recovered. From this, we developed an ecological record used to infer environmental conditions and how they changed through time. Variations in taxonomic diversity were quantitatively analyzed using rarefaction,

Thus far, only broad scale variations of early Eocene palynofloras have been documented in the Wind River Basin. The pollen and spore floras consist largely of non-monocot angiosperms and have a large percentage of Tiliaceae, Aceraceae, Leguminoseae, and Liliales. Fern spores (especially *Lygodium*) are also abundant, and Pinaceae pollen is rare. The location and organization of documented species through time suggests correlation with early Eocene warming through the EECO until the later Bridgerian crash based on individual families climactic preference. In the future, we plan to contrast lateral changes in uniform beds to variations seen between facies at one location. This will help better evaluate the large-scale palynological trends due to the climatic and geographic changes.

Craigia changchangensis, a new capsular fruit from the Eocene of Hainan Island, South China

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This study reports a new fruit fossil record of the genus Craigia, C. changchangensis sp. nov., from the Eocene coal-bearing series of Changchang Basin of Hainan Island, South China. This is the second fossil Craigia species found in South China, which is the modern distribution center of the genus Craigia, and provides new evidence to spur an investigation of the phytogeographical history of the genus.
A palynoflora study of the Eocene of the Changchang Basin, Hainan Island, indicated that the Eocene temperature was lower than today as Eocene flora contains many more subtropic-temperate components and fewer pantropic and tropic-subtropic components than does the modern flora (Zhao et al., 2009). In addition, the appearance of temperate plants, such as Abies and Tsuga, that can survive severe winters suggests that high-altitude mountains might have surrounded the Changchang Basin during the Eocene (Zhao et al., 2009). We speculate that the fossil Craigia species of Hainan Island might have lived in high-altitude mountains during the Eocene and became extinct later as crustalsubsidence reduced the altitude of the mountains and temperatures increased. Nonetheless, in Yunnan and Guangxi provinces, Craigia plants survived and evolved extant species due to these provinces' cooler climates.

Remarks on the Early-Middle Eocene biomagnetochronology based on planktic foraminiferal evidences from the Tethyan successions of northeastern Italy

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In the Early Paleogene the Earth experienced a pronounced warming trend that peaked during the Early Eocene Climatic Optimum (EECO; ca. 50 – 52 Ma). This long-term climate trend is punctuated by short-lived (< 200 kyr) warming events, known as hyperthermals, the most prominent of them is the PETM (Paleocene Eocene Thermal Maximum, ca. 55 Ma). After the EECO, the Earth climate system underwent a composite transition towards the modern icehouse world reached in the Early Oligocene (e.g., Zachos et al., 2001: Science 292; 2008: Nature 451). Even increasingly scientific attention is dedicated to definitely comprehend timing, nature and characteristics of the complex evolution of the Paleogene climate.
A main corollary of the great interest dedicated in recent years to the Paleogene climate is the generation of new stratigraphic high-resolution data. As a result, the biostratigraphic resolution for planktonic foraminiferal zonal schemes has significantly increased in the earliest Eocene across the PETM. At the same time, the requirement of reliable biohorizons for stratigraphic correlation across the other climate changes forces further ameliorations in the biostratigraphic classification of the entire early Paleogene. A recent and extensive review is available in the tropical to subtropical Paleogene planktonic foraminiferal Zonation by Wade et al. (2011: Earth Science Reviews 104).
Several complete Paleogene successions (Forada, Possagno, Alano, Farra), with a sound magneto-biochronostratigraphic and stable isotope record crop out in the Venetian Southern Alps of northeastern Italy. They have revealed to be well suited to explore the record of planktonic foraminifera in the early Paleogene.
All the biostratigraphic events utilized in the Early Eocene/middle Eocene standard zonal schemes have been recognized. However, our study shows that some foraminiferal events unexpectedly occur in a remarkably different position with respect to the available magnetochronological calibration.
Specifically, we present an updated magnetochronological calibration from the Tethyan realm of the lowest and highest occurrences (LO, HO) of the following zonal markers: LO of *Morozovella aragonensis,* LO and HO of *Guembelitroides nuttallii* and LO of *Acarinina cuneicamerata.*

The Early Eocene Climatic Optimum (EECO) as recorded by planktonic foraminiferal and stable carbon isotope changes in the classical Tethyan Possagno section (NE Italy)

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Increasingly scientific attention is dedicated to definitely outline the features of the composite, not-linear evolution of the Paleogene climate. The available paleoclimatic records (e.g., Zachos et al., 2001 Science 292, 2008 Nature 451) indicate that the Earth experienced in the Early Paleogene a pronounced warming trend that peaked during the Early Eocene Climatic Optimum (EECO; ca. 50 – 52 Ma, basically in Chron C23n) that represents the interval, ice free, with the highest global temperature recorded in the past 70 myr.
Although a relatively high data set has been recently generated from the analysis of several Paleogene successions, included numerous ODP Legs in Atlantic and Pacific Oceans (e. g., Lyle et al., 2002: Proc. ODP, Init. Repts.199; 2010: IODP Expeditions 320 and 32, Zachos et al., 2004: Proc. ODP, Init. Repts. 208; Pälike et al., 2009: IODP Prel. Rept. 320), several aspects concerning this crucial time interval still need to be addressed. The specific nature of climate variability, how stable climate was during the EECO interval and the origin of this event are still a matter of intense scientific debate thus forcing the acquisition of new widespread high-resolution data.
Given the importance of planktic foraminifera that are extremely sensitive to environmental modifications, the quantification of their changes is an excellent proxy for the comprehension of past surface-water variations during this interval of extraordinary warmth.
The EECO has been recently identified by Agnini et al. (2006: Earth and Planetary Science Letters 241) in the classical early Paleogene section of Possagno (Venetians Pre-Alps of northern Italy; Bolli, 1975: Schweizerische Palaeontologische Abhandlungen 9) that accounts a reliable magnetostratigraphy and calcareous nannofossil record. This continuous section, deposited in a bathyal setting, provides an excellent record of the Lower-middle Eocene transition as occurring in a marginal basin of the centralwestern Tethys.
Our detailed quantitative study of the planktic foraminifera shows a major change between 16 and 21 m-level resulting in a marked decline of the cold indices subbotinids balanced by prominent increase of the warm indices acarininids (from mean relative abundance less than 50% up to ca 80%). These significant variations well correlate the geochemical expression of the EECO event, consisting of a pronounced, composite negative $\delta^{13}C$ perturbation.
A further, crucial change is the distinct reduction in abundance of the specialized, symbiont-bearing, warm-indices morozovellids that virtually collapses from a mean abundance of ~24% in the lower part of the section to less than ~6% of the total population above the EECO and never recover up section. The causes of this apparently irreversible decline, occurred about 6 Ma before the *Morozovella* extinction, may include the decrease in temperatures and changes in the pCO_2 following the EECO event. The consequent modification in the water column structure may have negatively affected the ecological niches of the highly specialized muricate forms.

Hantkenina (Foraminiferida) in the Polish Outer Carpathians

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The Polish Outer Carpathians are situated in the western part of the Carpathian mountain belt that extends from the Vienna Forest to the Iron Gate on the Danube. The Outer Carpathian sedimentary domain was located at the NW margin of the Tethys Ocean and consisted of several longitudinal troughs and ridges. From the south to north the following sedimentary basins existed: the Magura, Fore-Magura set of basins, Silesian, Subsilesian, and the Skole basin. In the present-day configuration they represent individual structural units. The Silesian Ridge, separating the Silesian and Magura basins, was the most important elevation and source area within the Outer Carpathian sedimentary basin system (Oszczypko, 2006). In the troughs mainly flysch-type sediments were deposited while on the slopes and submarine rises hemipelagic and pelagic sediments developed. The entire sedimentation spanned the time between the Late Jurassic and the Late Miocene.

The planktonic foraminiferal genus *Hantkenina* has been sporadically recorded in the stratigrahical record of the Polish Outer Carpathians. *Hantkenina* has been found only in two settings, so far. Nowak (1954) first reported the discovery of *Hantkenina* from the Subsilesian unit in the area of Bielsko. In 1978, Gasiński presented the results of his studies on Nowak's material. Another setting is connected with the Fore-Magura thrust in the vicinity of Żywiec. In both cases *Hantkenina* has been recovered from the Middle Eocene variegated,pelagic marls. The microfossil assemblages are vey similar in their overall composition. They represent mixed foraminifera assemblages with planktonic taxa exceeding 80% of the total assemblage. However, the genus *Hantkenina* accounts only for 1%, at the most.

The Subsilesian basin was connected with the submarine, intrabasinal height situated in the marginal part of the Carpathian basin, north of the Silesian basin, while the Fore-Magura thrust sedimentation area was located in the middle part, on the southern slopes of the Silesian Ridge. Within the Outer Carpathian basin such settings favoured pelagic sedimentation, with sporadic intercalations of turbidites. The pelagic sedimentation, occupied relatively small areas in the entire basin. During the Early-Middle Miocene folding and thrusting the pelagic, ductile sediments were detached from their substratum and tectonically reduced. Their present day exposures are rare and structurally complicated.

The presented occurrences of the genus *Hantkenina* in the Polish Outer Carpathians seem to be connected with the most northerly situated sites along the northern margin of the NW Tethys. The hantkeninids, though generally scarce, had a worldwide distribution at low and mid latitudes (Coxall *et al.,* 2003). Their presence in the marginal parts of the basin points to the open marine deep-water conditions and good connection with world-wide circulation in the Middle Eocene.

References:

Coxall H., Huber B. T. & Pearson P. N, 2003. Origin and Morphology of the Eocene planktonic Foraminifer *Hantkenina*. *Journal Foram. Res.,*33,3: 237-261.
Gasiński A., 1978. Hantkenina in the Eocene at Bujaków (Polish Carpathians). *Rocznik Pol. Tow. Geol. (Ann. Societ. Polon.*) 48:39-53.
Nowak W., 1954. O stratygraficznym znaczeniu rodzaju *Hantkenina*. *Przegl. Geol.* 2, 9: 377-380.
Oszczypko N., 2006. Late Jurassic-Miocene evolution of the Outer Carpathian fold-and-thrust belt and its foredeep basin (Western Carpathians, Poland). *Geological Quarterly* 50, 1:169-194.

A high resolution compound specific carbon isotope study of the PETM in Northern Spain

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The Paleocene/Eocene Thermal Maximum (PETM) occurred approximately 55 Ma, lasting for 100 – 200 Kyr, initiating a period of global warming, biotic extinction, migration and turnover, and fundamental changes in the carbon and hydrological cycles[1] Marine and terrestrial sediments record the event, however discrepancy between the carbon isotope excursion (CIE) measured in the two realms has been observed ($\delta^{13}C$ marine 2.5 – 4‰, $\delta^{13}C$ terrestrial 6 – 8‰)[2,3,4]. Two hypotheses have recently been proposed for this discrepancy – the "marine modification" and the "plant community change" hypothesis[5]. The plant community change hypothesis states that the magnitude of the CIE is greater in the terrestrial realm owing to major changes in floral composition during the PETM from mixed angiosperm (flowering plants)/gymnosperm (conifers) flora, to a purely angiosperm flora [5,6].

To date, the plant community change hypothesis has been tested in North America and the Arctic. Presented here are preliminary results from eight sections in Northern Spain spanning the Paleocene/ Eocene boundary. The sections from East to West are Claret, Tendrui, Esplugafreda, and Berganuy in the terrestrial realm, La Cinglera and Campo, which collectively represent a shallow marine setting, and Zumaia and Ermua, which are deep marine sections.

Total organic carbon (TOC) $\delta^{13}C$ along this transect illustrate that the CIE associated with the PETM varies in magnitude between ca. 2 and 5‰; however there appears to be no direct link between magnitude and depositional environment. Furthermore, due to the high resolution nature of the $\delta^{13}C$ data, the onset of the CIE at all sections can be assessed in more detail than could previously be achieved from the carbonate isotope record. Preliminary results from compound specific carbon isotope analyses of higher molecular weight *n*-alkanes from all 8 sections appear to support the bulk $\delta^{13}C$ data. However, the results suggest that the bulk $\delta^{13}C$ records a lower magnitude excursion than the *n*-alkane data in the northern Spain PETM sections, as excursions of up to 8‰ are being found in the *n*-alkane $\delta^{13}C$ data. This apparent enhancement in the magnitude of CIE is particularly significant when considering the average chain length results, as thus far they record no observable change in those sections analysed. This could suggest that there is no appreciable reconfiguration of terrestrial higher plant biota coincident with the PETM across Northern Spain, indicating that plant community change is not responsible for overestimation of the CIE in the sections analysed.

References:

1. Bowen, G. J. *et al.* 2006. *EOS Trans. AGU*, **87**, (17) 165 - 169.
2. Bains, S. *et al.* 1999. *Science*, **285**, (5428) 724-727.
3. Bowen, G. J. *et al.* 2001. *University of Michigan Papers on Paleontology*, **33**, 73 - 88.
4. Schmitz, B. and Pujalte, V. 2003. *Geology*. 689-692.
5. Smith, F. A. *et al.* 2007. *Earth and Planetary Science Letters*, **262**, (1-2) 50-65.
6. Schouten, S. *et al.* 2007. *Earth and Planetary Science Letters*, **258**, (3-4) 581-592.

A model for neritic and bathyal dinoflagellates around the K/Pg boundary and their paleoenvironmental indications in the Eastern Alps

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Aiming to increase the paleogeographic database on dinoflagellates in the Paleotethys, their distribution was studied across the Cretaceous/Paleogene (K/Pg) boundary in four sections in the Eastern Alps. Knappengraben and Gamsbach sections are located in the Gosau Basin of Gams. They are continuous across the boundary and represent a bathyal environment. The section at Waidach north of Salzburg (Austria) contains neritic deposits of the Helvetic unit but shows a hiatus at the boundary. The section Goppling between Teisendorf and Oberteisendorf (Bavaria) belongs to a turbidite-rich deep-water system (Ultrahelvetic unit) and is considered to be continuous across the boundary. All studied sections comprise calcareous nannoplankton Zone CC26 (*Nephrolithus frequens* Zone) of latest Cretaceous age and part of the lowermost Paleocene Zone NP1 (*Markalius inversus* Zone), section Goppling reaches up to NP11. The dinoflagellate distributions yielded that *Trabeculidinium, Adnatosphaeridium* and *Codoniella* are restricted to the bathyal environment meanwhile *Manumiella* is restricted to the neritic environment.

In the Upper Maastrichtian, *Spiniferites, Pterodinium, Impagidinium* and *Achomosphaera* are dominant assemblages in the bathyal environment but *Areoligera, Manumiella* and *Trithyrodinium* are abundant in the neritic environment. The high abundance of heterotrophic taxa (*Trithyrodinium* and *Manumiella*) in the neritic Waidach section indicates a high nutrient supply. Two *Manumiella* spikes were recorded only at Waidach and interpreted to reflect slight coolings of oceanic surface waters. In the Danian, *Hystrichosphaeridium* dominated assemblages have been recorded in both neritic and bathyal environments. Acmes of *Spongodinium delitiense* are recorded ~1 m above the K/Pg boundary in the neritic and bathyal environments. These acmes could reflect slight coolings of surface waters in the earliest Danian.
The palynofacies analysis in the Gams Basin reflects a high abundance of AOM in the Maastrichtian and black phytoclasts in the Danian, which indicates intensified terrigenous run-off in the Danian with higher sea-floor oxygenation. In the Waidach section, palynomorphs are much more abundant; indicating a shelf to basin transitional area with dysoxic-anoxic conditions at the sea-floor.

Dinoflagellate cysts and Palynofacies across the Cretaceous/Paleogene boundary at the neritic Waidach section (Eastern Alps, Austria)

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In the area north of Salzburg (Austria), the Cretaceous/Paleogene boundary (K/Pg boundary) has been recognized in the neritic Waidach section (Helvetic thrust unit). The outcrop comprises calcareous nannoplankton Zone CC26 (*Nephrolithus frequens* Zone) of latest Cretaceous age (Gerhartsreit Formation) and part of the lowermost Paleocene Zone NP1 (*Markalius inversus* Zone) of the Olching Formation. The stratigraphic record across the K/Pg boundary is incomplete due to a minor fault. Well preserved and high diverse dinoflagellate assemblages of 36 samples are composed of a total of 163 dinocyst species and subspecies belonging to 62 genera. Dinoflagellate cysts do not show accelerated rates of extinction at the K/Pg boundary. The composition of the dinoflagellate assemblages, however, change drastically from *Areoligera* dominated assemblages in the Upper Maastrichtian to *Hystrichosphaeridium* dominated assemblages in the Lower Danian. Two *Manumiella* spikes were recorded in the Upper Maastrichtian (~1 m and 10 m below the K/Pg boundary) and interpreted to reflect slight coolings of oceanic surface waters. In the lower Danian, *Carpatella cornuta*, *Senoniasphaera inornata* and *Damassadinium californicum* have their first occurrences. An acme of *Spongodinium delitiense* (1 m above the K/Pg-boundary) indicates a decrease in paleoproductivity whilst the peridinioid/gonyaulacoid (P/G) ratio of all other samples suggests high paleoproductivity throughout the section. Moreover, this acme is interpreted as a transient cooling event of oceanic surface waters. Two palynofacies assemblages were distinguished indicating shelf to basin transitions and dysoxic to anoxic conditions.

