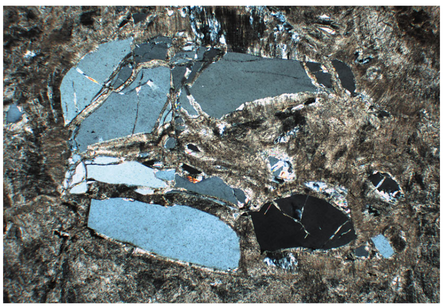
Government of **Western Australia**
Department of **Mines and Petroleum**

RECORD 2011/20

PROGRAMME & ABSTRACTS: The XVII International Congress on the Carboniferous and Permian

Edited by
E Håkansson & JA Trotter

ICCP 2011 PERTH


Geological Survey of Western Australia

GEOLOGICAL SURVEY OF
WESTERN AUSTRALIA

Record 2011/20

Programme & Abstracts: The XVII International Congress on the Carboniferous and Permian

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Perth 2011

About this publication
The XVII International Congress on the Carboniferous and Permian, held in Perth 3–8 July 2011, is jointly hosted by the University of Western Australia and the Geological Survey of Western Australia (GSWA). GSWA is releasing the Programme and Abstracts as part of its Record Series to ensure a wider distribution. The scientific content of the Record is the responsibility of the ICCP2011 Organising Committee. No editing was undertaken by GSWA.

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ICCP 2011 PERTH

XVII International Congress on the Carboniferous and Permian

3-8 July, 2011, The University of Western Australia, Perth

www.iccp2011.org

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Welcome to ICCP 2011

On behalf of the Congress Organising Committee, I welcome you to ICCP2011 at The University of Western Australia, Perth, Australia.

The Carboniferous-Permian (C-P) was a critical period in the history of our planet and included dramatic climatic changes from icehouse in the Permo-Carboniferous to greenhouse conditions at the end of the Permian. The latter has been associated with the great dying of life on Earth at the Permian-Triassic transition, these biotic crises having severely impacted the biosphere. Despite the widespread upheaval, ecosystems recovered from this catastrophe. Examining these extreme climate shifts and biotic crises provide some insights into understanding major environmental change, in the past, present, and future.

The ICCP2011 offers an international platform in which to engage, share our expertise, and contribute to solving truly global problems and we hope that the varied themes will provide lively discussion and scientific exchange. I hope that you find the scientific program stimulating but also encourage you to enjoy our beautiful University campus, and explore Perth and the surrounding areas during your stay in Western Australia.

Zhong Qiang Chen
Convenor, ICCP 2011 Organising Committee

Organising Committee for ICCP 2011:

Zhong Qiang Chen (Convenor), The University of Western Australia

John Backhouse, The University of Western Australia

Jenny Bevan, The University of Western Australia

Mignonne Clark, The University of Western Australia

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Eujay McCartain, Woodside Energy Ltd.

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Financial Sponsors

The Organising Committee gratefully acknowledges financial support from the following sponsors:

The University of Western Australia

Geological Survey of Western Australia

Faculty of Natural & Agricultural Sciences

Geoscience Australia

Geological Society of Australia

Association of Australasian Palaeontologists

Petroleum Exploration Society of Australia (WA Branch)

Woodside Energy Ltd

Centre for Petroleum Geoscience & CO_2 Sequestration, UWA

ENI Australia Pty Ltd

Curtin University of Technology

General information

Registration

The registration desk is located in Hackett Hall during the Ice-breaker on Sunday 3 July. From Monday 4 July, the registration desk will be moved to the The Undercroft (beneath Winthrop Hall with the clock tower). Staff at the registration desk will be able to assist you with any queries you may have relating to your registration and social function bookings. The registration desk will be open during the following times:

Sunday 3 July (Hackett Hall)	17:00-19:00 pm
Monday 4 July (The Undercroft)	08:30-17:00 am

Tea and lunch breaks

Lunch, morning and afternoon tea are included in your registration fee and will be served in The Undercroft during the programmed breaks. Drinks will be provided at the end of each day during the Poster Session at The Undercroft. If you are an accompanying member and would like to attend these functions, please see the staff at the registration desk. An additional ticket is A$50/day/person.

Internet access

Several computers in the Slide Preparation room are available for delegates to access internet. Please limit your time to ten minutes so that the facilities can be shared by as many delegates as possible.

Mobile phones

As a courtesy to speakers and other delegates, please ensure your mobile phone is turned off or in silent mode during all sessions and social functions.

Posters

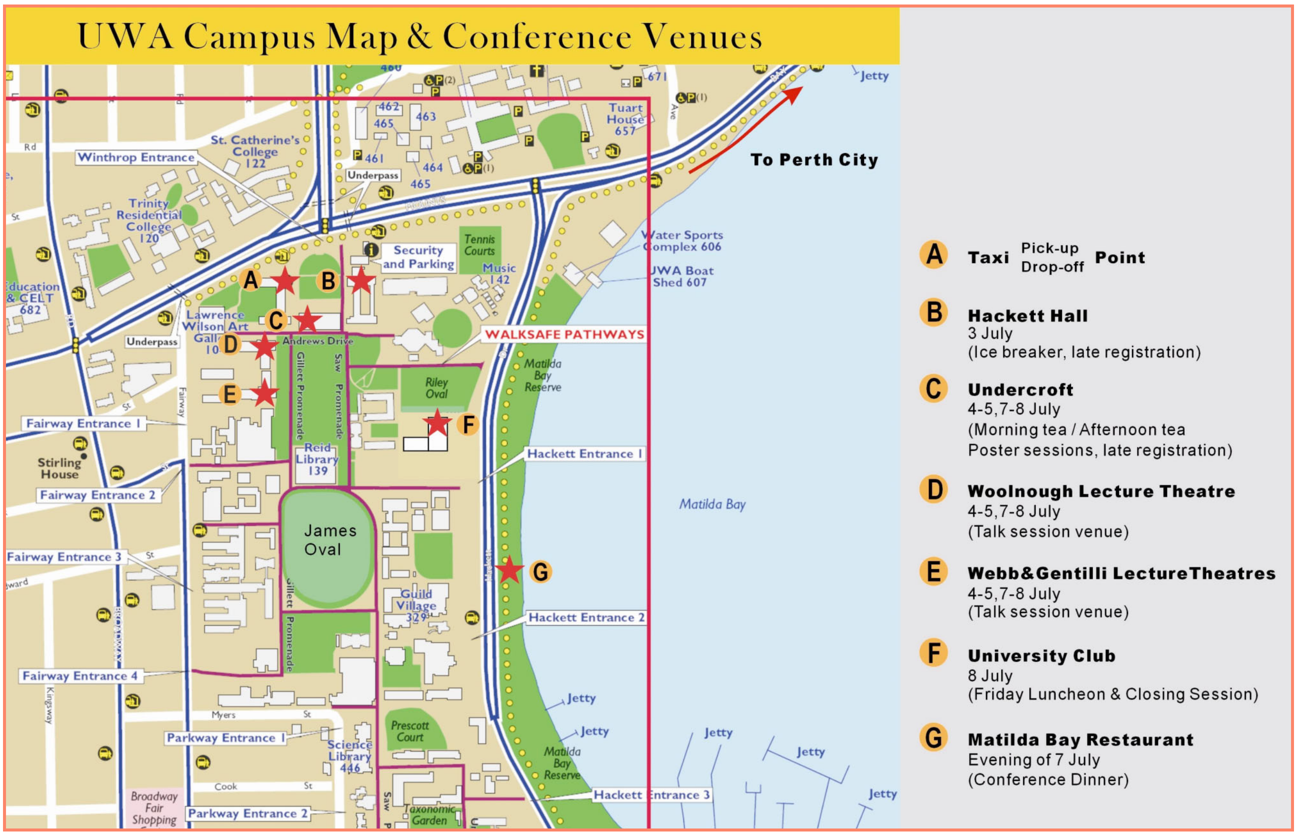
All posters will be displayed concurrently at The Undercroft from Monday to Friday. Poster and drinks sessions are scheduled at 17:00-18.30 on Monday, Tuesday, and Thursday. In addition, posters will be on display during morning/afternoon tea and lunch breaks on Monday-Tuesday and Thursday-Friday. The first author's name will be displayed on poster boards. Please find your poster board and attach your poster on Monday. All poster's must be removed by lunchtime Friday 8 July. It is the presenter's responsibility to place and remove their poster and the Congress organisers will not be responsible for posters left behind at the end of the Congress.

Speakers' preparation room

The speakers' preparation room is located on the first floor of Geology-Geography Building (Room 123) and will be open at 18:00-20:00 pm on Sunday 3 July and 8:30 am-17:00 pm on Monday-Tuesday, Thursday-Friday. All speakers must take their presentation to the speakers' preparation room a minimum of four hours prior to their presentation, or the day before if presenting in a morning session.

Congress venues

The UWA campus map shows the various venues for the Congress.



Public transportation between UWA and City downtown

A public transportation map, detailed bus numbers, and timetables will be provided in the Congress bag.

Taxis

The best pick-up and/or drop-off point is the Visitor Centre near the main University entrance from Mounts Bay Road–Winthrop Avenue corner.

Swan Taxis: 131 008

Car Parking

Council meter (coin) parking is available along Fairway, a short walk from the department.

Social programme

Ice Breaker & Welcome Reception

Time: 17:00-19:00 pm

Date: Sunday 3 July

Venue: Hackett Hall

Cost: Included in full Congress registrations. If you are a day registrant or accompanying person and would like to attend, please see the staff at the registration desk. Additional tickets are A$40 per person.

Congress Dinner

Time: 19:00-21:00 pm

Date: Thursday 7 July

Venue: Matilda Bay Restaurant

Cost: The Congress dinner is not included in the registration fee. The cost to attend is A$110 per person. If you have not booked and would like to attend, please check with staff at the registration desk regarding ticket availability. Matilda Bay Restaurant is just a short walk across the campus (see Venue map).

Congress Luncheon

Time: 13:00-14:30 pm

Date: Friday 8 July

Venue: The University Club

Cost: The Congress luncheon is sponsored and therefore included in the registration fee. Accompanying persons wishing to attend should enquire at the registration desk regarding ticket availability. Additional tickets are A$50 per person.

Business meetings

Date	Meeting name	Room	Time
Monday	SCS business meeting	Webb Lecture Theatre	17:30-18:30 pm
Tuesday	SPS business meeting	Webb Lecture Theatre	17:30-18:30 pm
Tuesday	ICCP Standing Committee meeting	John Glover Meeting room	Afternoon TBA
Thursday	IGCP572 business meeting	Webb Lecture Theatre	17:30-18:30 pm

Congress excursions

For more information see Congress website http://www.iccp2011.org

Pre-Congress excursion

Northern Canning Basin

Tuesday 28 June – Saturday 2 July

Guides: Arthur Mory (GSWA) and David Haig (UWA)

The excursion provides an introduction to the Lower Carboniferous and Permian exposures, and will also visit the well-exposed Upper Devonian carbonate reef complex at Windjana Gorge.

Mid-Congress excursions

Wednesday 6 July

Perth Core Library

Guide: Arthur Mory (GSWA)

A representative set of core sections from the Perth, Carnarvon and Canning Basins, including Hovea 3 (Permian–Triassic boundary), glacial deposits from the Barbwire Terrace, and upper Permian carbonate facies will be on display.

Collie Basin and Lake Clifton

Guides: Alan Millar (GSWA) and David Haig (UWA)

Artinskian to Kungurian coal measures at Collie (200 km south of Perth by road) Perth Basin, provide about 30% of the State's electricity. The coals lie within a fluvial–deltaic siliciclastic section exposed in large open-cut pits. The excursion will also visit modern thrombolites at Lake Clifton, and a local vineyard or two.

The Pinnacles and Lake Thetis

Guide: Jenny Bevan (UWA) and Eckart Håkansson (UWA)

The limestone pinnacles near Cervantes (245 km north of Perth by road) were developed within the Pleistocene Tamala Limestone, a largely nigma calcarenite present along much of WA's coast. Variable lithification by the precipitation of calcium carbonate has led to the formation of pillar-like structures, now exposed by erosion. Nearby modern stromatolites in Lake Thetis, and modern sediment within the littoral zone near Cervantes from one of the world's largest carbonate platforms, will also be visited.

Post-Congress excursion

Perth–Carnarvon Basins

Sunday 10 – Saturday 16 July

Guides: Arthur Mory (GSWA) and David Haig (UWA)

The excursion will visit coeval Sakmarian-Artinskian sections, 600 km apart, from both basins, as well examining cyclic clastic–carbonate shallow-water Kungurian cycles in the Carnarvon Basin, and will also visit the renowned stromatolites at Shark Bay.

Congress Programme

Overview

Tuesday 28 June – Saturday 2 July:

Pre-Congress Excursion

Sunday 3 July:

Ice-Breaker (17:00)

Registration (17:00)

Monday 4 July – Tuesday 5 July:

Symposia (09:00)

Registration (08:30 Monday)

Wednesday 6 July:

Mid-Congress excursions

Thursday 7 July – Friday 8 July:

Symposia (09:00)

Thursday 7 July:

Congress Dinner (19:00)

Friday 8 July:

Sponsored Luncheon (13:00)

Sunday 10 – Saturday 16 July:

Post-Congress excursion

Symposium Plan

Congress Opening and all plenary presentations will be held in the Woolnough Theatre

Monday

Opening		
Plenary		
Plenary		
Morning Tea		
S8	S13	S2
Lunch		
S8	S1	S2
Afternoon Tea		
S8	S1	S3
Posters & Drinks		
SCS Business Meeting		

Tuesday

Plenary		
S3	S13	S10
Morning Tea		
S3	S13	S10
Lunch		
S3	S7	S10
Afternoon Tea		
S3	S7	S10
Posters & Drinks		
SPS Business Meeting		

Thursday

Plenary		
S4	S5	S12
Morning Tea		
S4	S5	S12
Lunch		
S4	S6	S12
Afternoon Tea		
S4	S6	S14
Posters & Drinks		
IGCP Business		

Friday

Plenary		
S11	S9	S15
Morning Tea		
S11	S9	S15
Sponsored Luncheon		
ICCP 2011 Photo		
Summation & Close		

LECTURE THEATRES
left columns: Woolnough
centre columns: Gentilli
right columns: Webb

S1	SPS: Permian stage boundaries & correlation
S2	SCS: Carboniferous stage boundaries
S3	IGCP572: Latest Permian mass extinction
S4	IGCP572: Ecosystem recovery in the Early Triassic
S5	Paleo-Mesopalynology
S6	Gondwanan biota
S7	Carboniferous-Permian sea-level change & cyclicity
S8	Paleoclimatology, paleoceanography & seawater chemistry
S9	Mid-Permian events
S10	Carboniferous-Permian basin studies
S11	Coal & petroleum resources
S12	Reef complexes & carbonate platforms
S13	Paleozoic foraminfera
S14	Terrestrial ecosystems
S15	Paleontology general session

Plenary Speakers

Venue 1: Woolnough Theatre

Author	Title	Time
Richards B	The Carboniferous world: assembly of Pangea and onset of Late Paleozoic glaciations	Monday 4 July 09:30 – 10:10
Henderson C	The Permian world — ice house to extinction and everything in between	Monday 4 July 10:10 – 10:50
Benton M	Impact of the end-Permian mass extinction on land	Tuesday 5 July 09:00 – 09:40
Algeo T	The Early Triassic cesspool: marine conditions following the end-Permian mass extinction	Thursday 7 July 09:00 – 09:40
McCabe P	Coal and petroleum resources in Gondwanan basins	Friday 8 July 09:00 – 09:40

SYMPOSIUM 1: SPS: Permian stage boundaries and correlations

Day: Monday 4 July
Conveners: C Henderson (Chair), S Shen, V Davydov
Venue 2: Gentilli Theatre

Start	End	Talk	Authors	Title
13:50	14:20	1	Henderson C, Shuzhong S, Chen J	Completing the Permian time scale: progress on Cisuralian GSSP definitions
14:20	14:40	2	Chen J, Shen S, Henderson CM, Wang Y, Cao C,	High-resolution Cisuralian conodont biostratigraphy in South China and its role for the remaining Permian GSSPs
14:40	15:00	3	Davydov V, Schmitz M	Early Permian (Cisuralian) time scale and pan-Euramerican chronostratigraphic correlation
15:00	15:20	4	Shen S, Yuan D, Gorgij M, Cao C, Chen J, Henderson, C	Lopingian (Late Permian) biostratigraphy, chemostratigraphy and correlation between South China and Iran
AFTERNOON TEA				
15:50	16:10	5	Nicoll R, Metcalfe I, Mory A, Mantle D, Crowley J, Mundil R, Denyszyn S, Foster C	New U–Pb CA-IDTIMS isotopic age tie points for the Lightjack Formation, Canning Basin, Western Australia
16:10	16:30	6	Metcalfe I, Nicoll R, Crowley J, Ives M, Mantle D, Ruming K, Huyskens M, Foster C	New Middle Permian – Early Triassic U–Pb zircon CA-IDTIMS isotopic ages of tuffs in the Sydney Basin, Australia: international calibration of stratigraphy and biostratigraphy.
16:30	16:50	7	Nicoll R, Metcalfe I	The Permian conodont biostratigraphy of Australia and New Zealand
16:50	17:10	8	Izotov V, Sitdikova L, Izotov P, Borisov A	Analytical expression of the Golovkinskyi law of facies relationships of Upper Permian deposits (eastern part of Russian Plate)

SYMPOSIUM 2: SCS: Carboniferous stage boundaries

Day: Monday 4 July
Conveners: B Richards (Chair), X Wang, K Ueno
Venue 3: Webb Theatre

Start	End	Talk	Authors	Title
11:20	11:50	1	Aretz M (Keynote)	The challenge of redefining the Devonian–Carboniferous boundary
11:50	12:10	2	Poty E, Aretz M, Hance L	Belgian substages as a basis for international chronostratigraphic divisions of the Tournaisian and Viséan
12:10	12:30	3	Sevastopulo G	Correlation of the base of the Serpukhovian Stage in Northwest Europe and North America
12:30	12:50	4	Nikolaeva S, Richards B, Kulagina E, Alekseev A, Pazukhin V, Konovalova, V	Summary of Research at the Verkhnyaya Kardailovka section (South Urals) — a candidate for the Viséan–Serpukhovian boundary GSSP
			LUNCH	
13:50	14:20	5	Richards B & Task Group (Keynote)	Global correlations and the Viséan–Serpukhovian stage boundary
14:20	14:40	6	Nikolaeva S, Kulagina E, Pazukhin V, Kochetova, N	Mid-Carboniferous boundary beds in the Muradymovo section (South Urals, Russia)
14:40	14:50	7	Ueno K & Task Group	The Moscovian–Kasimovian and Kasimovian–Gzhelian boundaries — an overview and progress report
14:50	15:10	8	Leontiev D, Kossovaya O	Preliminary data on the pre-*sagittalis* interval from the Kasimovsky quarry section, Ryazan district, Russia
15:10	15:30	9	Qi Y, Wang X, Barrick J, Lambert L, Richards B, Groves J, Ueno K, Wang X, Lane R, Wu X, Hu K	Progress on the study of conodonts from candidate GSSPs for the bases of Carboniferous stages in South China
			AFTERNOON TEA	

SYMPOSIUM 3: IGCP572: Latest Permian mass extinction

Day: Monday 4 July
Conveners: T Algeo (Chair), K Grice
Venue 3: Webb Theatre

Start	End	Talk	Authors	Title
15:50	16:10	1	Grice K, Nabbefeld B, Twitchett R, Hays L, Williford K, Holman A, Summons R, McElwain J, Böttcher M	Exploring mass extinction events (Permian–Triassic & Triassic–Jurassic): association with global warming events using molecular fossils and stable carbon and hydrogen isotopes
16:10	16:30	2	Brookfield M, Hannigan R, Algeo T, Williams J	Sedimentology and geochemistry of the Permo–Triassic boundary section at Guryul ravine, Kashmir, India; and a comparison with the Texas Cretaceous–Tertiary boundary section
16:30	16:50	3	Wang C, Zhang Z, Xiong Y	Compound-specific hydrogen and carbon isotopic evidence for the origin of the nigma abundance anomaly around the Permian–Triassic boundary GSSP at Meishan, China
16:50	17:10	4	Huang C, Hinnov L, Chen ZQ and Tong J	Astronomical forcing of marine sediment cycles across the Permian–Triassic boundary interval

Day: Tuesday 5 July
Conveners: K Grice (Chair), T Algeo
Venue 1: Woolnough Theatre

Start	End	Talk	Authors	Title
9:40	10:10	5	Henderson C (Keynote)	Diachronous paleobiodiversity change during extinction and recovery — an Arctic perspective
10:10	10:30	6	Kaiho K, Koga S	Massive release of hydrogen nigma and methene at the end of the Permian did not cause ozone collapse
			MORNING TEA	
11:00	11:20	7	Huang C, Tong J, Hinnov L, Chen ZQ	Timing of the Permian–Triassic boundary mass extinction interval: evidence from global correlation of astronomically forced marine records
11:20	11:40	8	Algeo T	Enhanced continental weathering in the latest Permian to Early Triassic: effects on shallow-marine biotas
11:40	12:00	9	Shen S, Wang Y, Zhang H	The end-Permian mass extinction: a single- or two-phase extinction?
12:00	12:20	10	Korngreen D, Conway B, Orlov–Labkovsky O	Permo-Triassic transition at the Coastal Plain in Israel (David 1 borehole), north Arabian Plate margin

Symposium 3 continued

		LUNCH		
13:20	13:40	11	Ladjavadi M, Grice K, Edwards D, Boreham C, Metcalfe I, Summons R	The age and palaeoenvironmental conditions spanning the Permian–Triassic boundary in the northern onshore Perth Basin using biomarker distributions and stable isotopes (C, H)
13:40	14:00	12	Lai X, Yan C, Wang L, Jiang H, Sun Y, Chen Y	Uppermost Permian to Early Triassic conodonts in the Bianyang Section, Great Bank of Guizhou, South China
14:00	14:20	13	Chen J, Beatty T, Henderson C, Rowe H	Conodont biostratigraphy at the Dawen section in Guizhou and its implications for the Late Permian extinction
14:20	14:40	14	Ito K, Kaiho K, Oba M, Takahashi S	Oceanic euxinia, cyanobacterial bloom, and land vegetation collapse and recovery during the two-step mass extinctions spanning the Permian–Triassic boundary
		AFTERNOON TEA		
15:10	15:30	15	Zhang H, Shen S, Jin Y	Multiple original microspherules from the Permian–Triassic boundary event beds in South China
15:30	15:50	16	Takahashi S, Yamasaki S, Ogawa Y, Kimura K, Watanabe T, Kaiho K, Kakegawa T, Yoshida T, Tuchiya N	Euxinic maximum coinciding with the end-Permian mass extinction following progressive euxinia development inferred from trace elements and sulphide sulphur isotopes
15:50	16:10	17	Tohver E, Cawood P, Fletcher I, Sherlock S, Jourdan F, Lana C, Trindade R, Yokoyama E, Souza Filho C	Age of the Araguainha impact crater and implications for the Permo-Triassic carbon isotope record
16:10	16:30	18	Yamakita S, Takemura A, Hori RS, Aita Y, Yakahashi S, Kojima S, Kadota N, Kodama K, Ikehara M, Kamata Y, Suzuki N, Spörli K, Campbell H	Lithostratigraphy and conodont biostratigraphy of Upper Permian to Lower Triassic ocean floor sequences in Japan and New Zealand, originally deposited in low and southern middle latitudes in Panthalassa
16:30	16:50	19	Williams J, Hannigan R, Basu A, Ahluwalia A, Bhargava O	Paleo-environmental analysis of the Attargoo Permo-Triassic Section: a Neo-Tethyan Permo-Triassic section

SYMPOSIUM 4: IGCP572: Ecosystem recovery in the Early Triassic

Day: Thursday 7 July
Conveners: J Tong (Chair), M Frasier
Venue 1: Woolnough Theatre

Start	End	Talk	Authors	Title
9:40	10:10	1	Zonneveld, J-P, Beatty TW, Gingras M, Hyodo T (Keynote)	Patterns in Early Triassic infaunal recovery in northwestern Pangaea in the aftermath of the end-Permian extinction event
10:10	10:30	2	Fraiser M	When did marine ecosystems recover following the end-Permian mass extinction?
			MORNING TEA	
11:00	11:20	3	Chen J, Zhao L, Chen ZQ, Algeo T	Conodont rare earth elements from Chaohu, South China, document major marine environmental changes during the Early Triassic
11:20	11:40	4	Jia Z et al.	Changing characteristics of depositional environments during the Early Triassic in the Lower Yangtze region
11:40	12:00	5	Ikeda M, Sakuma H, Tada R, Takahashi S	Changes in biogenic Si and dust flux in the Panthalassic Ocean during the early Triassic "Chert Gap"
12:00	12:20	6	Huang Y, Tong J, An Z, Ji W	Littoral survival benthic communities in the aftermath of the end-Permian mass extinction from South China
			LUNCH	
13:20	13:40	7	Tong J, Chen ZQ, Chen J, Song H	Evidence for the Triassic recovery in South China
13:40	14:00	8	Altiner D, Payne JL	Origination and early evolution of the Order Involutinida in the aftermath of the Permian mass extinction: evidence for adaptation to a new mode of life in Early Triassic seas?
14:00	14:20	9	Tian L, Tong J, Xiong Y, Song H, Sun D	Development of oolites in the aftermath of the end-Permian mass extinction
14:20	14:40	10	Takemura A, Yamakita S, Komori H, Aono R, Hori RS, Aita Y, Kamata Y, Takahashi S, Ikeda M, Takemura S, Spörli K, Campbell H	Induan (Lowest Triassic) radiolarians from Arrow Rocks, New Zealand, and the radiolarian faunal transition above the P–T boundary
			AFTERNOON TEA	

Symposium 4 continued

AFTERNOON TEA				
15:10	15:30	11	Shi Z et al.	Early Triassic Griesbachian anachronistic world after the P–T mass extinction in Upper Yangtze area, SW China — is the Gaia Theory applicable?
15:30	15:50	12	Vuks V	Early Triassic foraminifers from the Gorny Mangyshlak and Caucasus to the Alps: new and published data
15:50	16:10	13	Goudemand N, Orchard M, Krystyn L, Brühwiler T, Ware D, Brayard A, Galfetti T, Bucher H	New conodont data from Waili (South China) and Mud (Northern India) and implications for the Induan–Olenekian boundary
16:10	16:30	14	Metcalfe I, Nicoll RS, Willink R, Ladjavadi M, Grice K	The Induan–Olenekian boundary in Western Australia: conodont biostratigraphy, carbon isotopes and constraints on post mass extinction anoxia
16:30	16:50	15	Goudemand N, Orchard M, Bucher H, Jenks J	Is *Chiosella timorensis* a good index for the Olenekian–Anisian Boundary?