The dinocyst record across the Cretaceous/Paleogene boundary of a bathyal mid-latitude Tethyan setting (Gosau Group; Gams Basin, Austria)

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For the first time, a high-resolution palynological study was carried out across the Cretaceous/Paleogene (K/Pg) boundary in two sections (Knappengraben and Gamsbach sections) of the Gosau Group near Gams (Gams Basin, Northern Calcareous Alps, Austria).
More than 178 dinoflagellate species and subspecies were identified from 89 rock samples concentrated around the K/Pg boundary. In most samples the dinocysts are moderate to well preserved but associated with reworked material. The dinoflagellate cyst assemblages from most samples are dominated (more than 90%) by gonyaulacoid cysts (e.g., *Spiniferites, Areoligera, Achomosphaera, Hystrichosphaeridium, Adnatosphaeridium, Pterodinium*). Peridinioid cysts occur in low and variable concentrations.
Some well known dinocyst marker species around the K/Pg boundary such as *Carpatella cornuta*, *Spongodinium delitiense, Trithyrodinium evittii, Palynodinium grallator, Manumiella druggii, Cordosphaeridium fibrospinosum, Membranilarnacia? tenella, Senoniasphaera inornata, Damassadinium californicum,* and *Dinogymnium acuminatum* are recorded in the studied samples. These marker species can be correlated with other dinocyst bioevents around the K/Pg boundary in the northern and southern hemisphere. In addition to these, *Trabeculidinium quinquetrum, Lejeunecysta izerzenensis, Batiacasphaera rifensis, Impagidinium maghribensis,* and *Cyclonophelium compactum* represent local markers. A *Spongodinium delitiense* acme is recorded in both studied sections (from 80 cm to 180 cm in Gamsbach section and from 100 cm to 220 cm in Knappengraben section above the K/Pg boundary) and is interpreted as a transient cooling event of oceanic surface waters. The stratigraphic distribution of the dinocyst species indicates that dinocysts have not been seriously affected by the mass extinction event at the K/Pg boundary.
Six dinocyst assemblages were identified by means of cluster analyses and four palynofacies assemblages have been distinguished based on the composition and abundance of kerogen groups (AOM, phytoclasts, palynomorphs). Their distribution does not reflect any regular pattern. The increase of phytoclasts in the Danian clearly indicates enhanced terrestrially derived input into the basin. Between the two studied sections major differences do exist palynologically and sedimentologically, which can be explained by small scale local lateral variations.

Cretaceous-Paleocene boundary in the Saratov VOLGA region as determined from Nannoplankton

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The Cretaceous-Paleogene boundary in the sections from the Saratov Volga Region may be clearly traced from replacement of the Maastrichtian chalky-marly rocks with the Paleocene clayey-siliceous ones. The upper part of the Maastrichtian there is represented by bluish gray marls with a layer of dense yellowish limestone in the top of the bed. The marls correlate with the CC25a nannoplankton sbz. The nannoplankton complex isolated from the lower part of the yellowish limestones correlates with the CC25b and CC25c sbz. The upper part of the limestones may be reliably referred to the CC26 zone.

A peculiar rock sequence, the Belogrodni fm overlies the Upper Maastrichtian limestones with distinct traces of a depositional break. This is represented by a member of alternating green glauconitic calcareous sandstones, aleurolites, siliceous calcareous clays. Shark teeth, solitary corals, poorly preserved mollusks occur in the basement and in the roof. In some parts of the Cretaceous-Paleogene boundary, boulders of Maastrichtian yellow limestones are observed, from 0,1 – 4 m in diameter. The thickness of a formation makes 0,2 – 15 m.

The rocks of the Belogrodni fm are discontinuously overlain with siliceous, slightly calcareous clays (gaizes) of the Syzran fm (100 m). The basement of the Syzran fm contains a layer of finely laminated black clays, with glauconite and poorly rounded fragments of the Belogrodni rocks.

The Belogrodni fm corresponds to the lower part of the Danian NP4 zone. The nannoplankton associations, traced from the most complete sections in the Pricaspian to the highly abridged left-bank sections of the Volsk Volga Region, allow to refer the Lower Syzran gaizes to the Early Paleocene and to correlate them with the upper part of the NP4 zone.

Over the entire examined area of the Volga right bank, the Paleocene beds lie transgressively over the broken underlying beds of the Late Maastrichtian. The greatest stratigraphic gap is characteristic of the sections from the Volga right bank; stratigraphically, this may comprise the upper part of the Maastrichtian, the Danian and probably the lowermost of the Selandian stage. The smallest stratigraphic gap is observed in the sections from the interior part of the Pricaspian Depression (Novouzenskaya, Eltonskaya key wells), with the Danian and the Selandian stages occurring in substantially larger stratigraphic extents.

The beds corresponding to the CC26 zone may probably correspond to the maximum of the Maastrichtian transgression accompanied by optimization of the biota paleoecological living environment, which is confirmed by a rich complex of foraminifers and nannoplankton and by the development of larger forms within the complexes.

The nannoplankton complexes from the Belogrodni and the Syzran fm are highly depleted. The complex generally lacks the species indicative of substantial climate cooling. The Early Paleocene marine basin might have been inherited from the Maastrichtian and the Danian ones. The latter one used to occupy a smaller area than the Maastrichtian or the Selandian basins: it advanced into the territory of the Volga right bank as major gulfs. This is testified to by the beds of the Belogrodni fm.

Paleogene palaeogeography and tectonic evolution of the Salzburg-Reichenhall basin and adjacent units in northern Eastern Alps

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The Eastern Alps include the remnants of two continent-continent collisional orogens, which are superimposed to each other. The earlier orogen formed at about the Early to Late Cretaceous boundary and represents, after the closure of the Penninic oceanic basin, the overriding plate of the second Middle Eocene to Oligocene orogen. In terms of the palaeogeographic and tectonic evolution of the Eastern Alps, the Paleocene to early Eocene time represents a transitional stage between these two paroxysmal orogenic events.

This study provides new petrographic (Dickinson-Gazzi method) and single-grain Ar-Ar white mica ages from sandstones of Paleogene siliciclastic successions of two units of the central northern Eastern Alps, which were exposed in two tectonic plates during the closure of the Penninic ocanic basin. (1) The Upper Cretaceous to Eocene Salzburg-Reichenhall basin (SR basin) is exposed at the northern leading edge of the Northern Calcareous Alps (NCA) overlying the Cretaceous Austroalpine nappe complex. The SR basin is interpreted to have initially formed as Upper Cretaceous pull-apart-type collapse basin at a sinistral overstep within a regional E-trending wrench fault crossing Salzburg city and overstepping the folded Permian to Lower Cretaceous NCA succession. The Late Cretaceous stage is governed by longitudinal infilling, mainly from E to SE, and steep lateral basin margins. Later, during Santonian to Paleogene, marl deposition suggests loss of the pronounced palaeo-topography, which re-appears with siliciclastic turbidites of Late Paleocene/Eocene age. (2) In contrast, the Rhenodanubian Flysch zone (RFZ) represents the Lower Cretaceous–Eocene infilling of a deep sea basin deposited in part on Penninic ocean floor and in part on a distal continental (European/Helvetic) margin.

Sandstone compositions of Paleogene Nierental Fm. (Untersberg section of Egger et al., 2009) of the SR basin are dominated by carbonatic framework constituents and calcitic cement. Hybrid sandstones comprise monocrystalline and polycrystalline quartz, some plagioclase and K-feldspar, white mica and angular volcanic clasts with doleritic and microcrystalline quartz/feldspar fabrics. Most samples plot into fields of orogenic sources. Ar-Ar ages of detrital white mica from Paleogene formations mainly range from 87 to 104 Ma and indicate that mainly amphibolite facies-grade metamorphic units of the exhuming Cretaceous orogenic wedge contributed to the basin fill.

Paleogene RFZ sandstones have abundant carbonate clasts (up to 40 percent of framework constituents) including bioclasts like bryozoa, foraminifera and lamellibranchiata constraining their shallow water origin. The siliciclastic detritus is dominated by mono-crystalline quartz and subordinate clasts from highly metamorphic rocks (e. g. sillimanite-bearing gneiss) and lithic volcanic clasts (acidic, phenocryst-bearing components). Ar-Ar white mica ages are, in contrast to the underlying Lower Altlengbach Fm. (ca. Maastrichtian) with dominant Variscan (372, 331 – 312 Ma) and some minor contribution of Mesozoic ages (176 – 205, 122 Ma), single grain ages from the Acharting Subformation (Acharting brook) and Anthering Subformation (Anthering section of Egger et al. 2009) are within a narrow age Variscan group (339 – 363 Ma and 321 – 366 Ma, respectively).

Together, the new data confirm for the Paleocene/Eocene boundary: (1) the distinct palaeogeographic position of the SR basin and RFZ on two different plates, (2) significant exhumation of the Cretaceous-aged metamorphic Austroalpine nappe complex, and (3) a significant bimodal (acidic, mafic) volcanic contribution to the Penninic and SR basins.

References:

Egger, H., Heilmann-Clausen, C., Schmitz, B., 2009. From shelf to abyss: Record of the Paleocene/Eocene-boundary in the Eastern Alps (Austria). Geologica Acta 7, 215–227.

Differential dissolution susceptibility of Paleocene-Eocene planktic foraminifera from North Pacific ODP sites

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We investigated shell characteristics and differential dissolution susceptibility for planktic foraminiferal species derived from upper Paleocene and lower Eocene deep-sea sequences, ODP Site 865 (Allison Guyot) and Sites 1209B, 1210B and 1212A (Shatsky Rise) in the North Pacific Ocean. The purposes of this study are: 1) assessing the effects of differential dissolution on upper Paleocene-lower Eocene planktic foraminiferal assemblages, at species level and within different biozones, in order to quantify dissolution susceptibility of genera and species; 2) investigating the differences in their shell characteristics; 3) revealing the connection between the shell parameters and the dissolution robustness of taxa and 4) identifying the key shell parameter(s) in the dissolution susceptibility of foraminiferal taxa.
Two independent experiments were carried out, one focusing on gradual qualitative deterioration of taxa by dissolution and the other by concentrating on the weight loss of taxa. To gain data on shell parameters such as wall thickness, porosity and pore size, we analyzed SEM images of taxa. The number of chambers in the last whorl of taxa and the size of specimens are determined using binocular microscopy.

Our results confirm previous experimental results on differential dissolution susceptibility among taxa at generic level (Nguyen et al. 2009, *Marine Micropaleontology*). Accordingly, the large muricate *Acarinina* and *Morozovella* are most resistant, followed by the cancellate *Subbotina* and the small muricate *Igorina*. At species level, the thick-walled *A. soldadoensis* and *A. subsphaerica*, the large *M. subbotinae* are the most resistant species. Most of the large *Morozovella* species such as *M. aequa*, *M. formosa-gracilis*, *M. velascoensis* and *M. pasionensis*, together with *A. nitida* show average dissolution resistance. Small muricate *Igorina* species, the cancellate *S. velascoensis* and the thin-walled *M. acuta* and *M. occlusa* are the most vulnerable species.

Among the test’s structural parameters, wall thickness and size are the key parameters in dissolution resistance of a species. We propose a dissolution resistance formula, based on these two shell parameters. Application of this formula reveals a good agreement between the calculated and the measured dissolution resistance, indicating that the formula is applicable to the experimental dissolution process. The agreement between our experimental results and in-situ experimental results as well as natural quantitative/qualitative records suggests that our experiments well mimic natural dissolution processes. Consequently, these experimental results are meaningful for interpretations of foraminiferal dissolution in natural environments, especially in studies on early Paleogene climatic events that are often associated with dissolution phenomena.

References:

Nguyen, T.M.P., Petrizzo, M.-R. & Speijer, R.P. (2009): Experimental dissolution of a fossil foraminiferal assemblage (Paleocene-Eocene Thermal Maximum, Dababiya, Egypt): Implications for paleoenvironmental reconstructions. Marine Micropaleontology, 73, 241-258.

Diatom and silicoflagellate response to the hyperthermal events of Late Paleocene-Early Eocene in biosiliceus deposits of West Siberia and adjacent areas

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Late Paleocene-Early Eocene (58 – 50 Ma) is one of the warmest interval of the Cenozoic with episodes of short-term hyperthermal events identified by isotopic data. The most long-term and best documented event is the climatic optimum on the Paleocene-Eocene transition (PETM; 55,5 million years), followed by a series of brief hyperthermals of smaller magnitude. In the area of Pechora depression to Turgay strait and North Kazakhstan, including West Siberia and the eastern slope of the Urals, this period corresponds to the maximum development of marine transgression with high biosiliceous production. Detailed diatom and silicoflagellate records in the most representative sections (Khanty-Mansiysk, Kamyshlov, Korkino, Chumlyak, Baka, Sokolovsky, Emba and Kyrgyzskoe) and boreholes (228 -Inta,19A-Ust'-Manya, 8, and 10 (Omsk depression) demonstrate the reaction of siliceous microbiota to paleoenvironmental changes. In the Trinacria ventriculosa - Hemiaulus proteus - Coscinodiscus uralensis - Coscinodiscus payeri - Pyxilla gracilis diatom Zones there are two levels of biodiversity increase caused by warm water masses from Tethys.

The first level is related to the Thermal Maximum at the Paleocene-Eocene transition (PETM). The Trinacria ventriculosa (top) and Hemiaulus proteus Zones are characterized by high taxonomic diversity, manifested in the appearance of some new taxa – genera Fenestrella, Craspedodiscus, Podosira, Moisseevia, Psedotriceratium, Soleum, radiation of Anaulus, Hemiaulus, Trinacria s.l. Grunowiella. Silicoflagellates demonstrate appearance of extreme morphotypes. In particular, new taxon Dictyopsis sibirica, referred to a new genus is described. Specific features of Trans-Uralian diatom assemblages of PETM – higher than in Middle Volga species diversity and abundance of Anaulus, Fenestrella, Coscinodiscus. Occurrence of Trinacria s.l., Hemiaulus, Stephanopyxis, Eunotogramma is limited, no typical PETM markers of the Middle Volga region – Trinacria cancellata, Gyrocylindrus antiqua, Navicula-like species. Endemic for the Trans-Urals basins are Grunowiella sp. A, Pseudostictodiscus novozelandicus, Pseudotriceratium fallax, P. chenevieri, Fenestrella rossica, F. barbadense, the above-mentioned silicoflagellates Dictyopsis sibirica. Established differences make questionable the existence of a stable connection between West Siberian sea-strait and “Russian sea” of the Middle Volga at this time.

The second level of the appearance of thermophil assemblages tentatively assigned to the upper part of the zone Pyxilla gracilis (Nannoplankton zone NP12) and correlates with the isotopic events of the second half of Ypresian. Recorded bioevent is associated with the re-invasion of the PETM markers (Craspedodiscus moellleri, Fenestrella antiqua, Thalassiosiropsis wittiana), predominance of Grunowiella species, first occurrence of two new genera - Brightwellia and Golovenkinia and new species - Triceratium basilica, Pyxilla sp. 1. The most taxonomically diverse complex is found in the North Kazakhstan (Kyrgyzskoe, Emba). In Pechora basin (borehole 228), similar changes are less pronounced. In the south-east part of Western Siberia (wells 8, 10, Omsk depression), this episode is stressed by the appearance of transgressive biosiliceous clays (thickness 4 – 6 m) with similar diatom assemblage.

A short-lived warming event in the middle Eocene of the Gorrondatxe section (Western Pyrenees): evidence of a Lutetian Thermal Restoration

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The Paleogene climate was characterized by a late Paleocene to early Eocene warming, which peaked in the so-called Early Eocene Climatic Optimum (EECO, ca. 51 – 53 Ma), followed by a progressive cooling that culminated at the early Oligocene. Superimposed on this long-term climate evolution were several short-lived warming events referred to as hyperthermal events. Most of them occurred before the EECO, in the Paleocene and earliest Eocene, being the Paleocene-Eocene Thermal Maximum (PETM) the most prominent one. The occurrence of hyperthermal events during the long-term middle-late Eocene cooling is scarcely documented, with the exception of the Middle Eocene Climatic Optimum (MECO, ca. 40 Ma). This poor knowledge is most likely due to recovery problems to obtain high quality cores from the deep-sea and the widespread occurrence of hiatuses around the early-middle Eocene (Ypresian-Lutetian) transition.
The Gorrondatxe section (Western Pyrenees) exposes one of the most complete and expanded deep-sea early-middle Eocene successions on land. Due to its suitability for multidisciplinary stratigraphic studies, the Global Stratotype Section and Point for the base of the Lutetian Stage has recently been defined in this section, at approximately 47.76 Ma ago. Detailed sedimentological, geochemical and paleontological studies across the Ypresian-Lutetian transition revealed the occurrence of a distinct clay-rich interval in the lowermost Lutetian, which bears many of the hallmarks of other early Paleogene hyperthermal events. A sharp ~1‰ decline of $\delta^{13}C$, a decrease in pelagic carbonate sedimentation and an increase in terrigenous supply mark the onset of this interval, which is followed by a gradual and long recovery to former characteristics. A simultaneous environmental change is recorded by an increase in low-latitude planktic foraminifera and changes in benthic foraminiferal assemblages, including an increase in the relative abundance of opportunistic species such as *Spiroplectammina spectabilis* and *Aragonia aragonensis*, showing that the disruption affected both the sea surface and the sea bottom. This disruption lasted about 160 ky, similar to the duration of the PETM. The sequence of events across the Gorrondatxe clay-rich interval and the correlation among the faunal turnover, the $\delta^{13}C$ decline and the sedimentological changes, altogether suggest the occurrence of a previously unknown hyperthermal event. As this short-lived warming event occurred during the long-term middle-late Eocene cooling, it is here regarded as a transient Lutetian Thermal Restoration.

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New insights on the Danian/Selandian boundary in the Basque Basin, Western Pyrenees: implications for (inter)regional correlation

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The early Paleogene is well recorded in numerous land-based sections of the Western Pyrenees, representing a wide range of sedimentary environments, from continental to deep marine. (Hemi)pelagic sediments are mainly exposed in outcrops along the coastline facing the Bay of Biscay, such as at the Zumaia reference section, which was recently selected as the Global Stratotype Section and Point (GSSP) for the bases of the Selandian and Thanetian Stages. The Sopelana section, located some 100 km west of Zumaia, near the city of Bilbao, is another reference section of the area, and is well-known for the quality of its Cretaceous/Paleogene boundary transition. This section also encompasses an almost complete Danian/Selandian (D/S) boundary transition, which can be correlated bed-by-bed with the GSSP at Zumaia, thus allowing the establishment of intrabasinal correlations of the main events and evolutionary processes affecting open-marine microfossils across this chronostratigraphic boundary.

Here we present an integrated sedimentological, micropaleontological (foraminifera) and geochemical study of the Sopelana and Zumaia sections in order to decipher the extent of the paleoenvironmental changes recorded across the D/S boundary and its implications for global climate and interregional correlation. The D/S boundary coincides with a prominent lithological change between the Danian limestone-dominated succession and the lower Selandian red to grey marly member. No distinct first or last occurrences of foraminiferal genera/species have been observed at the D/S boundary of Sopelana and Zumaia, although it is remarkable that both benthic and planktic foraminifera experience a significant decrease in test size at the lowermost Selandian. Another important event detected in this study is a progressive but systematic change in the coiling direction of the planktic species *Morozovella occlusa*, which evolved from an assemblage with proportionate coiling in the uppermost Danian to populations clearly dominated by a dextral coiling in the lowermost meters of the Selandian. These variations in test size and coiling direction might be related to changes in environmental parameters such as temperature, salinity and nutrient availability. In addition, benthic foraminifera show an increase in opportunistic taxa across the lowermost Selandian and a progressive decrease in calcareous-cemented agglutinated foraminifera, the later probably being related to a higher detrital supply to the basin floor during the marked sea level drop recorded in the Pyrenees across the D/S boundary. These microfossil events may be also related to climatic and paleoceanographic changes of global scale. Therefore, our understanding of these events and of their temporal sequence may shed light into the D/S boundary interval.

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First detailed analysis of Early Bartonian orthophragmines from the northern margin of Africa (Damouss section, NE Tunisia) and their paleobiogeographic aspects in theTethys

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In spite of our rather comprehensive knowledge on the Late Paleocene-Eocene orthophragmines from Europe and eastern Mediterranean region, we have almost no data from Africa and particularly from northern margin of the continent. The Eocene shallow-marine deposits at the northern part of the continent belong to Gondwana and lie in their setting to the south of Tethyan sea and are widely exposed in central Tunisia. In addition, the shallow-marine uppermost Lutetian- lower Bartonian limestones with a limited lateral extent are observed in the north-east of Tunisia between Hammamet and Gulf of Tunis. These carbonates, less than 15 meters in thickness and developed in an otherwise deep-marine sequence, are rich in orthophragmines and nummulitids. A section with limestones overlying a planktonic foraminiferal marly sequence near Damouss yielded loose specimens of orthophragmines and nummulitids at the lowermost part of a the foraminifera-dominated limestone sequence (sample DAM.3) that enables us to carry out a detailed taxonomic work on orthophragmines and make some comments on their paleobiogeographic affilations.

The orthophragmines in DAM.3 are quite diverse and are represented by 13 species belonging to genera *Discocyclina, Nemkovella*, *Orbitoclypeus* and *Asterocyclina*. These genera are represented by *Discocyclina pratti* [*D. pratti* ex. interc. *montfortensis* Less- *pratti* (Michelin)], *D. trabayensis* [*D. trabayensis* ex. interc. *elazıgensis* Özcan et Less- *trabayensis* Neumann], *D. sella* [*D. dispansa sella* (d'Archiac)], *D. discus* [*D. discus* ex. interc. *adamsi* Samanta et Lahiri -*discus* (Rutimeyer)], *D. radians* (d'Archiac), *Nemkovella* sp., *Orbitoclypeus douvillei* (Schlumberger), *O. haynesi* Samanta et Lahiri, *O. zitteli* Checchia-Rispoli*, Asterocyclina sireli* Özcan et Less, *A. alticostata* [*A. alticostata alticostata* (Nuttall)], *A. kecskemetii* Less, *A. stellata* (d'Archiac). These are accompanied by *Assilina* ex. gr. *alpina*, *Operculina* ex. gr. *gomezi*, *Gyroidinella magna*, *Fabiania cassis, Sphaerogypsina* sp., *Orbitolites* sp., *Asterigerina* sp., *Nummulites* spp., and Alveolinidae. The marly levels just below sample DAM.3 contain planktonic foraminifera of *Morozevella lehneri* Zone indicating an Latest Bartonian-Early Bartonian age for sample DAM.3.

Among the orthophragmines the most dominating taxon is *Orbitoclypeus haynesi*, an Early Bartonian species originally described from Kutch (NW India). In Kutch, this species is the only taxon belonging to the genus *Orbitoclypeus* and occur very abundantly at the type-locality. *O. haynesi* has been recorded from the Bartonian beds in Thrace (Turkey) but not known further west in Europe. *Orbitoclypeus varians* and *O. zitteli*, abundantly occuring in time-equivalent units in Turkey and Europe are almost absent in the studied section. Only a single specimen assigned to *O. zitteli* has been described. In addition, the four ribbed *Asterocyclina, A. sireli*, originally described from uppermost Lutetian of Turkey and recently discovered in Lower Bartonian Fulra Limestone in Kutch (India), is also identified in the studied sample. This taxon is not known in upper Lutetian-Bartonian beds in Europe. The other taxa identified in DAM.3 are widely occuring in the northern part of Tethyan sea (a territory from France to Turkey). Thus, our data suggest that Damouss orthophragmines contain both assemblages commonly occurring in western India and Turkey and also in Europe.

Paleoceanographic history of the Paratethys: a multidisciplinary study to understand their isolation progress and continental climate change during the Late Paleogene

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The terminal Eocene massive global cooling was one of the most pronounced events in the climatic evolution during the Cenozoic era. Due to the vast amount of DSDP and ODP cores, the open oceanic record of this greenhouse-icehouse transition has been extensively studied. However, significantly fewer studies have concentrated on isolated marginal seas or on terrestrial paleoclimatic changes at the time. Marginal seas, such as the Paratethys in East-Central-Europe are particularly interesting because they reflect global signals in a different intensity. Evidence for ocean water cooling near the Eocene/Oligocene (E/O) boundary at about ~34 Ma years is provided by a sudden rise in benthic $\delta^{18}O$ values and Circum-Atlantic ice-rafted debris sediment and the fossil record of Antarctic vegetation. The thermal isolation of Antarctica and the sudden growth of the Antarctic ice sheet might have caused changes in insolation and surface ocean density, which in turn are known to contribute to abrupt shifts in deep-ocean circulation with significant consequences for regional and global climate changes. Moreover, the northward drift and rotation of the African continent and a related microcontinent (i.e. Apulia) and their collision with the European foreland had a strong impact on the Cenozoic paleoceanography. This stratification was triggered by cold boreal deep water and warm Tethyan surface water leading to initial bottom currents. Surface water salinities increased and dysoxic bottom water conditions developed, periodically interrupted by supply of oxygen-bearing water. These drastic oceanographic changes are responsible for the repeated deposition of laminated organic-rich sediments considered as hydrocarbon source rocks from the Alpine Molasse Basins through the Central Paratethys. Therefore, the Central Paratethys represents a key area for studying isolation progress of the Paratethys and their paleogeographic, paleoceanographic and paleoclimatic changes. For this project, four continuous Eocene-Oligocene boundary sections of marine sediments from the Central Paratethys area has been investigated for their foraminiferal contents and for stable isotope geochemical properties of their tests. The benthic foraminiferal analysis for the estimating of bathymetry, water temperature, salinity, organic matter fluxes and bottom water oxygenation have been performed by multivariate statistical analysis (Q-mode PCA, BFOI) and by stable isotopes measuring. The stable isotopes ($\delta^{18}O$ and $\delta^{13}C$) have been measured on both monospecific (or monogeneric) planktonic and benthic foraminiferal tests. Proxy records for the reconstruction of past continental climate change constructed form stable oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotope compositions of terrestrial vertebrate tooth (i.e. rhinocerotids, anthracotherids, equids). The main goal of this project is to reconstruct the evolution history of the paleoenvironmental conditions and paleoceanography of the Central Paratethys during the Late Paleogene in comparison with continental paleoclimatic changes.

Playing with different rules: nummulite banks in a greenhouse world

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The biosedimentary structures known as "nummulite banks" are still matter of debate about their autochthonous or allochthonous origin. Nevertheless, it is obvious that they are limited in time to the whole Eocene, being made up by the larger species of the genus *Nummulites*. This means they occurred during the last times of the Jurassic-Paleogene greenhouse interval, under chemical compositions of both the atmosphere and the oceanic waters fairly different from the modern ones.

To understand the nummulite banks we need first to define them according to the features we can observe both in the field and in laboratory on the collected samples. The definition must fit the original description by Arni (1965) and be as close as possible to the subsequent interpretations by following students. The definition here adopted consider as the main distinctive features the monospecificity and the relatively low A/B ratio.

The autochthonous view of the banks is here chosen as working hypothesis. However, the parallelism of the banks with modern coral reefs, first advocated in the original description by Arni, is considered not completely suitable to describe the bank paleoenvironment. Some recent data (Guido et al., 2010) suggest the presence of bacterial activity inducing a synsedimentary cementation of the nummulite tests, enhancing their mechanical resistance to the water energy. If confirmed, this lead to an unexpected similiarity with much older "mud mounds" rather than with modern coral reefs. It is still to be investigated the influence of water chemistry, especially the Mg/Ca ratio, and of atmospheric pCO_2 on the calcification rate of the larger species of *Nummulites*. In a general way, the calcitic tests of larger foraminifera were favoured by low Mg/Ca ratios whereas the aragonitic skeletons of scleractinians were not. The decline of larger foraminifera and the rise of modern coral reefs in carbonate settings seems to adapt very well to the temporal changes in the oceanic chemistry. The influence of the temperature changes in the same period could have been overestimated.

References:
Arni P. (1965). L'évolution des Nummulitinae en tant que facteur de modification des dépôts littoraux. Mémoires du Bureau de Recherches Géologiques et Minières, 32: 7-20.
Guido A., Papazzoni C.A., Mastandrea A., Morsilli M., La Russa M.F., Tosti F. & Russo F. (2010). Automicrite in a "nummulite bank" from the Monte Saraceno (Southern Italy): evidence for synsedimentary cementation. *Sedimentology*. DOI: 10.1111/j.1365-3091.2010.01187.x

Cyclostratigraphy of the Early/Middle Eocene transition: a Pyrenean perspective

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An integrated bio-, magneto- and cyclostratigraphic study of the Ypresian/Lutetian (Early/Middle Eocene) transition along the Pyrenean Otsakar section (Payros et al., 2011) resulted in the identification of the C22n/C21r chron boundary and of the calcareous nannofossil CP12a/b zonal boundary; the latter is the main correlation criterion of the Lutetian Global Stratotype Section and Point (GSSP) recently defined at Gorrondatxe (Basque Country). By counting precession-related mudstone-marl couplets of 21 ka, the time lapse between both events was calculated to be of 819 ka. This suggests that the age of the CP12a/b boundary, and hence that of the Early/Middle Eocene boundary, is 47.76 Ma, 250 ka younger than previously thought. This age agrees with, and is supported by, estimates from Gorrondatxe based on the time lapse between the Lutetian GSSP and the C21r/C21n boundary. The duration of Chron C21r is estimated at 1.326 Ma. Given that the base of the Eocene is dated at 55.8 Ma, the duration of the Early Eocene is of 8 Ma, 0.8 Ma longer than in current time scales. The Otsakar results further show that the bases of planktic foraminiferal zones E8 and P10 are younger than the CP12a/b boundary. The first occurrence of *Turborotalia frontosa*, being approximately 550 ka older that the CP12a/b boundary, is the planktic foraminiferal event that lies closest to the Early/Middle Eocene boundary. The larger foraminiferal SBZ12/13 boundary is located close to the CP12a/b boundary and correlates with Chron C21r, not with the C22n/C21r boundary.

References:

Payros et al. (2011): Geological Magazine, doi:10.1017/S0016756810000890.

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Calcareous Nannofossil Fragmentation as a Dissolution Proxy: A Case Study from the Eocene-Oligocene Transition at ODP Site 1090 (Agulhas Ridge, South Atlantic Ocean)

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The Eocene-Oligocene Transition (EOT) (~34 Ma) is characterized by global cooling and Antarctic ice-sheet expansion, sea level fall, deepening of the calcite compensation depth (CCD), and significant turnover in marine and terrestrial biota. CCD deepening at the EOT is interpreted worldwide based on an increase in carbonate accumulation at multiple deep ocean sites. In the South Atlantic, the CCD is interpreted to have deepened by ~1 km, but a detailed CCD history across the EOT has not been previously developed for this region. In this study, quantitative analysis of calcareous nannofossil assemblage was carried out within the EOT interval at ODP Site 1090 (42°S; Agulhas Ridge; South Atlantic). The primary goals of this work were: (1) to assess the degree of dissolution affecting nannofossil assemblages; (2) to use the nannofossil dissolution signal as proxy for CCD variation; and (3) to characterize surface-water temperature and nutrient changes during the EOT using paleoecological information provided by nannofossils.

Within the EOT interval of ODP Site 1090, two indices of dissolution were calculated using the preservation state of two common taxa: *Coccolithus pelagicus* and *Reticulofenestra umbilicus* group. A third dissolution index was calculated using characteristics of the entire assemblage. Comparison between the nannofossil indices and carbonate content shows a striking correspondence, indicating that dissolution was a major factor controlling carbonate sedimentation and nannofossil preservation/ assemblage composition in the EOT interval at this site. Additionally, there is a good correspondence between carbonate content and *Blackites* and *Clausicoccus* abundance, suggesting that dissolution is also a major factor in controlling the stratigraphic distribution of these taxa.

Variation in nannofossil dissolution indices and carbonate content through the EOT interval of Site 1090 are interpreted to reflect CCD fluctuations. The CCD at this site markedly oscillates in the latest Eocene and then deepens in the earliest Oligocene in correspondence with oxygen isotope ($\delta^{18}O$) Step 2 (coincident with Oi-1). An intense dissolution interval is observed in the latest Eocene immediately prior to oxygen isotope Step 1. Within this dissolution interval, however, only one sample is totally barren of nannofossils and the total abundance varies with carbonate content, suggesting that nannofossil assemblages are good dissolution indicators even in extreme conditions of carbonate under-saturation. Nannofossil dissolution indices also define an interval of carbonate dilution just prior to oxygen isotope Step 2, which results from an increase in biosiliceous sedimentation.

A selection of well-preserved samples was used for the paleoecological interpretation of nannofossil assemblages across the EOT at Site 1090. A major assemblage change is observed near the E/O boundary (~33.6 Ma) and is interpreted to reflect an increase in sea-surface nutrient availability, possibly in conjunction with cooling. This event is followed by a gradual increase in fertility associated with cooling which culminated at Step 2. Following Step 2, nannofossil assemblages at Site 1090 indicate nutrient-enriched cold waters during the earliest Oligocene.

Boron proxy evidence for surface ocean acidification & higher pCO_2 during the PETM

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The Paleocene-Eocene Thermal Maximum (~55 Ma) has been widely attributed to a rapid input of a large mass (~4500 – 6000 GtC) of ^{12}C-enriched carbon into the ocean-atmosphere system. Patterns of calcium carbonate dissolution at the seafloor as well as modeling studies suggest that this was accompanied by a rapid decrease in ocean pH, followed by a gradual recovery. A further result of such modeling studies is the suggestion of an "overshoot" or supersaturated ocean phase after the recovery interval, when the CCD deepened to below its Paleocene depth and surface water carbonate saturation states rose to above pre-excursion levels. In an effort to document changes in the saturation state of surface waters, and infer potential effects on calcifying organisms and Mg/Ca and $\delta^{18}O$-based temperature estimates, we have measured B/Ca and Mg/Ca in mixed-layer planktic foraminifers from site 1209 in the Pacific and Sites 1262 and 1263 in the Atlantic. Previous work at these sites has documented large increases (50%) in Mg/Ca ratios in the mixed-layer planktic foraminifer species *M. velascoensis* and *A. soldadoensis* consistent with 5 to 6°C of surface warming. Our B/Ca results suggest a large drop in surface water pH coincident with the rise in temperature at the onset of the carbon isotope excursion followed by a gradual recovery to pre-excursion levels. The latter feature, coupled with a rise in total alkalinity resulting from dissolution of $CaCO_3$ is taken as evidence of a carbonate saturation overshoot phase starting ~100 ka after the onset of the carbon isotope excursion. We are currently measuring boron isotopes in the same taxa in order to quantify the pH changes suggested by the B/Ca data. Estimating the magnitude of the pH drop at the onset of the event will facilitate computations of the mass and rate of carbon input that triggered the PETM, as well as the magnitude of change in pCO_2.

Early Ypresian microfossil assemblages and stable isotopes during a distinct plankton peak in the Corbières (Aude, France) continental margin record

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The Corbières Foreland Basin represents the southeastern-most extension of the Aquitaine Basin. During the Ypresian a succession of marine, brackish and fluvio-lacustrine sediments were deposited in the Corbières (Aude, France) region. The present study focuses on the middle and upper part of the neritic „Blue Marls“. Samples from the overview section contain calcareous nannofossils indicating the zone upper NP11 and high sedimentation rates. Ostracoda, foraminifera and larger faunal elements suggest a shift from outer neritic to nearshore/delta-front environments. The lower third of the section is characterized by a strongly variable plankton/benthos-ratio (1 – 85%). A last pronounced peak in planktic foraminifera occurrence is linked to a near disappearance of all larger faunal elements and a change in the ostracod assemblage.

A detailed sampling (46 samples in 15 cm intervals) pinpoints the correlation between rising P/B-ratio and abundance and composition of the ostracod assemblage. Variations in the assemblages of the planktic and small benthic Foraminifera taxa suggest rapidly changing conditions, probably triggering the speciation event in the ostracod lineage *Echinocythereis isabenana-aragonensis*. During the depleted interval ostracoda and foraminifera numbers decrease, *Pseudouvigerina wilcoxensis* is nearly absent and buliminids, *Pulsiphonina wilcoxensis* as well as echinoderm spines peak. The depleted interval is slightly preceded by the first occurrence of the planktic taxa *Subbotina hornibrooki* and *Globoturborotalites bassriverensis*, the latter representing a PETM-excursion taxon. The subsequent interval is characterized by a rapidly increasing P/B-ratio, a dominance of *Globoturborotalites bassriverensis* and *Pseudohastigerina wilcoxensis* as well as an altered ostracod assemblage. Sedimentation of clastic material larger than 63µm increases approximately 100%. Bulk $\delta^{13}C$ values generally drop from around -1,0‰ to around -1,5‰ and then increase to -0.8‰ after the plankton peak. This negative excursion is probably linked to one of the global CIEs in zone NP11 (H-K), though the short represented timespan (approx. 15ka) renders a clear correlation difficult.

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The Middle Eocene Climatic Optimum (MECO) in the high latitudes of the North Atlantic: Temperature and Biotic change.

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Increasingly high resolution isotope- and novel organic geochemical proxy records have revealed that the long-term cooling trend of the middle Eocene was interrupted by a warming phase designated the Middle Eocene Climatic Optimum (MECO). It is suggested to represent an increase in sea surface temperatures of about 4°C, lasting approximately 400 kyr. The temperature evolution of the MECO is notably well-documented in the Southern Ocean. However, records of temperature- and biotic change during the MECO are largely missing from the higher northern latitudes. Here we document on the sea surface temperature evolution during the MECO reconstructed using TEX86 from Ocean Drilling Program (ODP) site 647 situated in the Labrador Sea. In addition, organic walled remains of dinoflagellates (i.e. dinocysts) were investigated in order to identify environmental change in response to the MECO.