SYMPOSIUM 5: Paleo-Mesopalynology

Day: Thursday 7 July

Conveners: J Backhouse (Chair), C Foster, W Kürschner

Venue 2: Gentilli Theatre

Start	End	Talk	Authors	Title
9:40	10:10	1	Kürschner W (Keynote)	Peculiarities of Permian–Triassic palynological records
10:10	10:30	2	Al-Barram I	Palynology and palynofacies of the Carboniferous (Pennsylvanian) – Permian (Cisuralian) Al Khlata Formation from Central and South Oman
			MORNING TEA	
11:00	11:20	3	Stolle E	Palynostratigraphic significance of *Pyramidosporites* Segroves 1967 in Permian strata of eastern Gondwana
11:20	11:40	4	Hermann E, Kürschner W, Hochuli PA, Goudemand N, Ware D, Bucher H, Roohi G	Permian–Triassic palaeoenvironment inferred from palynofacies data of Amb, Salt Range, Pakistan
11:40	12:00	5	Mantle D, Foster C, Nicoll R, Metcalfe I, Crowley J, Mundil R, Kelly T	Late Permian – Early Triassic palynology of the Bowen and Sydney basins: results and implications of new CA–IDTIMS isotopic ages
12:00	12:20	6	Bek J	A review of the genus *Lycospora*
			LUNCH	

SYMPOSIUM 6: Gondwanan biota

Day: Thursday 7 July
Conveners: S Shen (Chair), G Shi
Venue 2: Gentilli Theatre

Start	End	Talk	Authors	Title
13:20	13:50	1	Isbell J, Henry L, Limarino C, Koch Z, Ciccioli P, Fraiser M (Keynote)	The equilibrium line altitude as a control on Gondwana glaciation during the late Paleozoic Ice Age
13:50	14:10	2	Singh K, Saxena, A	Biodiversity of the Palaeozoic rocks in the North West Himalaya, India: a review
14:10	14:30	3	Baud A, Cordey F,Richoz S	Buday'ah (Oman) and Arrow Rock (New-Zealand): from a similar to a divergent evolution of Permian-Triassic oceanic successions
14:30	14:50	4	Chen ZQ, Dixon M	Benthic responses to extreme climate changes immediately after the Early Permian ice age: fossil record from a Gondwanan interior sea
AFTERNOON TEA				
15:10	15:30	5	Isbell J, Taboada A, Koch Z, Limarino C, Fraiser M, Pagani M, Gulbranson E, Ciccioli P, Dineen A	Emerging polar view of the late Paleozoic ice age as interpreted from deep-water, distal, glacimarine deposits in the Tepuel-Genoa Basin, Patagonia, Argentina
15:30	15:50	6	Aung AK	Permian rugose corals from southern Shan State, Myanmar: associated microfossils and paleogeographic implications
15:50	16:10	7	Hooker N, Breuer P, Tourqui H	Palynostratigraphy and palaeoenvironments of the Mississippian to Pennsylvanian succession in the subsurface, northern Saudi Arabia
16:10	16:30	8	Nicoll R, Mory A, Metcalfe I	Carboniferous conodont faunas in Australia and New Zealand
16:30	16:50	9	Limarino C, Spalletti L, Isbell J, Césari S, Geuna S	Paleoclimatic evolution of southwestern Gondwana during the Late Paleozoic: a record from ice-house to green-house conditions

SYMPOSIUM 7: Carboniferous-Permian sea-level change and cyclicity

Day: Tuesday 5 July
Conveners: E Poty (Chair), M Aretz, H Mii
Venue 2: Gentilli Theatre

Start	End	Talk	Authors	Title
13:20	13:50	1	Giles P (Keynote)	Glacioeustasy, transgressive-regressive (TR) cycles, mesothems and substages: Carboniferous and Permian faunal introduction events (FIEs) dressed in long-period orbital clothing
13:50	14:10	2	Bábek O, Kalvoda J, Cossey P, Devuyst F-X	Sequence stratigraphic interpretation of gamma-ray and magnetic susceptibility signals at the Tournaisian-Viséan boundary of southern Great Britain: a glacioeustatic control?
14:10	14:30	3	Aretz M, Chevalier E, Poty E, Chevalier J	Cyclicity in the Middle Viséan strata of Belgium
14:30	14:50	4	Poty E, Aretz M, Hou H, Hance L	Bio- and sequence stratigraphic correlations between Western Europe and South China: to a global model of the eustatic variations during the Mississippian
			AFTERNOON TEA	
15:10	15:30	5	Denayer J, Poty E	Uppermost Devonian and Mississippian sequence stratigraphy and rugose coral biostratigraphy of Zonguldak and Bartin area, NW Turkey
15:30	15:50	6	Waters C, Condon D	Nature and timing of Late Mississippian to Mid Pennsylvanian glacio-eustatic sea-level changes of the Pennine Basin, UK
15:50	16:10	7	Davydov V, Gradstein F, Hammer Ø	Late Mississippian-early Pennsylvanian greenhouse to icehouse transition in the northern subtropics: Serpukhovian, Bashkirian and Moscovian cyclic successions on Bear Island (Artic Norway)
16:10	16:30	8	Osleger D, Montanez I, Eros J	Late Carboniferous Onlap Curve, Donets Basin, Ukraine
16:30	16:50	9	Wang X, Sheng Q, Qi Y, Wang Y, Shen S, Ueno K	The Carboniferous and Lower Permian of South China: sedimentologic cycles and biotic events

SYMPOSIUM 8: Paleoclimatology, paleoceanography & seawater chemistry

Day: Monday 4 July
Conveners: E Grossman (Chair), M Joachimski, I Montanez
Venue 1: Woolnough Theatre

Start	End	Talk	Authors	Title
11:20	11:50	1	Passey B, Henkes G, Grossman E, Yancey T (Keynote)	Deep time paleoclimate reconstruction using carbonate clumped isotope thermometry: a status report
11:50	12:10	2	Webb G	Application of trace element geochemistry to ancient limestones: palaeoceanography, palaeogeography and palaeoecology
12:10	12:30	3	Giles P	Paleozoic ice-house and low-latitude brachiopod habitat temperature (BHTs): the cold hard truth from $\delta^{18}O_{\text{brachiopod calcite}}$
12:30	12:50	4	Melendez I, Grice K, Trinajstic K, Thompson K, Ladvardji M	Biomarkers and stable isotopes of euxinia and their role in fossil preservation
			LUNCH	
13:50	14:20	5	Montanez I, Eros J, Antognini J, Brand U, Poulsen C, Horton D (Keynote)	Climate-forcing feedbacks in the Carboniferous
14:20	14:40	6	Qie W, Zhang X, Grossman E, Du Y, Huang X	Carbon and oxygen isotopic records of Lower Carboniferous brachiopod shells from Southern Guizhou, South China
14:40	15:00	7	Algeo T	Circulation in the Late Pennsylvanian midcontinent sea of North America
15:00	15:20	8	Grossman E, Flake R, Yancey T, Olszewski T, Thomas D, Marcantonio F, Raymond A, Miller B	Circulation in the Carboniferous epicontinental seas of North American – stable isotopic evidence
			AFTERNOON TEA	
15:50	16:10	9	Cao C, Zen L, Davydov V, Shen S	The Cisuralian (Early Permian) carbon-isotopic perturbations and its palaeoclimatic implications in the southern Urals, Russia
16:10	16:30	10	Mii H, Shi G, Wang J	Permian middle–high latitude Gondwana palaeoenvironment stable isotope records from West Australia
16:30	16:50	11	Joachimski M, Lai X, Jiang H, Luo G, Shen S, Chen B, Chen J, Sun Y	Climatic warming in the latest Permian and the Permian–Triassic mass extinction
16:50	17:10	12	Song H, Tong J, Song H, Algeo T	Large seawater nigma isotope perturbations during the Early Mesozoic

SYMPOSIUM 9: Mid-Permian events

Day: Friday 8 July
Conveners: X Lai (Chair), Y Isozaki
Venue 2: Gentilli Theatre

Start	End	Talk	Authors	Title
9:40	10:10	1	He B, Xu Y, Huang X, Zhong Y, Luo Z (Keynote)	Temporal coincidence between the Emeishan large igneous province and the Guadalupian–Lopingian boundary
10:10	10:30	2	Lai X, Wignall P, Ali J, Widdowson M, Bond D, Sun Y	Understanding the volcanism–extinction link: Emeishan LIP and the Middle Permian mass extinction case study
			MORNING TEA	
11:00	11:30	3	Joachimski M, Chen B, Lai X, Sun Y, Shen S (Keynote)	Carbon and oxygen isotope geochemistry of the Guadalupian–Lopingian boundary
11:30	11:50	4	Li Z, Yang S, Crawford A, Li Y, Langmuir C, Sun Y, Yu X	Temporal-spatial-geochemical features and magmatic dynamics of the Permian large igneous province in Tarim Basin of NW China
11:50	12:10	5	Biakov A	The Middle Permian of northeast Asia: blossom and decline
12:10	12:30	6	Isozaki Y, Igo H	Provincial response of foraminifera to global extinction: the Late Guadalupian (Permian) giant fusuline case in mid-Panthalassa
12:30	12:50	7	Nishikane Y, Kaiho K, Takahashi S, Henderson C, Suzuki N, Kanno M	Recognition of the Guadalupian–Lopingian boundary in a chert sequence in Japan using conodont and radiolarian biostratigraphy, with reference to carbon isotope stratigraphy
			LUNCH	

SYMPOSIUM 10: Carboniferous-Permian basin studies

Day: Tuesday 5 July
Conveners: E Tohver (Chair), X Jin, M Dixon
Venue 3: Webb Theatre

Start	End	Talk	Authors	Title
9:40	10:10	1	Shi G (Keynote)	Where worlds collide: Permian analogues of Wallacea
10:10	10:30	2	McCartain E	The Lower Permian of East Timor: a possible distal expression of the west Australian Gondwanan Lower Permian tripartite successions
			MORNING TEA	
11:00	11:20	3	Playford P	The Permo-Carboniferous glaciation of Gondwana: its legacy in Western Australia
11:20	11:40	4	Haines P, Allen H-J, Wingate M, Kirkland C, Hocking R	Ice movement direction and detrital zircon provenance data for early Permian glacial deposits, Amadeus Basin, eastern Western Australia
11:40	12:00	5	Martin J, Redfern J, Williams B, Mory A, Horstwood M	The Early Permian glaciation of the Canning Basin, NW Australia: a sedimentological and provenance analysis of the Grant Group
12:00	12:20	6	Metcalfe I, Nicoll R, Mundil R, Denyszyn S, Crowley J, Mantle D, Willink R, Foster C	Late Permian U–Pb CA-IDTIMS isotope geochronology of the Bowen Basin, Eastern Australia
			LUNCH	
13:20	13:40	7	Normington V, Hill S	Late Palaeozoic regolith and palaeo-landscape features in southeastern Australia
13:40	14:00	8	Jin X, Huang H, Shi Y, Wang Y	The Permian of the Baoshan Block, western Yunnan, China: sedimentary development and basin configuration
14:00	14:20	9	Zi J, Cawood P, Fan W, Tohver E, McCuaig P	Timing of opening and subduction of the paleo–Tethys at Jinshajiang (SW China): perspectives from zircon U–Pb and Hf–O systematics of ophiolitic plagiogranites
14:20	14:40	10	Liu Y, Zhou D, Yang W, Feng Q, Liu H, Jiao X	Permian mantle-originated hydrothermal exhalative sedimentary rocks in San-Tang-Hu Basin and regional parallel analysis, Xinjiang, NW China
			AFTERNOON TEA	

Symposium 10 continued

AFTERNOON TEA				
15:10	15:30	11	Jutras P	Hutton's Unconformity on Arran, southwest Scotland: a double unconformity masked by a phreatic calcrete hardpan developed at the Devonian-Carboniferous boundary
15:30	15:50	12	Biakov A, Ganelin V, Budnikov I, Kutygin, R, Vedernikov, I	The Permian of notheast Asia: modern state and main problems
15:50	16:10	13	Bachmann G	Cyclic fill of the intracontinental Central European Basin in the latest Carboniferous, Permian and Triassic
16:10	16:30	14	Brenckle P, Collins J	Biostratigraphic–stratigraphic framework for the Carboniferous Kashagan Field, north Caspian Basin, Kazakhstan
16:30	16:50	15	Håkansson E, Schack Pedersen S	Mid to Late Permian pull-apart basins in North Greenland

SYMPOSIUM 11: Coal and petroleum resources

Day: Friday 8 July
Conveners: A George (Chair), S Lang
Venue 1: Woolnough Theatre

Start	End	Talk	Authors	Title
9:40	10:10	1	Lang S (Keynote)	Depositional analogues for Permian fluvial-deltaic reservoirs of Eastern Australia
10:10	10:30	2	Penney R, Al-Barram I, Stephenson M	Application of palynostratigraphy to petroleum bearing Permo-Carboniferous sediments — a case study from Oman's Haushi Group
MORNING TEA				
11:00	11:30	3	Esterle J (Keynote)	Understanding coal seam gas
11:30	11:50	4	Collins S, Esterle J, Golding S	High resolution lithotype cyclicity in the Late Permian Wallabella Coal Member
11:50	12:10	5	Zwingmann H, Clauer N, Liewig N	New time constraints on illite authigenesis processes in Permian Rotliegend reservoirs of Northern Germany
12:10	12:30	6	Bachmann G, Doornenbal H, Stevenson A, Carboniferous, Permian & Triassic SPBA Working Groups	Carboniferous, Permian and Triassic in Central Europe: results from the new petroleum geological atlas of the Southern Permian Basin
12:30	12:50			
LUNCH				

SYMPOSIUM 12: Reef complexes and carbonate platforms

Day: Thursday 7 July
Conveners: G Webb (Chair), I Somerville
Venue 3: Webb Theatre

Start	End	Talk	Authors	Title
9:40	10:10	1	Aretz M (Keynote)	Mississippian reefs and mounds in Europe, North Africa and China
10:10	10:30	2	Seyedmehdi Z, George A	Evolution of a latest Devonian – Early Carboniferous mixed carbonate–siliciclastic ramp (Fairfield Group) Canning Basin, northwestern Australia
			MORNING TEA	
11:00	11:20	3	Somerville I, Rodríguez S, Said I, Cózar P	Mississippian microbial mounds and coral reefs from Central Morocco
11:20	11:40	4	Gong E, Guan C, Zhang Y	Carboniferous reefs in China
11:40	12:00	5	Higa K, Sugiyama T, Murakami T	Biotic and environmental change through the Mississippian–Pennsylvanian boundary in a Panthalassan oceanic atoll, Akiyoshi Limestone, SW Japan
12:00	12:20	6	Nakazawa T, Ueno K, Kawahata H, Fujikawa M	Late Pennsylvanian to Middle Permian reef succession on Panthalassan oceanic atolls
			LUNCH	
13:20	13:40	7	Zhang Y, Gong E, Guan G	The study of Pennsylvanian reefal microbial carbonates in South Guizhou, China
13:40	14:00	8	Kossovaya O, Vachard D, Izart A	The main transformation in Permian reef biotas of the east European platform
14:00	14:20	9	Peryt T, Raczyński P, Peryt D, Jasionowski M	Upper Permian reef complex in the basinal facies of the Zechstein Limestone (Ca1), western Poland
14:20	14:40	10	Sitdikova L, Sitdikova E, Borisov A, Izotov V, Izotov P	Reef complex of Carboniferous deposits in part of the central Volga–Ural province

SYMPOSIUM 13: Paleozoic foraminfera

Day: Monday 4 July
Convener: D Haig
Venue 2: Gentilli Theatre

Start	End	Talk	Authors	Title
11:20	11:40	1	Charoentitirat T	New occurrence of genus *Monodiexodina* in West Thailand
11:40	12:00	2	Shi Y, Yan S, Yang X	Fusulinids in the Dianqiangui Basin during Early and Middle Permian, South China: pattern and causes of their diversification
12:00	12:20	3	Huang H, Jin X, Shi Y	An unusual *Verbeekina* fauna from Baoshan Block, SW China
12:20	12:40	4	Niu Z, Wu J	Permian fusulinid palaeobiogeography of southern Qinghai Northwest China
12:40	13:00	5	Wang Y, Wang W, Cao C, Shen S, Ueno K	Recent progresses on the Upper Permian boultoniids: their biostratigraphy and palaeogeography
			LUNCH	

Day: Tuesday 5 July
Convener: D Haig
Venue 2: Gentilli Theatre

Start	End	Talk	Authors	Title
9:40	10:10	6	Somerville I, Cózar P, Said I, Varchard D, Medina-Varea P, Rodriguez S	Serpukhovian foraminiferal markers from Central Morocco
10:10	10:30	7	Kalvoda J, Bábek O, Cossey P, Devuyst F, Hargreaves S	High resolution foraminiferal biostratigraphy of the Tournaisian-Visean boundary interval in the British Isles and the influence of sedimentary facies
			MORNING TEA	

Symposium 13 continued

MORNING TEA				
11:00	11:20	8	Herbig H-G, Pabst J, Könen J	The nigma of Mississippian pelagic facies approached by agglutinating foraminifera and carbonate microfacies
11:20	11:40	9	Khadjanijazova R, Davydoy V, Schmitz M	Fusulinid biozonation as a proxy of Milankovitch cyclicity: the record from Moscovian-Kasimovian transition in Donets Basin
11:40	12:00	10	Altiner D, Özkan-Altiner S, Yilmaz İ, Özdemir-Atakul A	Bashkirian-Moscovian boundary beds in southern Turkey: foraminiferal biostratigraphy and sequence stratigraphy
12:00	12:20	11	Ueno K, Hayakawa N, Nakazawa T, Wang Y, Wang X	*Carbonoschwagerina*-mimics from the Zongdi section of South China: new relatives or homeomorphic strangers?

SYMPOSIUM 14: Terrestrial ecosystems

Day: Thursday 7 July
Conveners: W Yang (Chair), G Bachmann
Venue 3: Webb Theatre

Start	End	Talk	Authors	Title
15:10	15:30	1	Pšenicka J, Kerp H, Opluštil S, Elrick S, DiMichele W, Bek J, John N, Ames P	Preliminary report on the earliest callipterid assignable to the morphogenus *Rhachiphyllum* Kerp from the late Moscovian (Asturian) Farmington Shale (Illinois Basin, USA)
15:30	15:50	2	Šimunek Z, Florjan S	Middle Pennsylvanian Bohemian and Poland corditaleans and their dispersed cuticles
15:50	16:10	3	Chaney D, DiMichele W, Tabor N	Floral responses to Pennsylvanian–Permian macro and micro climatic fluctuations across the North American portion of western Pangaea
16:10	16:30	4	Srivastava A, Agnihotri D	Development and diversification of *Glossopteris* flora in Early Permian sequences of Indian Gondwana
16:30	16:50	5	Yang W, Feng Q, Liu Y, Tabor N, Miggins D, Crowley J	Revised geochronology, cyclostratigraphy, and paleoclimatic conditions of an Uppermost Carboniferous – Lower Triassic terrestrial record of mid-latitude NE Pangea, Southern Bogda Mountains, NW China

SYMPOSIUM 15: Paleontology General Session

Day: Friday 8 July
Convener: E Håkansson
Venue 3: Webb Theatre

Start	End	Talk	Authors	Title
9:40	10:10	1	Ernst A, Håkansson E, Haig D	The upper Sakmarian–Artinskian bryozoan fauna of the Callytharra Formation, Western Australia
10:10	10:30	2	Lee S, Li W, Shi G	Palaeobiogeographical interpretations of *Kaninospirifer* Kulikov and Stepanov in Stepanov et al., 1975 and *Fasciculatia* Waterhouse, 2004 (Neospiriferinae, Brachiopoda)
			MORNING TEA	
11:10	11:30	3	Brauckmann C, Zessin W	Research on Permo-Carboniferous Odonatoptera in the last 30 years
11:30	11:50	4	Luo M, Chen ZQ	Grazing/gnawing traces from the Lower Triassic Kockatea Shale Formation, northern Perth Basin, Western Australia: taphonomy, palaeoecology and implications for the bioerosion ichnofacies model
11:50	12:10	5	Vanderlaan T, Ebach M	Strato-systematics: a new technique for refining marker taxa
12:10	12:30	6	He W, et al.	Changhsingian radiolarian fauna of northern Yangtze basin, South China
12:30	12:50	7	Singh G, Jha N, Mehrotra N	An algal bloom (green algae of zygnematalean affinity) from the Gechang Formation (Lower Permian) of Spiti Basin, NW Himalaya, India
			LUNCH	

Poster Session

Venue: The Undercroft

Author	Title
Backhouse J, Mory A	A review of the Late Carboniferous and Permian palynology of the northern Canning Basin, Western Australia
Biakov A	Permian biogeography of Boreal bivalves
Borisov A, Izotov V, Sitdikova L	Reflection of Milankovitch cycles in the petrophysical characteristics of Permian sedimentary deposits of Volga region
Brice D, Mottequin B	Rhynchonellid and spiriferid brachiopods as valuable tools for correlation of shelly faunas near the Devonian–Carboniferous boundary
Bu J, Li W, He W, Lu J	Carboniferous–Permian palaeobiological feature of Badain Jaran region, Inner Mongolia, and its tectonic implications
Chen ZQ, Harper D, Shi G	Benthic responses to Permian extreme climate changes: brachiopod evidence from north and south high-latitude to tropical regions
Chesnut D Jr	The fates of the Lhasa and West Burma Blocks
Chesnut D Jr	Assembly of Asia and tectonics of its Late Paleozoic basins
Chesnut D Jr, Greb S	Carboniferous of the Appalachian and Black Warror Basins
Davydov D, et al.	The onset and cyclicity of Bashkirian glaciation: the record from Bear Island, Arctic Norway, and Donets Basin, Ukraine
Djenchuraeva A	Biostratigraphy of the upper Moscovian–Kasimovian boundary sediments of low foothills of the Turkestan-Alai, South Tien-Shan
Falahatgar M, Mosaddegh H	Biofacies and microfacies of the Mobarak Formation (Mississippian), Kiyasar area, North of Iran
Goreva N, Alekseev A	New Russian sections as potential GSSP of the global Kasimovian and Gzhelian stages
He W, et al.	Palaeoecology of Changhsingian Ambocoeliidae brachiopods from South China and implications for the end-Permian mass extinction
Henkes G, Passey B, Grossman E, Yancey T	Clumped isotope geochemistry of Carboniferous brachiopods: early lessons from a novel paleothermometer
Herbig H-G	From coralline skeletons to specula biosedimentology of sponges in a Middle Pennsylvanian platform, Cantabrian Mts, northern Spain
Hoshiki Y, Ueno K, Wang Y, Qi Y, Wang X	Carboniferous foraminiferal faunal succession of upper-slope facies in the Yangtze Carbonate Platform: the Dianzishang section in Guizhou Province, South China

Author	Title
Hou H, Zhou H, Liu J	Microbial sedimentation after the end-Devonian mass extinction, Hunan platform, China
Kaiho K, Gorjan P, Oba M, Fukuda Y, Chen ZQ, Yamakita S	Accumulation and oxidation of hydrogen sulfide causing surface-water anoxia and acidification leading to the end-Permian mass extinction
Kani T, Kofukuda D, Fukui M, Isozaki Y	Capitanian (Late Guadalupian) Sr minimum in mid-Panthalassa paleo-atoll limestones
Kossovaya O, Izart A, Malkowski K, Vachard D	Multidiscipline study of the Lower Permian deposits in the Most Section, Central Urals
Kumpan T, Babek O, Kalvoda J, Fryda J, Krejci Z	The Devonian–Carboniferous boundary in the Moravian–Silesian Basin (Central Europe, Czech Republic): high-resolution stratigraphy
Lazar S, George AD	Facies architecture and evolution of the Late Carboniferous–Permian Pha Nok Khao Platform, Loei–Phetchabun Foldbelt, Northeast Thailand
Li S	Lower Permian depositional environments, North China
Metcalfe I, Sone M	Late Permian (Changhsingian) and Early Triassic (Induan) conodonts and the Permian–Triassic boundary in central Peninsular Malaysia
Mottequin B, Poty E	Unusual skip marks from the early Viséan Molignée Formation (Mississippian) of southern Belgium
Novak M	Foraminiferal biostratigraphy of the Upper Carboniferous to Middle Permian deposits in the Karavanke Mts. and Julian Alps, Southern Alps, Slovenia
Orlov-Labkovsky O, Korngreen D	Foraminiferal biostratigraphy of the Permian succession in Israel — new data.
Peryt D, Peryt TM	Foraminiferal "microbuildups" in a condensed section of the Zechstein Limestone, western Poland
Peryt T, Peryt D, Durakiewicz T	Carbon and oxygen isotopic composition of basal Zechstein (Upper Permian) rocks in northern Poland: implications for seawater chemistry and temperature
Qie W, Zhang X, Du D, Yang B	Conodont biostratigraphy of Tournaisian shallow water carbonates in central Guangxi, South China
Redfern J, al Hinai J, Brocklehurst S	The Late Carboniferous basal Grant Group unconformity, Canning Basin, Australia: a complex surface recording glacial, tectonic and halotectonic processes
Saito K, Kaiho K, Oba M, Ariyoshi S	Ocean redox history during the Early Triassic

Author	Title
Saito K, Kaiho K, Oba M, Takahashi S, Chen ZQ, Tong J	A terrestrial vegetation turnover in the middle Early Triassic
Shi, G	Argentinean-Siberian Late Palaeozoic marine biogeographic links: implications for Permian global marine biogeography and climate change
Stolle E, Buzkan I	First documented palynological record from Kasimovian deposits of the Zonguldak Coal Basin, NW Turkey
Sun Y, Lai X, Wignall P, Ali J, Widdowson M, Jiang H, Bond D	Understanding the conodont biostratigraphy of Emeishan Large Igneous Province and its bearing on mid-Permian biocrisis
Sungatullina G	Stage boundaries of the Middle and Upper Carboniferous based on conodonts from the Volga Region
Tewari R	Gondwana Megaspores Of India - architectural radiation, distribution, evolutionary and biostratigraphic significance
Tian S, Chen ZQ, Zha M	High-frequency cyclicity recorded in the aftermath of the end-Permian mass extinction: case study of the Lower Triassic Yinkeng Formation, Meishan section, South China
Tohver E, Lanci L, Wilson A	Magnetostratigraphic and geochronological age constraints on the lowermost Beaufort Group, Karoo Basin
Wang Y, Shi Z, Zeng D, Yi H	Earliest Triassic anachronistic carbonates in NW Sichuan, China: implications for the turbulent evolution of the Earth system after the P–T mass extinction
Xu M, Zhou Y, Li S, Chen Y, Yan S, Zhou Z	Carboniferous-Permian boundary recorded in North China Block: An operational approach
Xu Y, et al	Early Permian hydrothermal cherts from North China and Yangtze Blocks, eastern Palaeo-Tethys
Zahirovic S, Müller D, Seton M, Golonka J	Global plate motion models and paleogeography of the Permian and Carboniferous
Zhang K, Kou X, Chen ZQ	A Middle Permian seamount from the Xiahe area, Gansu Province, northwestern China: Zircon U–Pb age, biostratigraphy and tectonic implications
Zhao L	Comparative mineralogy of volcanic influenced coal seams in the Songzao Coalfield, China and the Sydney Basin, Australia
Zhao L, Chen ZQ, Algeo T, Chen J	Seawater REE patterns preserved in conodonts document intensified chemical weathering and marine anoxia during the latest Permian mass extinction
Zheng R, et al.	Geological events and their geochemical responses at the Permian–Triassic boundary, Huaying Mountain, eastern Sichuan, SW China

Abstracts

Orals and Posters

Palynology and Palynofacies of the Carboniferous (Pennsylvanian)-Permian (Cisuralian) Al Khlata Formation from Central and South Oman

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The Al Khlata Formation comprises glaciogenic deposits associated with the Late Carboniferous-Early Permian Gondwana glaciation. A total of 116 core and side-wall samples were analysed for palynology and palynofacies from this interval penetrated in 3 petroleum wells in South Oman and 2 short boreholes drilled in the Al Khlata outcrop area. The majority of samples analysed yielded palynological assemblages. All the recovered palynomorphs are indicative of terrestrial origin and also very similar to those from other parts of Gondwana. Penney et al. (2008) zonal scheme has been applied here and 5 out of the 7 biozones are identified in this study.

The recovered assemblages are comparable with those identified in the South American Late Carboniferous-Early Permian palynostratigraphic system, particularly of Brazil (e.g. Souza, 2006), suggesting a Bashkirian-early Sakmarian age for the Al Khlata Formation.

Palynofacies analysis revealed possible relationships within its components. Amorphous organic material (AOM) is prominent in diamictites, whilst less so in heterolithic siltstones. Cuticle and woody debris are more abundant in the heterolithic unit and sandstones than in massive diamictites or non–stratified siltstones. Furthermore, palynomorph showed better preservation in the (proximally derived) laminated siltstones. AOM exhibited inverse abundance relationship to zonate/cavate spores and to Black Woody Materials. In addition, palynofacies analysis has also produced a better understanding of deposition environmental settings and displayed potential to predict certain palynomorph trends. For example, zonate/cavate spore decrease in abundance from proximal to distal, and from shallower to deeper settings. These palynofacies results are compatible with the Jäger (2004) and Jäger & McLean (2008) findings on the Late Carboniferous palynofacies of European sections.

Circulation in the Late Pennsylvanian Midcontinent Sea of North America

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The Late Pennsylvanian Midcontinent Sea (LPMS) of North America, which covered an area of ~2.1 x 10P6P kmP2P during glacioeustatic highstands, was a stratified watermass with anoxic and intermittently sulfidic deep waters. Two factors that commonly contribute to the development of deepwater anoxia, i.e., a shallow marginal sill to limit watermass renewal and elevated marine primary productivity rates to stimulate benthic oxygen demand, were absent in the LPMS. Rather, a key factor was lateral advection of suboxic, denitrified intermediate waters from the eastern tropical Panthalassic Ocean (ETPO) through a ~1000-km-long deepwater corridor in the Greater Permian Basin region. These denitrified waters were similar (strongly 15N-enriched, 13C-depleted) to those of the modern Pacific at the same latitude (5-12˚N), where the oxygen-minimum zone rises to <100 m. Sequence stratigraphic analysis demonstrates that the intensity of denitrification in the ETPO was greatest during the early phase of post-glacial transgression and waned prior to the onset of fully interglacial conditions, similar to patterns observed in Pleistocene sediments of recent upwelling systems in the tropical Pacific and Arabian Sea. At shorter (kyr) timescales, variation in the intensity of freshwater runoff into the semi-enclosed LPMS influenced the depth and strength of the pycnocline, resulting in variations in deepwater redox conditions and organic carbon and trace-metal accumulation rates. The LPMS may serve as a model for paleoceanographic analysis of large, semi-enclosed, periequatorial epicontinental seas for which there is no modern analog.

Enhanced continental weathering in the latest Permian to Early Triassic: Effects on shallow-marine biotas

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The end-Permian crisis was accompanied by an increase in continental weathering rates due to warmer temperatures, acid rainfall, and a shift toward rapid-growth disaster vegetation. These changes resulted in a surge of soil- and bedrock-derived dissolved nutrients and particulate material into shallow-marine ecosystems that persisted for at least a million years into the Early Triassic. This surge may have been a contributory factor to the end-Permian marine mass extinction as well as to the delayed recovery of Early Triassic marine ecosystems owing to the harmful effects of siltation and eutrophication. At the organismal level, elevated turbidity levels reduce feeding activity, osmoregulation, growth rate, body size, larval recruitment, development, and survival. High concentrations of dissolved nitrogen and phosphorus result in lower rates of skeletal calcification, lower rates of fertilization and larval survival, and decreased resistance to borers and disease among calcifying organisms. Increased primary productivity and formation of "marine snow" accelerate benthic oxygen depletion with adverse effects for metazoans. Related changes in substrate consistency favored organisms adapted to soft, unstable substrates, e.g., 'paper pectens' such as Claraia, and reduced ecological tiering. At the ecosystem level, increased sediment fluxes result in biodiversity loss and reduced ecosystem resilience, accompanied by a shift in community structure to high-abundance, low-diversity assemblages dominated by miniaturized epibenthic forms and infaunal deposit-feeding polychaetes. The harmful effects of detrital sedimentation on Early Triassic marine ecosystems were compounded by other debilitating factors, e.g., elevated temperatures, widespread oceanic anoxia, and hypercapnia.