Sea-level changes across the PETM in the Pyrenees, part 1: evidence from coastal plain settings

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The behaviour of the sea level during the PETM is somewhat controversial, some authors maintaining that the event took place during a sea-level lowstand, others that it was coeval with a sea-level rise. These seemingly contradictory hypotheses have been reconciled by our studies in two ancient coastal plain in the Spanish Pyrenees, the Tremp-Graus Basin and the Basque-Cantabrian Basin. Based on outcrop and borehole information we show that a sea-level fall of more than 18 m occurred about 100 – 150 ka prior to the onset of the PETM, causing a seaward displacement of the shoreline larger than 16 km, a widespread incision of valleys in the alluvial plains and the subaerial exposure and excavation of the adjacent marine carbonate platforms. The sea level began to rise about 40 ka before the PETM producing the infilling of the incised valleys, and continued rising during and after the event leading to the aggradation of the alluvial plain. However, the sea level did not regain its pre-fall position until near the end of the PETM. Therefore, although rising, the sea level was comparatively low in the SE Pyrenean area during most of the PETM. Similar changes have been reported in Egypt, the Paris Basin and the Austrian Alps, attesting to the supra-regional (if not global) scope of the PE sea level cycle.

It has been suggested that the pre-PETM sea-level fall could have contributed to the CO_2/CH_4 emission that triggered the PETM, by oxidation of organic matter in subaerially exposed marine deposits and/ or by release of methane from the shelf, hypotheses that can be tested by taking into account other Paleocene sea-level changes. Four sea-level cycles of similar or even greater amplitude than the one considered here are recorded in the Pyrenees and elsewhere, none of which seems to be linked to a climatic warming, a fact arguing against a causal link between sea-level falls and thermal events. Yet, in comparison with them, the PE fall (and rise) was unusual by its rapidity, for the whole PE cycle was completed in about 400 ka, while the four preceding Paleocene cycles ranged between 1.5 and 3.5 Ma in duration. This circumstance entails that any genetic link with the PETM would rather be related to the rapid rate of the sea level fall predating the event than to its magnitude.

Alternatively, it is also possible that the PE sea-level cycle and the PETM are both a reflection of tectono-magmatic events in the north Atlantic, and therefore that their temporal concurrence are casual rather than causal.

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Sea-level changes across the PETM in the Pyrenees, part 2: evidence from a platform interior setting

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The Paleocene and lower Ilerdian are represented in the south-western Pyrenees by the Gallinera Group, a ca. 300 m thick unit of platform interior, shallow marine carbonates rich in algae and larger foraminifera. In the extensive outcrops of this unit, the PETM is generally recorded by a comparatively thin (< 2 m) interval of nummulite-rich marls located at the base of the Ilerdian succession. However, in the Ordesa-Monte Perdido National Park of Spain, the PETM is represented by an up to 25 m thick siliciclastic unit, named La Pardina Formation after its best outcrop, interpreted as a deltaic accumulation (Robador et al., 2009, Geogaceta 46, pp111-114). The outstanding exposures of the National Park offer a continuous cross-section of this ancient delta, in which three main facies can be differentiated, sketched in Fig. 1.

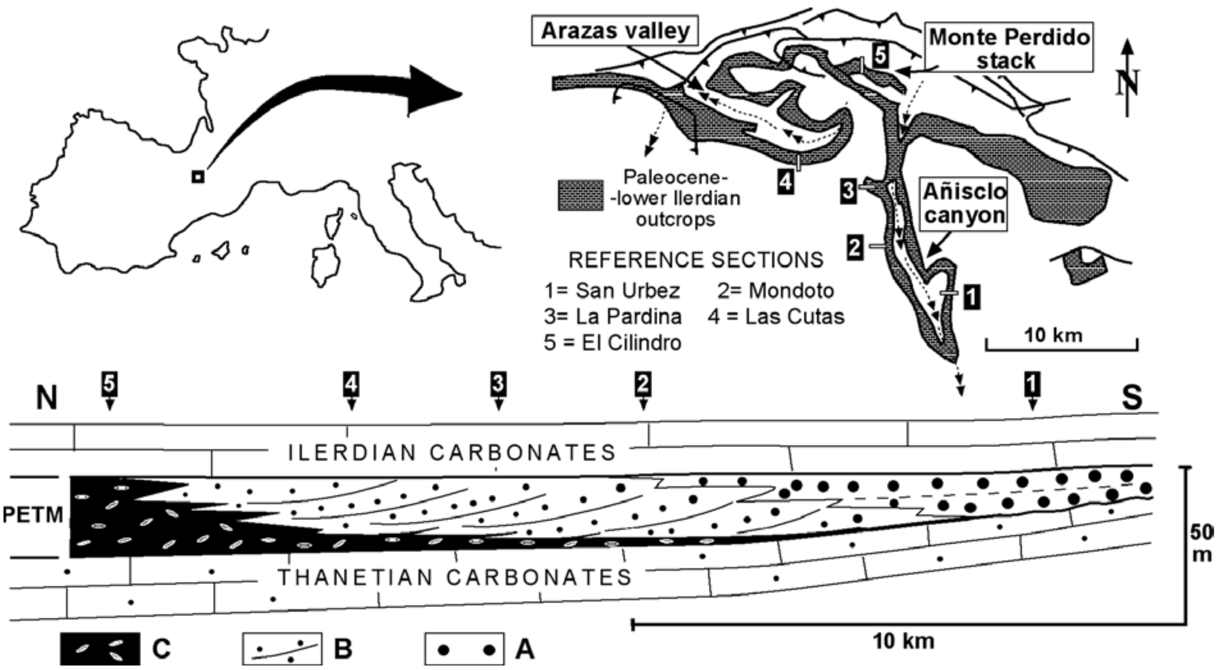

Figure 1.: Location, outcrop map, reference sections and cross-section across the Thanetian-Ilerdian boundary in the Ordesa-Monte Perdido National Park (Spain)

Facies A consists of unfossiliferous pebbly quartz sandstones, arranged in a fining-up sequence, and is interpreted as delta-plain distributary channel fill. Facies A abruptly overlies an irregular erosional surface carved in marine Thanetian sandy limestones, a facies shift that clearly indicates a sea level fall. Facies B is also made up of unfossiliferous quartz sandstones, now disposed in a coarsening-up sequence that, in proximal outcrops, is capped by facies A (Fig. 1). In favourable outcrops (e.g., La Pardina) large-scale foresets or clinoforms can be clearly perceived, recording the progradation of the delta front. Since other data demonstrate that the sea-level rose during the PETM (Pujalte et al. part 1, this volume), such progradation implies a massive clastic supply. Facies C is composed of nummulite-rich marls and marly limestones, interpreted as prodelta deposits. Facies C can be confidently ascribed to the PETM based on both biostratigraphic determinations and isotopic data, its vertical and lateral interfingering with facies B being the main evidence linking La Pardina delta and this thermal event.

Eocene *Podocarpium* (Leguminosae) from Hainan Island of South China and its phytogeographic implications

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The previous fossil records indicate that the extinct genus *Podocarpium* A. Braun ex Stizenberger 1851 of the Leguminosae was extensively distributed in Eurasian sediments from Early Oligocene to Pliocene. The fossil *P. hainanensis* sp. nov. recovered from the coal-bearing series of the Changchang Basin from Hainan Island of South China is described in this paper, and this is the oldest megafossil of *Podocarpium* up to the present. In view of the fossil record of *Podocarpium* and its extant relative groups of Africa, the ancestral population of this genus is speculated to originate in Africa on the basis of continental drift theory and the Out of India hypothesis. After the Indian plate collided with Eurasia, *Podocarpium* migrated to Asia from the Paleocene and arrived at Hainan Island of South China in the Eocene. During the Oligocene, it was able to enter Europe. The existence of a wide spread arid band between north and south China from the Paleocene to the Oligocene made it difficult for *Podocarpium*, a thermophilous and moisture-loving plant, to disperse northward. In the Miocene it spread extensively across subtropical to warm temperate areas in Eurasia and reached its peak after the arid band disappeared. Due to the influence of the Tibetan plateau uplift and climatic deterioration, distribution of *Podocarpium* rapidly shrank and it finally became extinct in Eurasia during the Pliocene.

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Environmental- and sea-level change revealed by dinoflagellate cysts during the Eocene-Oligocene transition at St. Stephens Quarry, Alabama, USA.

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The Eocene-Oligocene transition (EOT, ~34 Myr ago) represents the final transition from the early Paleogene “Greenhouse” into the present “Icehouse” by the initiation of Antarctic glaciation. The EOT is recorded in deep-sea benthic foraminiferal oxygen isotope ($\delta^{18}O$) records as two increasing steps, ~200 kyr apart. However, the relative contribution of cooling and increasing ice-volume cannot be separated from such $\delta^{18}O$ records. Independent temperature- and sea-level reconstructions are crucial for understanding the order of events enveloping the onset of Antarctic glaciation.

The classic reference section for the EOT, St Stephens Quarry (SSQ) in Alabama, USA, contains a relatively expanded and complete shelf succession. Previous studies at SSQ have already provided benthic foraminiferal stable isotope- and Mg/Ca based temperature information. Sea surface temperatures were reconstructed using TEX_{86} and planktonic Mg/Ca analyses. Altogether, these data show that the first step of the EOT (precursor or EOT-1) primarily reflects cooling, whereas the second step (or Oi-1) primarily reflects increasing ice-volume.

Here, we report on biotic change revealed by evaluating assemblages of fossil remains of organic walled dinoflagellates (dinocysts). Dinoflagellates are a group of unicellular surface dwelling algae and are often used to sensitively record environmental changes. We have inferred sea level change by evaluating dinocyst assemblages in the relatively shallow section of SSQ. This led us to revise the sequence stratigraphy and age model for SSQ. We document a minor sea-level fall associated with the EOT-1 and a more substantial sea-level fall at the Oi-1. At the EOT-1 we furthermore recorded the occurrence of a taxon typically associated with cold water. This is in accordance with the geochemically reconstructed temperature drop of 4 – 6°C. Early Oligocene assemblages above the Oi-1 are indicative of more productive and shallower lagoonal settings. Our records show that the EOT was a period of profound environmental change, also in the (sub)tropics.

Unravelling the PETM record in the "Sparnacian" of NW Europe: new data from Sinceny, Paris Basin, France

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In order to decipher the PETM (Paleocene-Eocene Thermal Maximum) impact on the "Sparnacian" diversified and interconnected paleoenvironments of the Paris Basin, and to ensure correlation of the events and processes identified, a high resolution temporal framework is essential. Historically, the Paris and adjacent basins are the cradle of stratigraphy, where the notion of "Sparnacian" took shape (Dollfus 1880), pointing terrestrial to lagoonal deposits with particular facies and faunas, interstratified between two easily distinguishable Thanetian and Ypresian sandy marine formations. Since that time stratigraphy has evolved, and we refer now to the lithostratigraphy of Aubry *et al*. (2005).
A 31.5 m deep drilling has been augered at Sinceny, a key locality for the "Sparnacian" of the Paris Basin. Various analyses have been performed on the samples collected: granulometry, XRD mineralogy, carbonate and organic carbon contents, biostratigraphy, palynofacies, rock-eval pyrolysis and chemostratigraphy ($\delta^{13}C$ of the dispersed organic matter). Seven lithological units are defined among which five may be attributed to the "Sparnacian" intercalated between fine glauconiferous sands of Late Thanetian and Early Ypresian, with in ascending order: 1) a carbonated silty medium-sized sand, 2) a sandy marl with carbonated concretions and limestone beds, 3) a plastic clay, oxidized at the bottom, but with increasing pyrite upwards, 4) lignite and clay beds, all pyritic but more shelly upwards, 5) a shelly crag with small flint pebbles ("Falun et Sable à Galets Avellanaires de Sinceny": FSGA). The CIE (Carbon Isotopic Excursion), proxy of the PETM, extents over nearly 20 m of the section. In this interval, isotopic values fluctuates around –26 to –28 ‰. They are more negative in the lower part and show short term fluctuations in the upper part, which may reflect changes in depositional environment. The *Apectodinium* acme, another proxy of the PETM, is recorded in the lagoonal facies. Clay minerals do not show any kaolinite influx in relation with the CIE, and interstratified kaolinite/smectite is characteric of the third unit. The palynofacies and pollen and spore assemblages are fairly similar to those from other "Sparnacian" NW European units, with some charcoal beds and *Plicapollis pseudoexcelsus*, Juglandaceae and other taxa acmes. The FSGA is chemostratigraphically (averaging –24 ‰) and biostratigraphically different (*Apectodinium* less abundant, other taxa present or abundant).
Correlation with published sections in the Paris Basin is possible using litho- and bio-stratigraphy, but not chemostratigraphy (Thiry et al, 2006). Indeed such a long, regular and unequivocal CIE had never been recorded in the Paris Basin, neither in Limay, nor in the Mont Bernon and Provins reference sections, all situated on the Paris Basin edges where the deposits are more prone to sedimentary hiatuses. The FSGA unit postdates the PETM episode and evidences the Ypresian s.s. transgression in the "Sparnacian" lagoonal setting. Correlation with the P/E successions of the Belgian, London and Dieppe-Hampshire Basins is also possible, although further high resolution data are necessary in the Paris Basin.

Biodiversity hotspots were cold during the Eocene

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In the present oceans marine biodiversity is highest in the warmest parts of the ocean, in the western part of the Pacific Ocean. Many hypotheses have been formulated about the processes underpinning this pattern, but the potential of the fossil record to discriminate between these hypotheses is poorly utilized.

The congruent biogeographical patterns of large benthic foraminifera (LBF) with that of other tropical shallow marine organisms show that LBF can be used for measuring overall diversity in tropical marine environments. Here I use the correlation of genus and species richness in LBF with environmental parameters during the late Lutetian to evaluate several hypothesis, and especially the positive correlation between temperature and diversity.

The Eocene ocean was very different from the present day ocean, with the highest diversity at the northwest shores of the Tethys Ocean. This biodiversity hotspot was not associated with the warmest area of the Eocene ocean, but with a very similar temperature window as the current area of maximum diversity. These data hint at a temperature limitation to marine biodiversity.

Primary biogeographic breaks in large benthic foraminifera reflect the pattern of oligotrophic water masses delimited by and due to gyral current systems and attenuated by upwelling systems. An analysis of the distribution patterns of *Nummulites* is used to provide initial insights in the distribution of water masses in the Eocene oceans. This analysis provides evidence for the existence of a faunal break in the Tethys seaway between Africa and Eurasia long before final closure. It also brings to light a large, highly productive area of relatively low biodiversity along the northern shores of Africa.

Paleomagnetic dating of *in situ* weathering profiles of Belgium and northern France: paleogeographic implications around the Paleocene-Eocene boundary

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The geological archives record «hyperthermic» crises, along with their consequences on the biota and physical environment. Among these, the PETM (Paleocene-Eocene Thermal Maximum) is often considered as the closest analogue to the current climate crisis due to its global character and the speeds at which the CO_2 rate and average temperatures increased. The shallow to deep marine environments from various paleolatitudes have been studied intensively (e.g. Aubry et al, 2007), but apart notable paleontological studies, the PETM impact on the terrestrial realm at a regional scale has probably not been studied and integrated enough (Zachos *et al,.* 2008). Moreover very few studies aimed at checking if the drastic rises of greenhouse gases and temperature had a real impact on the weathering profiles development during the PETM. Such a regional study is proposed in the “Sparnacian” terrestrial and lagoonal units of the Paris Basin, which offers rich and diversified interconnected paleoenvironments, and on its emerged interfluves and borders.

The paleoweathering profiles here considered belong to the so-called “Landenian” quartzites, or “Sparnacian” silcretes, and are locally well correlated to the first terrestrial units of the Tienen and Mortemer Fm, between the Upper Thanetian and Lower Ypresian marine units. However some silcretes and ferruginous sandstones are sometimes dated no better than Early Paleogene. To improve the error bar from 25 Ma to 5 Ma would mark a significant progress. Paleomagnetism is one of the methods useful to improve the uncertainty being often the status of those geological objects. Goethite and hematite, main iron oxides formed in weathering profiles, acquire a chemical remanent magnetization (CRM) in the direction of the ambient geomagnetic field. Consequently paleomagnetism is often considered as the most suitable method for dating weathering profiles (e.g. Idnurm & Senior, 1978; Ricordel-Prognon et al, 2010). The fossil geomagnetic direction enables one to calculate the virtual magnetic pole (VMP) of the site where magnetic minerals were precipitated. Dating the minerals is then possible by comparing their recorded paleomagnetic poles (VGP) with the apparent polar wander path (APWP) of the continent in which the site is located.

In situ weathering profile formed upon the Upper Thanetian glauconitic sands from the Grandglise section (Belgium) have been sampled in details and various analyses have been performed: granulometry, XRD and magnetic mineralogy, petrography, paleomagnetism. Haematite is the main magnetization carrier, directions are well clustered, with a low MAD (maximum angular deviation). However the dating obtained around the Paleocene-Eocene boundary is consistent with the stratigraphic position of the Grandglise paleosol and gives evidence of a fossil weathering, instead of a recent one related to a Neogene to Quaternary re-exposure often invoked for such red and variegated sandstones. Our results and others recently obtained in the neighboring Avesnois help to decipher the correlation between the Grandglise paleosol and surroundings silcretes and to precise the terrestrial paleogeographic evolution on the emerged areas during this critical interval.

Ichnological record of macrobenthic community changes across the Paleocene-Eocene Thermal Maximum in the Zumaia section, northern Spain

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The Zumaia section on the Biscay Bay coast can be considered one of the most complete, continuous and expanded sections of the Paleocene in open-marine facies in western Europe and the Mediterranean, where the Paleocene-Eocene boundary (P/E) is precisely determined at the base of a few metres thick package of red marls. The boundary interval contains trace fossils that were significantly affected by the environmental changes related to the Paleocene-Eocene Thermal Maximum (PETM). High-resolution ichnological analysis point to well marked different ichnological features before, during, and after the event.

A well developed normal, tiered burrowing community (larger and smaller *Chondrites*, *Planolites*, *Scolicia*, *Thalassinoides*, *Zoophycos*, and punctually *Avetoichnus*), is present in marls with glauconite, and in turbiditic sandstones and limestones, below the PETM, indicating oxic conditions and normal benthic food availability. Towards the P/E, ichnodiversity and ichnofossils abundance decrease, indicating progressive deterioration of the environmental conditions for macrobenthic community.