The Early Triassic cesspool: Marine conditions following the end-Permian mass extinction

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Marine redox conditions varied greatly in time and space during the latest Permian-Early Triassic global crisis. Although models of a pervasively anoxic deep ocean have been proposed, reevaluation of oceanic sections suggests a modest shift toward mainly suboxic conditions on the deep seafloor accompanied by strong expansion of the oxygen-minimum zone at intermediate water depths. In contrast to the relatively stable redox conditions in the deep ocean, shallow-marine sites were subject to frequent shifts between oxic and euxinic conditions for at least a million years. Such fluctuations resulted from recurrent expansion of a shallow oxygen-minimum zone into the ocean-surface layer in response to several types of environmental perturbations. First, global climates warmed abruptly during this interval leading to lower dissolved oxygen levels in seawater and a reduced latitudinal temperature gradient that suppressed overturning circulation and deepwater formation. Second, enhanced continental weathering led to erosion of soil organic matter and higher nutrient fluxes, stimulating marine primary productivity and the sinking flux of organic matter. This combination of perturbations produced redox conditions that were toxic to marine metazoans, resulting in the greatest mass extinction event of the Phanerozoic. The oceanic cesspool developed during the Permian-Triassic boundary crisis may provide insights concerning the consequences for modern oceans of global warming and nutrient flux changes wrought by human activities.

Origination and early evolution of the Order Involutinida in the aftermath of the Permian mass extinction: evidence for adaptation to a new mode of life in Early Triassic seas?

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Following the descriptions of well-known genera, *Involutina*, *Trocholina* and *Triasina*, many studies were carried out in the second half of the 20th century on the taxonomy and evolution of the Order Involutinida. However, the phylogenetic position of the earliest involutinids remains poorly understood. Some authors proposed the genus *Permodiscus* from the family Archaediscidae in the Paleozoic as the ancestor of the Order Involutinida and even reported some taxonomical entities in the Triassic under the genus *Permodiscus*, classified today as *Aulotortus* or *Triadodiscus*. Alternative hypotheses place the root stock of the Order Involutinida within Pseudoammodiscidae, '*Glomospirella*'-like Miliolida or Permian genera *Multidiscus* and *Neohemigordius* from the family Hemigodiopsidae. However, none of these studies were able to demonstrate the pattern of morphological transitions leading to the Order Involutinida along a measured stratigraphic section. In this study, we describe a new population comprising one new genus and two new species as the root stock of involutinids from the Great Bank of Guizhou of the Nanpanjiang Basin of South China. Derived from a *Pseudoammodiscus* ancestor in the late Smithian during the second step of the foraminiferal recovery phase in the Early Triassic, this new population comprises a two-layered wall, inner microgranular and outer hyaline, fibrous and aragonitic, and a planispirally coiled lenticular test with one lamella for one complete whorl of the deuteroloculus. The genus *Triadodiscus*, which may represent the last common ancestor of the Order Involutinida, is most probably the direct descendant of this new population characterized by a two-layered wall. We hypothesize that the acquisition of a fibrous aragonitic layer in the wall of the root stock of the Order Involutinida reflects adaptation to a new mode of life in the Early Triassic seas. Foraminifers in the Order Involutinida attained large sizes and later dominated foraminiferan communities on shallow water carbonate platforms of the Tethys. Extinction of Superfamily Fusulinoidea at the end of the Permian likely eliminated most or all symbiot-bearing foraminiferan lineages. As anoxia and productivity waned during the second half of the Early Triassic, reestablishment of oligotrophic conditions may have provided new opportunies for symbiont-bearing foraminifers on the shallow sea floor. The acquisition of an outer hyaline wall may represent modification for better insolation of the interior of the test through more transparent shells.

Bashkirian-Moscovian boundary beds in southern Turkey: foraminiferal biostratigraphy and sequence stratigraphy

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Bashkirian-Moscovian boundary beds, made up of carbonate and mixed siliciclastic-carbonate lithologies, are widely exposed along the Tauride Belt in southern Turkey. Three overlapping sections spanning the Lower Bashkirian (Askynbashky) to Lower Moscovian (Solontsovsky) beds have been measured and collected on a bed-by-bed basis.

The Bashkirian portion of the sections has been divided into five zones: namely *Pseudostaffella praegorskyi-Profusulinella staffellaeformis* Zone (Askynbashky); *Pseudostaffella gorskyi-Eoschubertella obscura* Zone (lower Tashastinsky); *Ozawainella pararhomboidalis* Zone (upper Tashastinsky); *Pseudostaffella subquadrata-Profusulinella tashliensis* Zone (Asatausky); and *Profusulinella praeprisca* Zone (Asatausky). The lower Moscovian (Solontsovsky) is characterized by the *Profusulinella prisca-Aljutovella aljutovica* Zone.

The Bashkirian-Moscovian boundary is delineated by the first occurrence of *Profusulinella prisca*, one of the end members of the *P. staffellaeformis-P. paratimanica* lineage. This level also coincides with the first occurrence of *Aljutovella aljutovica*. The datum corresponding to the first occurrence of the genus *Eofusulina* is slightly higher than that of the zonal markers of the basal Moscovian.

Stacking patterns of upward-shoaling meter-scale cycles in the measured sections indicate the presence of two third-order sequences dated as Askynbashky to lowermost Asatausky and Asatausky to Solontsovsky. A prominent quartz arenitic sandstone intercalated within the Upper Bashkirian carbonate succession has been interpreted as a falling stage systems tract corresponding to stratal offlap during the culmination phase of the second glacial interval in the Carboniferous. Following the sea-level fall in the earliest Asatausky, a new carbonate regime was installed in the Asatausky-Solontsovsky interval by a glacio-eustatic sea-level rise. The Bashkirian-Moscovian boundary seems to be located within the transgressive systems tract of this new carbonate regime.

Mississippian reefs and mounds in Europe, North Africa and China

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The perception of Mississippian reefs and mounds has largely changed over the last two decades. The abundance of reefs and mounds during the Mississippian was lower compared to the Middle Palaeozoic peak, but they are spatially and temporally much more common than previously thought. Timing and duration of reef development and dimensions of the reefs varied considerably on a regional scale, but the global picture indicates reef development throughout the entire Mississippian period. Reefs and mounds have been found in very different shallow and deeper-water facies and different organisms and communities contributed to their formation. Although microbial communities often played a crucial role in the formation of the build-ups, the Mississippian mounds and reefs cannot be reduced to a post-disaster phase of mud-dominated buildups after the late Devonian extinction events.

The single reef and mound is directly bound to the local tectono-sedimentary history, but global governing factors as palaeoclimate and geodynamic evolution control the regional and global reef patterns.

Mississippian reefs and mounds are widely distributed in Europe from the upper Tournaisian onward. The deeper parts of ramp-dominated shelf systems are often occupied by mud-dominated buildups. This is not restricted to the Waulsortian Facies of the upper Tournaisian, but a more general phenomenon as evidenced by the late Viséan of Great Britain.

During Viséan times, very different bioconstructors formed reefs in various parts of the rimmed-shelf systems. The Belgian Dinantian gives a rare insight into reef formation in marginal marine settings and shows that microbial communities and microconchids dominated. On carbonate platforms, reef formation is often hampered by small-scaled sea-level oscillation, and reef dimensions stayed relatively low. However, when accommodation space was available, reefs could attain thicknesses of several hundred meters. This is especially true along the edges of late Viséan shelf systems in Europe, Northern Africa and Turkey, where a reef association comprising microbes, sponges, corals, and bryozoans became abundant. These reefs were often cannibalized during the collapse of the shelf systems (Variscan Orogeny), and today are only documented in olistoliths.

The reef record from southern China is surprisingly scarce. Newly discovered Upper Tournaisian mounds from the Guizhou Province are presented herein. These mounds have some similarities to buildups known from the late Frasnian and middle Famennian of Belgium.

The challenge of redefining the Devonian-Carboniferous boundary

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The Devonian and Carboniferous subcommissions established in 2008 a working group for the redefinition of the Devonian/Carboniferous boundary. This became necessary after revised conodont data in the GSSP section La Serre showed an earlier entry of the guide taxa Siphonodella sulcata just above a facies shift. These data revived the discussions not only on the suitability of the GSSP section, but also on the criterion itself. These points had already been the origin of lively discussion before and when the GSSP was selected in the late 1980s. Today, the situation has not fundamentally changed, but before discussing sections the criterion for the boundary has to be critically evaluated.

The morphological characteristics of the two species *S. praesulcata* and *S. sulcata* are still disputed and the univocal determination of specific morphotypes has not been achieved. Thus the use of this evolutionary lineage for the boundary definition creates more problems than it solves. Other conodonts have proven to suffer from similar problems or are rare or their stratigraphical entries are often delayed (e.g. protognathodids). Thus, conodonts may not be regarded as the primary tool for definition of the new boundary, when the aim is maintained to ensure stratigraphic stability and to keep the boundary near to the historical Gattendorfia criterion. The focus on conodonts in these stratigraphic levels results in few available data of other groups for high-resolution biostratigraphy, and thus the potential of groups like foraminifers may be underestimated today.

A potentially interesting alternative is the correlation of the Devonian/Carboniferous boundary with the Hangenberg event. This event could offer the possibility for correlation into very different facies and very different techniques and biostratigraphic markers can recognize it. However, the base of the black shale is very likely diachronuous because of its transgressive character, and thus the later sea-level drop or the maximum flooding surface might be the best levels for the boundary. However, the redefined boundary has to be on biostratigraphic grounds and thus further work is needed to place these two levels into a high-resolution biostratigraphy. Data from techniques like geochemistry and palaeomagnetism have to be integrated into the new definition in order to establish a check-list for the boundary, which should help to overcome shortcomings or problems in specific sections and facies.

Cyclicity in the Middle Viséan strata of Belgium

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The cyclic nature of latest Viséan (Brigantian) platform successions has been known for a long time, e.g. Yoredale cycles in North England. These cycles have been correlated with glaciation and deglaciation pulses during the buildup of a (first) major ice-sheet on Gondwana.

However, the succession of Livian (Middle Viséan) platform carbonates in the Namur-Dinant Basin shows a comparable marked cyclicity. The composite stratigraphic section (Lives Fm + Seilles Mb) shows the presence of at least 33 sedimentary sequences. These sequences are 1-20 m thick and two-folded. Bioclastic packstones and grainstones, representing marine subtidal environments, are topped by stromatolitic and peloidal boundstones and mudstone, representing intertidal and supratidal environments. In few cases sequences end with palaeosoils and bentonite levels can be intercalated into the succession. These sequences, interpreted as paraseqeunces, allow very detailed correlations between the different sedimentation areas. The abundance of intratidal and supratidal facies decreases significantly after the lower third of the succession. Overall retrogradational and aggradational stacking patterns dominate the Livian, but no clear general trend has so far been worked out.

The entire Livian substage is considered to correspond to a single third order sequence. The LST of this sequence is most likely not represented in the platform succession. The maximum flooding surface is found in the top of the Lives Fm, thus showing the position of the TST. The Seilles Mb is interpreted as HST and LSST. Spectral analyses of bathymetric curves indicate that the oscillations are products of glacio-eustatic sea-level oscillations, which are controlled by the four main Milankovitch cycles (413 ky, 112 ky, 34 ky, 21 ky).

Thus the Livian record of the Namur-Dinant Basin may indicate that the buildup of a Gondwanian ice-sheet took place earlier than currently acknowledged. It thus falls in line with recent publications on oxygen and carbon isotope records, which shift the onset of the Carboniferous-Permian Glaciation even further down.

Sequence stratigraphic interpretation of gamma-ray and magnetic susceptibility signals at the Tournaisan-Viséan boundary of southern Great Britain: a glacieustatic control?

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We studied the response of outcrop spectral gamma-ray (GRS) and magnetic susceptibility (MS) logs to carbonate facies stacking patterns across the regionally significant, early Carboniferous transgressive-regressive cycle in southern Great Britain. The aim was to trace correlatable log patterns in coeval carbonate ramp and basinal settings and discuss the driving controls of the GRS and MS signals. A robust ramp-to-basin correlation was produced based on GRS and MS data analysis, facies stacking patterns and foraminifer biostratigraphy. A prominent (forced?) regression, which can be correlated from shallow-water- to deep-water settings occurred just above the Tn-V boundary. Several T-R cycles of early Viséan age in the North Staffordshire Basin, which are correlated with a prolonged subaerial exposure in the South Wales carbonate ramp, support the idea of a major glacieustatic sea-level fall just above the Tn/V boundary proposed by previous authors. Thickness distribution of the correlated units suggest that the petrophysical signal is mainly related to updip and downdip shifts of the carbonate factory, which drives the dilution effect of fine-grained siliciclastics in $CaCO_3$. No significant changes in siliciclastic input were found during the peak regressions in contradiction to previous studies from elsewhere suggesting that the GRS and MS are related to the influx of siliciclastics from continents during peak regressions, especially in flat-topped carbonate shelves.

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Cyclic fill of the intracontinental Central European Basin in the latest Carboniferous, Permian and Triassic

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The intracontinental Central European Basin (CEB; also referred to as Southern Permian Basin) extends some 1500 km from England to Poland and came into existence after the Variscan orogeny when Pangaea was almost assembled. The up to 10 km thick basin fill comprises a complete global transgressive-regressive sea level cycle that lasted approximately 300 Ma from latest Carboniferous to recent times. The global cycle can be subdivided into at least nine major depositional cycles (DC 1–9) ranging from a few Ma up to 75 Ma.

DC 1 is characterised by intensive magmatism and minor redbed sedimentation (Lower Rotliegend; latest Carboniferous to Early Permian); DC 2 and 3 consist of fining-upward redbeds (Upper Rotliegend; Early to Middle Permian); DC 4 begins with fining-upward redbeds and contains, in its upper part, marine sediments grading into redbeds that comprise the continental PTB (Upper Rotliegend, Zechstein to Middle Buntsandstein; Late Permian to Early Triassic). Redbed sedimentation carries on in DC 5 whose middle part consists of marine carbonates that grade into overlying redbeds (Middle Buntsandstein, Muschelkalk to Middle Keuper; Early to Late Triassic). DC 6 starts with redbeds that give way to marine sediments comprising the TJB (Middle Keuper to Dogger; Late Triassic to Middle Jurassic).

Each of the DC 4 to 9 shows a transgressive phase, peak transgression and a regressive phase. The sediments of the early transgressive phase, overlying a basal unconformity, are of post-rift character and in most cases show relatively low subsidence rates and facies variations. Peak transgressions are represented by deep marine environments that are occasionally characterised by euxinic sedimentation. The regressive phases mostly coincide with the most intense tectonic activities (rifting, inversion) and exhibit relatively high subsidence rates and facies variations. The regressive phase of each DC is terminated by a major erosional unconformity that, in turn, is the basal unconformity of the succeeding DC. Halotectonic pulses, triggers of late Permian Zechstein salt diapirs, commonly coincide with the rifting phases. Instead of sea level changes, the cycles can also be described in terms of rising and falling base levels, which seems especially appropriate for the continental DC 2 and DC 3.

Carboniferous, Permian and Triassic in Central Europe: Results from the new Petroleum Geological Atlas of the Southern Permian Basin

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The new Southern Permian Basin Atlas (SPBA) presents a comprehensive overview of over 150 years of petroleum exploration and research – the joint effort of 6 National Geological Surveys, 28 industrial sponsors and 144 authors. The intracontinental SPB is also referred to as the Central European Basin and is a major producer of hydrocarbons. The atlas describes in detail the geologic evolution and hydrocarbon potential of the individual stratigraphic units and is illustrated with numerous depth and isopach maps, tectonostratigraphic correlation charts, log correlation panels and hydrocarbon field examples.

The SPB extends some 1500 km from England to Poland and came into existence in latest Carboniferous times after the Variscan orogeny. Its total fill is up to 10 km in the Northwest German and Polish depocentres. Most of the basin proper is underlain by Early Carboniferous limestones as well as flyschoid deposits followed by the thick Late Carboniferous coal measures of the Variscan foredeep. The latter provide important source rocks for natural gas, some of which may be reservoired in the intervening sandstones. Intracontinental basin evolution started in the latest Carboniferous to Early Permian on the former foredeep with widespread, mostly acidic, magmatism due to strike-slip faulting and crustal thinning (Lower Rotliegend). The Middle and Late Permian are characterized by playa sedimentation with thick redbeds (Middle, Upper Rotliegend) and, finally, marine carbonates and thick evaporites (Zechstein) providing reservoirs and seals for natural gas as well as sulphide ores and potash deposits (e. g. Kupferschiefer and Stassfurt seam, respectively). Lower Triassic redbed sandstones (Buntsandstein) also provide reservoirs for natural gas. Only a few of the Middle and Late Triassic marine carbonates and continental redbeds accumulate hydrocarbons, namely the Rhaetian sandstones.

SPBA: DOORNENBAL, H. & STEVENSON, A., eds. (2010): Petroleum Geological Atlas of the Southern Permian Basin Area.– 342 pp.; The Netherlands.

A review of the Late Carboniferous and Permian palynology of the northern Canning Basin, Western Australia

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The Upper Carboniferous – lower Permian succession of the Canning Basin is up to 2800 m thick and is dominated by sandstone facies of the Reeves Formation and Grant Group – best developed in the Fraser River-1 and Grant Range-1 wells. At the base is an interval with *Spelaeotriletes ybertii*, but without saccate pollen. Slightly higher, the base of the *S. ybertii* Assemblage is marked by the first appearance of saccate pollen. Above the *S. ybertii* Assemblage is a thin interval with a distinctive form of *Cristatisporites* that corresponds to the *Diatomozonotriletes birkheadensis* Assemblage. Above the *D. birkheadensis* Assemblage a change to lower diversity palynological assemblages probably corresponds to a sequence break. In both Fraser River-1 and Grant Range-1, *Microbaculispora tentula* appears as a regular component of assemblages and is the eponymous species for the zone. The first appearance of *Pseudoreticulatispora confluens* at shallower depths defines the base of the overlying *P. confluens* Zone.

The remainder of the Permian succession consists of 1200 m of siliciclastic facies that extend to the Triassic, the palynozonation of which is best represented in Blackstone-1 and Puratte-1. In both wells the *P. confluens* Zone covers a thick interval and is succeeded by a shale interval containing the *Pseudoreticulatispora pseudoreticulata* Zone. The succeeding *Striatopodocarpidites fusus* and *Microbaculispora trisina* zones cover relatively thin intervals and are followed by the *Praecolpatites sinuosus* Zone, which extends for several hundred metres through most of the Noonkanbah Formation. The overlying *Microbaculispora villosa*, *Dulhuntyispora granulosa* and *Didecitriletes ericianus* zones are condensed by comparison with basins further south and are succeeded by thicker intervals of *Dulhuntyispora parvithola* Zone. Puratte-1 has a very thin interval of *Protohaploxypinus microcorpus* Zone.

Correlation of the WA palynozonation with international stages is via associated macrofauna, and given the lack of macrofauna from the subsurface and the rarity of palynomorphs from most outcrops is highly dependent on consistent stratigraphic designations. In effect there is a degree of uncertainty in age determinations for much of the Upper Carboniferous–Permian succession.

Buday'ah (Oman) and Arrow Rock (New-Zealand): from a similar to a divergent evolution of Permian-Triassic oceanic successions.

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The Oman Mountains expose the middle Permian to lower Triassic Buday'ah section of oceanic sediments close to the Tethyan Gondwana margin. The tectonically truncated Permian litho-units start with a basal volcanic sequence composed of pillow basalt showing transitional and enriched MORB signatures (Maury et al., 2003: Lapierre et al., 2004). In different parts of the pillow lava succession, inter-pillow cavities are filled up with red lime-mudstone with rare middle Permian ammonoids, and lenses up to 1.2 m thick red ammonoid-limestone cover the irregular upper surface of the pillows. A *Clarkina* conodont fauna of latest Capitanian age occurs near the top of the limestones (C. Henderson and A. Nicora *in* Baud & Bernecker, ed., 2010 and *in* Baud et al., submitted). The following red radiolarian chert spans the latest Capitanian to Wuchiapingian age with the radiolarian assemblage *Follicucullus ventricosus – F. scholasticus* (F. Cordey *in* Baud & Bernecker, ed., 2010, and *in* Baud et al., submitted).

Described by Spörli et al. (2006, 2007) and by Takemura et al. (2007), a similar Permian chert-dominated ocean floor sequence, but accreted from Panthalassa, occurs at Arrow Rocks, Northland, New Zealand. Latest Capitanian to Wuchiapingian red radiolarian cherts overlies middle Permian red limestone lenses in basaltic rocks with the same radiolarian assemblage in the lower part. The Changhsingan succession consists of dark grey siliceous mudstone in Buday'ah and bedded siliceous mudstone and chert in Arrow Rocks. The main change between the two oceanic sections occurs in the Late Changhsingian: Arrow Rocks sedimentation grades again to pale green bedded cherts in late Changhsingian whereas Buday'ah displays calcareous clay mudstone across the Permian-Triassic boundary. Reported from Arrow Rocks there is a thin Permian/Triassic boundary interval consisting of alternating black siliceous shale and grey chert (Spörli et al., 2006) and above the basal Triassic (Induan) succession consists of red cherts and siliceous mudstone. No more chert nor siliceous mudstone are present in Buday'ah but Induan platy lime mudstone and calcareous shales with calcispheres (casts of radiolarians?) followed by Olenekian papery lime mudstones, thus showing a highly divergent evolution.

The difference could be explained by differential plate tectonic displacement. Arrow Rocks sequence moved over a long distance from a relatively low latitude position in the Middle Permian to a high latitude one in mid-Triassic times (Spörli et al., 2007). Meanwhile Buday'ah's succession on the Gondwana margin was displaced towards a lower latitude position from Middle Permian to Triassic. Consequently, these oceanic successions differences from the late Changhsingian onward may be related to the divergent geodynamic evolution.

A review of the genus *Lycospora*

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Lycospora is the most abundant and most frequently reported Palaeozoic miospore genus. However, based upon SEM and LM (including Nomarski illumination) studies of dispersed and in situ lycospores a subdivision of the genus *Lycospora* is proposed. Seventy-one in situ records of lycospores have been compared and these data indicate that only twenty-nine dispersed species should validly be termed lycospores. The study suggests three new synonymies and reports sixty-three species that should be removed from the genus *Lycospora.* Six morphological groups of lycospores are proposed; the *Lycospora granulata* Group, the *Lycospora micropapillata* Group, the *Lycospora brevijuga* Group, the *Lycospora pellucida* Group, the *Lycospora uber* Group and the *Lycospora subtriquetra* Group. Each group is named for the first published dispersed species it contains and includes a list of the holotypes of dispersed and in situ lycospores that comprise it, as well as measurements of these species. The assignment of species to groups was based upon the spore morphology and diameter, the stratigraphic occurrence of the holotype and the geographic distribution of the species. As characterized by their holotypes, the cingulate forms are reported in strata of Viséan to Bolsovian age, while the cingulizonate forms are known from the Viséan to the Stephanian. Spores of this type have been reported in association with female cones assigned to *Lepidocarpon* and *Achlamydocarpon* and from male cones assigned to *Lepidostrobus*. Cones assigned to these genera are known to have been produced by *Lepidophloios* (*Lepidocarpon*) and *Lepidodendron* (*Achlamydocarpon*). Bisporangiate cones assigned to *Flemingites* are known to have been borne by *Paralycopodites*. These cones have been reported to contain microspores assignable to the *Lycospora granulata* Group and megaspores assignable to *Lagenoisporites* or *Lagenicula*. As this indicates, morphologically different megaspores can be produced by flemingitalean cones and are assigned to two distinct genera. However, the microspores borne in the same cone together with these generically distinct megaspores are not assigned to different genera, but rather are retained within one genus, *Lycospora.* Microspores assigned to *Lycospora*, whether produced by monosporangiate or bisporangiate cones, fertilized megaspores assignable to at least three discrete genera (*Lagenicula, Lagenoisporites*, and *Cystosporites*, most notably *C. giganteus*).

Impact of the end-Permian mass extinction on land

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There is wide debate about the nature and timing of the recovery of life after the devastating end-Permian mass extinction. Understanding these points is crucial as this time represents the best test of how life responds to near-complete annihilation, and so feeds into current understanding of macroevolution, biodiversity, and conservation biology. In the sea, some complex organisms such as ammonites recovered within 1-2 Myr, whereas other components of the ecosystem, such as sessile reef-builders, did not re-emerge for 8-12 Myr. There are similar discrepancies with terrestrial faunas, some regional studies showing that ecosystem diversity had recovered within 1 Myr of the crisis, others suggesting that ecosystems did not stabilize for 10-15 Myr. In terms of pattern, ecological analysis shows poor evenness in earliest Triassic faunas, even if species numbers seemed to have recovered, and so these were apparently unstable *disaster* biotas. Determining when an ancient ecosystem was stable is harder, however – is it when evenness values have returned to pre-extinction patterns, when turnover (balance of species origination and extinction) shows pre-extinction volatility, or when food webs or trophic pyramids have acquired their classic Mesozoic form? One problem is that some top predators in Triassic seas, such as medium- to large-sized marine reptiles, did not *recover*, but appeared as entirely new components of the ecosystem. New data from China and Russia begin to shed some light on these questions.

Permian biogeography of Boreal bivalves

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Boreal bivalve specific characteristics include low endemism (there is only one endemic subfamily – Kolymiinae), complete absence of many pectinids (pterinopectinids, posidoniids, entoliids, annuliconchids etc.), alatoconchids, isognomonids, carditids, lucinids, some genera widely spread in the Tethyan basins (*Goniophora, Cassianella, Costatoria* etc.). In the Boreal climatic zone, two high-rank biochores are determined, corresponding to its western and eastern parts, which named the **Western Boreal** and **Eastern Boreal Realms**.

The **Western Boreal Realm** includes England, Baltic countries, Poland, north of the Russian Platform, Pechora Basin, Volga Basin, Greenland, and Canadian Arctic Archipelago. This realm is primarily distinguished with the wide development of pteriaceas (*Bakevellia*), myalinids (*Myalina, Pseudomyalina, Liebea*), mytilids, *Pseudomonotis*, *Cyrtorostra*, *Netschajewia*. At some locations (Greenland, Spitsbergen, Pechora Basin), rare *Inoceramus*-like bivalves (*Evenia*, *Maitaia*, *Costatoaphanaia*, *Aphanaia* etc.) are noted. The Pechora Basin, especially the Pai-Khoy, where *Inoceramus*-like bivalves occur more frequently, should probably be considered with other biochores of the eastern part of the Boreal zone as an independent province. Upper Permian bivalve assemblages of Spitsbergen are characterized by the quite peculiar endemic fauna with prevailing pectinids. It contains almost no characteristic elements of Western Boreal basins (except for individual representatives of the genus *Liebea*).

The **Eastern Boreal Realm** is primarily characterized by the presence of the endemic subfamily of *Inoceramus*-like bivalves – Kolymiinae. Representatives of another subfamily, Atomodesmatinae, including the realm-endemic genera *Intomodesma, Costatoaphanaia*, and *Okhotodesma* are also widely spread. Almost throughout the whole Permian, the Kolyma-Omolon and Verkhoyan-Okhotsk Provinces are clearly separated. The **Kolyma-Omolon Province** is characterized by such endemic genera as *Omolonopecten, Biarmopecten*, as well as a large number (totally about 80) of endemic species, mainly genera *Aphanaia*, *Kolymia*, *"Heteropecten"*, *Schizodus*, *Pyramus*, *Myonia* etc. The **Verkhoyan-Okhotsk Province** is characterized by three endemic genera (*Verchojanogramyssia*, *Cyrtokolymia*, *Okhotodesma*) and about 90 endemic species. The **Mongol-Transbaikal Province** is quite clearly distinguished, characterized by some Tethyan (*Leptodesma*), western-Boreal forms (*Cyrtorostra* and *Liebea*), and clear species endemism, traced on various stages of the geological history. The **Novaya Zemlya Province** is characterized, especially in the Middle and Late Permian) by some genera common with the Verkhoyan-Kolyma basins (*Kolymia*, *Maitaia, Vnigripecten, Intomodesma*, etc.). Simultaneously, significant endemism and the presence of some Western Boreal elements (*Liebea, Cyrtorostra, Pseudomonotis, Netschajewia* genera) are typical. The **Taimyr Province** communities are significantly similar to the Verkhoyan-Okhotsk ones. However, it is distinguished by essential scarcity on the background of widely spread *Streblopteria*, *Myonia* dominating Kolymiidae; here are also Western Boreal *Liebea.* The **Yukon Province** is characterized by the presence of some taxa (*"Streblochondria"* ex gr. *ufaensis*, *Vnigripecten* sp., and others) common with Verkhoyan-Omolon communities.

The middle Permian of northeast Asia: Blossom and decline

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Throughout Northeast Asia, the beginning of the Middle Permian (the early Roadian) was marked by a significant rise (2–2.5 times) in biotic diversity of all fauna groups. The main groups of biota (smaller foraminifers, brachiopods, bivalves, and ammonoids) were flourishing at that time. This biologic diversity was mainly due to the major transgression event beginning at that time and the suggested climatic warming. The intense processes of carbonate sedimentation took place in some basins of the Kolyma-Omolon region.