In red marls with green spots deposited during the PETM the trace fossils disappeared rapidly. Nevertheless, the sediment is bioturbated, mottled ichnofabrics, but without trace fossils preserved. This can reflect the global increase in temperature, and the concentration of benthic food in the very shallow water saturated surface sediment layer, in which preservation of trace fossils was impossible due to low sediment cohesion (soupground). An about 20 cm thick interval with primary horizontal lamination and the absence of bioturbation is present in the lower part of the red marls, probably indicating drastic oligotrophy conditions during climax of the PETM, and local depletion of oxygen within the sediments, although probably not true anoxia. The environmental perturbation significantly affected the whole benthic habitat, as shown by the correspondence with the main phase of the benthic foraminiferal extinction.

After the PETM, in light grey marls and marlstones, the normal, tiered burrowing community (mainly *Planolites, Thalassinoides, and Zoophycos*) recovered gradually and slowly, in a delayed return to pre-PETM environmental conditions.

The changes in the trace fossil assemblage across the PETM document the impact of this event on the macrobenthic community, in response to the global warming and related environmental variations, and the similarities and differences in the response of micro- macrobenthic communities to global phenomena. Thus, ichnological analysis reveals as a very useful additional tool to understanding atmosphere-ocean dynamic during PETM and a potential way in future climate research.

New foraminifera species described by K.H.A. Gohrbandt from the Helvetikum north of Salzburg

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Paleogene sections of the Helvetic tectonic units have been studied for micropalaeontology and stratigraphy by K.H.A. Gohrbandt (1963, 1967). During these investigations a series of new planktonic foraminiferal species have been observed. In the earlier publication the topic of the research concerned the Paleocene, whereas in the publication from 1967 only a short contribution on new Eocene species has been published. Some of these new species have been discussed by Blow (1979) and Olsson et al. (1999).
Concerning the pencil drawings of the species description and deviating interpretations, a revision supported by SEM figures is necessary. The types of these species are deposited in the Micropalaeontological Collection of the Museum of Natural History Vienna (NHMW). Additionally, paratypes and sample residues have been kindly presented by K.H.A. Gohrbandt. Following species have been revised:

Globorotalia haunsbergensis Gohrbandt, 1963
valid name: *Globanomalina chapmani* (Parr, 1939)

Globorotalia ? traubi Gohrbandt, 1963
valid name: *Igorina traubi* (Gohrbandt)

Truncorotalia marginodentata aperta Gohrbandt, 1963
valid name: *Morozovella marginodentata* (Subbotina)

Globanomalina wilcoxensis globulosa Gohrbandt, 1967
valid name: *Pseudohastigerina wilcoxensis* (Cushman & Ponton)

Globorotalia mattseensis Gohrbandt, 1967
valid name: *Igorina broedermanni* (Cushman & Bermudez, 1949)

Globorotalia wartsteinensis Gohrbandt, 1967
valid name: *Igorina wartsteinensis* Gohrbandt

Globorotalia salisburgensis Gohrbandt, 1967
valid name: *Igorina salisburgensis* (Gohrbandt)

Globorotalia pseudochapmani Gohrbandt, 1967
valid name: *Globanomalina pseudochapmani* (Gohrbandt)

Globigerina hagni Gohrbandt, 1967
valid name: *Parasubbotina hagni* (Gohrbandt)

A new planktonic foraminifera species (Hantkenina gohrbandti nov. spec.) from the Middle Eocene of the northwestern Tethys (Mattsee, Austria)

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The planktonic foraminifer genus *Hantkenina* is characterized by planispiral coiling and hollow chamber extensions, called tubulospines. It evolved gradually from the genus *Clavigerinella*, which shows radial elongate, clavate or digitate chambers, but no tubulospines. This evolutionary trend and the transition from *Clavigerinella* to *Hantkenina* was demonstrated from the Austrian Holzhäusl section (Coxall et al., 2003) and from the Kilwa drill sites in Tanzania (Pearson et al., 2004). At both localities, a newly discovered species, which has been named *Hantkenina singanoae* by Coxall and Pearson (2006), was considered to be the missing link between the two genera. However, the chambers of this species are terminate in a distal hood (proto-tubulospine), and it appears unclear how, and unlikely that, straight tubulospines of the younger *Hantkenina* species could evolve from this bent feature.

Rögl & Egger (2010) reported on a newly discovered planktonic foraminifer, which is characterized by pointed chamber ends with a nub (proto-tubulospines) and in some cases by the first tubulospines appearing in a juvenile growth stage. This species forms the evolutionary link between the genera *Clavigerinella* and *Hantkenina* and is considered to be the real ancestor of the genus *Hantkenina*. For this species the name *Hantkenina gohrbandti* nov. spec. is introduced (Rögl & Egger, in press). The new species is named in honour of Klaus H. Gohrbandt (Gulf Breeze, Florida, USA; former employee of Rohöl-Aufsuchungs AG, Vienna) for his fundamental work on the Paleogene of the Helvetikum north of Salzburg.

References:

Coxall, H.K., Huber, B.T. and Pearson, P.N., 2003. Origin and morphology of the Eocene planktonic foraminifer Hantkenina. Journal of Foraminiferal Research, 33, 237-261.

Coxall, H.K. and Pearson, P.N., 2006. Taxonomy, biostratigraphy, and phylogeny of the Hantkeninidae (Clavigerinella, Hantkenina, and Cribrohantkenina). Cushman Foundation Special Publication, 41, 213-256.

Rögl, F. and Egger, H., 2010. The missing link in the evolutionary origin of the foraminiferal genus Hantkenina and the problem of the Lower/Middle Eocene boundary. Geology, 38, 23-26.

The Chicxulub asteroid impact and mass extinction at the Cretaceous-Paleogene boundary

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The Cretaceous-Paleogene (K-Pg) boundary ~65.5 million years ago marks one of the three largest mass extinctions in the past 500 million years. The extinction event coincided with a large asteroid impact at Chicxulub, Mexico, and occurred within the time of Deccan flood basalt volcanism in India. Here, I review the records of the global stratigraphy across this boundary, revealing that a single ejecta-rich deposit compositionally linked to the Chicxulub impact is globally distributed at the Cretaceous-Paleogene boundary [1,2]. These results are supported by recent studies (i) detailing the exact position of the well-known iridium anomaly in several continental shelf and deep-sea K-Pg sites [3,4], (ii) showing that high-energy deposits from around the Gulf of Mexico correlate stratigraphically with the Chicxulub impact and the K-Pg mass extinction [5], and (iii) providing evidence for dinosaur remains within Chicxulub ejecta-rich beds that were presumably deposited from tsunami backwash currents in northern Mexico [6]. To conclude, the temporal match between the ejecta layer and the onset of the extinctions, and the agreement of ecological patterns in the fossil record [7] with modeled environmental perturbations (for example, darkness and cooling), suggests that the Chicxulub impact triggered the mass extinction.

References:
[1] Smit, J., 1999, Earth-Science Reviews, 27, 75-113
[2] Schulte, P., et al., 2010, Science, 327, 1214-1218
[3] Miller, K.G., et al., 2010, Geology, 38, 867-870
[4] Berndt, J., et al., 2011, Geology, 39, 279-282
[5] Bralower T., et al., 2010, Geology, 38, 199-202
[6] Schulte, P., et al. 2011, Sedimentology, (in review)
[7] Jiang, S., et al., 2010, Nature Geoscience, 3, 280-285

The record of the Latest Danian Event in ODP Leg 165 (Caribbean Sea): Evidence for a hyperthermal event?

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The Paleocene to early Eocene is punctuated by several transient, ~20 – 200 ky lasting hyperthermal events of which the Paleocene-Eocene Thermal Maximum (PETM) was the most prominent one. Abrupt shallowing of the lysocline/CCD, negative stable carbon isotope excursions, and benthic faunal turnover all imply a major perturbation of the ocean system during these events. Our recent research at the Southern Tethyan shelf suggests the presence of an additional hyperthermal event associated with sea-level fluctuations slightly preceding the Danian-Selandian boundary, the Latest Danian Event (LDE) [1]. At Zumaia, Northern Spain, a negative ~0.5‰ carbon isotope excursion is present in the uppermost Danian that may correlate to the LDE [2]. Moreover, cyclostratigraphic studies have shown that several deep-sea sites are characterized by a prominent peak in both Fe and MS data at cycle $Pc_{100}38$ in the uppermost Danian: this applies to all Walvis Ridge (Atlantic) and Shatsky Rise (Pacific) sites as well as Site 1001 in the Caribbean Sea ("Top Chron C27n Event") [3]. These results suggest that the LDE in the Tethys and the Top Chron C27n Event in the Atlantic may be correlative. We have conducted mineralogical, geochemical, and micropaleontological investigations to characterize this event in the Western Atlantic. Our first results from ODP Leg 165 Site 1001 reveal that the Top Chron 27n event [3] corresponds to a ~12 cm thick clay layer. Mineralogical analyses reveal a sharp ~50% drop of the carbonate content in the clay layer and a disproportionally high increase of the phyllosilicate content in the insoluble residue compared to the quartz and illite content. Bulk rock isotope analyses show an abrupt negative ~0.6‰ carbon isotope excursion at the onset of the clay layer, followed by a 1 m thick interval where isotopic shows a tailing back to pre-event values. The magnitude and pattern of the carbon isotope excursion is very similar to the results for the LDE in the Tethys and at Zumaia. In conclusion, our results demonstrate a supra-regional transient perturbation of the carbon cycle during the LDE in the Tethyan realm, the Atlantic, and possibly the Pacific Ocean.

References:
[1] Bornemann, A. et al., 2009, J Geol Soc London, 166, 1135-1142
[2] Arenillas, I. et al., 2008, Terra Nova, 20, 38-44
[3] Westerhold, T. et al., 2007, Paleo 3, 257, 377-403

Element chemostratigraphy across the Paleocene-Eocene thermal maximum at Demerara Rise, Central Atlantic

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Changes of redox conditions during the Paleocene-Eocene thermal maximum (PETM) are currently investigated to constrain the spatial and water depth-dependent pattern of warming, carbon input, and O_2 deficiency in the global ocean [e.g., 1,2]. Here, we are reconstructing paleoredox changes across the PETM in the tropical, western Atlantic (ODP Leg 207, Demarara Rise) by a set of stable isotope and element geochemical data. In addition, we address changes in the detrital flux. Generally, the PETM record on the Demerara Rise shows a pronounced and sharp lithologic change from calcareous chalks to laminated, clay-rich beds present in several drill sites across a depth transect. Herein, we report a first dataset from the deepest site 1258 (lower-bathyal to upper-abyssal paleodepth, ~2000 m).
The typical stable isotope pattern anomaly across the PETM is somewhat disturbed at this site since carbon isotopes show a negative anomaly with values as low as -10‰ and oxygen isotopes reveal a positive excursion. These isotope signatures are indicative for the formation of ^{13}C-depleted carbonates in the claystone from early diagenesis at the seafloor. However, calcareous nannofossil faunal assemblages (Joachim et al., this volume) and the $CaCO_3$ distribution both show typical PETM patterns similar to other deep-sea sites. A strong drop in Si/Al ratios concomitant to the onset of the PETM points either to (i) reduced Si input derived from silicic organisms (e.g., radiolarians) or (ii) lowered input of (aeolian?) quartz since most other element/Al ratios indicative for the siliciclastic fraction do not change (K, Na, Ti, Fe, Rb, Zr). However, Mn/Al ratios and bulk Mn enrichment factors (EF) compared to crustal values show a substantial drop during the PETM onset, followed by a gradual recovery to pre-event values. In contrast to the depletion of Mn, other typically redox-sensitive elements (e.g., V, Cr, Co) or element /Al ratios show no major change across the PETM, and U as well as Mo are close to the detection limit. These results indicate that W Atlantic deep waters were oxygenated before and after the PETM, but lower in dissolved oxygen content during the onset of this hyperthermal event, suggesting a considerable vertical expansion of the oxygen minimum zone correlative to carbonate dissolution.

References:
[1] Nicolo, M.J. et al., 2010, Paleoceanography, 25, PA4210
[2] Chun, C.O.J. et al., 2010, Paleoceanography, 25, PA4202

Black shales from the Latest Danian Event and the Paleocene-Eocene thermal maximum in central Egypt: Two of a kind?

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The Latest Danian event (LDE) at ~61.7 Ma is considered to be one of the earliest of a series of Early Paleogene transient warming events ("hyperthermals") that peaked later in the Paleocene-Eocene thermal maximum (PETM; ~55.5 Ma). However, environmental changes during the earlier transient warming events and their magnitude compared to the PETM are still poorly constrained. We present high-resolution micropaleontological, geochemical, and mineralogical data of the LDE and PETM in one continuous section from the southern Tethyan margin [1]. There, both hyperthermals are characterized by a distinct set of event beds overlying an erosional unconformity. Both events are associated with intense carbonate dissolution and substantial changes in the benthic foraminifera fauna. Both events show an abrupt drop of siliciclastic input (sediment starvation) correlative the onset of black shale formation as well as a strong enrichment in redox-sensitive trace elements. The evidence for a longer recovery phase with enhanced P-sedimentation during the PETM attests to the significantly stronger environmental impact of this event compared to the LDE. According to Rock-Eval and elemental analysis, the LDE as well as the PETM event beds have up to 4% organic carbon, low amounts of volatile hydrocarbons, but high amounts of highly weathered and inert organic matter ("black carbon"). Extreme high temperatures for the maximum release of hydrocarbons of the PETM and LDE samples correspond to thermal heating of >170°C, which is incompatible with the sediment burial history. Therefore, we suggest that the organic matter in both event deposits does not reflect well-preserved marine biomass but predominantly represents a mixture of heavily weathered autochthonous marine material and allochthonous combustion residues. Differences in preservation are also likely to account for the divergent stable isotope anomalies of organic carbon: the well-known negative carbon isotope anomaly at the PETM and a positive anomaly at the LDE. Although warming, water column stratification, and enhanced nutrient input during the hyperthermal events may have promoted anoxic conditions on the shelf, our results support rapid sea level rise and clastic starvation as one additional important mechanism for black shale formation and carbon sequestration during the LDE and PETM.

References:

[1] Schulte, P., et al., 2011, EPSL, (in review)

Appearance of gigantic biogenic magnetite during the PETM: A progress report

D. Schumann[1,2], T.D. Raub[3], R.E. Kopp[4], J.-L. Guerquin-Kern[5,6], T.-D. Wu[5,6], I. Rouiller[2,7], A.C. Maloof[4], A.V. Smirnov[8], D.S. Powars[9], S.K. Sears[2,7], U. Lücken[10], L.V. Godfrey[11], S.M. Tikoo[3], N.L. Swanson-Hysell[4], Reinhard Hesse[1]*, J.L. Kirschvink[3], H. Vali[1,2,7]

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During the Paleocene-Eocene Thermal Maximum (PETM) ~55 Ma, global temperatures jumped 5 – 9°C within less than 10,000 years (Sluijs et al., 2007; Zachos et al., 2008). Despite the ongoing debate on what triggered the event that lasted ~180 ky, large releases of greenhouse gases, in particular methane from gas hydrates, probably contributed to the rapidity and extent of the warming event. The event was associated with a significant diversification of the terrestrial fauna and flora but also of marine life. Numerous deep-sea benthic foraminifera species disappeared and new forms evolved.

Kaolinite-rich clay sediments deposited during the PETM at subtropical paleolatitude in the Atlantic Coastal Plain at Wilson Lake and the Ancora borehole (ODP Leg 174AX), N.J., contain abundant ~40- to 300-nm cuboidal, elongate-prismatic and bullet-shaped magnetofossils resembling crystals in living magnetotactic bacteria . Kopp et al., (2007) and Lippert & Zachos (2007) used ferromagnetic resonance (FMR) spectroscopy, other rock magnetic methods, and transmission electron microscopy (TEM) of magnetic separates to characterize the sediments. Aside from abundant bacterial magnetofossils, these same sediments also contain exceptionally large novel biogenic magnetite crystals unlike any previously reported from living organisms or from sediments (Schumann et al. 2008). The spearhead-like, spindle-like and elongated hexaoctahedra magnetite crystals exhibit chemical composition, lattice perfection and oxygen isotopic composition consistent with a biogenic origin. The spearheads and spindles can be up to 4000 nm long, up to ten times larger than magnetite produced by magnetotactic bacteria. The giant biogenic magnetite crystals appeared and disappeared during the PETM. Magnetotactic bacteria usually live in the suboxic zone of sediments in fresh, brackish, and marine environments. The development of a meter-scale suboxic zone with high iron bioavailability - a product of dramatic changes in weathering and sedimentation patterns driven by severe global warming - may have resulted in diversification of magnetite-forming organisms. Using FMR and TEM, we mapped the magnetofossil distribution and identified three magnetic facies in the clay: one characterized by a mix of detrital particles and magnetofossils, a second with a higher magnetofossil-to-detrital ratio, and a third with only transient magnetofossils. The distribution of these facies suggests that suboxic conditions promoting magnetofossil production and preservation occurred throughout inner middle neritic sediments of the Salisbury Embayment of the N.J. paleocoast (Kopp et al., 2009). Such a distribution is consistent with the development of a system resembling a modern tropical river-dominated shelf like the Amazon shelf.

Comparative quantitative analyses of a nummulite bank and a "normal" nummulitic limestone, Middle Eocene of Pederiva di Grancona and Mossano sections (Veneto, Northern Italy)

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The present work aims to compare "normal" nummulitic limestones and nummulite banks by means of numerical and quantitative aspects. In particular, the number of A- and B-forms in each sample were counted to calculate the relative density and the A/B ratio.

Five hand samples were taken, four from the Pederiva di Grancona section (SBZ 17, lower Bartonian) and one from the Mossano area (SBZ 18, upper Bartonian), both in the Berici Mts. (Veneto, Northern Italy), less than 10 km from each other. In Pederiva one sample (PRV 1) was collected from the bank facies, characterized by high density of large B-forms of *Nummulites lyelli*; three other samples were taken from the overlying beds, in "normal" nummulitic limestones (samples PRV 2-4). In Mossano one sample from the nummulitic limestones with *Nummulites biedai* has also been taken for comparison. The sample from Mossano contains a diverse assemblage of coralline red algae, echinoids, and bivalves. The foraminifers include alveolinids, nummulitids and discocylinids. In all the levels sampled there is a high number of megalospheric *Nummulites,* but the number of B-forms is usually low in comparison with the unusual abundance found in the Pederiva bank. Therefore, it is suggested that all samples from the Mossano and Pederiva sections, with the only exception of PRV 1, are referred to "normal" nummulitic limestones.