The early Wordian was characterized by a decrease in taxonomic diversity and biota stagnation. Biogenic carbonate rocks have high $\delta^{13}C$ values (up to +5.9‰). The second half of the Wordian was characterized by almost a two times increase in the taxonomic diversity in all fauna groups. This event is assumed to have been due to a small transgression and some climatic warming, in association with high $\delta^{13}C$ values (+5.7‰) of biogenic carbonates. Intense carbonate sedimentation continued within some sedimentary basins of the Kolyma-Omolon region. Basalt volcanism manifested itself within the Ayan-Yuryakh, Balygychan and Okhotsk basins. The Kiaman reversal took place at that time or slightly before it. The early Capitanian was signified by a large extinction event. Many forms, which had dominated the Middle Permian assemblages, became extinct including the high endemics of the Kolymiidae subfamily in the West Boreal Realm. The biotic diversity of main biota groups became in general 1.5–2.5 times lower than it was before the crisis. This event was everywhere associated with drastic changes in sedimentation. The formation of carbonates ceased. Different gravitites became wide-spread, and their formation could have been related to fast repeated sea level fluctuations. Fauna was migrating in different directions. A negative excurse of $\delta^{13}C$ values of biogenic carbonates is reported (up to +0.8-1.1‰).
Through almost the entire Capitanian, all biota groups had a low taxonomic diversity. The Capitanian-Wuchiapingian boundary is marked by an intensified activity of the Okhotsk-Taigonos volcanic arc. This supposition is supported by the U-Pb SHRIMP data obtained for the volcanic diamictite matrix, regression, and anoxic environments.

The Permian of northeast Asia: Modern state and main problems

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The Permian of Northeast Asia has been studied for more than 80 years, and these studies have become much more intensified in the past two decades. Since then, many crucial results have been obtained on different aspects of stratigraphy, biostratigraphy, sedimentology, isotopic geochemistry, paleogeography, and biogeography. These results are as follows:

1. The main Permian sedimentary basins are identified by their geodynamic settings. Sedimentation models have been elaborated for some basins.
2. The structural-facial zonation for the territory of Northeast Asia has been prepared; new regional stratigraphic schemes are developed for Verkhoyansk-Okhotsk and Kolyma-Omolon-Chukotka regions. The biostratigraphic schemes are presented, based on brachiopods, bivalves, smaller foraminifers, and ammonoids.
3. The taxonomic diversity dynamics of main biotic groups is examined and major biospheric events are established. Many events, such as the mass extinction events, are traced far beyond Northeast Asia and can be used for world-wide correlations.
4. The paleogeographic distribution of bivalves of the Boreal Super Realm has been studied and characterized, and the differences from the Gondwanan and Tethys Super Realms are determined.
5. A unified, regional curve of carbon isotopes from biogenic carbonates has been compiled in elementary fashion, and a number of isotopic events are established. The new absolute values of sea temperatures are obtained for some intervals of the Permian sequences. A high-precision U-Pb SHRIMP dating of zircons has been started.

Despite certain research progress, many problems still remain the subject of discussion, and among them the most important ones are as follows:

1. The definition of the lower boundary of the Permian and the problem of the Asselian Stage.
2. The correlation with international stage boundaries. At present, only the lower boundary of the Roadian Stage is reliably established.
3. The formation of biogenic limestones in the Omolon Massif and in some other basins including the Omulevka, Prikolyma, and Wrangel.
4. The bipolarity of the Permian faunas throughout Northeast Asia and Gondwana.

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Reflection of Milankovitch cycles in the petrophysical characteristics of Permian sedimentary deposits of Volga region

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It is recognized that climate changes have a periodicity similar to the changes of the Earth astronomical parameters. These periods were traced from the modern to the late Triassic and valued at 25 ka, 44 ka, 100 ka, 133 ka, and 400 ka years, respectively. The shortest cycles may be related to the period of precession of the rotation axis – 25 ka. In the past 100 years, stratigraphers have recognized many rhythms of various orders from the Upper Permian of the Volga region. Here, all stratigraphic units of the Permian were established based on rhythmic packages, lithology and other rock physical parameters.

Informative parameters are natural radioactivity which assesses their clay (it generally correlates with the depth of terrigenous sedimentation pool) and magnetic susceptibility that reflects the type and origin of magnetic material in the rocks. High values of magnetic susceptibility of sandstone show material deposited directly from the fracture zones of igneous rocks (Urals) and low values indicate re-sedimentation of the local coarse-grained material or bring it out of the internal part of platform. High values of magnetic susceptibility of shale can be attributed to fine grains of magnetite and maghemite from destruction zones of igneous rocks and soil horizons. Increased susceptibility of clays indicates extensive development of soil-forming processes and favorable climatic conditions. Observations of continental Permian-Triassic sections indicate that a stable accumulation of sediment is often seen on clay incision site with a maximum cardinality no more than 5-15 m. In temporal terms this amounts to no more than 10-20 thousand years (rate of strata accumulation is about 1 mm/year). Changes in lithological parameters, natural radioactivity and magnetic susceptibility in sections of the Kazanian and Tatarian sequences permit recognition of the 8-16 m, 20-25 m, and 50-80 m thick cycles. Value and nature of cycle periods allows construction of a simple mathematical model of sedimentation. Stochastic model has a fractal form, the presence of breaks and erosion leads to fractional dimension of the time axis, which allows to predict the average speed for various integral foliation intervals of power cut. Reconstructing the history of sedimentation can't be made for a particular section because of undefiniteness paleogeographic environments and phase fluctuations of astronomical parameters.

Fractal model of sedimentation and erosion, taking into account breaks, allows to conclude that the observed periods of rhythmic sedimentary strata of the Volga region correspond to Milankovitch cycles of about 25000 years (8-12 m) - 44000 years (10-16 m), 100000 years (20-25 m), 400000 years (50-80 m). The total absolute length of the studied period is 10 million years.

Research on Permo-Carboniferous *Odonatoptera* during the last 30 years

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Though extremely rare giant Permo-Carboniferous Odonatoptera are among the most famous fossils. In particular *Meganeuropsis* Carpenter, 1939 (Early Permian, USA) and *Meganeura* Brongniart, 1885 (Late Carboniferous: Late Pennsylvanian, Central France) reach a wing-span of about 70 cm. After a long time of scientific stagnation, the interest strongly increased again during the last 30 years when some new Late Carboniferous species have been discovered in Germany: *Stephanotypus schneideri* Zessin, 1983 (Stephanian C) and *Erasipterella piesbergensis* Brauckmann, 1983 (Westphalian D) as well as *Zessinella siope* Brauckmann, 1988, *Erasipteroides valentini* (Brauckmann, 1985), and *Namurotypus sippeli* Brauckmann and Zessin, 1989 (Namurian B: Marsdenian; Hagen-Vorhalle) which represents the hitherto most ancient and best known Palaeozoic Odonatoptera. Since then, several new taxa have been reported from different regions of the world as shown in the following selection: (i) Among the most ancient are *Shenzhousia qilianshanensis* Zhang et al., 2006 and *Sinomeganeura huangheensis* Ren et al., 2008 from the recently discovered collecting area in Qiliangshan, Ningxia Hui Autonomous Region in northern China (Namurian C/D) as well as *Eugeropteron lunatum* Riek, 1984 and *Geropteron arcuatum* Riek, 1984 from ?Namurian C strata in NW Argentina. (ii) The Piesberg site near Osnabrück (Westphalian D) has yielded five new species of which *Piesbergtupus hielscheri* Zessin, 2006 is already published whereas the other specimens are currently under study by the present authors. (iii) *Bohemiatupus elegans* Prokop and Nel, 2010 (Late Carboniferous) was discovered in western Bohemia, Czech Republic. (iv) Several new species have been recently reported from Late Carboniferous and Permian deposits in France. (v) The famous classical Mazon Creek sites (Illinois; Westfalian C/D) delivered three nymphs and a wing fragment of a new meganisopteran family (Aulertupidae Zessin and Brauckmann, 2010). In particular, the nymphal wing structure are important for detailed studies on the relationships of early Odonatoptera and Ephemeroptera.
The new material also included new specimens of previously described species have been reported, for example from the Early Permian of Kansas and. Zessin (2008a) provided an actualized compilation of the Permocarboniferous Odonatoptera. The same author (Zessin 2008b) also generally discussed different biological aspects of this group wheras Nel at al. (2009) revised parts of the classical collections of Meganisoptera from Central France.

In addition to the famous giant dragonflies also smaller species are now described from the Permo-Carboniferous, such as *Zessinella siope* (wing-span = 5 cm) and *Bechlyia ericrobinsoni* Jarzembowski and Nel, 2002 (wing-span = less than 5 cm). The latter also shows certain characters of Protozygoptera and thus indicates that "modern" Odonata already originate in the Late Carboniferous (Pennsylvanian).

Biostratigraphic/Stratigraphic framework for the Carboniferous Kashagan Field, North Caspian Basin, Kazakhstan

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The Kashagan Field, which contains substantial petroleum reserves in upper Visean-Bashkirian rocks, is one of a number of isolated carbonate buildups deposited on the Primorsk Arch from the Late Devonian into the Early Pennsylvanian. A biostratigraphic framework utilizing calcareous microfossils (foraminifers, algae, *incertae sedis*) was developed from the extensive coring program that included a deep Devonian penetration and several appropriately spaced penetrations of shallower intervals. As is customary for the North Caspian region, substage correlations are expressed, where practicable, in the terminology of the unified Russian Platform horizon scheme. The stratal architecture of the buildup includes a transgressive, backstepping phase from the late Famennian into the late Visean followed by highstand progradation in the latest Visean and Serpukhovian. During highstand deposition the bank developed distinctive platform and slope facies. The former is composed of cyclic, shallow-water, ooid, intraclastic, and bioclastic packstones and grainstones, whereas the upper slope contains microbial boundstones that display vertical and lateral variations in a variety of skeletal components. Middle to lower slope and basinal facies are unknown due to a lack of core coverage. Critical horizon indicators are scarce in the late Visean-early Serpukhovian platform facies; therefore, a local microfossil zonation was substituted for the traditional horizon scheme, providing a more reliable correlation tool across the field for that time period. Following highstand progradation, sea-level drop around the Mississippian-Pennsylvanian boundary subaerially exposed the buildup, leaving little or no record of late Serpukhovian deposition on the platform but an increasingly complete late Serpukhovian section across the slope. Deposition resumed in the early Bashkirian with accumulation of predominantly shallow-water platform sediments similar to those found in the Visean and Serpukhovian, and continued into the late Bashkirian. Emergence in the Pennsylvanian ended carbonate production and left an eroded Bashkirian surface across the top of the buildup that was eventually covered by fine-grained siliciclastics and muddy carbonates during the later Pennsylvanian and Early Permian. In both microfossil succession and stratigraphic development Kashagan closely mimics Tengiz, its sister field located at the eastern end of the Primorsk Arch.

Rhynchonellid and spiriferid brachiopods as valuable tools for correlation of shelly faunas near the Devonian/Carboniferous boundary

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From the brachiopod viewpoint, the Latest Famennian (Strunian) is marked by radiations among rhynchonellids and spiriferids, which developed morphological characters heralding the early Carboniferous faunas. However, both orders suffered dramatic losses during the Hangenberg event, which occurred just below the Devonian/Carboniferous (D/C) boundary, and recorded a significant post-event recovery during the Tournaisian as was the case for the productids.

Due to their short stratigraphical range and their extensive geographical distribution, rhynchonellids and spiriferids are very useful to recognize the D/C boundary in the absence of conodonts and/or ammonoids in neritic facies.

Typically Late Famennian in age, several rhynchonellid taxa did not cross the D/C boundary such as the rhynchoporid *Araratella*, the trigonirhynchiids *Centrorhynchus* and *Paurogastroderhynchus*, the petsmariid *Megalopterorhynchus*, and the rozmanariids *Hadyrhyncha*, *Novaplatirostrum*, *Pugnaria*, *Rozmanaria* and *Tetragonorhynchus*. Cyrtospiriferids such as *Cyrtospirifer*, *Dichospirifer* and *Sphenospira* became extinct at the end of the Strunian.

The base of the Tournaisian recorded the first occurrences of several genera among the rhynchonellids such as *Allorhynchus* (Allorhynchidae), *Hemiplethorhynchus* (Trigonirhynchiidae), and *Shumardella* (Petasmariidae) concomitantly with the first apparitions of the spiriferids *Eomartiniopsis* (Martiniidae) and *Kitakamithyris* (Elythidae).

The D/C boundary can also be recognized on the basis of species belonging to genera which appeared in the Late Famennian and which crossed it. This is especially the case of the representatives of the rhynchonellid genera *Macropotamorhynchus* (Trigonirhynchiidae), *Rhynchopora* (Rhynchoporidae), and *Sedenticellula* (Stenoscismatidae). Among the Spiriferida, it is mainly the case of those of the family Spiriferidae (e.g. *Parallelora*, *Prospira*).

These data need to be complemented by those provided by productids known around the D/C boundary. Moreover, further work is required to reach a better assessment of the consequences of the Hangenberg event on brachiopods.

Sedimentology and geochemistry of the Permo-Triassic boundary section at Guryul ravine, Kashmir, India; and a comparison with the Texas Cretaceous-Tertiary boundary section

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The Permo-Triassic boundary at Guryul Ravine, Kashmir, as defined by the first appearance of *H. parvus*, is at +3.2 metres above the base of the Khunamuh Formation, a predominantly dark grey argillite unit with sporadic thin limestones, which rest on late Permian sandy limestones of the Zewan Formation. In the basal 3 metres of the Khunamuh Formation, several bioclastic limestones occur. The first two, within the lowermost 1 metre are coarse shell beds with hummocky cross-stratifications suggesting deposition from interference waves. Such deposits are often attributed to storm waves, though such waves are also generated by tsunami. Given the average grainsize of the bioclastic beds (coarse sand to granules), the waves forming the beds would need to range from amplitudes of 1 metre at 10 metres depth to 3 metres at 100 metres depth for long period waves of 1000 sec (typical of tsunami), to amplitudes of about 1 metre at 10 metres to 4 to 40 metres at 100 metres depth for short period waves of 25 to 10 seconds (more typical of storm waves). The background clay sediment suggests a deeper shelf environment closer to 100 than to 1 metres depth, and thus open ocean waves above 4 metres amplitude for both storms and tsunami (though most open ocean storm waves are at the 10 sec period end giving amplitudes of +40 metres). In the overlying 2 metres of the Khunamuh Formation, thin graded bioclastic beds may also have been deposited from such waning waves. The faunas in the basal 3 metres show no systematic taxonomic changes: and earliest Triassic faunas only appear with *H. parvus* at +3.2 metres. Major and trace element analysis shows no systematic changes in this basal 3.2 metres, though extreme fluctuations begin around +5 metres. Though framboidal pyrite indicates anoxia at +1metre, Th/U ratios remain high above 3 (the dysoxic/oxic transition) until +9 metres and Molybdenum isotopes suggest anoxic conditions began at +4 metres. The basal few metres of the Khunamuh Formation may thus have been deposited rapidly from successive storm or tsunami waves. This basal Khunamuh section closely resembles the Cretaceous-Tertiary boundary section in Texas, and may have been deposited in the same way from waning tsunami. However, preliminary Platinum Group Element (PGE) analysis of the Khunamuh section indicates terrestrial rather than extraterrestrial PGE values and ratios and thus a non-impact cause of any tsunami. Expanded sections, like Guryul ravine, need to be studied in detail to separate specific end Permian events which is not possible in more condensed sections like Meishan.

Carboniferous- Permian palaeobiological feature of Badain Jaran region and its tectonic implications

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The studied area, Badain Jaran, is the joint area of Kazakhstan, Tarim, North China and Siberia plates. The Lower Carboniferous is overlying the Middle or Upper Devonian by an angular unconformity in this area, indicating Kazakhstan, Tarim, North China and Siberia plates collided together to form a joint continent, and the Palaeo-Asian Ocean disappeared since the Middle-Late Devonian in the Badain Jaran area. Subsequently, the joint continent experienced an extensional stage and the rifted Badain Jaran basin developed in the studied area, with three evolutional stages. During the Early Carboniferous, tetracorals (assigned to *Yuanophyllum* and *Thysanophylloides* assemblages) and brachiopods *Gigantoproductus* elements are abundantly recorded in the Baishan Formation. The fauna is similar to the contemporary fauna of South China, typical of Tethys-Type. During the Late Carboniferous- earliest Permian, abundant corals (such as *Caninophyllum shuangjingziense* etc.) and fusulinids (assigned to *Triticites* and *Pseudoschwagerina* assemblages) are recorded in the Amushan Formation. The fauna is similar to the contemporary fauna of South China, typical of Tethys-Type. During the late Early Permian- Middle Permian, abundant brachiopods, assigned to S*piriferella* - *Kochiproductus* – *Yakovlevia* assemblage, are recorded in the Maihanhada and Shuangbaotang formations. The fauna is typical of a mixed Boreal-Tethyan fauna. Based on the analyses that the Palaeo-Asian Ocean had disappeared since the Middle- Late Devonian in Badain Jaran region and the conclusion that the fauna changed from a Tethys-Type of the Early Carboniferous- earliest Permian into a mixed type of Boreal-Tethyan provinces of the late Early Permian- Middle Permian, we propose that the presence of the mixed Boreal-Tethyan fauna in the studied area was a result that the joint plate converged by Kazakhstan, Tarim, North China and Siberia plates, drifted northward to a middle palaeolatitudinal position during the late Early Permian- Middle Permian.

The Cisuralian (Early Permian) carbon-isotopic perturbations and its palaeoclimatic implications in the southern Urals, Russia

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The Carboniferous-Permian ice sheets have been, recently, well documented to be the largest glaciations prevailed in the southern and peri-Gondwanan continents, and consisted of multiple episodes of glaciations. In order to investigate its coevally carbon-isotopic responses in the northern hemisphere, bulk carbonates have been analyzed for the carbon isotope excursions ($\delta^{13}C_{carb}$) in three marine sections from the Carboniferous/Permian boundary to middle Artinskian strata in the South Urals. A gradually $\delta^{13}C_{carb}$ increasing trend has been observed in the interval from the base of Asselian to early Sakmarian in the Usolka section, which is generally consistent in timing with the increasing development of Glacial III or P1 from the latest Carboniferous to early Sakmarian (Early Permian) prevailed in southern Gondwana. A double-negative $\delta^{13}C_{carb}$ shift occurred around the Asselian/Sakmarian boundary in both the Usolka and Kondurovsky sections, which may have great potential to serve as a chemostratigraphical marker for intercontinental correlation. The following highly positive excursion of $\delta^{13}C_{carb}$ in early Sakmarian indicates the maximum expansion of Glacial III or P1. The strong $\delta^{13}C_{carb}$ perturbations in the middle Sakmarian strata of Kondurovsky section are possibly related to the glacial fluctuations of Glacial P2 in Gondwanaland. These strong perturbations are largely correlative with those documented previously in other areas of Russia, the North American Craton and South China. The late Sakmarian $\delta^{13}C_{carb}$ excursion is characterized by a sharp drop with very negative values around -12‰, which steadily is extended into the Artinskian period in the Dal'ny Tulkas section. We suggest that the deeply depleted $\delta^{13}C_{carb}$ values in the Artinskian strata of Dal'ny Tulkas section might result from the regionally enhanced input of organic carbon after the melt-out of ice sheets of Glacial P2 and the subsequent degradation and isotopic re-fractionation of the microbial chemosynthetic processes on the buried organic matter. If so, this sharp $\delta^{13}C_{carb}$ drop and its following long-term excursion with much negative values probably indicates the ending of Glacial P2 and regionally inter-glacial responses during the Artinskian in the Urals area.

Floral responses to Pennsylvanian-Permian macro and micro climatic fluxuations across the North American portion of western Pangaea

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Plant-bearing beds of latest Pennsylvanian and earliest Permian are found in dominantly nonmarine portions of sedimentary basins in western Pangaea. These basins at the time of deposition, with the exception of the western-most sites, were situated in the tropics. All contain paleofloras that are; on average, of mixed wetland and dryland composition. There was a strong west-east climate gradient north of the central Pangaean mountain ranges; wetter in the east and drier in the west. Imposed upon this east-west continent-scale gradient there is a stratigraphic shift from wetter to drier in all basins near the Pennsylvanian-Permian transition. Superposed on these stratigraphic patterns; revealed by detailed outcrop study; are smaller-scale fluctuations of wet and dry intervals. At a given locality, the wet "Pennsylvanian" floras and dry "Permian" floras are temporally separated. This probably reflects variation in moisture availability between glacial-interglacial cycles. The distribution of wet and dry floras also evolved in separate, regional, ways due to the east-west climatic gradient. The Appalachian (Dunkard) Basin succession was more consistently "wet" throughout this entire transition, and was more consistently "wet" than the Illinois Basin that fluctuated between "wet" and "dry." On the eastern shelf of the Texas Permian Basin there are thin, presumably short lived, episodes of peat swamps and associated wet floodplains that persisted nearly to the end of the Pennsylvanian. These "Pennsylvanian-type" floras (ferns, calamites) are intercalated with deposits bearing xeromorphic "Permian-type" floras (conifers, cordaitaleans, callipterids) that ultimately dominate Early Permian floras. As the numerous basins in New Mexico and Utah were "dry" to "arid" there is a noticeable lack of mappable economic scale organic-rich deposits of Late Pennsylvanian-Permian age. In New Mexico, mixed floras from floodplain deposits suggest landscape complexity, and give way to fully "Permian-type" assemblages during the latest Pennsylvanian. In Utah, slightly further north of the paleoequator, mixed floras, similar to those of New Mexico, are confined to floodplain complexes sandwiched between eolian dune sands. The local micro temporal interdigitation of "wet" and "dry" floras can be explained as the consequence of climate change driving the waxing and waning of continental glaciations as well as the repetitious presence/absence of large peat bodies in the eastern basins. On the other hand the cause or causes of the east-to-west climate gradient appear to have been complex and are presently incompletely understood. As climate plays a direct role in the growth, occurrence, or development of features in the stratigraphic record we have three parallel but independent sources of data that support these findings, paleobotany, sedimentology, and paleopedology. The fossils soils found across western Pangaea north of the central mountain ranges exhibit features characteristic of more consistently wet conditions in the Dunkard Basin than the more carbonate rich soils of the western basins. Sedimentologically the Dunkard Basin dries during this transition from organic soils (coal) to no coal while in the west it starts in a no coal setting and ends in ergs and/or evaporite deposits.

New occurrence of genus *Monodiexodina* in West Thailand

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Early Permian fusulinoidean genus *Monodiexodina* admixed with calcareous sandstone in Mae Sot area of Tak and Si Sawat area of Kanchana Buri provinces lithostratigraphically belongs to the Pharaka and Khao Muang Khrut formations, respectively. These areas are geotectonically located in the Sibumasu Block of the eastern Cimmerian continent. The stratigraphic occurrence of *Monodiexodina* has been scarcely documented among Permian schwagerinid fusulinoideans. This work is one of the first detailed stratigraphic studies to describe the environment of *Monodiexodina* deposits. In Mae Sot area, Tak Province, the measured section is along the small creek. It is approximately 35 meters thick and divided into 3 parts: lower (8 meters), middle (16 meters) and upper parts (11 meters). The lower part is composed of siltstone to fine-grained calcareous sandstone and highly weathered shale beds overlain by parallel beds with low-angle cross and planar lamination of calcareous sandstone containing abundant occurrence of the genus *Monodiexodina*. In the middle part, the siliciclastic beds are composed of highly weathered shale interbedded with thin bedded shaley-siltstone. Thick beds of well-sorted quartz-rich sandstone and faint sedimentary structure have been observed in the upper part. Recently *Monodiexodina* has also been found in calcareous sandstone lenses in the Si Sawat area of Kanchana Buri Province in West Thailand. Due to the high degree of weathering, unfortunately, the stratigraphic section in this area is not well defined. Based on the data obtained from Mae Sot of Tak Province, the silt to fine-grained sand containing monospecific assemblage of *Monodiexodina* in particular beds interbedded with shaley-siltstone and shale is quartz rich with calcareous cement and is often low-angle cross-laminated or planar-laminated on a millimeter scale. It is inferred to have accumulated under predominantly low to moderate energy conditions, on the basis of their small constituent grain size, and presence of parallel lamination. Although, *Monodiexodina* was suggested to be in shallow marine and high energy environment, the *Monodiexodina* under consideration here was tolerant of fine grained siliciclastic input in a low to moderate energy environment.

Conodont rare earth elements from Chaohu, South China document major marine environmental changes during the Early Triassic

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Following the end-Permian mass extinction, the Early Triassic witnessed the most depleted biodiversity and devastated environments of the Earth's Phanerozoic history. In the oceans, dramatic environmental perturbations are indicated by large fluctuations in carbon isotope profiles. Changes in seawater chemistry may provide insights into marine environmental conditions during this interval. Rare-earth elements (REEs) patterns preserved in biogenic apatite (conodonts) are ideal proxies for revealing original seawater chemistry. REEs can provide information regarding the influence of weathering fluxes on seawater chemistry, processes that fractionate REEs between solid and aqueous phases, and variation in seawater redox conditions.

To date, little work has been undertaken on REEs from the post-extinction oceanic records of the Early Triassic. Here, we present REE results from analysis of conodonts from the Lower Triassic of the Chaohu area, South China and discuss the implications of our findings for changes in seawater chemistry and marine environmental conditions following the end-Permian crisis. REEs from conodont apatite were measured in 40 samples of Griesbachian to Spathian age at the West Pingdingshan section using LA-ICPMS techniques. Profiles of all proxies (total REE, Ce/Ce*, La/Sm, Sm/Yb, Th/La and E/Eu*) exhibit pronounced multiple peaks near the Induan-Olenekian boundary (IOB), indicating frequent perturbation of oceanic environments at that time. Total REEs increase significantly and probably indicate an increased weathering flux of continental siliciclastics around the IOB. Log Ce/Ce* ratios are mostly between -0.1 and 0.2 and can be interpreted to reflect mainly suboxic redox conditions during the Griesbachian with a shift toward more anoxic conditions at the IOB. Major changes in REEs also occur at the Smithian-Spathian boundary (SSB), where a pronounced increase in La/Sm and La/Yb ratios reflects LREE enrichment and a concurrent increase in Sm/Yb ratios reflects MREE depletion. These patterns are consistent with a decrease in freshwater input due to climatic change across the SSB.

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High-resolution Cisuralian conodont biostratigraphy in South China and its role for the remaining Permian GSSPs

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The GSSPs for the Cisuralian stages, including the bases of the Sakmarian, Artinskian and Kungurian stages, are still under investigation. After the Cisuralian field workshop in the Urals in 2007, it has been proved that the proposed GSSP sections, such as the Kondurovsky (the base of Sakmarian), Dal'ny Tulkas (the base of Artinskian) and Mechetlino (the base of Kungurian) sections are more or less problematic. High-resolution Cisuralian conodont biostratigraphy, along with fusuline and geochemical studies were carried out recently at two well-preserved complete sections (Yangchang section in Ziyun, Nashui section in Luodian) in Guizhou Province, South China. The conodont succession from the topmost part of Carboniferous to the Kungurian-Roadian boundary revealed that South China contains the most complete high-resolution conodont succession and should play a key role in resolving the remaining Permian GSSPs and provide valuable information for global correlation. The Carboniferous-Permian boundary can be well recognized by the first occurrence of the conodont Streptognathodus isolatus in South China. Recent studies in both Urals and South China suggest that the FAD of Sweetognathus merrilli within the lineage from S. expansus to S. merrilli is no longer suitable for defining the base of the Sakmarian Stage. Instead, mesogondolellids such as *Mesogondolella gutta* or *M. monstra* can serve as an alternative choice to define the Asselian-Sakmarian boundary in both South China and Urals. The *S. binodosus-S.anceps-S.whitei* lineage is confirmed in Southern Guizhou, thus the first occurrence of *S. whitei* provides the mark for the Sakmarian-Artinskian boundary in South China. The index conodont for the base of Kungurian, *Neostreptognathodus pnevi*, which was previously considered absent in the Tethyan region, is discovered at Yangchang and Nashui sections for the first time. The serrated conodont species *Jinogondolella nankingensis* that defining the Cisuralian (Kungurian)-Guadalupian (Roadian) boundary is very rare at both sections, even if when it's recovered, the morphological features are different from the typical forms found in West Texas.

Conodont biostratigraphy at the Dawen section in Guizhou and its implications for the Late Permian extinction

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Conodont biostratigraphy across a microbialite unit (calcimicrobial framestone) at the Dawen section, Great Bank of Guizhou, South China was investigated, in conjunction with closely-sampled carbon isotope analysis. A total of 26 conodont samples were collected, covering an interval from 8.5m below the microbialite unit to 17m above the skeletal packstone-microbialite contact. After careful study on the recovered conodont elements, three biozones were differentiated, in ascending order as: *Clarkina zhejiangensis*-*Hindeodus eurypyge* Zone, *Hindeodus parvus sensu lato* Zone, *Clarkina lehrmanni-Isarcicella staeschei* Zone. To ensure the taxonomic result on the high degree of morphological variability exhibited by conodont populations is unimpeachable, morphometric analysis were undertaken on 31 well preserved *Hindeodus* specimens. As a result, a *Hindeodus* lineage (*Hindeodus praeparvus*-*H. parvus sensu lato*-*H. postparvus*) was distinguished, among them the first occurrence (FO) of *H. parvus parvus* in the lower Daye Formation, at about 7.45m above the contact surface served as the index for the Permian-Triassic boundary at the Dawen section. In addition, correlation was made with the Meishan section, Zhejiang Province, which suggests that the top of the packstone bed is correlative to bed 24e and the initiation of microbialite deposition correlative with bed 27a at Meishan, therefore, the extinctions, within current levels of resolution, were simultaneous at both locations.

Benthic response to extreme climatic change immediately following the Early Permian ice age: fossil record from a Gondwanan high-latitude interior sea

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The most dramatic climatic change in our planet's Phanerozoic history occurred during the Permian period. The icehouse climate which prevailed in the latest Carboniferous to earliest Permian and resulted in huge ice sheets covering much of the Gondwana continent, abruptly terminated in late Sakmarian (Early Permian). This climatic change has been linked to pronounced changes in overall marine diversity, latitudinal diversity gradients, and extinction and origination rates. In tropical plant communities, major structural changes have also been shown. This study uses quantitative approaches to assess structural changes in high-latitude marine benthic communities, based on the fossil record from the Sakmarian successions in the onshore Carnarvon Basin, Western Australia. In addition to indicating possible paleoecological responses to the long-term warming trend, quantitative analysis may also reveal if there were rapid environmental fluctuations or short-term ecological disruptions in marine communities during deglaciation.

During the Permian, the Byro Sub-basin was located within an interior sea which extended from the PalaeoTethys Ocean southwesterly in to Gondwana. The studied glacial-nonglacial successions, belonging to the Carrandibby and Callythara Formations, respectively, are well exposed in the Callythara Springs type sections, where they consist of friable sediments interbedded with some limestone. We have collected 32 large bulk samples, from which all macroscopic fossils (> 3 mm in length/ or width) were extracted and identified to the species level. Each sample formed a shelly community. Detailed community proxies, including species richness (SP), individual number (N), Shannon entropy (H), exponential of H [Exp (H)], Dominance index (D), numbers equivalent of D (D'), Evenness index (E), bias-corrected Evenness index (Δ), and total number of species (TS), have been applied to evaluate community structural changes in response to extreme climate changes. All proxies for communities from the glacial succession exhibit low diversity and a high abundance and thus a high dominance index. In contrast, all proxies for communities from the post-glacial succession exhibit high diversity and low dominance. Shannon and dominance indices fluctuate in the lower post-glacial succession.

In addition, Cluster analysis (CA) and Principal coordinate analysis (PCA) are employed to quantitatively determine community associations. Both CA and PCA reveal four distinctive community associations (CA): one including all glacial communities and three over the rest of the 29 communities. Similar to the single communities, the glacial CA exhibits low diversity and high dominance, whereas the deglacial CAs exhibit much higher diversity and low dominance. Community associations tend to increase in diversity up-section throughout the Carrandibby and Callythara Formations. Accordingly, pronounced community structural change from low diversity and high dominance to high diversity and low dominance marks the deglaciation event recorded in this Gondwanan succession.

Impact of Permian icehouse-greenhouse climatic changes on benthic ecosystems: Brachiopod's fossil record from high-latitude to tropic regions

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The Permian witnessed one of Earth's most dramatic climatic transitions in its Phanerozoic history. The Late Carboniferous to earliest Permian glaciation resulted in huge ice sheets covering the most of the Gondwana. The integration of palaeogeographical, biogeographical and geochemical data show that the main phase of the glaciation terminated in late Sakmarian (Early Permian) and our planet was characterized by greenhouse climate during the Middle Permian. The global warming was accelerated during the Late Permian and such a deleterious climate also prevailed throughout much of the Permian-Triassic transition. Thus, the extreme climates tested benthos' adaptation tolerance during the Permian times. The impact of climatic changes, particularly the Late Permian global warming, on marine benthos is assessed in this paper by analyzing the Permian fossil records of brachiopod faunas from both south and north high-latitude regions (Western Australia and Greenland-Spitsbergen) to tropic region such as South China. Brachiopod faunas are mostly sessile organisms and thus sensitive to climate change. The assessment of the Permian brachiopod assemblages from these regions shows that benthos had very different responses to the icehouse, greenhouse and icehouse-greenhouse climatic regime changes in various latitude zones. High-latitude marine ecosystems were more severely impacted by both icehouse and greenhouse climates and were low in biodiversity. The brachiopod-dominated benthic communities there had a very low diversity, although their abundance may have been very high or very low under these extreme climatic conditions. The Early Permian deglaciation event triggered a rapid increase in biodiversity in high-latitude marine ecosystems, but caused a decrease in biodiversity in tropic oceans. The icehouse-greenhouse transition saw a slow increase in biodiversity in tropic oceans, but a long-term decline in biodiversity in high-latitude regions. The Early Permian ice age resulted in invasion of cold-water brachiopod species to the tropic marine ecosystems. The greenhouse climate may have weakened gradient changes of benthic distributions. The cold-water elements spread to tropic ecosystems, while the warm-water species broadened their life habitats to high-latitude ecosystems. Brachiopod body size underwent a significant reduction during the period of greenhouse towards its peak. The latter extreme climate, coinciding with the devastated end-Permian mass extinction, destroyed most benthic communities in global oceans.

The Fates of the Lhasa and West Burma Blocks

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Both the Lhasa and West Burma continental blocks are thought to have originated as part of Gondwana. Both blocks rifted from Gondwana and drifted northward across the Tethys Ocean to collide with an amalgamated Asia. After collision, a new north-dipping subduction zone developed along the southern edges of the blocks. New accretionary complexes were constructed with southward-younging wedges. Supra-subduction-, rifted-margin-, and other ophiolites may have been incorporated along the block boundaries. Blueschist facies of the accretionary rocks would be expected.

When the Indian continental block collided with the Lhasa block, the collision deformed the Lhasa Block. The metamorphism, uplift and erosion of the Lhasa Block has made it difficult to identify the accretionary complex, forearc basin and volcanic arc. However, when the Indian continental block collided with the West Burma block, the West Burma block was rotated clockwise ninety degrees as several eastern blocks were forced out laterally to the southeast, a classic example of expulsion (escape or extrusion) tectonics. Although the Indian block collided with the West Burma block, the deformation of the West Burma block was not severe. The Tertiary accretionary complex is preserved as the Indoburman Ranges in western Myanmar (Burma) and eastern India. The forearc basin is preserved as the Chindwin Syncline and most of the West Burma Lowlands. The Tertiary volcanic arc is preserved as masses of volcanic and plutonic rocks west of the Sagaing Fault. Movement along the Sagaing fault is part of the expulsion tectonic system. However, the fault may have formed along an older plate boundary.

Modern earthquake epicenters in Myanmar clearly display the old Benioff zone, but focal mechanisms along this Benioff zone show that most of the movement today is lateral as India slides past the West Burma block. Movement along the Sagaing Fault also continues today. The 1839 earthquake that partially destroyed the Pahtodawgyi stupa at Mingun, attests to its activity. Northeast-trending Plio-Pleistocene volcanoes near Monywa may reflect opening of a conjugate fault formed by differential movement on either side of the West Burma Block.
The little-deformed West Burma Block may be one of the best on-land examples of a subduction arc complex in the region. More field work is needed to describe these rocks and test these models.

Assembly of Asia and Tectonics of Its Late Paleozoic Basins

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Asia has a very complex tectonic history. It is comprised of numerous blocks, each with its own evolution. The blocks tended to amalgamate in a north-to-south order, generally after drifting northward across the Tethys Ocean. A north-dipping subduction zone across the southern edge of Asia re-developed after each block collision (along the new southern edge). These are usually marked by accretionary complexes, ophiolites, and arc magmas. The North China Block, the South China Block, and perhaps the Indochina Block may have been isolated blocks in the Tethys during mid-Paleozoic times. However, most of the later blocks appear to have rifted from the northern edge of eastern Gondwana and drifted northward to Asia.

There are many interesting hypotheses regarding the timing, orientation and tectonic settings of the blocks and the orogenic belts between them. Sedimentary basins on the blocks can provide clues to these tectonic histories. I am gathering information about the assembly of Asia, the changing tectonic setting of each block, and the tectonic control over sedimentation. For example, Devonian to Triassic carbonates were continuously deposited in a Bahamas Platform-like setting in the South China Block. However, Pennsylvanian and Permian coal-bearing rocks unconformably overlie Ordovician and older rocks over most of the North China Block (Late Ordovician through Mississippian rocks are missing), and, in the Baoshan Block, the Pennsylvanian strata are the ones that are missing, the other Devonian through Permian strata are largely present. Permo-Carboniferous diamictites and Gondwanan fauna and flora on some of the blocks point to a Gondwanan origin, whereas, other blocks have tropical-to-temperate strata with a Cathaysian fauna and flora. These differences illustrate the separate histories of these basins and blocks. Examples from several of the blocks will be shown and discussed.

Carboniferous of the Appalachian and Black Warror Basins

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The Appalachian and Black Warrior basins, coupled with the Illinois Basin, form one of the most extensive, continuous outcrops of Carboniferous rocks in the world. Through the use of new cross-sections across the eastern basins, we illustrate lithostratigraphic units and their thicknesses across basinal extent of over a thousand kilometers. Moreover, our new correlation charts should help make sense of the many stratigraphic names used for each region.

Tectonic, eustatic and other influences over basin development and sedimentary fill are also discussed. We describe the limited radiometric dating that is available and the constraints that this dating places upon depositional rates within the basin.

In addition, new biostratigraphic range charts are shown for the Carboniferous flora, conodonts, ammonoids, trilobites, echinoderms and corals. New occurrences in the basin are also described and some are new to North America. In addition, new photographs of some ammonoids and trilobites are provided. Results of the studies can be downloaded at kyps.org.

A second effort will follow soon to cover new information and topics not undertaken in the first study. The topics in the second study will include foramnifera, brachiopods, ostracodes, vertebrates, and new floral and faunal discoveries in these two eastern basins. Please contact the authors if you would like to participate.

High Resolution Lithotype Cyclicity in the Late Permian Wallabella Coal Member

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A millimeter scale investigation of coal lithotype end members (bright, dull, mixed and stone) in the Late Permian age Wallabella Coal Member (Tinowon Fm) revealed seven separate dulling upward cycles over an 8.15m coal seam (within two major dulling upward sequences over the entire seam) that were initiated by a peak in the thickness of the bright (vitrain) bands. The investigation was conducted in an exploration core Myall Creek 3, situated on the Roma Shelf on the western edge of the Bowen Basin in central Queensland, Australia. An overlying tuff (257.0±1.5Ma) places this coal into a time of glacial retreat in eastern Australia as the continent drifted northwards. Generally, the Wallabella Coal member displays an overall dull appearance due to its abundance (~60%) of inertinite group macerals. The dull lithotype is interpreted to be the result of low subsidence and frequent exposure and oxidation in a cratonic setting. Vitrain band thickness averages <2mm, with infrequent bands >10mm. The absence of abundant thick bands, coupled with palaeogeographic and tectonic setting relative to other coals in the basin, is interpreted to result from its cold tundra setting. Stable carbon isotopic analysis of bright and dull bands from within each of the cycles show $\delta^{13}C$ values exhibiting a range from -25.4‰ to -23.4‰. Whereas a slight difference in the $\delta^{13}C$ values occurred between lithotypes, the overall depletion trend of values from the base to the top of coal remained the same. The lower half of the coal shows depletion of ^{13}C at a much lower rate than the top half of the seam. These two rates of change correspond to the two dulling upward sequences observed. Rank is not considered to be the cause of the ^{13}C depletion as this seam displays an inverse rank profile and coalification enriches ^{13}C. Consequently, these isotopic trends are thought to reflect climatic and environmental cycles. The high amount of attrital, oxidized macerals is attributed to decomposition as a result of permafrost melt of the smaller tundra vegetation, an inferred mechanism behind increased water availability leading to ^{13}C depletion up-seam. Compared to the modern rates of peat accumulation in cold climates, it is reasonable to deduce this seam took 80-100Ka to accrue. As a result, Milankovitch cycles such as axial tilt and precession are inferred to influence the cycles observed in the geochemistry and lithotype of the coal, combined with successions from forested to non-forested plant communities against a background of larger scale allogenic subsidence and climatic shift.

Late Mississippian-early Pennsylvanian greenhouse to icehouse transition in the northern subtropics: Serpukhovian, Bashkirian and Moscovian cyclic successions on Bear Island (Arctic Norway)

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Sediments of Serpukhovian through Moscovian age on Bear Island, Arctic Norway represent a succession that is not well understood in the local Barents Sea and the global scales. In the area, the monotonous quartzitic sandstones (humid alluvial fan) of the Nordkapp Formation are sharply replaced by cyclic Landnørdingsvika Formation of interbedded red mudstones, yellow-brown sandstones and red conglomerates that together represent an intricate interfingering of flood-plain, alluvial fan and marginal marine sediments. The succession is of Visean through Serpukhiovian age. The presence of calcrete paleosols in the Landnørdingsvika Fm contrasts with the development of coals in the Nordkapp unit. The Landnørdingsvika Fm with transitional contact is replaced by marine Kapp Kåra Formation, divided into three members: Bogevika, Efuglvika and Kobbebukta. The Bogevika Mb consists of limestones, shales and sandstones apparently organized in a series of small-scale (< 10 m thick) shoaling upward cycles. For the first time, early Bashkirian fusulinids *Plectostaffella* and *Semistaffella* were found near the base of the Bogevika Mb. Middle Bashkirian *Staffelaeformis staffelaeformis* and *Pseudostaffella ex gr. grandis* were found near the top of the member. This implies that marine trangression in the Barents Sea started about 10 Ma earlier than understood so far.

At least nine cycles are recognized in the Bogevika Mb. The duration of this time (~3.5-4 Ma) brings the hierarchy of stratigraphic sequences in the Bashkirian succession of Bear Island within the Milankovitch frequency band. Unconformity bounded sequences record intermediate-scale (~400 Ka) sea-level fouth-order cycles that are consistent with Middle-Upper Pennsylvanian cyclothems in Kansas, USA. The Efuglvika Mb consists of white to grey, thinly to massively bedded and variably cherty limestones with textures ranging from grainstone to wackestone. 13 shoaling-upwards cycles passing from bioturbated chert-rich wackestones into chert-free grainstones, sometimes with erosive or karstified tops are recognized in the member. Fusulinids *Profusulinella prisca* and *Schubertella* found near the base of the member are indicative of a significant (4-5 Ma) gap between Bogevika and Efuglvika Mbs. The biostratigraphy of the member is incomplete, and estimation of the duration of the cycles is uncertain. Limestones, shales and conglomerates of the Kobbebukta Mb contain latest Moscovian *Beedeina nytvica, Taitzehoella* and primitive *Protriticites*, implying a 2-3 Ma unconformity at the base of the unit.

Early Permian (Cisuralian) time scale, and pan-Euramerican chronostratigraphic correlation

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A quantitative biostratigraphic and radiometric calibration is presented for the Mississippian through Early Permian global time scale, based upon high-precision IDTIMS U-Pb zircon ages for interstratified ash beds in the paralic Carboniferous successions in Donets Basin and from type sections of the southern Urals of Russia. In Donets Basin zircon ages for twelve tuffs are used to radiometrically calibrate the detailed litho-, cyclo- and biostratigraphic framework. Chemical abrasion of zircons, use of the internationally calibrated EARTHTIME mixed U-Pb isotope dilution tracer, and improved mass spectrometry guided by detailed error analysis have resulted in an age resolution of < 0.05%, or *ca* 100 ka. This precision allows the resolution of time in the Milankovitch band, and confirms the long-standing hypothesis that individual highfrequency Pennsylvanian cyclothems and bundles of cyclothems into fourth order sequences are the eustatic response to orbital eccentricity (*ca* 100 and 400 ka) forcing. Tuning of the fourth order sequences in the Donets Basin to the long-period eccentricity cycle results in a continuous age model for the middle to late Pennsylvanian (Moscovian-Kasimovian-Ghzelian) strata of the basin and their record of biological and climatic changes through the latter portion of the Late Paleozoic Ice Age. Twenty-four ash bed ages in three outer ramp and basinal sections of the Pre-Uralian foredeep bracket the biotic definitions of global stages and regional substages from the base of the Upper Pennsylvanian Kasimovian Stage to the base of the Lower Permian Artinskian Stage; four additional ash bed ages constrain the global Bashkirian and Serpukhovian Stages.

Quantitative stratigraphic methods (CONOP9) are applied to a compilation of over 2600 bioevents in 28 stratigraphic sections supplemented by our dated volcanic horizons to refine the Mississippian-Early Permian global time scale. The unprecedented density of radiometric calibration points for the Pennsylvanian-Permian transition provides a highresolution (~0.1 Ma) global chronostratigraphic standard for testing and improving biostratigraphic correlations across Euramerica. We integrate radiometric ages, biostratigraphic correlation, and cyclostratigraphic tuning of major cyclothems to the long period (404 ka) eccentricity cycle to elucidate the tempo, magnitude, and forcing of eustatic changes and cyclothemic deposition associated with the waxing and waning of Gondwanan ice sheets, and establish a pan-Euramerican chronostratigraphic framework for most of Pennsylvanian and Early Permian time.

Uppermost Devonian and Mississippian sequence stratigraphy and rugose coral biostratigraphy of Zonguldak and Bartın area, NW Turkey

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The Mississippian succession of Zonguldak and Bartın area in Northwestern Turkey, known from several sections, shows typical shallow-water shelf carbonate facies. The lithostratigraphy of this area is re-studied and re-interpreted for the sequence stratigraphy. Dating and correlation are mainly based on rugose coral biostratigraphy, completed by foraminifer biostratigraphy. Almost all Mississippian rugose coral biozones defined in Western Europe are identified in Turkey, especially in the Viséan. The third order sequences known in Europe are also recognized. The lowermost part the Kışla Fm is the oldest fossiliferous unit of Zonguldak and Bartın areas. It yields stromatoporoids, quasiendothyrid forams and rugose corals typical of the RC0 biozone of Poty et al. (2006) and indicating a Strunian (Latest Devonian) age. It corresponds to the TST of the third order sequence 1 of Hance et al. (2001). The upper part of the Kışla Fm and the lower part of the overlying Ulutam Fm show very shallow-water facies almost devoid of coral. This succession is not dated and the sequences are not specified. The oolitic limestone of the upper part of the Ulutam Fm is identified as the HST of the sequence 4 and yields uppermost Tournaisian fauna. The topmost part of the Ulutam Fm is thought to correspond to the lowermost Viséan because the overlying Kokaksu Fm yields typical Moliniacian (lower Viséan) fauna. Among them, the rugose corals *Dorlodotia briarti* and *Siphonodendron ondulosum* are the guide taxa for the RC4β and RC5α biozones respectively. The middle and upper parts of the Kokaksu Fm are the most fossiliferous units. They yield typical Livian and Warnantian (middle-late Viséan) fauna from RC5β to RC7β biozones, among which *Siphonodendron martini*, *S. pauciradiale*, *S. asiaticum*, *Lithostrotion araneum*, *L. vorticale*, *Clisiophyllum garwoodi*, *Haplolasma* sp. *Caninophyllum archiaci*, *Palaeosmilia murchisoni*, *Aulophyllum fungites*, etc. At least two sequences are recognized in the formation, namely sequences 7 and 8. The topmost beds of the Kokaksu Fm yield Brigantian (uppermost Viséan) corals as *Nemistium* sp. and *Palastraea* sp., indicating the RC8 biozone. The overlying Dört Degirmen Fm is made of shale and sandstones containing plant remains but also rare limestone intercalations that yield several brachiopods and foraminifers indicating an uppermost Viséan age.

Biostratigraphy of the Upper Moscovian-Kasimovian boundary sediments of low foothills of the Turkestan-Alai (Southern Tien-Shan)

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Establishment of the Moscovian-Kasimovian boundary is debatable at present (Ueno and Task Group, 2009). For this, researches in different regions are very important.

We have studied the Upper Moscovian-Kasimovian boundary sediments of low foothills of the Turkestan-Alai (Southern Tien-Shan) in interfluves of Shuran-Shunk-Karatanga rivers, where these sediments are widely spread. Conglomerates predominate in the lower (Upper Moscovian) interval and the top of the section is represented by the Kasimovian rocks. These sediments were studied in five sections, which are characterized by high concentration of fusuline faunas. Connection of fusulinids with certain intervals of the section made it possible to reveal two zonal complexes with index-species changing each other (from the bottom): *Fusulinella schwagerinoides and Protriticites pseudomontiparus – Obsoletes obsoletus.* Subsequently, these units were called the Shunkmazar and Jilginsai horizons.

Upper Moscovian, Shunkmazar horizon, *Fusulinella schwagerinoides Zone*

<u>Type section</u> is located in Shunkmazar gorge.

<u>Boundaries.</u> *Fusulinella schwagerinoides Zone* has provisional closing up with underlying sediments, because they are represented by conglomerates and have not initial faunal substantiation. The upper boundary is drawn according to closing up of the zone with overlying *Protriticites pseudomontiparus – Obsoletes obsoletus Zone*.

<u>Foraminifera assemblage.</u> 48 foraminifera species were discovered in sediments of the zone. Except index-species, there are taxa: *Fusulina cf. schelwieni Staff, F. bona Chernova et Rauser, F. dunbari Sosnina, f. mjachkovensis Rauser etc, Putrella donetziana (Lee), P. brazhnikovae (Putrja), Hemifusulina moelleri Rauser.* Some species of *Neostaffella, Ozawainella, Shubertella and Fusiella* genera cross from underlying beds.

Kasimovian, Jilginsai horizon, *Protriticites pseudomontiparus – Obsoletes obsoletus Zone*

<u>Type section</u> is located on right bank of the Karatanga River.

<u>Boundaries.</u> Closing up with underlying zone was established in "Shunkmazar" and "Shunkmazar III (302) sections and closing up with overlying *Montiparus montiparus Zone* was established in "Karatanga" section.

<u>Foraminifera assemblage.</u> For the first time appearing following abundant species of *Protriticites* and *Obsoletes* genera are characterized for the zone: *Protriticites pseudomontiparus Putrja, P. subovatus Bensh, P. entis sp. nov., Obsoletes dagmarae Kireeva, O. minutus asiaticus Bensh, etc*. Some species of *Schubertella, Fusiella, Ozawainella, Fusulina, Fusulinella* genera cross from underlying beds and supplement foraminifera assemblage of the zone.

Correlations of described zones are conducted with analogous sediments of the Russian Platform: the Myachkovian and Krevyakinian horizons, Urals: Lazarevian and the low part of Abzanovian horizons, and with Donbas: C_2^me Zone and N_2-N_3 – O_1-O_2 limestones.

The bryozoan fauna of the Callytharra Formation (upper Sakmarian - Artinskian), Western Australia

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Permian sediments of Western Australia are commonly characterized by a high content of bryozoans. However, only very limited studies of these faunas have so far been reported, leaving their potential for regional stratigraphy, global palaeobiogeography and palaeoecological reconstructions largely unexplored. This preliminary presentation constitutes the first results of a long term project investigating these bryozoan faunas.

The Lower Permian (upper Sakmarian – Artinskian) Callytharra Formation is a prominent, ~ 120 meter thick unit in the Southern Carnarvon Basin, with scattered outcrops through most of the Merlinleigh sub-Basin. The formation is predominantly composed of various types of limestone and marly shales, typically with a very rich benthic invertebrate fauna dominated by bryozoans, brachiopods and crinoids. During earlier studies made mainly in the first half of the last century, more than 40 bryozoan species were recorded from the Callytharra Formation.

The lower part of the Callytharra Formation (~ 55 m) contains mainly bryozoan and bryozoan-brachiopod-crinoid packstones. These beds are extraordinarily rich in bryozoans, with bifoliate cystoporate *Ramipora ambrosoides* (Bretnall, 1926) as the most prominent constituent. Also present are rigidly branched trepostomes (*Dyscritella*), bifoliate cystoporates (*Ramipora*, *Linguloclema*, *Fistulamina*), abundant delicate as well as robust fenestrates (*Minilya*, *Penniretepora*, *Polypora*, *Mackinnyella*), delicate rhabdomesines (*Streblotrypa*, *Streblascopora*, *Rhabdomeson*), and encrusting cystoporates (*Fistulipora* sp). In the upper part of this succession thin-bedded limestones occur which contain almost exclusively delicate fenestrates with long supportive skeletal rods.

The upper part of the Callytharra Formation (~ 65 m) is dominated by winnowed bryozoan grainstone, with interbedded muddy limestone locally in the upper part of the succession. Large, unfragmented colonies of the bifoliate cystoporate species *Evactinostella crucialis* (Hudleston, 1883), *Hexagonella hudlestoni* Crockford, 1957, and *H. australis* (Bretnall, 1926) are very conspicuous throughout this part of the formation, while *Ramipora ambrosoides* (Bretnall, 1926) is still common. Other elements of the bryozoans fauna are robust and delicate fenestrates (*Polypora*, *Mackinneylla*, *Shulgapora, Minilya*, *Septapora*), delicate rhabdomesines (*Streblotrypa*, *Streblascopora*, *Rhabdomeson*, *Rhombopora*), and branched trepostomes (*Dyscritella, Stenopora*). The interbedded muddy limestones are particularly rich in both delicate and robust fenestrates, with subordinated delicate rhabdomesines (*Streblascopora*). The fenestrate bryozoans possess long hooked skeletal rods, necessary for stable growth on soft substrate. These beds were apparently formed in quiet environment with muddy substrate. Bryozoans so far identified from the Callytharra Formation comprise species previously reported from the Lower Permian of Timor, Thailand, Iran and Oman.

Understanding Coal Seam Gas

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Spatial variability in coal seam gas content and composition impacts on estimations of gas in place for commercial and mine site drainage, as well as greenhouse gas fugitive emissions. Gas can be generated through thermogenic or biogenic processes, but it is retained through physical adsorption in the micropore structure of the organic fraction of the coal or carbonaceous lithologies under hydrostatic pressure. Fluctuations in temperature and pressure throughout the burial and uplift history of the coal deposit will determine the resulting gas saturation or proportion of measured to ultimate gas holding capacity at a given pressure and temperature. As a result, domains of varying gas content for coals of similar properties (grade, rank and lithotype), can be determined by examining the spatial distribution of gas content gradients (e.g. the rate of increase in gas content with depth or hydrostatic pressure). Within a given gas domain, increases with depth can be steep, shallow or show reversals with gas contents decreasing with depth in stratigraphic zones. These different domains and zones can sometimes, but not always, relate to geological structure, intrusions, distance from subcrop or hydrodynamics. Isotopic analysis assists in unraveling the origins of the gas and controls on its distribution. Examples from the Permian age coals of the Moranbah-German Creek Coal Measures in the Bowen Basin of Australia, show regional to local variation that exhibits a variety of trends that reflect coal measure architecture, and impact on production behaviour.

Biofacies and microfacies of the Mobarak Formation (Mississippian), Kiyasar area, northern Iran

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The Mobarak Formation is near the city of Kiyasar in the south-eastern portion of Sari, northern Iran. This formation conformably overlies the Geirud Formation (Upper Devonian). Mobarak Formation is covered unconformably by sandstones attributed to the Dorud Formation (Lower Permian). Similarities exist between fauna recorded in the Kiyasar section with faunal assemblages known in the Mobarak Formation from other regions in eastern and central Alborz. Originally, the Mobarak Formation was identified by Assereto (1963) to comprise rocks overlying the Mila Formation (Upper Cambrian) and below the base of the Nesen Formation (Upper Permian) in the Mobarak Abad area (north-eastern Tehran).

The Alborz Mountains range is located along the Alpine-Himalayan tectonic belt. The geological information and paleomagnetic data show that Iran was part of Gondwana continent until Late Paleozoic or Early Triassic and was located in north-eastern Gondwana. The thickness of the Mobarak Formation in the Kiyasar section is 250 m. Based on the lithological features, this formation can be divided into four members as follows, from below, Unit 1, includes 34 m of black, thin to medium-bedded limestone alternatings with brown, medium-bedded, dolomitic limestone with interbedded shales and marls. Bioclasts are mainly brachiopods, foraminifers, crinoids and bryozoans. The basal part of this unit is characterized by a thin-bedded shale that conformably overlies sandy limestone of the Geirud Formation. In the upper part of this unit, thick-bedded shales are observed. Unit 2 includes 60 m of medium-bedded limestone with interbedded shale and marl with debris of crinoid, bryozoan and brachiopod and with abundant foraminifera. The Lower part of this unit does not outcrop. The upper part of the unit contains medium-bedded limestones with interbedded shales with abundant green algae. *Calcisphera* is also observed in the bedded limestones of this unit. Unit 3 is 106 m thick, with deposition of thick-bedded limestone followed by alternating, medium-bedded limestone with ichnofossils and black shales and marl. The limestones of this unit contain brachiopods, ostracods, crinoids and green algae as well as foraminifera. *Calcisphaera* and bryozoans also occur in the bedded limestones of this unit. Brachiopod fossils and green and red algae were also recorded. It is important to note that in the middle part of this unit there is a marker horizon with abundant solitary corals. Unit 4 has a thickness of about 50 m which starts with dark marls and dolomitic limestones followed by limestones with interbedded shale containing brachiopod fossils, red and green algae, bryozoans and crinoidal fragments. In the uppermost part of this unit occurs a thick bed of yellow to brownish shales with intercalated limestone, and overlain by sandstones of the Dorud Formation (Lower Permian) with a disconformity.

Based on field and laboratory studies, 4 facies belts have been recognized which contains: 1-Inter-tidal facies belt, 2-Lagoonal facies belt, 3-Barrier (Shoal) facies belt and 4-Open-marine facies belt. They are respectively interpreted as upper-ramp, middle-ramp and lower-ramp carbonates developed in a shallowing-upward sequence.