Two problems were encountered in the present study:

1- The results here presented are significantly different from the ones presented in previous papers. In the literature the "normal" A/B ratio for a nummulite limestone is traditionally reported as 10/1. We found in "normal" limestones A/B ratios variable between 86/1 and 348/1, whereas the A/B ratio in the bank facies resulted about 42/1.

2- Little is known about the methods used to calculate the A/B ratios on nummulite limestones. The best explanation is given by Kondo (1995), who measured the A/B ratio on a quadrat (15 x 15 cm) on the outcrops; he did not specify, however, if the counting was made either directly in the field or on the photographs; moreover, it is not clear whether different species of *Nummulites* were counted altogether or the B-forms and A-forms counted were all cospecific. Furthermore, we do not know if the outcrops were fresh or weathered and the surfaces were surely rough and not homogeneous. For our work we used rectangles of 19 cm^2 (5 x 3.8 cm) on polished surfaces in order to count all the visible specimens of *Nummulites.*

The results of the present study show that in the Pederiva bank the numbers of both A- and B-forms are high with respect to the examined area. The A/B ratio is low in comparison with the "normal" nummulitic limestones. Regarding the latter, the absolute number of B-forms is usually very low, only one for Mossano, PRV 2 and 3, and only two for PRV 4. Due to this problem, the A/B ratio (348/1, 236/1, 86/1, and 117/1 respectively) could be subjected to a significant error.

Climatic controls on Late Cretaceous through Paleogene ecosystems

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Climate change has long been considered a driver of marine invertebrate species extinction, origination, and compositional turnover, yet the nature of these relationships remains unclear. Here, we use shallow marine faunas dominated by mollusks from the late Cretaceous through Oligocene of the Gulf Coastal Plan (GCP) of the United States of America (Tennessee, Georgia, Alabama, Mississippi, Louisiana, and Texas) to determine whether and how climate affects the diversity and turnover of these assemblages. The GCP was a shallow subtropical shelf on a passive margin that remained at relatively constant latitude during the studied interval, making it an excellent natural laboratory in which to study these questions. Additionally, the GCP contains some of the world's best-preserved and most diverse Cretaceous and Paleogene mollusk faunas in the world. We have complied a large faunal dataset and a complementary dataset of temperature estimates derived from the oxygen isotopic composition of the fossils themselves. Faunal data consist of field and literature counts of 4,000 taxa (identified to the species level in about 90% of cases), tallied from over 1,700 samples and 280,000 occurrences. Temperature data are derived from mollusks, otoliths, and corals, and are often seasonally resolved records, providing minimum, maximum, and mean temperature. Temperature data result from our own work and the literature, and are comprised of over 7,000 isotopic measurements.

We use the ecological modeling technique capture mark recapture (CMR), modified for paleontological data, to analyze the effects of temperature on the origination and extinction of these assemblages. CMR has several advantages, namely, it can account for unequal time bin duration and the changing likelihood of observing a species in each time bin due to variable sampling intensity, preservation, and geographic spread of fossiliferous outcrops.

Temperature is found to significantly influence both origination and extinction, and exerts a much stronger influence than other potential controls, such as sea level. Specifically, the seasonal range of temperature (i.e., the degree to which temperature varies over a year) is the most significant temperature variable, followed closely by minimum temperature. When seasonal range is small, extinction and origination are low, and as seasonal range widens, both increase. This relationship is stronger for extinction than origination. These relationships result in relatively high and unchanging diversity for most of the Paleogene, until increasing seasonality and cooling caused a long-term diversity decline during the late Eocene through early Oligocene. Although there are no marine invertebrate faunas known from the Paleocene-Eocene Thermal Maximum (PETM), we can compare latest Paleocene faunas to those of the earliest Eocene to evaluate the long-term effects of the PETM. Extinction rate was relatively unchanged across the Paleocene-Eocene boundary, however, origination rate significantly dropped across it, indicating a slight effect of the PETM at this level of resolution. The effects of temperature on marine invertebrates described here could result from organisms encountering novel temperatures as seasonal range widened. Or, these results may arise from variables associated with seasonality, such as consistency and productivity of the planktonic food source.

Deep ocean temperature response to astronomical forcing in the Eocene 'greenhouse'

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Changes in Earth's axial tilt ('obliquity') are known to preferentially influence the intensity of solar insolation received at high latitudes. A large-scale and permanent ice sheet first appeared on Antarctica at the beginning of the Oligocene Epoch, 34 million years (Myr) ago. The concurrence throughout the Oligo-Neogene (last 34 Myr) of a large Antarctic ice sheet with dominance of the obliquity cycle (41 thousand year frequency) in globally distributed palaeoclimate records suggests that high latitude ice sheets may 'amplify' global climate response to regular obliquity forcing. Conversely, it has been hypothesised that the documented absence of large ice sheets during earlier Palaeogene warm 'greenhouse' climates would have led to a damped climate response at the obliquity frequency. Here we test this hypothesis using a new 2.4 Myr-long benthic foraminifer oxygen isotope record through the early to middle Eocene transition. We find that the dominant spectral frequency in our deep sea record is that of obliquity, despite the absence of large high latitude ice sheets. We also observe an Eocene breakdown in the Oligo-Neogene pattern of astronomically paced changes in deep ocean sediment calcium carbonate content and benthic foraminiferal oxygen isotope composition – something that we attribute to the deglaciated early Eocene climate state. Our findings indicate a novel method with which to test for the existence of substantial ice sheets during past greenhouse climates.

Deep ocean acidity change over the Eocene Oligocene Transition

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The Eocene Oligocene Transition (EOT, 34 – 33.5 Ma) represents a fundamental shift in the evolution of Cenozoic climate from a “greenhouse” to an “icehouse” state. The onset of major Antarctic Cenozoic glaciation across the EOT took place rapidly, likely as a threshold response to slow atmospheric and superimposed orbital forcing and was associated with a pronounced perturbation in the global carbon cycle (*DeConto & Pollard, 2003; Coxall et al., 2005*). This carbon cycle perturbation is poorly understood. Here we report a preliminary record of δ^{11}B-pH in benthic foraminiferal calcite from IODP Pacific Equatorial Age Transect Expedition 320 in the eastern equatorial Pacific, to shed new light on the timing and magnitude of changes in deep ocean acidity across the EOT.

References:

Coxall et al. (2005) Nature, 433, 53-57; DeConto & Pollard (2003) Nature, 421, 245-249.

High-resolution study of PETM record in the key section of NE Peri-Tethys

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In the lithological record of NE Peri-Tethys, sediments corresponding to Paleocene/Eocene Thermal Maximum (PETM) are displayed as sapropelitic bed (SB) extended over the wide territories. Recent study showed the SB correspondence to carbon isotope excursion (CIE), decline of benthic foraminifera, occurrence of short-lived nannofossils *Rhomboaster* spp. and asymmetric discoasters, acme of *Apectodinium augustum* dinocysts (Gavrilov et al., 2003). To better understand the exact consequence of all events involved into PETM development in the NE Peri-Tethys, we made new thorough collections of the SB and surrounding sediments in the key section exposed along Kheu R., Kabardino-Balkaria, northern Caucasus, Russia. The SB was sampled with 2 cm frequency and underlying and overlying sediments – with 15 cm frequency.

Underlying the SB sediments are soft greenish marls containing abundant and diverse nannofossils and showing gradual $\delta^{13}C$ decrease from 2.5‰ to 1.5‰. ~1.3 m below the SB, 10 cm thick clayey layer evidently related to dramatic sea-level fall occurs. Just below this level, first representative of *Rhomboaster* lineage (*R. intermedia*) appears. Above this erosional (?) surface, nannofossil abundance drop significantly causing low $CaCO_3$ content culminated in 12 cm thick non-calcareous clay underlying the SB. *Rhomboaster* cf. *cuspis* first appear ~0.5 m below the SB with the beginning of $\delta^{13}C$ decrease.

The SB (0.5 m) is built up of rhythmic alternation of non-calcareous black thinly laminated clay (8 – 10% TOC) and brown calcareous clay (3 – 5% TOC) forming 5 couplets. At the base of SB dramatic negative $\delta^{13}C$ (2.9‰) and $\delta^{18}O$ (5.5‰) excursions and both curves show significant fluctuation within the SB. FADs of *Apectodinium augustum* and *Wilsonidium pechoricum* dinocysts are found at the base of SB (see Iakovleva et al., this volume). Lowermost part of SB is the most enriched in TOC and lack in nannofossils. Poor nannofossil assemblage reappears in the calcareous layer of lower couplet where *Rhomboaster* spp. and asymmetric *Discoaster anartios* and *D. araneus* appear. Wide fluctuations in the ratio of *Discoaster*, *Toweius* and *Fasciculithus* between couplets are marked and calcareous dinocysts *Thoracosphaera* spp. become abundant at individual levels (up to 40%). All these characterizes very warm and frequently changing nutrient-rich environment during SB accumulation.

Negative $\delta^{13}C$ excursion persists in the 0.5 m interval of greenish calcareous clay overlying the SB and begins gradually decrease upsection but never reaches pre-PETM level (2 – 2.5 ‰) keeping values around 1‰. All nannofossil taxa declined during SB accumulation became recovered in overlying sediments including typical for late Paleocene species of *Heliolithus, Fasciculithus, Toweius, Neochiastozygus,* and *Placozygus sigmoides*, as well as “excursion” taxa of rhomboasters and asymmetric discoasters, and this assemblage persists up to facial change to cherty deposits in ~4.0 m above the SB where few nannofossil specimens only can be find.

The main conclusion of this study is the finding that minor environmental perturbations preceded exceptionally rapid and dramatic PETM onset and recovery of normal environment occurred very gradually. Nannofloral communities almost completely survived during PETM in the basin of NE Peri-Tethys but disappeared during recovery period.

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Large amplitude variations in carbon cycling and terrestrial weathering during the latest Paleocene and earliest Eocene

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Global temperatures rose ~6°C from the late Paleocene ca. 58 Ma to the Early Eocene Climatic Optimum (EECO) ca. 52 – 50 Ma. Superimposed, were certainly two geologically brief (< 200 kyr) intervals of extreme warming, the Paleocene-Eocene thermal maximum (PETM) and Eocene thermal maximum 2 (ETM-2 or H-1); at least four more events, H-2, I-1, I-2 and K/X, probably occurred. Both the long-term rise and short-term “hyperthermals” have been linked to massive injections of ^{13}C-depleted carbon into the ocean-atmosphere system and greater continental weathering. However, relationships remain uncertain, principally because detailed and coupled proxy records do not extend across the entire interval of interest.

Mead Stream, New Zealand, exposes a ~650 m-thick sequence of limestone originally deposited on an upper continental slope from the late Cretaceous to the middle Eocene. Previous work has provided accurate ages for this expanded section, and has shown that the PETM, ETM-2, H-2, I-1 and I-2 hyperthermals are marked by pronounced negative carbon isotope excursions (CIEs) and clay-rich horizons (marls), the latter caused by excess terrigenous dilution. 283 new samples were collected, mostly above the I-2 event; these were analyzed for carbonate content, lithology, and bulk carbonate carbon isotopes. A greatly expanded (100 m-thick) unit represented by a series of marl beds lies above I-2 and correlates to the EECO. Carbonate contents are generally 60 – 90% throughout the studied interval, with lows being marls. The $\delta^{13}C$ is generally low but, in detail, represents a series of negative CIEs with magnitudes ranging between 0.2 – 0.6‰. Of these, the K/X/ETM-3 event is the most pronounced (0.6‰).

The late Paleocene-early Eocene $\delta^{13}C$ record at Mead Stream is remarkably similar to that generated at Site 1262 at Walvis Ridge (south Atlantic), except that lows in $\delta^{13}C$ span intervals of relatively high sedimentation (terrigenous dilution) rather than intervals of relatively low sedimentation (carbonate dissolution). We suggest that over ~6 million years, there was a series of short-term climate perturbations, each characterized by massive carbon input and greater continental weathering. The suspected link involves global warming and enhanced seasonality in precipitation. We are evaluating this model further by identifying hyperthermal events in DSDP sites from the Indian Ocean, and assessing whether they are related to carbonate dissolution or siliciclastic dilution.

Paleoenvironmental reconstruction of a lake deposit from the early Eocene Wutu coal mine, Shandong Province, East China

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The Wutu coal Mine in East China is famous for its diversified and well-preserved early Eocene mammal fauna that represents one of the best early Paleogene reference fauna in Asia. It has yielded numerous specimens of modern placental mammals that coexisted with primitive mammals. Although some authors even proposed a late Paleocene age for the Wutu Formation based on the presence of some primitive mammals with North American affinities such as neoplagiaulacid multituberculates and carpolestid plesiadapiforms, it is now widely accepted to be of early Eocene age, based on the diversified mammal association of 51 species many including derived taxa belonging to modern orders.

The site has been revisited in the scope of a Sino-Belgian bilateral cooperation program in order to date the deposits more precisely and to reconstruct the paleoenvironment. The new specimens collected come from coal layers 5 and 7 of the Middle coal-bearing Member of the Wutu Formation about 250 – 280 meters deep. Among them are a skull of the perissodactyl-like ungulate mammal *Olbitherium* and the oldest *Prunus* endocarps. But the most important results come from three borehole cores of the Wutu Formation and the underlying deposits, representing a total thickness of about 500 meter. Thin sections indicate that these sediments were deposited in a lacustrine environment. Palynological analysis suggests a cooler climate than that in other early Eocene localities of supposedly similar age and latitude in Western Europe and North America. Carbon isotope analysis performed on the bulk organic matter from the Wutu sediments allows to determine the age of the deposits more precisely and to reconstruct the evolution of the lake through time.

Hyperthermal and greenhouse events in the Paleogene sequence of the Central Western Carpathians (PETM, EECO, MECO): multiproxy records from the Kršteňany section

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The Paleocene - Eocene boundary is marked by one of the most prominent event of global warming and perturbation of carbon cycle in the Cenozoic history. Multiproxy records of this hyperthermal event (PETM) and successive greenhouse events (EECO and MECO) have been determined in the Kršteňany section (Central Western Carpathians).

The pre-PETM interval of the section contains the Mid- to Late Paleocene microfauna of planktonic foraminifera with index species of the P3 and P4 Biozones - *Globanomalina cf. pseudomenardi*, *Morozovella apanthesma*, *Igorina pusilla* and *Parasubbotina varianta*. Nannofossils exhibit the presence of *Fasciculithus* and bloom of *Braarudosphaera*.

The PETM is approximated in the transitional interval from the grey and ochry-yellow marls in the depth between 45 m – 42 m. The base of the PETM is affected by dissolution (BFEE) and higher up marked by carbon isotope excursion with negative shift from +0,24 to –1.62 ‰ $\delta^{13}C$ (~CIE). Foraminiferal microfauna of the PETM dominated by sphaerical and haevily calcified acarininids (*A. subsphaerica*, *A. berggrenii*), *Globanomalina luxorensis*, etc. Nannofossils show the decline of *Chiastmolithus*, appearance of excursion taxa (*Discoaster araneus*) and presence of index species of the NP 10 Biozone (*Tribrachiatus contortus*, *T. orthostylus*). The specific components of the PETM interval represent pyritized diatom frustules and pteropods. In paleomagnetic scale, the PETM interval records the reverse polarity, corresponding to the C24r magnetozone around the P/E boundary.

The post-PETM sequence of the Kršteňany section proceeded to the Early Eocene climatic optimum (EECO), which is evidenced by the large-sized anguloconical and muricate foraminifers like *Morozovella lensiformis*, *M. formosa*, *M. occlusa*, *Acarinina strabocella*, *A. cuneicamerata*, *A. pentacamerata*, *A. praetopilensis*, *Muricoglobigerina seni*, etc. The share of subbotinid species, which are constrained to be the cool-temperate forms, increased to the Late Ypresian in *Subbotina (T) boweri* Zone. Ypresian nannofossils consist of the species, which provided the last occurrences in the NP 12 Biozone (*Tribrachiatus orthostylus*, *Ellipsolithus macellus*, etc.). Subsequent interval reveals a radiated nannoplankton bloom of the family *Discoasteraceae*, which more than 10% share indicates the EECO (mainly *D. barbadiensis* and *D. saipanensis*). Normal polarity of the C24n magnetozone has been recognized in the interval between 36 – 38 m (Middle Ypresian).

Lutetian – Bartonian sequence is rich in morozovellid, truncorotaloid and morozovelloid species. Their abundance is indicative for the Mid Eocene climatic optimum – MECO. The most frequent species of foraminiferal microfauna are follows: *Morozovella aragonensis*, *M. crater*, *M. spinulosa*, *Acarinina (T.) topilensis* and *Morozovelloides crassata* (E 8 – E 13). Late Lutetian – Bartonian formation is significantly enriched by *Turborotalia centralis* and *Orbulinoides beckmanii* (E 12) Nannoplankton zones of the NP 14 – NP 16 has been recognized based on the species of *Discoaster sublodoensis*, *Chiphragmalithus alatus* and *Discoaster tani nodifer.* The MECO is pronounced at the carbon isotope curve, where the sequence in interval between 17.0 – 5.0 m shows the distinct negative excursion of $\delta^{13}C$ up to – 6.75 ‰. The Mid Lutetian sequence records the normal polarity (18.2 – 32.4 m), which could correspond to the C21n magnetozone.

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Identification and characterization of early Eocene hyperthermals in shallow marine sequences

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In less than 20 years, the PETM has grown into a text-book example of rapid global warming in deep time. Simultaneously, observations on deep-sea cores resulted into the proposal of a series of additional early Paleogene transient paleoclimatic events, such as Dan-C2, ELPE, ETM-2 ("h1"), ETM-3 ("X-event" or "k"). These were discovered through anomalies in lithology, color changes, isotopic excursions, elemental distributions, and anomalous microfaunas. Another hyperthermal proposed, the Latest Danian Event (LDE; Bornemann et al., 2009 – *Jour. Geol. Soc. Lond.*) was first identified in shallow sequences in Egypt, bearing strong similarities with the regional expression of the PETM: laminated black shales with anomalous benthic and planktic microfaunas; Speijer, 2000 – *GFF*; Schulte et al. this volume; Stassen et al. this volume). Besides the LDE, studies of continental margin records remain highly challenging with respect to identifying the secondary hyperthermals.

In theory, numerous lower Eocene sequences worldwide should yield coverage of ETM-2 or ETM-3, but thus far these events have largely been documented from outcrops of deep water deposits (New-Zealand, Italy; e.g. Nicolo et al. 2007 – *Geology*; Agnini et al. 2009 – *Paleoceanography*). It has not yet been convincingly demonstrated that these events left a distinct signature in shallow continental margin records. In order for these proposed hyperthermals to become established as significant events affecting the global biosphere, they also need to be identified and analyzed in shallow margin (and terrestrial) sequences. However, this is not an easy task. Shallow marine marly sequences and especially those in outcrops provide several extra challenges compared to (most) open ocean drill cores, such as discontinuous exposure, weathering, faulting, and unconformities. Additionally, the stratigraphy of outcrop sequences is not constrained from the start by physical properties such as paleomagnetic data, which leaves the initial stratigraphic constraints usually based on low-resolution biostratigraphy from general stratigraphic surveys. On the other hand, potentially thick continental margin sequences provide one major benefit: the possibility to dissect in high-resolution the full sequence and development of a hyperthermal event.

We have conducted studies in Belgium, Egypt and France towards identification and characterization of early Eocene hyperthermals and find anomalous faunal patterns and isotopic excursions which seem to relate to ETM-2 (Pirkenseer et al. this volume; Stassen et al. this volume) or ETM-3. Our study on the new Kallo core (Belgium), drilled through ~100 m of Ypresian clays which were deposited in the mid-latitude shallow North Sea Basin, reveals a 5 m-thick interval which appears to correlate closely with ETM-3. It is characterized by a temporary influx of planktic foraminifera and *Asterigerina kaasschieteri*, a benthic foraminiferal species that is considered indicative of deposition in a shallow and warm sea. After the brief microfaunal incursion, the fauna that was present prior to this event became more or less re-established. Further constraints on the relation with ETM-3 should come from stable isotopic studies on well-preserved planktic and benthic foraminifera. Early Eocene hyperthermals prove difficult to track in shallow water sequences, but our results seem to indicate that also these lesser hyperthermal events had short- and long-term impacts on the development of shallow marine ecosystems.

The Latest Danian Event along a paleobathymetric gradient in the Nile Basin (Eastern Desert, Egypt)

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The Latest Danian Event (LDE; Bornemann et al. 2009) in the Nile Basin is characterized by an anomalous lithology and geochemistry, a negative $\delta^{13}C$ shift and a peculiar succession of benthic foraminiferal faunas. In the field the LDE is commonly developed as a couplet of a purplish-brown marl bed and a black shale bed intercalated in the Dakhla Formation, with a total thickness of 5–25 cm. The lower LDE bed has a laminated texture and contains abundant pyritic molds, fish remains and coprolites; together with absence of benthic microfossils evidencing anoxia at the sea floor. We studied benthic foraminifera in five sections along a paleobathymetric transect ranging from middle-outer neritic to bathyal paleodepths. In all sections the lower LDE bed is barren of benthic foraminifera, whereas the upper bed records an incursion of a low-diversity benthic shallow-water assemblage dominated by *Neoeponides duwi*. The LDE appears to be related to the rapid transgressive phase after the lowstand of a regional (global?) sea-level cycle, causing anoxia at the sea floor. The presence of *N. duwi* and the associated assemblage, earlier interpreted as shallowing, is more likely explained by this shallow-water assemblage migrating to deeper waters, thereby filling niches temporarily vacated by other taxa.

The correlative occurrence of a 1–2 per mil negative $\delta^{13}C$ excursion in several Egyptian sections as well as in the eastern Atlantic (Zumaia, Spain: Arenillas et al., 2008; Bornemann et al., 2009) and in ODP Hole 761B offshore NW Australia (Bornemann et al. 2009; Quillévéré et al., 2002) in concert with micropaleontologic, geochemical and sedimentological characteristics suggest a perturbation of the global carbon cycle characteristic of a hyperthermal event. The latter is supported by deep-water warming at Shatsky Rise, ODP 1209, in the pacific Ocean (Westerhold et al., in rev.). This would also explain why the record bears strong similarities with the PETM in Egypt (see poster by Stassen et al., CBEP 2011).

References:

Arenillas, I., Molina, E., Ortiz, S., Schmitz, B., 2008. Foraminiferal and stable isotopic event stratigraphy across the Danian−Selandian transition at Zumaya (northern Spain): chronostratigraphic implications. Terra Nova 20, 38−44.

Bornemann, A., Schulte, P., Sprong, J., Steurbaut, E., Youssef, M., Speijer, R. P., 2009. Latest Danian carbon isotope anomaly and associated environmental change in the southern Tethys (Nile Basin, Egypt). Journal of the Geological Society 166, 1135-1142.

Quillévéré, F., Aubry, M.-P., Norris, R.D., Berggren, W.A., 2002. Paleocene oceanography of the eastern subtropical Indian Ocean: an integrated magnetostratigraphic and stable isotope study of ODP Hole 761B (Wombat Plateau). Palaeogeography, Palaeoclimatology, Palaeoecology 184, 371-405.

Westerhold, T., Röhl, U., Donner, B., McCarren, H. K., Zachos, J. C., in review. A complete high-resolution Paleocene benthic stable isotope record for the central Pacific (ODP Site 1209). Paleoceanography.

Dissecting the PETM along the New Jersey Coastal Plain

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The Paleocene - Eocene has become recognized as a climatically dynamic period with relatively short intervals of rapid global warming, called hyperthermals, superimposed on a warm background climate. The Paleocene-Eocene thermal maximum (PETM) is the best known and most extreme. High-resolution isotopic and biotic studies on sedimentary sequences of the New Jersey Coastal Plain provided evidence to unravel the progression of environmental changes during the onset of the PETM, but did not include evidence based on sea floor biota. In addition, the exact part of the PETM represented in the sediments at different locations is unclear because a widespread regional unconformity truncates its upper part. We present high-resolution stable isotope and benthic foraminiferal records on the expanded PETM intervals in the well-documented Wilson Lake and Bass River core sites. Correlations with other core sites (Clayton and Ancora) enable us to reconstruct the environments of deposition of this siliciclastic shelf during the Paleocene/Eocene transition.This benthic study helps to further unravel the regional biotic responses and feedback mechanisms effective during rapid global warming of shallow (neritic) marine environments.

Uppermost Paleocene foraminiferal assemblages in the glauconitic sands of the Vincentown Fm. consist of sparse, small planktic foraminifera and a diverse benthic fauna with a mixture of epifaunal and infaunal components. These sands were deposited at very low sedimentation rates in middle to outer neritic environments, under the influence of strong currents which inhibited the deposition of small particles (planktic foraminifera, clay). The onset of the PETM at the transition from glauconitic sands to silty clay (Marlboro Fm.) is marked by the abrupt carbon isotopic excursion (CIE) of 4‰, and a change to a more opportunistic, lower diverse, outer neritic assemblage dominated by *Tappanina selmensis*, *Pulsiphonina prima* and *Anomalinoides acutus*. This onset seems to be captured in the most expanded sections in the near shore areas (Clayton & Wilson Lake), where a transitional fauna is recorded, in contrast to the more off shore areas (Ancora & Bass River) where the record is very condensed as show by a very high accumulation rate of foraminiferal shells.

Stable isotope records indicate that all studied locations contain the peak interval of the PETM CIE (also called its “core”). Diversity trends indicate a steady recovery during the PETM, as reflected in the gradual decrease in abudance of opportunistic species. Overall, environmental parameters indicate that at the beginning of the PETM ocean current strength decreased abruptly, leading to elevated sedimentation rates of fine-grained material while the influx of fresh water may have increased. In addition, while water depth increased rapidly, the environment became more eutrophic and oxygen levels fell, leading to stress for the benthic biota. This implies that the continental margin regions, such as New Jersey, may have become major carbon sinks during the peak of the PETM. Regional unconformities truncate the upper parts of the PETM peak interval in the Wilson Lake and Clayton cores, so that only about 70 kyr is reflected in the sediment. Stable isotope records of Bass River and Ancora indicate the continuation of the PETM interval, including parts of the recovery phase below the regional unconformity (Bass River ~ recovery phase I & Ancora ~ recovery phases I and II). The overlying lower Eocene glauconitic sandy clays of the Manasquan Fm. contain a fauna comparable to the one of uppermost Paleocene, and indicate persistent high primary production but a return to more vigorous currents at shallower depths, although somewhat deeper than during the latest Paleocene.

Multiple environmental perturbations in the Nile Basin, Egypt: expressions of hyperthermals?

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Since the recognition of the Paleocene-Eocene thermal maximum as a global hyperthermal event, focus has shifted to the periods following and preceding the PETM in order to assess whether the PETM was a unique biotic event, or rather just one in a succession of early Paleogene hyperthermals, albeit the most severe one. We discuss data of three environmental perturbations that have been linked to hyperthermals, namely the Latest Danian Event (LDE, Qreiya section), PETM (Dababiya section) and Eocene thermal maximum 2 (ETM-2, Dababiya section), comparing these to the long term regional trend (Aweina section). High-resolution observations show remarkable similarities between the three event deposits with respect to lithologic and paleoecologic disruptions. This points to similar processes operating in the Nile Basin and seems to suggest the occurrence of at least two hyperthermal events mimicking the PETM.

The lower event beds of the LDE and PETM are dark organic-rich marls and shales with abundant coprolites and fish remains. In their lower part, these beds are laminated and devoid of benthic life, pointing to severe oxygen deficiency at the sea floor. In the succeeding beds, pioneering faunas consisting of recolonizing opportunistic species (respectively *Neoeponides duwi* and *Anomalinoides aegyptiacus*) represent repopulation associated with ameliorating conditions at the sea floor. $\delta^{13}C_{org}$ isotope records reveal the well-known rapid 3‰ negative excursion at the PETM, whereas the LDE shows a 1‰ negative excursion, followed by a short-lived 3‰ positive excursion. In contrast, ETM-2 event beds are brownish shales with few fish remains and with no indications for severe oxygen deficiency. The absence of pioneering fauna suggests that no complete collapse of the ecosystem occurred, although biotic shifts are present. ETM-2 corresponds to a short-lived 3‰ positive $\delta^{13}C_{org}$ excursion followed by a gradual 6‰ negative excursion. The recovery phases of all three events are associated with calcarenitic limestones suggesting periods of condensation during the recovery phases of the carbon cycle perturbation and the ecosystem.

During all three events, benthic foraminiferal turnovers and associated anomalous planktic foraminiferal assemblages (*Acarinina* blooms) indicate transient environmental anomalies, disrupting the ecosystems of the entire water column. In comparison to long term ecologic trends, these events represent unique biotic reactions. These periods appear to be associated with rapidly rising sea levels, fluctuating sedimentation rates and higher organic carbon fluxes. The positive isotope excursions may reflect the effect of water-mass stratification under high productivity regimes. In summary, the local paleoenvironmental changes during all three events were similar but different in magnitude and are probably related to changes in productivity and sea level.

Reconstructing Post Cretaceous/Paleogene Boundary Climate and Ecology at Mid-Waipara River and Branch Stream, New Zealand

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The Cretaceous-Paleogene (K/Pg) boundary marks a catastrophic global extinction event. Whilst the extent of mass extinction is well documented, there is ongoing debate about the immediate and longer term climatic and environmental changes triggered by the event. Several records of the K/Pg boundary are present in the northern South Island of New Zealand, representing a range of terrestrial and marine environments. Previous studies of terrestrial palynomorphs and siliceous microfossils from these sections suggested significant cooling and terrestrial vegetation reconfiguration in the earliest Paleocene. Extinctions or local disappearances of thermophilic taxa at the K/Pg boundary are consistent with the hypothesis of a short-lived “impact winter”.

The Mid-Waipara (MW) K/Pg boundary section, north Canterbury, has been identified as suitable for organic geochemical study because sufficient organic carbon is present in the siliciclastic sediments and is thermally immature. Sediments were deposited in outer shelf to upper slope depths under a neritic watermass. New estimates of sea surface temperature (SST) variation based on TEX_{86} elucidate the relationship between biological and climatic changes that followed the K/Pg event.
Within the 0.25 m-thick interval identified as the “fern spike” in basal Paleocene sediments in this section there is no indication of a significant change in SST relative to the Cretaceous (22 – 25°C). Foraminiferal and radiolarian biostratigraphy indicates that this interval spans ~100 kyrs and includes a fern succession from colonising ground ferns to tree ferns, the latter suggesting a temperate, humid climate. The transition from ferns to a conifer-dominated pollen assemblage corresponds with a remarkable decrease in TEX_{86} values. These cooler SSTs persist over 10 m, throughout which the dominant conifer pollen type is *Phyllocladites mawsonii*, indicative of cool-temperate conditions. Preliminary biostratigraphic correlation suggests that this interval is condensed, possibly truncated at the base, and may be correlated to a more expanded biogenic silica-rich interval in the pelagic K/Pg boundary sections in eastern Marlborough, northeastern South Island including Branch Stream section. These results support siliceous microfossil evidence for pronounced cooling in early Paleocene in New Zealand.

Organic biomarker records provide further insight into terrestrial and marine ecological reconfiguration through the K/Pg boundary transition at MW. Major reorganisations of the phytoplankton and archaeal communities are indicated by pronounced changes in sterol and tetraether distributions following the K/Pg boundary. Transient disruption of terrestrial higher plants at the boundary is verified by suppression of *n*-alkane and triterpenoid concentrations, succeeded by a gradual recovery into the Early Paleocene. Furthermore, we investigate this disruption using compound specific stable carbon isotope analysis of *n*-alkanoic acids preserved in both sections. The scenario envisaged may be summarised as climate instability following the K/Pg boundary event, culminating in cool climatic conditions and a strengthened local upwelling regime leading to widespread deposition of diatom-rich siliceous sediments, lasting for around 1 Myr.

Life in the Deep-Sea during Eocene Hyperthermal Events

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The Paleocene-Eocene Thermal Maximum and other early Eocene hyperthermals were short-lived (10^4 – 10^5 years) episodes of exceptionally warm climate, linked to emission of large amounts of iso-topically depleted carbon into the ocean-atmosphere system. During these episodes there was severe dissolution of carbonate on the seafloor, and there is evidence for low oxygen conditions at least in parts of the world's oceans. The hyperthermal events were of varying intensity, with deep-sea temperatures increasing by 5 – 6°C during the PETM, about 4°C during Eocene Thermal Maximum 2 (ETM2 or Elmo,1.8 myr after the PETM) and about 2.5°C during Eocene Thermal Maximum 3 (ETM3 or X event, 3.2 myr after the PETM). Benthic foraminiferal assemblages were studied along a depth transect (1500 – 3600 m) on Walvis Ridge (SE Atlantic) across these three hyperthermal events. Severe dissolution associated with the PETM allowed no preservation of carbonate along the full depth transect during the most intense part of that event. Dissolution persisted over a shorter period at the shallower site, and was less intense during later hyperthermals. Globally deep-sea benthic foraminifera suffered severe extinction during the PETM but not during later hyperthermals, which occurred before the faunal diversity recovered. During all hyperthermals, benthic assemblages are characterized by low-diversity and dominance of relatively small and thin-walled specimens (as e.g. the epifaunal *Nuttallides truempyi*), although at least one infaunal species (*Oridorsalis umbonatus*) shows increased wall thickness during the PETM. Benthic foraminiferal accumulation rates and relative abundance of species indicate a lower supply of food to the seafloor at Walvis Ridge during all three hyperthermals, possibly because of decreased open-ocean productivity during periods of warming and increased ocean stratification. Benthic assemblage data from above the dissolution interval of the PETM indicate that an Oxygen Minimum Zone expanded downwards over the shallower site in the earlier and later stages of the main Carbon Isotope Excursion (CIE) associated with the PETM. Benthic foraminifera were present throughout the CIE associated with ETM-2 at the deepest site, but absent to very rare in a few samples from the shallowest site. Assemblages show a similar, but less extreme pattern than that during the PETM, with development of low-oxygen conditions during the earliest and latest stages of the event. There is no evidence in the benthic assemblages from ETM-3 that OMZs expanded to the depth transect. We thus see evidence for ocean acidification in the SE Atlantic during all three early Eocene hyperthermal events, but for development of low oxygen conditions only during warm events with an estimated deep-sea warming of more than 2.5°C.

Asian Paleocene-Early Eocene Chronology and biotic events

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Biostratigraphic, chemostratigraphic, and magnetostratigraphic studies of the Paleocene and early Eocene strata in the Nanxiong Basin of Guangdong, Chijiang Basin of Jiangxi, Qianshan Basin of Anhui, Hengyang Basin of Hunan, and Erlian Basin of Inner Mongolia, China, in last ten years provide the first well-resolved geochronological constrains on stratigraphic framework for the early Paleogene of Asia.

Asian Paleocene and early Eocene strata are subdivided into four biochronological units based on the fossil mammals (Land Mammal Ages). From oldest to youngest, they are the Shanghuan, the Nongshanian, the Gashatan, and the Bumbanian Asian Land Mammal Ages (ALMA). Recent paleomagnetic data from the Nanxiong Basin indicate that the base of the Shanghuan lies about 2/3 the way up Chron C29r. Nanxiong data and recent paleomagnetic and isotopic results from the Chijiang Basin show that the Shanghuan-Nongshanian ALMA boundary lies between the upper part of Chron C27n and the lower part of Chron C26r, close to the Chron C27n-C26r reversal. This record favors a correlation of Shanghuan-Nongshanian ALMA boundary to the Torrejonian-Tiffanian North American Land Mammal Age (NALMA) boundary and to the Danian-Selandian stage boundary in the marine record. The paleomagnetic and isotopic results from the Erlian Basin show that typical Gashatan faunas persist into Chron C24r and may range into Chron C25r and possibly C26n, and the records from the Nanxiong Basin indicate that both Nongshan and Guchengcun formations may correlate to the upper part of Chron C26r. These results would imply that the Nongshanian-Gashatan ALMA boundary may correlate within the Tiffanian NALMA. The paleomagnetic and isotopic evidences from the Hengyang Basin indicates that the transient carbon isotope excursion that marks the Paleocene-Eocene boundary is present between the Limuping and Lingcha formations, and the boundary is placed at the uppermost reversed polarity interval correlated to Chron C24r and to the Thanetian/Ypresian stage boundary in the marine record. The Bumbanian Lingcha fauna seems to correlate with the Wasatchian-0 faunal zone of North America to within ~10^4 yr.