When did marine ecosystems recover following the end-Permian mass extinction?

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Some evidence suggests that at least 5 million years elapsed before life on Earth returned to pre-extinction complexity following the end-Permian mass extinction. Emerging research suggests that marine ecosystem recovery after the mass extinction was influenced by paleolatitude, length of time after the mass extinction, and shoreface architecture. However, the timing of full biotic recovery is still largely unknown. Lack of such knowledge of ecosystem restoration is an important problem because it hampers our ability to more completely understand the inter-relatedness between environmental conditions and evolutionary processes. Marine paleocommunities from the Dienerian Daye Formation in Ghuizhou Province, China and the Spathian Virgin Limestone Member in Nevada, U.S.A. deposited in eastern Paleotethys and eastern Panthalassa, respectively, were examined to test the hypothesis that biotic recovery following the mass extinction was spatially and temporally varied.

The Second Member of the Daye Formation was deposited on a shallow, gently-sloping ramp. Though the Daye assemblage is characterized by very high ichnodiversity, trace fossils extend only within the lowest tier (0 to -6 cm); vertical bioturbation is low (ii 1 to ii 3); size of burrows is small (mm-scale); and bioturbation is primarily horizontal (BPBI 4-5). This diverse ichnocoenosis deposited during the first half of the Early Triassic at a low paleolatitude in relatively shallow water suggests that recovery from the end-Permian extinction was complex and cannot be explained by one spatial or temporal attribute.

During the Early Triassic “metazoan reef gap”, the role of reef-building was filled by microbial communities in the form of microbialites found in Lower Triassic rocks around the world. Spathian age strata in the western U.S. A. record microbe-sponge reefs that represent the oldest post-Paleozoic metazoan framework reefs. The Early Triassic consortium of framework-building sponges and microorganisms differs significantly from Permian and Middle Triassic reefs in that the sponges are not heavily calcified. This new finding supports the hypothesis that reef ecosystem evolution and biotic recovery following the end-Permian mass extinction were dampened by elevated $p\mathrm{CO_2}$.

Glacioeustasy, transgressive-regressive (TR) cycles, mesothems and substages: Carboniferous and Permian faunal introduction events (FIEs) dressed in long-period orbital clothing

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Moderate to high-magnitude glacioeustatic TR events in the Late Viséan Windsor Group of eastern Canada record orbital forcing at scales ranging from the major eccentricity (400 ka) to the Precession Index (17.2 – 20.4 ka). Faunal introduction events (FIEs) in the same succession are more slowly paced, and approximate a longer period (2.38 Ma) of the eccentricity, or alternatively, the same period controlled by the modulation of the obliquity. The latter periodicity is specifically linked with climatic cooling events and glaciation.. FIEs in the eastern Canadian Viséan succession are correlated with substage boundaries in equivalent strata in the British Isles. The late Dinantian British substages closely reflect their precursor subdivisions, the now largely forgotten mesothems. Thus, TR cycles, mesothems and substages all link to long-period glacioeustasy in the Late Viséan. In eastern Canada, Viséan glacioeustatic cycles of variable thickness can be traced regionally in spite of contrasting local tectonics. Other portions of the global Carboniferous and Permian characterized by major glaciations should also show similar orbital control over flooding (and faunal introduction) events. Since FIEs define substage boundaries, we can test their pacing using modern time scales.

Within predictable errors in the estimation of the long-period orbital pacing, substage boundaries cited for the Permian to Moscovian interval in GTS 2004 fall, with one exception, on numeric increments of the 2.38 Ma obliquity modulation, anchored to the top-Permian numeric boundary. If the top-Permian anchor point of 251.0 Ma is set alternatively to 251.3 or 251.4 Ma as suggested by some researchers, all Permian to Moscovian substage boundaries match orbitally predicted numeric boundaries. If we consider DCP 2003 as an alternative time scale to GTS 2004, four of five conflicting estimates for Permian substage boundary positions also fall (within error) on other increments of the obliquity modulation when the top Permian anchor point is set at 251.4Ma. This matching to orbitally-forced increments cannot make a preferential choice for “correct” substage boundary, but the matching itself is a remarkable demonstration that long-period orbital forcing is linked, through paleoclimate or eustasy, to faunal change. Pacing of FIEs is variable because not every orbitally driven cyclic event is of equal consequence to sea level or fauna.

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Paleozoic ice-houses and low-latitude brachiopod habitat temperatures (BHTs): the cold hard truth from $\delta^{18}O_{[brachiopod\ calcite]}$

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Long-standing debate over the integrity of $\delta^{18}O$ data for fossil shells has deterred many researchers from using these isotopes for paleotemperature determinations. At issue is the progressive and statistically significant linear depletion in isotopic content with increasing age, attributed by some to increasing diagenetic alteration. Others cite this trend as evidence that $\delta^{18}O_{[seawater]}$ has evolved from significant depletion in lower Paleozoic time to present levels. The extended range in isotopic composition of the older datasets is likewise attributed by some to the effects of diagenetic smearing of the original shell compositions. Accepting the argument for seawater isotopic evolution, the detrended $\delta^{18}O$ data reflect shell compositions at low latitudes which closely match predicted shell calcites crystallized within normal salinity ranges, but at temperatures which at least occasionally spanned brachiopod vital limits. For low-latitude settings, these wide-ranging paleotemperatures offer new insight into Earth's glacial and non-glacial modes. Extended ranges of the Paleozoic $\delta^{18}O$ dataset discourage conventional application of the calcite thermometer and a revised approach is suggested. A running mean of ph-adjusted brachiopod habitat temperatures (BHTs) shows that Paleozoic low-latitude oceans were, on average, cool to cold relative to the modern interstadial tropical ocean. Even the Triassic tropical ocean was slightly cooler, on average, than the modern ocean. At times during Pennsylvanian, Serpukhovian, Tournaisian and Ordovician-Silurian glaciations, tropical seas were significantly colder than at the Last Glacial Maximum (LGM). Land-based ice sheets within tropical latitudes can be reasonably predicted at those times. Mg/Ca temperatures are in close agreement with the $\delta^{18}O$ temperatures estimated here, suggesting mean BHTs during the coldest times as much as 5°C below BHTs estimated for the LGM. Abundant and diverse Paleozoic brachiopod communities reflect these cool tropical oceans, consistent with modern brachiopod ecological preference for colder waters. Amplified Paleozoic temperature oscillations suggest recurring global warming events which episodically drove these cold tropical oceans to temperatures significantly higher than the warmest modern tropical ocean. Considering only mean BHTs, however, it is difficult to argue for ice-free periods of significant duration from the mid-Ordovician to the top-Triassic.

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Carboniferous reefs in China

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Carboniferous was a unique period of reef-building in Late Paleozoic, with the flourishing of rugose corals as well as other reef-building organisms such as stromatoporoids and bryozoans. The paleogeographic framework of the Early Carboniferous in China was carried over from that of the Late Devonian. During the Early Carboniferous, South China was a sea shelf that became shallower from southwest to north, and to northeast, and there were many carbonate platforms in various sizes on the sea bottom. Some coral-bryozoan patch reefs were built on the platforms and stromatolitic algal reefs, on the margin slopes during the Visean. In china, the reefs of the Early Carboniferous were built mainly by bryozoans and rugose corals, followed by various types of algae. During the Late Carboniferous in South China, the reef-builders were mainly Fomitchevella, a rugose coral, and phylloid algae, whereas in North China, the reef-builders were chaetetes, bryozoans, and corals.

The bryozoan-coral reef near Langping town, Tianlin County, Guangxi Province is the only Early Carboniferous framework reef so far known in China and the reef is considered an inner-platform pinnacle reef. Only a few small-scale Carboniferous reefs built by Chaetetes develop in North China, and they are distributed mainly in the Taizi River Basin, eastern Liaoning Province. In southern Guizhou Province, a large coral reef is composed of a framework of the main body built by Fomitchevella. There are a lot of phylloid algae reefs in Triticites belt of the Upper Carboniferous in the location

The Frasnian-Famennian mass extinction event wiped out the reef-building communities in the Late Devonian. In the Carboniferous, new communities were built up again that were different from those of the Devonian. Two types of reef communities could be recognized. One is algae reef-building community, which shows features of junior reef-building community that may indicate influences by mass extinction event in Late Devonian. The other is metazoan-colonial coral reef-building community, which is formed independently with blooms of new coral communities in the Carboniferous. There is no evolutionary relationship between the two types of communities.

The reef communities in China have recovered their reef-building functions in the Carboniferous. The reef community of Carboniferous evolved in both microscopic and macroscopic directions. Most areas of China should be in an environment with a warm climate in the Carboniferous.

New Russian sections as potential GSSP of the global Kasimovian and Gzhelian stages

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Kasimovian and Gzhelian stages were established in the sections of the Moscow Basin (Russia). The great progress in the biostratigraphy of these stages in type and references sections was achieved during the last two decades. Most important data were compiled in field-trip guidebooks for the Field Meeting of the I.U.G.S. Subcommission on Carboniferous Stratigraphy (Alekseev and Goreva, 2009). The Task Group to establish the Moscovian-Kasimovian and Kasimovian-Gzhelian boundary reached agreement to focus work on *Idiognathodus sagittalis* and *Id. turbatus* as potential biostratigraphic markers of the base of the Kasimovian. Biostratigraphic analysis of the Moscovian-Kasimovian transition was done in the neostratotype of the Kasimovian Stage – Afanasievo section (Moscow Basin). The most important signature is presence of conodonts *Idiognathodus sagittalis-Id. turbatus* plexus in the lower part of the Neverovo Formation. Afanasievo section was proposed as a possible candidate for the stratotype of the lower Kasimovian boundary because both discussed conodont taxa occurs together with fusulinid *Montiparus* (Goreva *et al.*, 2009). Relatively abundant conodonts of the *Idiognathodus sagittalis-Id. turbatus* plexus were discovered recently in more deepwater facies of the Neverovo Formation at the Stsherbatovka quarry (Oka-Tsna Swell, Ryazan Region, near of Kasimov Town). The middle part of the Neverovo Fm. (marls and shales with limestone intercalations) contains abundant macrofauna and conodonts, most of these belong to the *Idiognathodus sagitalis – I. turbatus* plexus. These dates demonstrate wider distribution of the complex of marker conodont species for the base of the Kasimovian (250 km southeast from the Afanasievo section). The accepted marker for the Gzhelian Stage, *Idiognathodus simulator*, was discovered together with additional marker fusulinid species *Rauserites rossicus* in the stratotype Gzhel and neighboring Rusavkino secton (Moscow Basin) and Usolka and Dalniy Tyulkas sections (South Urals). The new section where *Idiognathodus simulator* was found is Yablonevyy Ovrag Quarry (hypostratotype of the Gzhelian) in Zhiguli Mountains (Samarskaya Luka). It contains foraminifers, brachiopods and Rugosa corals at the same levels. *Idiognathodus simulator* was found in the base of bed 8, which traditionally considered as bottom of the Gzhelian Stage (on fusulinds). Kholodnyy Log section in the Perm Region (west slope of Middle Urals, Perm Region) appears to be a new possibility for the study of the Kasimovian-Gzhelian transition, because *Streptognathodus pawhuskaensis* was found there.

Is *Chiosella timorensis* a good index for the Olenekian-Anisian Boundary?

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The First Appearance Datum (FAD) of the conodont *Chiosella timorensis* has been proposed as an index for worldwide recognition of the Olenekian-Anisian Boundary (OAB, Early-Middle Triassic boundary). However, we have recently found *C. timorensis* within a sample from Nevada, which also contains ammonoids that are diagnostic of the late Spathian *Haugi* Zone. We discuss how this discovery challenges our current understanding of the phylogenetic relationships among the conodonts occurring around the IOB. Based on a reassessment of the material from Desli Caira (Romania) and Guandao (South China), the two GSSP candidates for the OAB, we propose a new biochronological scheme for this time interval.

New conodont data from Waili (South China) and Mud (Northern India) and implications for the definition of the Induan-Olenekian Boundary

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New conodont collections recovered from Waili (Guangxi, South China) and Mud (Himachal Pradesh, India), the latter being a GSSP candidate for the Induan-Olenekian Boundary (IOB), led us to describe several new taxa and to recognize numerous new morphotypes of the important neospathodid *dieneri, cristagalli, pakistanensis* and *waageni* groups.

Based on our revised taxonomy we also reassessed the published material from the North Pingdingshan section near Chaohu (South China), the other candidate GSSP for the IOB. Our revised determinations enable to construct new, higher resolved local biozonations based on the more robust maximal association approach. Our new biochronological scheme around the IOB has a good lateral reproducibility in the Tethyan realm. Intercalibration with the ammonoid record and the implications for the definition of IOB are also discussed.

Exploring mass extinction events (Permian/Triassic & Triassic/Jurassic): Association with global warming events using molecular fossils and stable carbon and hydrogen isotopes

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Biomarker evidence for photic zone euxinic (PZE) conditions within Permian/Triassic (P/Tr) sections, where concentrations of sulfide are sufficient to support anoxygenic photosynthesis, come from components derived from pigments of Chlorobi. Evidence for such conditions occurs at 6 localities globally. Perturbations in the marine sulfur cycle and thus the redox-state of the ancient seas are also reflected in $\delta^{34}S$ of pyrite (e.g. from China, Italy, Iran, Western Australia, East Greenland, Western Canada and Spitsbergen) supporting widespread euxinic conditions in both Palaeotethys & Panthalassa oceans. Various aromatic biomarkers have been detected in high abundances in samples prior to the marine ecosystem collapse in East Greenland, Spitsbergen, South China & Western Canada. We have proposed that lignin derived from land plants, present during the Late Permian is their likely source. We provide sedimentological data, biomarker abundances & compound specific isotopic data ($\delta^{13}C$ & δD) along with bulk isotopes ($\delta^{34}S_{pyrite}$, $\delta^{13}C_{carbonate}$, $\delta^{13}C_{org}$) for Late Permian sections. At two localities sedimentological and geochemical data supports a marine transgression & collapse of the marine ecosystem occurring in the Late Permian. $\delta^{13}C$ data of algal and land-plant derived biomarkers, $\delta^{13}C$ carbonate & organic matter support synchronous changes in $\delta^{13}C$ of marine and atmospheric CO_2, attributed to a ^{13}C-depleted source (^{13}C depleted methane &/or CO_2 derived from degradation of organic matter due to the marine ecosystem collapse). Evidence for waxing and waning of PZE throughout the Late Permian is provided by Chlorobi derived biomarkers & $\delta^{34}S$ pyrite implying multiple phases of H_2S outgassing and potentially several prolonged pulses of extinction. A number of mechanisms have been proposed to account for the Triassic/Jurassic mass extinction, including the release of CO_2 associated with emplacement of the Central Atlantic Magmatic Province. A negative carbon isotope excursion has been detected in many sections, also supporting a perturbation in the global carbon cycle. It is clear that major and abrupt ecological change including 80% extinction among terrestrial plant species coincides with increased atmospheric CO_2 concentration (CO_{2atm}, based on stomatal analysis of fossil Ginkoales leaves) & a negative excursion in $\delta^{13}C$ of fossil wood from a section at Astartekløft, East Greenland. We have evidence for carbon cycle perturbation, extreme heat stress and fire in the form of molecular and compound specific stable isotopic compositions of biomarkers from the boundary section.

Circulation in the Carboniferous Epicontinental Seas of North American – Stable Isotopic Evidence

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Previous studies have identified $\delta^{13}C$ events in the Carboniferous that imply major shifts in the global carbon cycle. However, inherent in this interpretation is the assumption that epicontinental seas are chemically representative of the global ocean. We use stable isotope analyses of brachiopod shells to examine salinity gradients and circulation of the North American epeiric sea. Time slices (late Chesterian and early Virgilian) and formations were chosen that provide shallow marine environments with good geographic coverage. New data were produced for the Illinois Basin (Mattoon and Grove Church Formations and Appalachian Basin (Glenshaw Formation) based on 98 brachiopod shells found to be well preserved based on plane light and cathodoluminescence microscopy and trace element analyses. These data were supplemented by published data for nonluminescent brachiopod shells from the US Midcontinent (USM), Eastern Shelf of the Midland Basin (Texas), and the Bird Spring Basin (Arrow Canyon, Nevada). Upper Chesterian samples from the Illinois Basin (Grove Church) yield low $\delta^{13}C$ and $\delta^{18}O$ values (1.1‰ and -3.1‰ respectively) compared with those from the Bird Spring Basin (3.7‰ and -1.4‰). This trend is interpreted as reflecting terrestrial influence in the midcontinent and freer exchange with the Panthalassa Ocean at the western margin of North America. Samples from the Virgilian transect shows a progression of $\delta^{13}C$ and $\delta^{18}O$ enrichment moving west from near the Appalachians (1.9‰ and -3.8‰) to the Illinois Basin (3.2‰ and -2.4‰) and finally to the USM (4.2‰ and -1.5‰). This is interpreted as the transition from nearshore, terrestrial influence with lower salinity to well-mixed conditions with normal salinities. Mass balance calculations based on the $\delta^{18}O$ of the brachiopod shells suggest salinities of 25 and 31 for the Appalachian and Illinois Basins, respectively, assuming Kansas brachiopods grew in waters of 34.5‰ salinity. These results agree with climate models and paleobotanical data that suggest ever-wet, ever-warm climate. The central USM (Kansas) and southern and western gateways (Texas and Nevada, respectively) provide the highest $\delta^{13}C$ values for the North American epicontinental sea for each time slice, interpreted as full marine salinity. Virgilian $\delta^{13}C$ values, however, remain 1-2‰ lower than those for other regions (northern Laurussia, Uralian seaway, western Paleotethys, and western Panthalassa), highlighting the restricted character of the epicontinental seas of North American.

Ice movement direction and detrital zircon provenance data for early Permian glacial deposits, Amadeus Basin, eastern Western Australia

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Early Permian glacial pavements across Western Australia typically show ice movement directions towards the north to northwest, with local deviations. Recently discovered pavement sites around the Dover Hills in the western Amadeus Basin (one site previously reported in 1961) give unequivocal evidence of ice movement towards the west based on chatter marks in association with glacial striae. The general sense of movement is also supported by the orientation of Permian-filled paleovalleys and scours.

The pavements are preserved on an undulating unconformity surface on the early Neoproterozoic Heavitree Quartzite. The overlying sandstone, conglomerate and diamictite are locally mapped as Buck Formation, a presumed equivalent of the Paterson Formation in the southern Canning and Officer basins to the west. There are no biostratigraphic data, but the Paleozoic maximum depositional age provided by detrital zircon dates, eliminates the possibility that these deposits could belong to any of the Neoproterozoic glacial episodes recognised in the Amadeus Basin.

Detrital zircon dating using SHRIMP U-Pb methods on two samples constrains the provenance of sandstone from the basal Buck Formation. A sample from the pavement area near the Dover Hills yielded predominately late Neoproterozoic to early Paleozoic (~660–510 Ma) and late Mesoproterozoic to early Neoproterozoic (~1230–880 Ma) ages. The youngest concordant zircon is 466 ± 11 Ma (1σ). The age spectra closely resemble those reported from Ordovician to Devonian strata of the central and eastern Amadeus Basin, with relatively little contribution from the underlying Heavitree Quartzite or local basement sources. This is consistent with derivation largely from an upper Amadeus Basin succession uplifted during the mid to late Paleozoic Alice Springs Orogeny, and with the evidence for westerly ice movement.

A sample from the Pollock Hills (130 km west of the pavement site) contains a much higher proportion of zircons of Paleoproterozoic and late Mesoproterozoic age, with peaks suggesting ultimate derivation from the Arunta and Musgrave basement provinces, but likely reworked from the older (Neoproterozoic to earliest Paleozoic) portion of the Amadeus Basin which is widely exposed to the southeast of the sample site.

Mid to Late Permian pull-apart basins in North Greenland

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Long lived, stable carbonate platforms dominating deposition along the northern margin of Laurasia were overtaken by siliciclastic regimes late in the Permian. In North Greenland this break-down was preceded by a short, yet pronounced episode of pull-apart basin formation associated with strike-slip movements along the near 1000 km long on-shore part of the break-up suture between Eurasia and Laurentia. Successive episodes of strike-slip movement along this suture through the Mesozoic have masked or obliterated most of the signs of the earlier tectonic events, with only two basins remaining sufficiently well constrained to be discernible today.

However, in spite of being more or less simultaneous the two basins recognized are highly different, depending on their location in relation to the pre-existing fundamental structures.

One basin is dominated by open marine, fossil rich platform carbonates and deep-sea mudstones, with abundant turbidites and olistostromes, and with a documented thickness in excess of two kilometers.

The other basin is dominated by fluvial and lacustrine siliciclastics with a pronounced volcanoclastic component originating from a series of small syndepositional volcanic centres developed along the basin margins. As a result of later tectonic events the succession is broken up in a series of slices in a major tectonic melange, hence little can be inferred about the total accumulation. The composite thickness measured in the better preserved parts of the succession is in excess of one kilometer.

Temporal coincidence between the Emeishan large igneous province and the Guadalupian-Lopingian boundary

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The Emeishan large igneous province (LIP) emplaced on the Middle Permian carbonate platform of Maokou Formation provides an ideal place to study relative temporal relationship between the Emeishan volcanics and Guadalupian-Lopigian Boundary (G-LB). The Emeishan basalts overlying exclusively eroded Maokou Formation implies that the volcanism began at late Middle Permian, catastrophic deposits occurred at the margin of the LIP are further indication of carbonate platform collapse at the end of Maokou stage. Systematical correlation of Maokou Formation shows that domal uplift occurred prior to the Emeishan volcanism, indicating that a mantle plume is probably responsible for this LIP. Geochemical stratigraphic correlation of the Emeishan LIP, Xianwei Formation and claystones at G-LB in Southwestern China shows that the felsic member in the uppermost Emeishan flood basalt, the lowest part of Xuanwei Formation and the claystones at G-LB are located on an isochron horizon, implying the emplacement of the Emeishan volcanism at the G-LB or the termination of Emeishan LIP at G-LB. SHRIMP zircon U-Pb dating of silicic ignimbrite in the uppermost Emeishan basalts, clay tuff at the Middle-Late Permian boundary at the Chaotian section and the lowermost clastic rocks of the Xuanwei Formation suggests that the Emeishan felsic extrusive rocks were erupted at ~257-263 Ma. Given that the felsic magmatism occurred in the uppermost lava succession, these dates are interpreted as the termination age of the Emeishan flood volcanism. This termination age is remarkably close to the estimated Middle-Late Permian boundary age (260.4±0.4Ma) and previous dating on mafic intrusions, implying a short duration of a few Myrs of volcanism. Both the temporal coincidence and the rapid eruption lend support to the conclusion that the Emeishan volcanism may be the cause of the end-Guadalupian mass extinction. In addition, study on claystones at GSSP Penglaitan section shows that the claystones around G-LB are divided into two groups, one below the G-LB is derived from mafic source probably derived from the Emeishan LIP, the claystones above the G-LB are felsic source derived from continental Arc of north margin in Tethys. This further constrains the temporal coincidence between the Emeishan LIP and the G-LB.

Palaeoecology of Changhsingian Ambocoeliidae brachiopods from South China, and implications for the end-Permian mass extinction

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The purpose of this paper is to review and decipher the palaeoecology of a group of related and small-sized Ambocoeliidae species including *Paracrurithyris pigmaea*, *Crurithyris tazawaia* nov. sp. and *Attenuatella mengi*. Morphologically, *Paracrurithyris pigmaea*, *Crurithyris tazawaia* and *Attenuatella mengi* are similar in their small body size, ovate outline, thin shell, and an open delthyrium. These characters suggest they possibly may have adopted a pseudoplanktonic life style, at least at some stage during their life cycle. However, it should be noted that *Paracrurithyris*, unlike *Crurithyris tazawaia* and *Attenuatella mengi*, has a smooth shell. Such a smooth and also paper-thin shell of *Paracrurithyis pigmaea* may have enabled the intake of nutritious particles directly into their cavity without having to open its shells. On the other hand, the absence of spines may be indicative of the species' lower or reduced demand for food, compared to species with spines. Using this scenario, our analysis of the morphological differences among the three species would suggest that *Paracrurithyris pigmaea* may have behaved more effectively in gathering food compared to *Attenuatella mengi* and *Crurithyris tazawa*. Additionally, although *Crurithyris tazawaia* and *Attenuatella mengi* have a common external feature (hair-like spines), they differ significantly in outline and muscles, with *Crurithyris tazawaia* having a transversely ovate outline and weaker muscles. These differences may suggest that *Attenuatella mengi* might have a greater mobility for gathering food than *Crurithyris tazawaia*. The above-mentioned hypothesis of function ecology based on shell morphology is supported by the difference of stratigraphical and palaeogeographical distribution of the species concerned here. *Paracrurithyris pigmaea* has a longer stratigraphical range (and survived the peak of the end-Permian mass extinction) than the other two species in South China. *Attenuatella* appears to have had a stronger floating ability, therefore allowing it to attain a much wider geographical distribution globally than the other species. By implication, therefore, the fact that *Paracrurithyris pigmaea* survived the peak of end-Permian mass extinction while *Crurithyris tazawaia* and *Attenuatella mengi* failed could suggest a crush of marine productivity at latest Permian leading to and causing the end-Permian mass extinction.

Changhsingian radiolarian fauna of northern Yangtze basin, South China

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Palaeogeographically, the Yangtze Basin was mainly subdivided into a deep-water trough hosting siliceous sediments and a shallow-water carbonate platform during the Permian. Upper Changhsingian (Upper Permian) Radiolarian faunas from Chaohu, Meishan, Rencunping and Hushan sections have been compared in the diversity and taxonomic composition. The Hushan section is exposed along the north margin of the northeastern Yangtze Basin, and Chaohu, Meishan and Rencunping sections are located south of the Hushan section.

Recently, a number of investigations reveals that radiolarian diversity, abundance and taxonomic composition mainly vary with water depths (Kuwahara 1999; Feng & Ye 2000; He 2006, He et al., 2008), although they could be affected by paleotemperature, palaeosalinity, radiolarian dissolution in water column, ocean upwelling, nutrition and taphonomic factors (Berger 1968; Empson-Morin 1984; Tan & Chen 1999; De Wever *et al.* 2001). Albaillellaria and Latentifistularian forms occurred in deeper water, commonly in outer shelf to basin and Entactinarian and Spumellarian forms commonly in shallow water.

The upper Changhsingian radiolarian fauna includes 24 species in 16 genera at the Hushan section, 15 species in 12 genera at the Chaohu section, 4 species in 3 genera at the Meishan section and 7 species in 6 genera at the Rencunping section. It appears, therefore, that the diversity of upper Changhsingian radiolarian fauna from the Hushan section is higher than the diversity from the sections south of Hushan.

The Albaillellaria and Latentifistularia forms account for 50% of the fauna at the species level in the upper Changhsingian at Hushan section, 30–40% at Chaohu (without Albaillellaria forms), 40% at Meishan, and 21% at Rencunping in taxonomic composition. It can be seen, therefore, the percentage of Albaillellaria and Latentifistularia forms from Hushan is higher than that from the sections south of Hushan. This indicates the water depth was deepening from south to north in the northern part of the Yangtze basin during the late Changhsingian.

The Permian World – Ice House to Extinction and everything in between

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We live during an interglacial episode with rapidly accumulating greenhouse gases, resulting in climate change threatening a sixth extinction. Evidence of our last ice age in the form of tills and glacial striations can be seen in Western Canada where there is also a record of diachronous post-glacial extinction of large mammals prior to the current greenhouse. The 46.5 Myrs of the Permian was very much like the last 46.5 Kyrs of the modern world! In the Early Permian world there are glacial tills or dropstones in deposits in Argentina and eastern Australia. Much later, the latest Permian bears witness to the largest extinction event in Earth history, likely a result of a runaway greenhouse. In between, there are numerous marine and non-marine basins affected by climate change, tectonic events and extinction of various large amphibians and synapsids as well as marine biota. High-resolution biostratigraphy, chemostratigraphy and geochronology are necessary to properly tell this story. A combination of biostratigraphy and geochronology from sections in Bolivia and the Urals is leading to new interpretations regarding evolutionary trends within Sweetognathid conodonts. The result is that glacial-eustatic cyclothems from the Great Basin of the USA, previously correlated with the Artinskian, are now regarded as latest Asselian to earliest Sakmarian, about 5 million years earlier, thereby changing our understanding regarding the timing of Gondwanan glaciation termination. Conodonts from Oman are also changing our views regarding the timing of the opening of the Neotethys Ocean from Early Wordian to around the Kungurian-Roadian boundary, also about 5 million years earlier. This study contributes to the overall Permian plate tectonic history, from the Pangean supercontinent at the beginning to the initiation of breakup toward the end. Diachronous Late Permian extinctions are recognized within a temporal framework determined by new biostratigraphic and carbon isotopic data from the Canadian Arctic. A long-lived boreal *Mesogondolella* lineage is replaced during the late Changhsingian by specimens of *Clarkina* comparable to species and subspecies previously recognized only in the Tethys. This migration event, probably triggered by climatic warming associated with Siberian Trap volcanism, also coincides with the extinction of sponges. Fly ash attributed to Siberian Trap volcanism has been recovered at this same level as well as two lower intervals. Correlation using carbon isotopes indicates that this migration, extinction and fly ash level coincides with the lower part of bed 23 at Meishan, about 200,000 yrs prior to the Tethys extinction - a timeframe to consider as we look ahead to our own changing world.