Both Shanghuan and Nongshanian faunas are mainly composed of Asian endemic taxa. The coincidence of faunal turnover at the Shanghuan-Nongshanian boundary with the Torrejonian-Tiffanian boundary and Danian-Selandian stage boundary in far separated ecosystems may indicate independent ecologic and/or evolutionary response to climatic changes. The Gashatan fauna shows less endemism and has taxa shared with those of the Clarkforkian NALMA in North America at the generic level. The Bumbanian fauna is cosmopolitan. A sudden appearance of modern mammalian orders at the Gashatan-Bumbanian boundary is the same pattern as observed in North America and Europe, indicating the faunal turnover is related to the transient global warming event at the Paleocene-Eocene boundary known as the Paleocene-Eocene Thermal Maximum (PETM).

Calcareous nannofossil assemblages response to the Middle Eocene Climatic Optimum hyperthermal event

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Calcareous nannofossil assemblages show specific paleoecological affinities and thus can be utilized for palenviromental reconstructions. We investigated calcareous nannofossils modifications at the Alano section (NE Italy), during a significant temporary reversal in the middle-late Eocene long-term cooling trend, the Middle Eocene Climatic Optimum (MECO). This warming event is characterized by a prominent perturbation both in oxygen and carbon stable isotopes occurred at Chron C18r-C18n transition (ca. 40 Ma) and lasting ca. 500 – 600 kyr (Bohaty et al., 2009). Our data from the bathial Alano section indicate that the MECO interval seems to coincide with significant changes in calcareous nannofossil assemblages. Eutrophic/cold taxa and reworked specimens show an overall increase in abundance during the warming event. Conversely, oligotrophic/warm taxa are characterized by a peculiar anticovariant trend with respect to meso-eutrophic taxa, decreasing significantly during the MECO and post-MECO intervals. These results are thought to be interpreted as a transient enrichment in dissolved nutrients in warmer sea surface waters and suggests that the enhanced availability of nutrient in the water column overrides other environmental factors in the make-up of calcareous nannofossil assemblage. Morevover, the increase in reworking is consistent with an augment in terrigenous input, likely due to accelerated chemical weathering triggered by the enhanced hydrological cycle. An interesting issue is to investigate if the biotic response to the MECO is global and unique over wide areas and depositional settings or is more related to local conditions. To this purpose we are currently comparing calcareous nannofossils modifications at the Alano section (NE Italy) with those occurred in other MECO reference oceanic sites (U1333 and ODP1051). Our preliminary results from ODP Leg 320 (U1333) in the Pacific Equatorial Ocean, show dramatic changes in preservation state with the number of specimens counted on a specific area (1 mm^2) virtually collapsing during the event. Initial results, although very preliminary, coming from NW Atlantic are also promising. The final step will be to compare all data available in order to obtain a more global perspective on nannoplankton response to the MECO.

References:
Bohaty, S. M. et al. (2009), Paleoceanography, 24, PA2207.

Revision of middle Eocene calcareous nannofossil biostratigraphy and calibration to magnetochronological time scale.

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The recent studies for stabilizing the Lutetian GSSP provide great enhancements in middle Eocene biostratigraphy and calibration with the magnetostratigraphy. In particular, an important reassessment has been suggested for the planktonic foraminiferal events traditionally used to identify the base of Lutetian: the lowest occurrence of *Hantkenina* spp. (Bolli, 1957) or *Hantkenina nuttalli* (base of the P10 Zone, Berggren et al., 1995) and of *Guembelitrioides nuttalli* (base of the E8 Zone Pearson et al., 2004; Berggren & Pearson, 2005) that appear at different stratigraphic levels and at a much younger age (3 – 5 my) than previously considered in the standard calibration schemes (Orue-Etxebarria et al., 2006; Bernaola et al., 2006; Payros et al., 2007; Larrasoaña et al., 2008; Wade et al., 2011). Furthermore, the detailed calcareous nannofossil biostratigraphic investigations of the Agost section (Larrasoana et al., 2008; Tori and Monechi, in prep.) have improved the calibrations and modified the species ranges, showing that several of the most used calcareous nannofossil events need to be revised. Among the others a review and revision of the lowest occurrences of the following taxa: *Dictyococcites scrippsae, D. bisectus* and *Reticulofenestra reticulata* have been proposed.
New results on the occurrences of *D. scrippsae* and *D. bisectus* (either $<$ or $>10\,\mu m$) indicate that the chronology of the middle Eocene needs reassessment, being these taxa well abundant before the Bartonian. In order to clarify and support these data, additional high-resolution sampling and analysis on calcareous nannofossils has been performed on sequences (Bottaccione, Contessa, Gorrondatxe sections and Hole 762C) with a good magnetostratigraphy calibration.

Orbital forcing and carbon cycle variations in relation to changes in climate and ecosystem in late Paleocene.

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During the Late Paleocene (59 to 56 Mya), global surface temperature rose by 2 – 6°C and culminated in extreme transient global warming event (> 5°C) called the Paleocene-Eocene thermal maximum (PETM), characterized by a massive carbon input. While the PETM has been documented in exceptional detail, late Paleocene background trends did not receive much attention. Recent high-resolution work has shown significant carbon cycle dynamics on Milankovich timescales in deep sea sections. Such cycles yield the potential to correlate marginal marine sequences to the deep sea in unprecedented detail. Moreover, marginal marine sequences may reveal how the cycles related to climate. High accumulation rate Upper Paleocene shelfs deposits have been recovered in the Bass River core during Ocean Drilling Program Leg 174AX, on the New Jersey shelf. The lithology is siliciclastic sands and silts with biogenic carbonate and organic matter and is therefore very suitable for integrated palynological, organic and inorganic geochemical analyses. Here we will present preliminary dinoflagellate cyst assemblages and geochemical results across the Upper Paleocene to assess cyclicity and associated paleoecological changes.

Assessing the use of fish otolith stable O and C isotope geochemistry as a paleotemperature and seasonality proxy: results from the early Eocene climatic optimum (EECO) in Belgium

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Evidence for a highly variable climate superimposed on global trends during the early Paleogene is rapidly accumulating. This variability is mainly known from high-resolution deep-sea sedimentological and stable isotope records. However, focusing on marginal marine sections reveals indispensible insight in the nature of this variability, as they represent areas were local and global climate and biota are linked in many ways. These include faunal shifts in space and time and variable oxygen isotope signatures of biominerals secreted by many benthic and planktic organisms. Also, by studying adjacent basins, local expressions of latitudinal climatic gradients can be obtained. In our study, paleotemperature data of the early Eocene climatic optimum (EECO) from the mid-latitude marginal marine Belgian Basin are discussed. The Belgian Basin, part of the southern North Sea bight, comprises a fairly continuous early Eocene sedimentary record. It is dominated by fossiliferous sands and clays, which have suffered only minor deformation.

Paleotemperatures are derived from fish otolith $\delta^{18}O$ compositions of four non-migratory benthic species belonging to the families Congridae and Ophidiidae. Well-preserved otoliths from several levels and localities within the middle to late Ypresian were selected. After manual polishing, bulk and incremental microsamples (along concentric growth bands) were drilled and analyzed by a mass spectrometer. A cross-plot of bulk otolith $\delta^{18}O$ vs. $\delta^{13}C$ results shows a discrepancy between both families used. Ophidiid data probably represent true bottom water temperatures of the Belgian Basin. The mean annual temperature (MAT) of the EECO is calculated at 27.5°C, which is in line with other proxy results. However, variations in MAT up to 6°C occur, suggesting a more pronounced expression of climate variability in mid-latitude marginal basins than in tropical areas. Incremental analyses revealed a ~9.5°C mean annual range of temperatures, similar to present-day seasonality. These results show that marginal marine environments such as the Belgian Basin are well suited to infer paleoclimate variability.

During the past decade, the use of fish otoliths as (paleo)environmental indicators has increased, leading to recognition and improved understanding of their various applications. However, some difficulties remain, such as detecting possible influence of freshwater influx affecting paleotemperatures, the sensitivity of calculated paleotemperatures to a certain paleotemperature equation, and pursuing non-biased microsampling of aragonite powder within a single otolith. Future directions of our research include comparison of otolith stable isotope data with those from other sclerochronological proxies such as bivalves and foraminifera, constraining variations in aragonite accumulation rate and correcting for averaging errors during otolith carbonate microsampling.

The Aftermath of the Cretaceous-Paleogene Bolide Impact

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It is now widely acknowledged that the Cretaceous–Paleogene (K/Pg) mass extinction (65.5 Ma) is related to an asteroid impact. However, the detailed environmental consequences of this impact are still unclear. Proposed responses include a brief cooling episode and subsequent long term warming. However, rather than a single cooling event, distribution patterns of organic-walled dinoflagellate cysts (dinocysts) at the El Kef section (Tunisia) suggest multiple cooling and warming pulses during the earliest Danian. These fluctuations have yet to be confirmed elsewhere and their interference with (long term) background environmental variations is unknown. This emphasizes the need for high resolution temperature records across the K/Pg boundary.

The expanded Elles K/Pg section (Tunisia), close El Kef, provides such a record. Therefore, dinocyst assemblages from the Elles section have been studied to verify earlier reported environmental changes. Dinoflagellates are highly sensitive to changes in environmental parameters and therefore ideal to qualitatively assess climatological and ecological turnover across the K/Pg transition. Indeed, our preliminary findings confirm the patterns as recorded at El Kef earlier, suggesting multiple cooling pulses and major changes in productivity in the earliest Danian. Although the palynological record shows distinct trends in environmental parameters, other methods are required to further quantify these changes. In the past decade, various novel quantitative proxies have been developed based on Glycerol Dibiphytanyl Glycerol Tetraethers (GDGTs) i.e. TEX_{86}, MBT/CBT and the BIT-index. These proxies are applied to the Elles section to quantify changes in sea surface temperature, mean annual air temperature and the input of soil organic matter, respectively, and confirm the environmental trends as recorded by dinocysts. This complete, high resolution climate record across the K/Pg boundary allows verification of earlier reported environmental changes and enables worldwide correlation and comparison. Next steps will be to generate higher resolution temperature records based on the used organic biomarker indices.

It's about time: A revised Cenozoic tropical planktonic foraminiferal biochronology

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The recent enhancements in deep sea drilling recovery, multiple coring and high resolution sampling both offshore and onshore, has improved planktonic foraminiferal calibrations to magnetostratigraphy, cyclostratigraphy and/or modified species ranges. This accumulated new information has allowed many of the planktonic foraminiferal bioevents of the Cenozoic to be revised and a reassessment of the planktonic foraminiferal calibrations. Here we present an amended low-latitude (tropical and subtropical) Cenozoic planktonic foraminiferal zonation. We compile 187 revised calibrations of planktonic foraminiferal bioevents from multiple sources for the Cenozoic. We review and synthesize these calibrations to both the geomagnetic polarity time scale (GPTS) of the Cenozoic and astronomical time scale (ATS) of the Neogene and late Paleogene. On the whole, these recalibrations are consistent with previous work; however, in some cases, they have led to major adjustments to the duration of biochrons. Recalibrations of the early middle Eocene first appearance datums of *Globigerinatheka kugleri*, *Hantkenina singanoae, Guembelitrioides nuttalli* and *Turborotalia frontosa* have resulted in large changes in the durations of Biochrons E7, E8 and E9. We have introduced (upper Oligocene) Zone O7 utilizing the biostratigraphic utility of '*Paragloborotalia' pseudokugleri*. The revised and recalibrated datums provide a major advance in biochronologic resolution and a template for future progress to the Cenozoic time scale.

Diachronous turnover in calcareous nannofossils following the EECO in the Tethys; evidence from Avedat, southern Israel

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The warm period of the EECO terminated in cooling. For a time, this trend restored typical Late Mesozoic paleoceanography, but cooling continued through the Middle and Late Eocene, until the later Tertiary oceanic thermal stratification pattern became established.

The Early and Middle Eocene of the Avedat plateau was deposited on the southern Levant margin of the Tethys. Calcareous nannofossil populations belong to zones NP 11 to NP 16, transecting the EECO. The initiation of cooling terminating of the EECO in Zone NP 13 was accompanied first by a discoaster acme and by an increase in nannofossil diversity that peaked in NP 14. A sharp fall in diversity followed, along with a significant reduction in discoasters taken to indicate the end of the oligotrophic regime. The next event related to this trend was at the NP15/16 transition, when Coccolithus-type forms were replaced by Reticulofenestra-type forms. The Coccolithus / Reticulofenestra biotic turnover marks the most important paleoceanic change of the Tertiary among the calcareous nannoplankton. The replacement became globally irreversible in the Late Paleogene, and the new pattern of dominance continues to the present.

However, this change took place 7 Myr earlier at Possagno (Agnini et al., 2006), at the first cooling of the EECO in NP 13. This substantial diachroneity is attributed to the paleoposition of the Possagno region at the northern edge of the Tethys at a significantly higher latitude, where cooling took place earlier. Cooling was much later at the tropical Levant paleolatitude.

Thus, on the one hand, calcareous nannofossil assemblages are among the first oceanic plankton to respond to the global reorganization of the later Tertiary following the EECO. On the other hand, the effects of global cooling were not instantaneous, and rippled latitudinally across the calcareous nannofossil assemblages of the Tethys.

Age concern – testing the astronomical calibration of the early Paleogene and the K/Pg boundary

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The detailed reconstruction of Earth's history requires a very precise geological time scale. Imprints of Earth's orbital variations common in paleoclimatic records have been utilized to establish a very stable and accurate time scale for the last ~40 Ma by astronomical tuning. Astronomical tuning of geological data depends on long-term numerical solutions for insolation quantities of the Earth. Uncertainties in these computations beyond 42 Ma and uncertainties in radiometric dating limited the construction of an accurate astronomically calibrated time scale for the early Paleogene. However, attempts to construct a robust orbitally tuned time scale for this interval by integrating radioisotopic and astronomical dating are only partially consistent.

Here we present a comparison between the expression of the very long eccentricity cycle (~2.4 myr) minima of the new orbital solutions for Earth's eccentricity (La2010) and geological data which contain eccentricity modulated precession cycles. Our aim is to test how far back in time the amplitude modulation of eccentricity is stable in the La2010 solution and thus finally obtain an accurate astronomically calibrated time scale for the late Paleocene to early Eocene. We use X-ray fluorescence (XRF) core scanning iron (Fe) intensity data obtained on marine sediments drilled by the Ocean Drilling Program (ODP). These records have a robust cyclostratigraphic framework based on the stable 405-kyr cycle in the early Paleogene and show well expressed very long eccentricity cycle minima. Our results suggest a remarkable consistent pattern between geological data and the latest astronomical solution. Based on the first order calibration using the very long eccentricity minima we present a new astrochronology which indicates that the synchronisation of astronomical and radioisotopic rock clocks might be much more problematic than previously thought.

The Palaeogene of Schöningen (N-Germany): a long-term record of land-sea interaction during the last greenhouse climate

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In recent years the mine Schöningen Southfield which is operated by Eon, formerly Braunschweigische Kohlebergwerke (BKB), exposed a rather continuous section most probably starting in the Late Paleocene and ranging into to the early Middle Eocene. The succession includes 10 coal seams with clastic interbeds, all of which show marine influence to various degrees. A generalized section which may serve as a reference for the Early Eocene at the intersection between land and sea in the area has been compiled from numerous overlapping partial sections which have been described and sampled mostly in rather high resolution. Detailed sedimentological, organic geochemical and palaeobotanical/ palynological investigations are in progress.

The poster depicts a number of sedimentary and biotic aspects characterizing distinct environments and biota alternating and interacting along a shoreline which migrated back and forth within a broad estuary at the southern margin of the North Sea basin. Facies distribution was influenced by eustatic sea level changes, basin subsidence due to subsurface salt withdrawal and varying input of clastic material from the terrestrial catchment area.

Though the Early Eocene is globally considered to be the peak of the Cenozoic greenhouse phase the climate was punctuated by a number of hyperthermal events which were postulated mainly on the basis of evidence from the oceanic realm. The records from the Schöningen section indicate, however, that their effects on the terrestrial environments may have been significantly modified by the local conditions. However, the observed shift from alternating wet/dry conditions to a perhumid climate at the Lower to Middle Eocene transition is clearly more regional in nature.

Siliceous Plankton Response to the Southern Ocean Warming During the Late Middle Eocene: Results from ODP Site 748

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Intense, transient warming of surface and deep waters in the southern high latitudes is interpreted during the Middle Eocene Climatic Optimum (MECO; ~40 Ma). The climate and biotic effects of this event in Antarctica and the surrounding oceans, however, have not been documented in detail. Here, we report the results of a high-resolution, quantitative study of siliceous microfossils at ODP Site 748 (southern Kerguelen Plateau, Indian sector of the Southern Ocean). This study is the first to document the ebridian, silicoflagellate, and diatom reponse to the MECO warming event. Within a ~1.4 myr interval spanning the MECO, quantitative analysis of the rich and diverse siliceous microplankton assemblages shows a significant increase in biosiliceous sedimentation at Site 748.

The siliceous microfossil assemblages present in the MECO interval of Site 748 are unusual in that they are dominated by ebridians, with radiolarians as a secondary major component. Silicoflagellates and diatoms comprise only a minor fraction of the assemblage, in contrast to modern-day siliceous plankton assemblages of the Southern Ocean. As reported for the dinocysts and nannofossils from the same site, siliceous microfossils indicate a brief period of elevated nutrient availability in the Southern Ocean during the peak warming interval of the MECO. In addition, ebridian and silicoflagellate assemblages show an increase in endemism prior to, and immediately after the peak warming interval, confirming the patterns previously reported for other groups of fossil plankton. Peak warmth is characterized by high abundance of cosmopolitan silicoflagellates (e.g., *Naviculopsis* spp.) and ebridians (e.g., *Ammodochium* spp. and *Ebriopsis* spp.). In addition, large and unusual morphotypes of both silicoflagellates and ebridians are abundant within the MECO interval. In particular, the occurrence of a rich and extremely variable assemblage of the silicoflagellate *Dictyocha grandis* appears to be linked to the rapid rise in sea-surface temperatures immediately prior to peak warmth, and a pronounced turnover is observed in both silicoflagellate and ebridian assemblages at the onset of peak warming.

These observations lend support to the pattern and magnitude of temperature change indicated by geochemical proxy data at multiple Southern Ocean sites. Additionally, rapid assemblage changes in multiple autotrophic and heterotrophic siliceous microfossil groups indicate a reorganization of Southern Ocean plankton communities in response to greenhouse warming associated with the MECO event.

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