Diachronous paleobiodiversity change during extinction and recovery – an Arctic perspective

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The Permian (298.7-252.2 Ma) of NW Pangea (Western and Arctic Canada) displays a long term biodiversity loss with extinctions of colonial rugose and tabulate corals at 289 Ma, fusulinaceans at 283 Ma, solitary rugose corals at 263 Ma, brachiopods, bryozoans and echinoderms at 254 Ma and hyalo- and demosponges at 252.4 Ma. This record stands in stark contrast to the Tethys Sea (S. China) where these same biotic groups become extinct between 252.4 and 252.2 Ma. These results point to a complex dynamic between long-term changes in NW Pangea and shorter-term ecologic collapse, ultimately leading to Earth's greatest extinction event. Increasing evidence for the extinction points to Siberian trap volcanism as the trigger for a runaway greenhouse effect by producing immense amounts of CO_2 from degassing and combustion of organic matter, leading to global warming and ocean stratification and acidification. A long-lived boreal *Mesogondolella* lineage, culminating in the Sverdrup Basin with *M. rosenkrantzi* and *M. sheni*, is replaced during the late Changhsingian by specimens of *Clarkina*, comparable to species and subspecies previously recognized only in the Tethys, including *Clarkina* cf. *changxingensis*, *C. hauschkei*, and *C. meishanensis*. This migration event, probably triggered by climatic warming, also coincides with the sponge extinction. Fly ash attributed to Siberian Trap volcanism has been recovered at this same level, as well as two lower intervals. Correlation using new carbon isotopic data indicates that this migration, extinction and fly ash level coincides with the lower part of bed 23 at Meishan China, about 200,000 yrs prior to the Tethys extinction. Most models suggest 95% of marine species become extinct during the end-Permian event, but this biodiversity collapse varies significantly with paleogeography, complicating deep-time comparisons with the modern. Recovery from the extinction is also diachronous with many studies pointing to the lower Olenekian (1 million years post-extinction) and Lower Anisian (5 million years post-extinction) as intervals with increasing diversity of marine biota. However, some shorefaces along NW Pangea display a habitable zone in which available ecologic niches were occupied with diverse and larger size trace fossil makers, almost immediately after the extinction. Biodiversity changes both before and after the Late Permian extinction are variable and highly diachronous, pointing to the need for increasingly higher resolution correlation methods, if we are to truly understand ecosystem dynamics around Earth's greatest extinction.

Completing the Permian time scale: Progress on Cisuralian GSSP definitions

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GSSPs for the base of the Permian, and for Guadalupian and Lopingian stages are all ratified; only three Cisuralian stage GSSP proposals (Sakmarian, Artinskian, and Kungurian) remain. The Permian Time Scale will be complete when these are ratified. Two alternative definitions for the base-Sakmarian (295 Ma) GSSP have been considered, including the chronomorphocline from *Sweetognathus expansus* to *Sw. merrilli* at 115 mab of the Kondurovsky section in the Urals. *Sweetognathus merrilli* is widespread and its first occurrence in Kansas in the upper part of the Eiss Limestone Member is well constrained, but the presence of associated *Streptognathodus* spp. indicates diachroneity within this "lineage". As a result, a second definition at the FAD of *Mesogondolella uralensis* within the chronomorphocline of *M. pseudostriata* to *M. arcuata* to *M. uralensis* at 51.6 mab of the Usolka section is now preferred. This taxon is present at Kondurovsky at 104.2 mab. The best GSSP section for the base-Artinskian (290 Ma) is the Dal'ny Tulkus section in Russia, at a point defined by the FAD of *Sweetognathus* "*whitei*" within the chronomorphocline *Sw. binodosus* to *Sw. anceps* to *Sw. "whitei"* at 2.7 mab of bed 4. The succession of *Sw. binodosus* to *Sw. "whitei"* can also be recognized in the lower Great Bear Cape Formation, southwest Ellesmere Island and in the Luodian Section in South China. The defining species is in quotes because *Sweetognathus whitei* from the Schroyer–Florence limestone cyclothem of the Chase Group, Kansas, co-occurs with species of *Streptognathodus* suggesting an older Late Asselian age. Specimens of *Sw. "whitei"* in the Canadian Arctic and in the Urals are found above high frequency cyclothems indicating a post-glaciation interval. A Kungurian (282 Ma) GSSP located near Mechetlino on the Yuryuzan River has been considered as a possible stratotype for the base-Kungurian at the FAD of the conodont *Neostreptognathodus pnevi* in bed 19, but subsequent tests found very few conodonts and ash beds did not yield useful dates. Therefore the Rockland section in the Pequop Mountains, Nevada, which also demonstrates the chronomorphocline from *N. pequopensis* to *N. pnevi,* is now under study. *Neostreptognathodus pnevi* was thought to be absent from the Tethys, but specimens have now been recovered from the Luodian section of South China; the lack of a chronomorphocline suggests that this is a migration event, indicating only proximity to the Kungurian boundary. Carbon isotopes, strontium isotopes from conodonts and geochronologic dates provide important additional correlation tools.

Clumped isotope geochemistry of Carboniferous brachiopods: Early lessons from a novel paleothermometer

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Carbonate clumped isotope geochemistry is based on the temperature sensitivity of the relative abundance of carbonate ions containing ^{13}C-^{18}O bonds. This emerging method has applications in paleoaltimetry and paleothermometry, and has the potential to elucidate past relationships among temperature, ice volume, and the global carbon cycle. The clumped isotope temperature signal is independent of the isotopic composition of seawater and can be used with traditional oxygen isotope paleotemperature equations to calculate the isotopic composition of ancient seawater. Isotope values of marine carbonates serve as a baseline for evaluating the physical and biogeochemical evolution of Earth, and calcitic brachiopods are a standard material for Paleozoic paleoceanography because of their ability to retain original isotopic compositions and their widespread distribution in the sedimentary record. Here we present carbon, oxygen, and clumped isotope data from Carboniferous brachiopod shells from North America and Russia. The shells were screened for diagenesis by a combination of elemental and textural analysis and cathodoluminescence microscopy. Inferred paleotemperatures from shallow, hypersaline North American epicontinental seas during the late Tournaisian (Iowa) were ~40°C, while early Visean paleotemperatures (Missouri) were somewhat cooler (~35°C). Calculated seawater $\delta^{18}O$ values are ≥1‰, consistent with evaporation in restricted, low-latitude seas. In contrast, Serpukhovian paleotemperatures from the Moscow Basin average 26 to 33°C with calculated seawater values of -2.1 to -0.8‰. The warm temperatures for North American seas are problematic, and partial closed-system redistribution of clumped isotopes cannot be ruled out. Early Pennsylvanian brachiopods from Arrow Canyon, Nevada have anomalously low clumped isotope values (though high $\delta^{18}O$) that suggest high-temperature (>100°C), closed-system alteration during burial. Thus, independent burial history data are essential for clumped (as well as stable) isotopes. Conversely, clumped isotope thermometry may be a powerful tool for evaluating basin-scale burial histories. We also present results from a clumped isotope calibration study for modern molluscs which shows that molluscs deviate from clumped isotope calibration curves developed for other biogenic carbonates (e.g. corals, foraminifera, otoliths). Differences between these calibrations have implications for brachiopod and mollusc-based clumped isotope paleothermometry as well as assumptions of equilibrium isotope fractionation during shell precipitation.

From coralline skeletons to spicules – biosedimentology of sponges in middle Pennsylvanian carbonate platforms, Cantabrian Mountains, Northern Spain

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During the earliest Pennsylvanian, an extended and more than 1500 m thick carbonate platform developed in the northeastern Cantabrian Mountains (northern Spain). It was progressively overwhelmed by carbonate-siliciclastic successions of the Variscan orogen front, until marine sedimentation ceased between late Kasimovian and Gzhelian. In the southeastern part of the mountains a multitude of synorogenic facies occurred throughout the Pennsylvanian. Short-lived and less extended carbonate platforms originated in mixed carbonate-siliciclastic delta settings. Partly, the carbonate rocks were gravitationally redeposited in adjoining flysch basins. Sponges are virtually ubiquitous in the studied Moscovian and Kasimovian carbonate successions. They occur in a wide range of environments and contribute to buildup formation.Coralline demosponges include chaetetids and sphinctozoans. Chaetetids are widely distributed in the Moscovian. They occur in (1) chaetetid level-bottom communities, (2) monospecific chaetetid biostromes, and (3) in spicular sponge-syringoporid-chaetetid buildups. They also form the capping facies of (3) and of beresellid-chaetetid-buildups. Massive, lamellar, digitate and oncolitic growth types occur, partly with intergrown microbial laminae, but preferential growth was in less agitated water. In the late Moscovian, chaetetids were completely replaced by sphinctozoans and became extinct. Both taxa do not co-occur. Sphinctozoans are surprisingly common and diverse and the Cantabrian Mountains seem to be a hot spot for the late Palaeozoic evolution of the group. Delicate to slender taxa, in places forming dense meadows, inhabited eutrophic muddy lagoons. In carbonate dominated lagoonal settings they intermingled with the stick-like growing dasycladacean Anthracoporella. On extended carbonate platforms predominantly large sphinctozoans dwelled in spicular sponge-echinoderm-sphinctozoan buildups below wave base. Only few body fragments of non-coralline demosponges and few hexactinellids are known, but sponge spicules, mostly of demosponge affinity, are widespread. Spicules occur in spicular sponge-syringoporid-chaetetid buildups and in spicular sponge-echinoderm-sphinctozoan buildups below wave base. Common occurrences in algal buildups and in sphinctozoan meadows stress the importance of demoponges also in lagoonal environments. Spicules of the boring sponge Aka from a bryozoan-crinoid-brachiopod buildup were preserved within the excavated galleries.

The enigma of Mississippian pelagic carbonate environments approached by agglutinating foraminifera and carbonate microfacies

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Classification and interpretation of Palaeozoic pelagic carbonate environments are hampered by assumed monotony of carbonate facies and missing of generalized facies models, although varying basin topography, oxygen supply and bathymetry in general have to be considered. Based on case studies from the late Mississippian of Menorca (Balearic Islands, Spain) and the Cantabrian Mountains (northern Spain) we show that agglutinating foraminifera are an important tool for an improved interpretation. Their usage is based on the Gutschick-Sandberg model, which differentiates three biofacies: (1) Saccaminid biofacies – 'upper platform slope', quite diverse fauna, predominating encrusting taxa (*Tolypammina*) and globular, often spined taxa (e.g. *Pseudoastrorhiza*, *Thurammina*); (2) *Hyperammina* biofacies – 'middle platform slope', low diverse, predominating tubular species of *Hyperammina*; (3) *Reophax* biofacies – basin, oxygen-deficient, with notable occurrences of "*Reophax*". An additional *Ammodiscus* biofacies (*Ammmodiscus* + *Hyperammina* + *"Reophax*") is recognized between (2) and (3) in less oxygen-deficient basinal settings. In Menorca, an about 10 m thick series of late Viséan carbonate pelagites with intercalations of mostly red shales developed between black bedded cherts below and a shale-greywacke succession above. Limestones consist exclusively of thin-bedded, light grey radiolarian mudstone. Almost constant presence of "*Reophax*"and *Ammodiscus* indicates predominance of the *Ammodiscus* biofacies. Associated *Hyperammina* are low diverse. Mostly tiny, extremely thin and long morphotypes and forms with restricted aperture prevail. Both are not indicative of the proper *Hyperammina* biofacies. Rare, commonly ramiform, dwarfed conodont elements and blind trilobites confirm the ultrapelagic setting. Nevertheless, composition of the foraminifer fauna varies, indicating gradually shifting environments. In the Cantabrian Mountains variegated pelagic limestones and a middle bedded chert member form the some thirty meter thick, predominantly Viséan Genicera Formation. In the type section at least seven carbonate microfacies types are discerned, including common pelagic bioclastic wackestone, partly with iron stromatolites, radiolarian mudstone, and microbial mudstone. Based on repeated changes from *Hyperammina* to "*Reophax*" biofacies conspicuous deepening at the base and the top of the formation, and subordinate depth variations within the formation are discerned and correlated with microfacies. Only debris-flow sediments in the upper part of the lower member pretend less deep water of the Saccaminid biofacies.

Permian--Triassic palaeoenvironment inferred from palynofacies data of Amb, Salt Range, Pakistan

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Proposed causes for the end-Permian mass extinction include palaeoenvironmental changes related to the emplacement of the Siberian Traps, such as global warming and widespread marine anoxic conditions. In order to find new evidence for environmental changes, the content and composition of the particulate organic matter (POM) of one of the key regions for the Permian-Triassic time interval has been studied and the preliminary results are presented. All 30 prepared samples from the Amb section in the Salt Range (Pakistan) were productive and yield exceptionally well preserved organic particles including spores and pollen.

The studied interval encompasses the uppermost part of the Permian Chhidru Formation and the basal part of the Early Triassic Mianwali Formation. POM assemblages of the Chhidru Formation are dominated by terrestrial phytoclasts. Within the sporomorph group bisaccate pollen (especially striate bisaccate pollen) are dominant. Acritarchs are rare or even absent in the basal part of the studied interval of the Chhidru Formation and increase slightly up-section towards the formational boundary. Within the Kathwai Member, the basal member of the Mianwali Formation, acritarch numbers reach very high abundances indicating transgression near the formational boundary. Sporomorph percentages of the total POM assemblage are similar compared to the underlying Chhidru Formation.

Amorphous organic matter, which could indicate the presence of low oxygen levels in the depositional environment, has been found only in negligible quantities. On the contrary, the particulate organic matter content indicates well oxygenated conditions throughout the studied Permian-Triassic boundary interval.

Reduviasporonites, which is a prominent component of various other Permian-Triassic successions, has not been observed so far.

Biotic and Environmental change through the Mississippian-Pennsylvanian boundary in Panthalassan oceanic atoll, the Akiyoshi Limestone, SW Japan

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The Mississippian-Pennsylvanian (M/P) boundary is well known as a representative of global climate change from greenhouse to icehouse. The Akiyoshi limestone, a Panthalassan oceanic atoll in the Late Paleozoic, preserves some characteristic deposits caused by emergence events, and one of them was originated from the eventual cool down through the M/P boundary.

The limestone succession in the measured section was stratigraphically divided into three parts based on sedimentological facies: the bioclastic grainestone/packstone and oolitic grainstone facies (the lower part), the rudstone/floatstone facies with black pebbles and tidal flat deposits (the middle part), and the boundstone facies constructed by frame building metazoans such as rugose corals and chaetetids (the upper part). The bioclastic packstones altered by freshwater diagenesis are in the uppermost part of the lower facies, and the black pebbles are concentrated in the lowermost part of the middle facies, which are typical evidences of the emergence events.

According to the conodont and foraminifer study, these fossil assemblages change distinctively from the Serpukhovian to the Late Bashkirian characterizing the stratigraphic level of the emergence event. The typical tidal flat deposits occur in the middle facies, which was characterized by lime-mudstone to wackestone with poor and simple biota composed only of ostracods. These remarkable deposits suggest that a wave resistant system was constructed by framework-builders around the edge of flat basement which appeared after the emergence event through the M/P boundary. The boundstone facies of the upper part contain abundant reef frameworks constructed by chaetetids and compound rugose corals. The environmental change of the M/P boundary performed an important role in comprising the Akiyoshi Oceanic Atoll.

There was a shift of +1‰ in the bulk analyses on carbon isotopic composition through the M/P boundary, which is harmonious with the result reported by Mii *et al*. (2001). This Panthalassan oceanic atoll recorded the global climate change in oceanic environment at the M/P boundary, which triggered the construction of a reef complex by skeletal metazoans, such as chaetetids, producing an atoll during the Late Carboniferous.

Palynostratigraphy and palaeoenvironments of the Mississippian to Pennsylvanian succession in the subsurface, northern Saudi Arabia

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A stratigraphic test well recently drilled in northern Saudi Arabia, produced over 1500 feet of continuous conventional core, part of which extends through the Mississippian and continues into the Pennsylvanian. It is an important reference section for palynological and sedimentological study of pre- and post-Hercynian Carboniferous sediments in the region.

The Mississippian succession comprises, at the base, a series of early-middle Tournaisian red clastic sediments of the uppermost part of the Jubah Formation. This succession is characterized by the C6 Palynozone, followed conformably by late Tournaisian to early Visean mudstones of the lower Berwath Formation, containing the C5 Palynozone. These organic-rich mudstones are marginal marine for the most part, but show a marine maximum at the top, marked by a gamma ray peak (C10 mfs), which is characterized by an influx of prasinophytes, in the lower part of the late Visean-early Serpukhovian C4 Palynozone. The upper Berwath Formation is consistently more silt- and sand-prone, but still shallow marine. Sedimentology indicates fluvial distributary channel, bay, lagoonal and tidal deposits. The youngest upper Berwath Formation encountered so far is of late Serpukhovian age containing the C3B Palynosubzone, in which the oldest rare monosaccate pollen occur with common fern spores, reflecting a warm moist climate.

The Pennsylvanian Juwayl Formation of glaciogenic origin lies unconformably (Hercynian Unconformity) over the Mississippian Berwath Formation. Despite a limited depositional hiatus the palynofloral change across this boundary is significant, reflecting the major onset of Gondwanan glaciation. Warm climate assemblages are replaced by low diversity, cold climate spores of the Bashkirian C3A Palynosubzone, combined with spores and acritarchs reworked from Lower Silurian to Carboniferous. Sedimentology of the lower part of the Juwayl Formation show evidence of braided fluvial, at the base, extending to lacustrine (including diamictites) and estuarine to shallow marine deposition. The marine incursion probably represents a minor sea level rise following glacial retreat. It is followed by a palynologically barren, terrestrial succession, which is correlated to a Moscovian spore assemblage in a nearby well, reflecting a change to warmer and more moist climatic conditions. Comparison with the Carboniferous succession of central-southern Saudi Arabia and Oman implies that glacial retreat in northern Saudi Arabia occurred earlier (middle Pennsylvanian) than in the south (latest Pennsylvanian-Early Permian).

Carboniferous foraminiferal faunal succession of upper-slope facies in the Yangtze Carbonate Platform: The Dianzishang section in Guizhou Province, South China

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The Yangtze Carbonate Platform of South China develops extensive Late Paleozoic successions, ranging from shallow-platform facies to basinal ones. In the Carboniferous on this platform, foraminifers (mainly fusulines) occur abundantly in shallow-platform areas, whereas in a deeper-basin environment, conodonts are essentially dominant. We studied a Carboniferous carbonate section showing slope facies to understand the general characteristics of lithostratigraphy and foraminiferal biostratigraphy of the Yangtze Carbonate Platform.

The studied Dianzishang section is located about 120 km SW of Guiyang in Guizhou Province of China. The measured part of the section, exposed along the Kongdong River, is about 82 m thick and consists mainly of well-bedded limestone turbidites. Their graded beds often contain coarse bioclasts, which were derived from shallow platform areas. Siliceous (cherty) bands/nodules and slumping beds are commonly observed. Based on these lithological features, the Dianzishang section is considered as representing an upper-slope environment on the Yangtze Carbonate Platform.

Foraminifers are abundant in this section, with 21 identified genera. In the lower part of the section, up until about 27 m level from the base, *Valvulinella* occurs continuously, whilst *Pseudostaffella* (s.s.) is recognized in the uppermost part of the section. These data suggest that the section covers from the Visean to the middle Bashkirian. In addition to these foraminifers, *Eolasiodiscus* is found in about 49 m level of the section, which indicates that this level is already the Serpukhovian. Moreover, we identified a species probably referable to *Globivalvulina bulloides* in about 61 m level from the base. This could potentially characterize the base of the Bashkirian in this section. These levels, however, are recognized within slumping intervals, which hampers detailed recognition of base-Serpukhovian and base-Bashkirian of this section.

For the Carboniferous chronostratigraphy of the Yangtze Carbonate Platform, foraminiferal (fusuline) biostratigraphy is the primary tool for shallow-marine successions, whereas in more basinal areas, conodonts have been employed for this purpose. Upper-slope successions, in which both foraminifers and conodonts generally occur abundantly, are thus important to establish rigid chronostratigrapic framework of this platform. In this study, we have presented an example of lithostratigraphy and foraminiferal faunal succession of upper-slope facies in a Carboniferous succession of the Yangtze Carbonate Platform. It provides new litho- and biostratigraphical aspects for upper-slope facies sediments in the platform.

Microbial sediments occurring after the end-Devonian extinction event on the Hunan Platform, South China

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A post-Hangenberg Event microbial sediment overlies disconformably the bauxite-clay beds or fenestral limestone of the uppermost Devonian Mengguanao Formation in the central and southern Hunan Province, southern China. It is restricted to shallow water carbonate facies and formed during the beginning of the earliest Carboniferous transgression. The overlying strata consist of well-bedded wackestones to packstones followed by undulating thin-bedded limestones intercalated with shales, containing abundant macrofossils. The upper boundary of the microbialite beds coincides with the occurrences of Siphonodella levis and S. sinensis, which are considered as markers of the Carboniferous in the shallow-water facies. and have been correlated with the sulcata and duplicate zones of pelagic facies, respectively.

The microbial sediments, 7 to 30 m thick, consist mostly of oncolites and part intraclasts with stripped and nodular appearance in all the studied sections. Two types of oncoids are distinguished: single-nucleus and multi-nucleus with micritic and clotted laminae. The bright and dark layers in clotted laminae are formed by accumulation of a large number of spheroids, 85 μm in outer diameter. The growth direction of 52 cap-shaped oncolites was measured and shows a high ratio of subvertical upward growth, indicating an in situ formation of the oncoids. Intraclasts in packstone and grainstone vary greatly in size, and are poorly sorted, and are characterized by organic-rich, clotted fabrics. Occurring together with oncolites, the intraclasts exhibit graded rhythms of alternately coarse and fine grain sizes or large and small quantities. These grained carbonate facies are not microbialites deposited in situ but were accumulated by fragments, eroded and transported from lithified or partly lithified microbial mats.

The earliest Carboniferous microbial sediments in Hunan are similar to those occurring after the mass extinction in the latest Ordovician and the end-Permian. Thus, the microbialite resurgence in association with low diversity ecosystems must be a common feature of post-extinction. Similar microbial facies has also been found in the Guangxi and Guizhou Provinces of southern China. Further study of these sections promises to provide again a window into the patterns and processes of marine ecosystem recovery following the mass extinction events.

Astronomical forcing of marine sediment cycles during the Permian-Triassic Boundary Interval

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The mass extinctions near the Permian-Triassic boundary (PTB) resulted in the greatest dying of life on Earth. The cause of this catastrophe remains enigmatic. High-resolution chronology is crucial to understanding the recorded pattern of biotic evolution and possible causes for the extinctions. Magnetic susceptibility data from Shangsi, South China shows evidence for astronomical forcing through the PTB interval, including the presence of strong 405-kyr cycling. Radioisotope dating combined with 405-kyr eccentricity tuning provides a high-resolution absolute timescale through the PTB interval. The 405-kyr and radioisotope dating combined with 405-kyr tuned MS series from Shangsi show that the 405-kyr-cycle predominates throughout the PTB interval. In contrast, ~100-kyr cyclicity dominates the Permian segment. Here, 100-kyr-scale MS maxima correlate with high-amplitude precession-scale MS variations. Minima in the ~1.5-Myr, 405-kyr and ~100-kyr cycles converge at 252.6 Ma, approximately 200 kyr before the onset of the main mass extinction near the PTB. In the Triassic aftermath, the recorded astronomical signal is different, with predominant 405-kyr cycles; 100-kyr cyclicity strengthens again 2 Myr after the minima occurred. This pattern indicates a change in the response of the depositional environment (or magnetic susceptibility) to astronomical forcing before and after the mass extinction interval.

The astrochronology interpolates the timescale between the radioisotopically determined absolute dates; this facilitates estimation of ages for specific events in the PTB crisis, including magnetic reversals, biozone boundaries, and the mass extinctions. Future efforts will focus on confirming the astrochronology presented here through correlation with time series data from other sections (e.g., Meishan), and renewing discussions on biotic extinction and evolution rates in order to sharpen the profile of the PTB killing mechanism(s).

Timing of the Permian–Triassic boundary mass extinction interval: Evidence from global correlation of astronomically forced marine records

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The cause of the great Permian-Triassic boundary (PTB) mass extinctions remains unknown. A crucial step in identifying the cause involves a precise timing of the "Mass Extinction Interval" (MEI) in order to reconstruct the pattern of biotic evolution and the chronologic record of potential triggers. Here we present an estimate of the PTB MEI duration based on astronomical tuning of multiple cyclic sedimentary records. Magnetic susceptibility data from an extended record of the Shangsi section, South China, provides evidence for strong 405-kyr orbital eccentricity forcing throughout the PTB interval. This allows development of an astrochronology for the PTB interval based on the 405-kyr orbital eccentricity metronome that has been proposed for the Mesozoic timescale. Radioisotope dating combined with 405-kyr astronomical tuning provides an absolute timescale through the PTB interval at unprecedented high resolution. An estimated ~700 kyr duration for the MEI at Shangsi based on the 405-kyr tuning is supported by eccentricity-tuned estimates of three other sections in China (Meishan, Huangzhishan, and Heping), and two Alpine sections (Gartnerkofel, Austria and Bulla, Italy) from the eastern and western margins of the Palaeo-Tethys Ocean during PTB time. This suggests that the PTB mass extinctions were not the result of a single catastrophic event. Siberian trap volcanism was largely synchronous with the MEI and appears to be the most likely cause of the mass extinctions; astronomically paced climate change may also have played a role.

An unusual *Verbeekina* fauna from Baoshan Block, SW China

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The Permian fusulinids in Baoshan Block, SW China are dynamic in paleobiogeographic affinity and especially significant as transitional faunas between warm-water Tethyan and cool-water Gondwana areas during Early-Middle Permian. A *Verbeekina* fauna has been newly discovered from the upper Shazipo Formation of Xiaoxinzhai section in southern Baoshan Block. Systematic study documents 12 species of 5 genera in this fauna, such as *Verbeekina verbeeki, V. americana, Rugososchwagerina subrotunda, Sumatrina annae brevis, Pseudodoliolina pseudolepida* and *Rugosochusenella*?. Judging from its faunal composition and stratigraphic occurrence, this fauna is late Murgabian to Midian (approximately Wordian to Capitanian) in age.

The discovery of this fauna again substantiates the presence of warm-water Families Verbeekinidae and Neoschwagerinadae in the Baoshan Block. Furthermore, these families became predominantly abundant and diverse in this fauna, compared with earlier Permian fusulinids in this Block. The total generic diversity of this fauna, however, is still much lower than coeval tropical fusulinids. Therefore, the Baoshan Block probably provided ameliorated but not optimal environment during late Murgabian to Midian for fusulinids which are best adapted for warm shallow water.

Another distinct feature of the studied fauna is the unusual abundance of *Verbeekina* individuals. This could be easily confirmed by outcrop observation and inspecting thin sections. *Verbeekina* specimens are overwhelmingly abundant and represent one main component of limestones yielding the studied fauna, whereas tests of associated genera are much rarer. Such abundance feature together with aforementioned low generic diversity possibly implies relatively stressful environment for fusulinids to live, as faunas with similar characteristics have been reported from temperate water area.

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Littoral survival benthic communities from South China in the aftermath of the end-Permian mass extinction

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After the end-Permian mass extinction, bivalves became the dominant species of shallow benthic community. The Permian-Triassic interval is crucial for studying the composition and environmental conditions of benthic community. The Gaoqiao and Zhongzhai sections in South China which were both onshore environment in the earliest Triassic deposited clastic sediments and yield abundant benthic fossils.

The Permian-Triassic boundary in Zhongzhai section is defined by the first appearance of Conodont Hindeodus parvus. Bivalve *Pteria ussurica variabilis*-*Claraia stachei* and *Claraia wangi-Claraia griesbachi* assemblages can be recognized in the Griesbachian strata. The main taxa of the *Pteria ussurica variabilis-Claraia stachei* assemblage include *Pteria ussurica variabilis*, *Eumorphotis teilhardi*, and *Claraia stachei*. The *Claraia wangi-Claraia griesbachi* assemblage is dominated by *Claraia guizhouensis*, *Claraia griesbachi* and *Claraia dieneri*. The survival community in Gaoqiao is dominated by bivalves and ostracods. Bivalve *Pteria ussurica variabilis-Eumorphotis venetiana* and *Claraia wangi-Claraia concentrica* assemblages are recognized. The *Pteria ussurica variabilis-Eumorphotis venetiana* assemblage is dominated by *Pteria ussurica variabilis* and *Eumorphotis venetiana*, while *Claraia wangi-Claraia concentrica* assemblage is mainly composed of *Claraia concentrica, Claraia wangi, Claraia griesbachi, Claraia dieneri* and *Leptochondria virgalensis*. Most taxa of the four assemblages are epibyssate and suspension-feeders.

Bivalves were associated with *Microconchus* and Ostracoda in clastic deposits of earliest Triassic. The coiled tubes *Microconchus*, which were previously considered as *Spirorbis*, are attached to the shell of bivalves. *Microconchus* can also be found in the basal part of Triassic from western Tethys. It is an epibiont suspension feeder, and strongly euryhaline species. Ostracoda *Hollinella tingi* and *Langdaia suboblonga* are also abundant in the earliest Triassic with high dominance and low diversity. *Hollinella tingi* and *Langdaia suboblonga* were filter-feeders indicating dysoxic to anoxic marine environments.

Changes in biogenic Si and dust flux in the Panthalassic Ocean during the Early Triassic "Chert Gap"

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"Chert Gap", which is characterized by the disappearance of radiolarian chert from latest Permian to Early Triassic, is widely considered as resulted from decreased productivity of biogenic Si in the pelagic realm at the end-Permian mass extinction. However, biostratigraphy and δ13Corg stratigraphy of the lower to middle Triassic pelagic sequence in Inuyama, Japan suggests that the sedimentation rate of the Lower Triassic shale and siliceous shale is higher by factor of 2 to 5 than that of the Middle Triassic bedded chert sequence (Sakuma et al., in review). In order to estimate the temporal changes of biogenic Si and terrigenous material fluxes, we established cyclostratigraphy for Lower Triassic siliceous shale-shale sequence, according to the method described by Ikeda et al. (2010), and continuously measured major element composition of the sequence using XRF microscanner. The estimated terrestrial material flux during Smithian was higher by factor of 5 than that during Spathian to Ladinian. The biogenic Si flux during Smithian was also higher by factor of 2 than that during Spathian to Ladinian. This result is contrary to the conventional wisdom of decreased biogenic Si flux during “Chert Gap”. Our results suggested that “Chert Gap” resulted from the dilution of biogenic Si by anomalously high terrestrial material flux in the low latitude pelagic Panthalassa.

The equilibrium line altitude as a control on Gondwana glaciation during the late Paleozoic Ice Age

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Much attention is given to environmental drivers during the late Paleozoic Ice Age (LPIA). However, the role that the equilibrium-line altitude (ELA) had on initiating and ending LPIA glacial events is undocumented. The ELA marks the altitude on glaciers that delineates areas of annual net accumulation from net ablation. The land surface must reside above the ELA for glaciers to form. Therefore, glaciation results from lowering of the ELA during global cooling or by tectonically elevating the landscape above the ELA. Latitude and precipitation also influence the ELA. LPIA glacial events varied in time, space, and volume across Gondwana; here, we speculate on how the ELA influenced glaciation during the LPIA.

The LPIA began in western and southern South America with the growth of small ice centers during the Viséan and Namurian. In western Argentina, alpine glaciation and glacimarine deposition occurred in fjords cut into the Protoprecordillera, a fold-thrust belt that developed during subduction of Chilenia beneath the Cuyania crustal block. Glaciation occurred due to uplift of the range above the ELA. Termination of glaciation occurred when the range collapsed below the ELA due to a transition into an extensional tectonic regime during the late Namurian.

During the Late Pennsylvanian and Early Permian LPIA acme, extensive glacimarine deposits indicate that glaciers reached sea level corresponding to a lowering of the ELA due to global cooling. An abrupt contact between glacial and postglacial deposits across polar and sub-polar Gondwana records global warming and the Sakmarian retreat of glaciers out of the basins.

Three additional glacial events in Eastern Australia, represented by small ice centers, ended in the Capitanian. The magnitude of global cooling during these events is debatable as there is an absence of glacial indicators in basins located farther south during the Permian (than the eastern Australia basins) in Tasmania, Antarctica, South Africa and Patagonia. From the late Sakmarian until the Capitanian, the Transantarctic Basin, which resided over the South Pole, was characterized by widespread deposition of fluvial coal measures; whereas glaciated eastern Australia lay outside of the polar circle. An absence of glacial deposits within the South Polar Circle indicates an elevated ELA located well above sea level. This suggests that severe global cooling was not the cause of the 3 Australian glaciations, but that conditions specific to eastern Australia drove these late phase events.

Emerging polar view of the late Paleozoic ice age as interpreted from deep-water, distal, glacimarine deposits in the Tepuel-Genoa Basin, Patagonia, Argentina

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The Pampa de Tepuel and Mojón de Hierro formations in the Tepuel-Genoa Basin of Patagonia constitutes a ~4000 m thick Mississippian (late Viséan) to Permian (Artinskian) succession that may contain as many as 6 glacimarine and glacially-influenced marine horizons. During much of the late Paleozoic, Patagonia was located near or within the South Polar circle. Thus, these strata represent the thickest and most complete record of polar conditions for the late Paleozoic ice age (LPIA). Recent paleomagnetic interpretations by Pankhurst et al. (2006), Ramos (2008), and Rapalini et al. (2010) suggests that Patagonia was a separate crustal block during much of the Paleozoic and that it collided with Gondwana during the latest Pennsylvanian and Early Permian. In these scenarios, the Tepuel-Genoa Basin was interpreted by López Gamundi and Breitkreuz (1997) as a foreland basin and by Forsythe (1982) and Ramos (2008) as either a forearc or a peripheral foreland basin. Regardless of tectonic scenario, rapid basin subsidence was required to produce such a thick Carboniferous to Permian succession.

Strata of the Pampa de Tepuel and lower portion of the Mojon de Hierro formations consist of thick mudrocks; discontinuous blocks of sandstone; folded sandstones; lonestone-bearing shales/rhythmites; thin bedded sandstones; massive sandstones; massive, stratified, and thin-bedded diamictites; and graded- and reverse-graded, clast-supported conglomerates. These units are here interpreted as hemipelagic, mass movement (slide blocks and slumps), iceberg rafted, turbidite/bottom current, sandy debris flow, muddy debris flow, meltwater plume, and grounding line fan deposits. Analysis of grooved, striated, and polished surfaces within the Pampa de Tepuel Formation suggest formation as iceberg keel marks, slide block glide planes, and due to Cenozoic tectonism. Horizons of slump/slide blocks, dropstones, and diamictites interspersed with thick successions of hemipelagic deposits suggest that sedimentation occurred primarily in deep water beyond the basin's shelf-slope break and that during possible relative sea-level low stands, clastic systems, including glaciers, shed clastics into the deep basin. Fossil-bearing horizons occur above "low-stand" deposits and may represent condensed zones that developed during "transgression/high-stand" and/or retreat of glaciers and clastics across the shelf. Plant fossils and deltaic deposits located high in the Mojón de Hierro and in the Río Genoa formations indicate shallowing of the basin later in the late Early Permian.

Provincial response of foraminifera to global extinction: Late Guadalupian (Permian) giant fusuline case in mid-Panthalassa

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The Guadalupian paleo-atoll limestone (Iwato Formation) in SW Japan was primarily formed in low-latitude mid-Panthalassa and later tectonically accreted to South China (Japan) margin during the Jurassic. The present biostratigraphic study clarified that the Iwato Formation consists of 5 biozones; i.e. four fusuline assemblage zones (Assemblage zone 1 to 4) and a barren interval on the top. Assemblage zones 1 to 4 correspond to the *Neoschwagerina craticulifera* Zone, *N. margaritae* Zone, *Yabeina globosa* Zone, and *Lepidolina multiseptata* Zone of the conventional Tethyan fusuline stratigraphy, respectively. The former two are correlated with the Wordian, whereas the latter two and the barren interval to the Capitanian in Texas. As to the extinction of large-tested fusulines at the end of the Guadalupian, the following significant aspects were newly clarified in the biostratigraphy and paleobiogeography of the Permian fusulines. The stratigraphic relationship of the *Lepidolina*–dominant interval above the *Yabeina*–dominant one was confirmed for the first time after the long-time controversy owing to the absence of their co-occurrence from a single section. Furthermore, the occurrence of the unique taxon *Lepidolina kumaensis* Kanmera was detected for the first time in mid-oceanic paleo-atoll limestone. This species was known to occur mostly from conglomeratic rocks enriched with terrigenous clastics, in a sharp contrast with *Yabeina* species dominant in pure carbonates. The age of the *L. kumaensis*-bearing horizon was also constrained to the Capitanian. With respect to the migration history of a mid-oceanic seamount, the development of the two coeval fusuline biogeographic territories in the low-latitude mid-Panthalassa domain, i.e., the *Yabeina* territory on the south and the *Lepidolina* territory on the north, was supported. The boundary between these two territories likely lay around 12 degree in the southern hemisphere according to the latest data of paleomagnetism. The new facts suggest that the extinction of large-tested fusulines occurred simultaneously throughout the tropical-subtropical domains of the Permian Panthalassa, regardless of the fusuline provincialism and probably of latitude difference.

Oceanic euxinia, cyanobacterial bloom, and land vegetation collapse and recovery during the two-step mass extinctions spanning the Permian-Triassic boundary

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The largest mass extinction occurred in oceans and lands at the end of the Permian, 252 million years ago. Oceanic euxinia, cyanobacterial blooms, and land vegetation collapse spanning the mass extinction have been reported. However their relationship has not yet clarified. We conducted a high-resolution study on sedimentary organic molecules at the Huangzhishan section located at 40 km southeast of the GSSP Meishan section, South China, deposited in shallow-water platform. In this section, fossil records indicate that marine mass extinction across the Permian-Triassic (P-T) boundary includes two-step extinctions with a span of hundreds of thousand years, similar to those of the Meishan section. Here we report new findings on euxinic, bacterial, and land vegetation indices of organic molecules in the Huangzhishan section. The results show that (1) oceanic euxinia at the end of the Permian coincided with the first mass extinction and terrestrial vegetation collapse, (2) after the first extinction cyanobacteria bloomed in the ocean, and land vegetation recovered from lichens to ferns then to conifers but collapsed near the P/T boundary, and (3) in hundreds of thousand years after the second marine extinction above the P/T boundary, the second bloom of cyanobacteria occurred in the ocean, and land vegetation recovered from ferns to conifers. The two terrestrial vegetation collapses coincided with spikes of photic zone euxinia indicator. Therefore, hydrogen sulfide which accumulated in the ocean may have released to the atmosphere triggering acid rain, leading to the terrestrial vegetation collapses. This research will help to expect phenomena caused by global warming in the near future.

Changing characters of the depositional environments during the Early Triassic in the Lower Yangtze Region, East China

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The causes and mechanisms for the end-Permian mass extinction and subsequent complex biotic recovery during the Early Triassic have puzzled geologists and palaeontologists for more than two decades. In the Lower Yangtze region, East China, the Lower Triassic successions are extensively exposed across the entire region, and thus may record biotic recovery progress from the most devastating crisis of Earth life. The Global Stratotype Section and Point (GSSP) for the Permian-Triassic (P-Tr) boundary and one of the Induan-Olenekian GSSP candidates are both located in this area. Many marine fish and reptiles (Ichthyosaurus) fossils have also been found from the Lower Triassic successions of this region. Stratigraphically, the Griesbachian (lower Induan) is composed mainly of alternating yellowish, thin-bedded calcareous marls and shale with a few muddy limestone layers. Both the Dienerian and Smithian comprise grey, thin- to medium-bedded muddy limestone and calcareous mudstone with marls and limestones increasing up the section. In addition, the thin-bedded dolomite or dolomitic limestone also characterizes the Smithian successions. The Spathian sequence consists of grey, medium- to thick-bedded limestones and dolomitic limestones, in which wavy cross-beddings, hummocky cross-beddings, brush surfaces, carbonate pebbles, and ooids are rather common from place to place.

Remarkable changes of sedimentary features up the section show a shallowing cycle towards the top of the Lower Triassic in this vast region. Lateral facies changes cross the studied areas indicate that the lower ramp and intra-platform basins were very common in the Lower Yangtze seas during the Induan times. Palaeo-environments diversified during the Smithian-Sapthian interval and varied from carbonate platforms, ramps to even lagoon environments. Frequent changes in depositional environments might have provided sufficient nutriments for biotic rapid recovery during the late Early Triassic times in the Lower Yangtze seas.

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The Permian of the Baoshan Block, western Yunnan, China: sedimentary development and basin configuration

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The Baoshan Block in western Yunnan, China is a continental block with relatively well-developed Cambrian to Triassic sedimentary successions. It is separated from the Changning-Menglian Belt to the east by the Lancangjiang, Kejie and Nandinghe faults, and from the Tengchong Block to the west by the Nujiang Fault. The block diminishes and becomes unnoticeable northwards, and extends southwestwards into the Shan states of Myanmar. The Baoshan Block is considered to be the Chinese portion of a greater block which Jin (1994) named the Baoshan-Shan Block.

The mid-Carboniferous (Namurian) uplift interrupted the sedimentation and deformed the relief of the Baoshan Block. The basin to accommodate Permian sediments was of an uneven and tilted floor. It extended from the northern to southern part of the block. Meanwhile the southwestern part of the block remained in an emerged state.

The Permian succession starts with the clastic Dingjiazhai Formation, which rest unconformably on Lower Carboniferous limestones in the northern part and Devonian siliciclastics in the southern part of the block. The three-fold succession of diamictite—pebbly mudstone—dark mudstone and shale of the formation is commonly interpreted as representing deposits of glacial—deglacial—post-glacial periods in a marine environment. Together with the presence of cold/cool-water faunas of Gondwana-affinity in this formation they led to the understanding that the Baoshan Block remained at the northern margin of Gondwana in the Early Permian. Deposition of limestones started around the Sakmarian/Artinskian boundary in the top part of the Dingjiazhai Formation. But it was immediately terminated by the eruption of the Woniusi Basalts.

The Woniusi Basalts filled in the lowes of the basin, with a thickness of almost 700 m in the northern part and about 500 m in the southern part. The southwestern part of the block lacks records of basalts. This eruption resulted in a rather flat surface, which was weathered for some time before the next sedimentation.

Coastal clastic sediments, mainly red beds, formed on a weathered surface of the Woniusi Basalts (northern and southern parts) and Devonian limestones (southwestern part). This is a time of warmer climate and lowest relief of the Baoshan Block since the beginning of the Permian.

Carbonate formations appear with the next transgression in the early Wordian, which flooded the whole Baoshan Block and the adjacent Shan states. The carbonates are conformable with the underlying clastics. This round of carbonate deposition sustained through to at least the Middle Triassic in most places of the Baoshan Block with variations in bed thickness and lithology. The middle Permian to Middle Triassic hiatus first described by Geological Survey of Yunnan (1980) can now be eliminated based on the studies in recent years.

Carbon and oxygen isotope geochemistry of the Guadalupian-Lopingian boundary

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The Guadalupian-Lopingian (G-L) boundary represents one of the major extinction events in Earth history. Carbon isotopes of whole rock carbonate and oxygen isotopes of conodont apatite were studied in the Tieqiao and Penglaitan G-L boundary sections (South China) to document changes in the carbon cycle and palaeoclimate during this critical time interval. In contrast to earlier studies, we observe no negative excursion in δ13C in the middle Capitanian. A 1‰ increase is registered in the J. xuanhanensis to *J. granti* Zone, followed by a decrease of 1‰ within the *C. postbitteri postbitteri* Subzone and a 2‰ decrease in the *C. dukouensis* to *C. assymmetrica* Zone. Oxygen isotopes of conodonts were studied on mono-generic hindeoid and gondollelid assemblages. Oxygen isotope ratios of gondolellids are higher in comparison to oxygen isotope ratios measured on hindeodids supporting earlier interpretations of gondollelids to have lived in cooler and thus deeper waters in comparison to hindeodids. Oxygen isotopes of gondollelids suggest warming of ambient water temperature of about 4° C in the late Capitanian (*J. postserrata* to *J. granti* Zone), cooling of 6 to 8° C across the G-L boundary and in the earliest Wuchiapingian and again significant warming in the Wuchiapingian (*C. dukouensis* to *C. liangshanensis* Zone). These temperature variations are difficult to explain by climatic changes induced by Emeishan volcanism. Changes in sea level seem to parallel changes in water temperature suggesting that changes in water depth and thus water temperature potentially in combination with superimposed climatic changes may have been responsible for the observed temperature changes. This study documents that oxygen isotope studies on Permian conodonts should be performed on mono-generic conodont samples and that oxygen isotopes measured on conodonts not only provide valuable palaeoclimatic information but may also help to constrain the life habitat of the various conodont taxa.

Climatic warming in the latest Permian and the the Permian-Triassic mass extinction

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Oxygen isotopes of Late Permian and Early Triassic conodonts were studied to document climatic changes in the latest Permian and across the Permian-Triassic boundary (PTB). Oxygen isotope records measured on gondollelid conodonts from the Meishan GSSP section (Zheijang Province/South China) decrease by around 1‰ at the transition of the *Clarkina changxingensis* to *Clarkina yini* Zone translating into warming of 4° C. In the *Clarkina yini* Zone, *Clarkina* and *Hindeodus* P1 elements as well as *Clarkina* P1 and ramiform elements have comparable oxygen isotope ratios indicating that *Hindeodus* and *Clarkina* were thriving in comparable water depths with comparable temperatures. In the *Clarkina meishanensis* to *Hindeodus changxingensis* Zone, oxygen isotopes of *Clarkina* and *Hindeodus* decrease by 1.5 and 2‰, respectively, translating into significant warming of low latitudinal surface waters of 6 and 8° C. This significant temperature increase is confirmed by oxygen isotope analyses on conodonts from the Shangsi section (Sichuan Province/South China). The minor temperature increase recorded by *Clarkina* suggests that *Clarkina* migrated to slightly deeper and thus colder waters in conjunction with the sea level rise in the latest Changhsingian. No changes in palaeotemperature are observed at the PTB.

The negative oxygen isotope shifts coincide with negative shifts in carbon isotopes suggesting that changes in the global carbon cycle potentially triggered by Siberian trap volcanism and related thermal metamorphism of organic carbon rich sediments resulted in higher greenhouse gas levels and climatic warming. However, warming in the latest Permian occurred shortly after the main extinction phase and it is thus questionable whether climatic warming was a major cause of the Permian-Triassic mass extinction or only resulted from the major environmental perturbations during this critical time interval.

Hutton's Unconformity on Arran, southwest Scotland: a double unconformity masked by a phreatic calcrete hardpan developed at the Devonian-Carboniferous boundary

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Because it is partly masked by a phreatic calcrete hardpan, a rare and poorly-known type of lithodemic unit that can transgress stratigraphic boundaries, there has been ongoing controversy concerning the exact position of Hutton's historic unconformity on the Isle of Arran in southwest Scotland, which was the first to ever be formally identified. This unconformity separates folded Neoproterozoic to lower Paleozoic metasedimentary rocks from upper Paleozoic red beds. The massive phreatic calcrete hardpan developed in Fammenian red conglomerate of the Upper Old Red Sandstone above the unconformity, but it also assimilated regolith that had previously developed in the underlying Dalradian basement rocks, thus obscuring them and giving the impression that the unconformity is at a lower position. In the upper parts of the calcrete, there are small preserved remnants of the Fammenian host sediment that was lying above the basement regolith, and this deeply calcretized conglomerate is in turn disconformably overlain by Tournaisian red conglomerates and sandstones of the Kinnesswood Formation. The younger unconformity has previously gone unnoticed, although it can also be observed at two other localities in NE Arran. In the nearby localities of Kintyre and Bute, the Fammenian-Tournaisian transition is marked by a low angle unconformity, with no intervening phreatic calcrete. On Great Cumbrae, still in southwest Scotland, the contact is hidden by a large dyke, but the Kinnesswood Formation includes older beds (the lower and middle Foul Port members) than on Arran, Kyntire and Bute (the upper Foul Port Member only), and the all-pervasive salt-withdrawal structures that are found in this older part of the succession suggest that it may be contemporaneous to the phreatic calcrete hardpan, the petrogenesis of which is typically associated with the mixing of fresh and salty groundwaters at the periphery of hyper-arid evaporitic basins. Hence, in lowermost Tournaisian times, the local sedimentary basin (the North-East Arran Trough) became more limited in extent, allowing uppermost Devonian beds to experience deep phreatic calcretization at the periphery of evaporitic playas before being onlapped by younger Tournaisian beds when the area of active deposition expanded again.

Accumulation and oxidation of hydrogen sulfide causing surface-water anoxia and acidification leading to the end-Permian mass extinction

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We show that accumulation of H_2S during the Changhsingian, was followed by its transient oxidation, then surface-water anoxia and acidification can be linked to the end-Permian mass extinction. New and published sulfur-isotope ratios ($^{34}S/^{32}S$) measured in carbonate-associated sulfate from the neritic Paleotethys (China, Italy, and Hungary) and in sulfide in the pelagic central Panthalassa (Japan) indicate that high values during the ~1 m.y. before the mass extinction, indicating euxinia, and the mass extinction coinciding with a global fall in $\delta^{34}S$ values, as well as a shift in $\delta^{13}C$ values, indicates global oxidation of H_2S. New organic-geochemical data from the neritic Paleotethys (China and Italy) – from the same samples used for the isotope analyses – showing high arylisoprenoids/phenanthrene, dibenzothiophene/phenanthrene, and trisnorneohopane (Ts)/trisnorhopane (Tm) ratios and low pristane/phytane ratios during the Changhsingian are consistent with the development of euxinia during the ~1 m.y. before the mass extinction. These organic-geochemical ratios are reversed just prior to the mass extinction (seen at Meishan and Bulla), indicating a brief period of oxidized (oxic) shelf waters probably by mixing of surface water, which caused the intrusion of euxinic waters with neutrients onto the shelves leading the oxidation of H_2S and high-productivity-TOC conditions. They induced surface-water anoxia and acidification in ~20 kyrs during the mass extinction, suggesting this was a rapid global event and the cause of the mass extinction.

A massive release of hydrogen sulfide and methene at the end of the Permian did not cause ozone collapse

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The largest mass extinction of animals and plants in both ocean and land occurred in the end of the Permian, mostly coinciding with the largest flood basalt volcanism in Siberia. Recently enhanced UV radiation by ozone collapse induced by mass release of H_2S and CH_4 was proposed as a cause of the mass extinction. Our isotope-data indicate that $\delta^{34}S_{sulfide}$ values harmonize with $\delta^{13}C_{org}$ values at an abyssal section in central Panthalassa across the end-Permian mass extinction. This implies a low oceanic sulphate concentration in the *Neogondolella changxingensis* and *Hindeodus parvus* zones, spanning the mass extinction level and the P/Tr boundary. Similar phenomena on $\delta^{34}S_{CAS}$ and $\delta^{13}C_{carb}$ at two neritic sections in South China have been reported by Luo et al. (2010) and this paper. Luo et al. (2010) demonstrated that the oceanic sulfate concentration may have fallen to less than 15%, perhaps as low as 3%, of that in the modern oceans. Our isotopic data of pelagic and neritic regions strengthen this argument and indicate that the low oceanic sulphate concentration occurred globally. In the case of oceanic sulfate concentration being 3% to 15% of that of modern ocean and a massive release of hydrogen sulfide (H_2S) from the euxinic ocean to the atmosphere and of methene (CH_4) from Siberian igneous province to the atmosphere, our box-model calculations (based on the chemical reactions of sulfur, CH_4, and inorganic molecules in the troposphere) indicate that the chemical reaction caused an increase in atmospheric ozone by 70% of all atmospheric ozone, and a slight decrease in atmospheric O_2 by up to 10% of all atmospheric O_2 coinciding with the mass extinction. The results indicate that the massive release of H_2S and CH_4 to the atmosphere did not cause an increase in UV in the end-Permian mass extinction interval against previous suggestions. A significant decrease in atmospheric O_2 also did not occur.

High resolution foraminiferal biostratigraphy of the Tournaisian-Visean boundary interval in the British Isles and the influence of sedimentary facies

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The first appearance of *Eoparastaffella simplex* in the evolutionary lineage *E. ovalis* to *E. simplex* which defines the Tournaisian-Visean boundary is preceded by a sequence of FADs that can be followed across Eurasia including the British Isles: *E.* ex gr. *interiecta*, *Lysella gadukensis*, *E.* ex gr. *florigena*, *E. ovalis* M3, and *E. ovalis* M2 just below the boundary and *E. asymmetrica* at, or just above the boundary. The LADs of *Elevenella parvula* and *Darjella monilis* in the upper part of MFZ 8 represent other stratigraphically important foraminifer bioevents.

The fact that the T-V boundary interval is characterized by several foraminifer FADs/LADs is very helpful because the distribution of *Eoparastaffella* species in the British Isles is strongly facies controlled. Common late Tournaisian foraminiferal associations are characterized by high abundance but low taxonomic diversity with fauna dominated by morphologically diverse *Eblanaia* and Tournayellidae but lacking the stratigraphically important *Eoparastaffella*. These impoverished associations occur in- heterozoan-photozoan (foramderm) facies and are similar to microfauna and facies of the Rundle group of Western Canada, which have been attributed to cool water upwelling and eutrophication. On the other hand *Eoparastaffella* is very abundant in oligotrophic photozoan facies and oolitic limestones. The dominance of *Eblanaia* and other tournayellids in the late Tournaisian can be compared with bulliminid dominance in the Cretaceous and Paleocene upwelling belts of the southern Tethys and to a similar belt that has been postulated in the early Carboniferous of the southwestern margin of western Laurussia. An alternative explanation to trophic levels may be the transition from a higher humidity climate in the late Tournaisian of the British Isles to semi-arid conditions close to the T-V boundary. Further progress in Mississippian high resolution foraminiferal biostratigraphy will have to take into account lateral variations in trophic regime in addition to depth stratification.

Other notable features are the rare FADs of Visean guides such as *E. simplex* and *E. ovalis* M2 in foraminiferal associations where evolutionary older *Eoparastaffella* strongly dominate and variations in the proportions of *Eoparastaffella* species which may indicate interspecies competition in addition to sedimentary sorting.

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Capitanian (Late Guadalupian) Sr minimum in the mid-Panthalassa paleo-atoll limestones

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We present a detailed secular change of the Middle-Late Permian seawater $^{87}Sr/^{86}Sr$ ratio with the "Capitanian minimum" detected in the mid-Panthalassan (superocean) paleo-atoll carbonates and their Pb-Pb isochron age. The analyzed Middle-Upper Permian limestones at Kamura and Akasaka in SW Japan occur as exotic blocks within the Jurassic accretionary complex. Both sections span across the Guadalupian-Lopingian (G-L) boundary characterized by the major crisis of large-tested fusulines and rugose corals.

At the Kamura section, the ca. 30 m-thick Capitanian interval, i.e. the *Yabeina* (fusuline) Zone, *Lepidolina* Zone, and the barren interval, is characterized by extremely low $^{87}Sr/^{86}Sr$ values, lower than 0.7070. Likewise almost identical isotopic signature was detected from the same interval in the Akasaka section with the lowest value of 0.70688. This value gives the minimum $^{87}Sr/^{86}Sr$ not only of the Paleozoic but also of the Phanerozoic. This interval with the lowest $^{87}Sr/^{86}Sr$ value continued throughout almost the entire Capitanian for ~5 m.y., and then within the topmost Capitanian (13 m-thick barren interval) immediately before G-LB, $^{87}Sr/^{86}Sr$ values rapidly increase by 0.00073 up to 0.70761. This rapid increase in Sr isotope suggests that a huge amount of highly radiogenic terrigenous clastics and relevant water mass have been shed abruptly into Panthalassa probably by establishing new connection of the intra-Pangean drainage systems directly to the superocean. The development of such connection might be related to large-scale continental rifting, e.g., the initial breakup of Pangea.

We will also report preliminary results of our Pb-Pb isochron age of the Capitanian limestone.

Fusulinid biozonation as a proxy of Milankovitch cyclicity: the record from Moscovian-Kasimovian transition in Donets Basin

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The Donets Basin of Eastern Europe contains one of the most complete global Carboniferous marine to paralic sedimentary successions with almost no gaps in its depositional record. The successions possess an exceptionally well-established marine invertebrate and terrestrial floral biostratigraphy. Although foraminifers are well studied in the DB, the existing record of Moscovian and Kasimovian is controversial or incomplete. Here we present new data from M and N Formations in Donets Basin that correlates with Podilian, Myachkovian and Lower Kasimovian of Moscow Basin. Nine biozones in the Moscovian – Kasimovian transition have been distinguished in the region. Analyses of the facies and microfacies and fusulinid biota allow recognition of three distinct assemblages that formed in different habitats depending on sea level fluctuations. The beginning of transgression associated with packstone to wackestone microfacies is enriched with siliciclastics and characterized by monospecific population of *Hemifusulina*. Late transgression to highstand brings mudstone microfacies with assemblage of mature *Beedeina*, *Neostaffella, Ozawainell; Taitzehoella* specimens characterizes the offshore limestones. The micritic matrix of these limestones comprises degraded or decomposed calcite bioclasts, the origin of which is almost completely wiped out, indicating the low sedimentation rate of such limestone. These limestones are usually thin-bedded and formed when the maximum sea level stand reached stability. At the beginning of regressions the most abundant and diverse population of fusulinids mainly *Fusulinella* and *Schubertella* dominated biota appears in the coarse biostatic sediments. Each biozone corresponds to one full cycle started with a transgression, the stressful episode for the majority of fusulinids with exception of *Hemifusulina*, continued by the maximum transgression, characterized by *Beedeina* dominant species, and completed by regression with abundant *Fusulinella-Schubertella* association. *Beedeina* species show the same evolution trend in the many regions of the Paleotethys and proposed zones can be recognized in the Moscow Basin, Central Asia, China, Southern Urals and Cantabrian Mountains. The diverse *Fusulinella* species associated with regression episodes reveal higher degree of provinciality, when the marine connection between provinces was interrupted by exposed land.

Permo – Triassic (P/T) transition at the Coastal Plain in Israel (David 1 borehole, north Arabian Plate margin)

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The Permo–Lower Triassic succession in the central costal plain of Israel (David 1 borehole; 5010 – 5998 m depth, 998 m thick) lies only in the deep subsurface. The sequence was located on shallow carbonate marine margin (at present NW of the Arabian Plate). It consists of mixed shallow-water carbonates with siliciclasts that were supplied by the south-eastern hinterland. The sequence exhibit suppressed carbonate ecosystems characterized by generalist fusulinid assemblages from Middle to lower Upper Permian. The sediments were deposited during a regional transgressive phase with increasing marine influence northward in space and time.

The Middle-lower Late Permian sequence (5645 – 5998 m depth, 353 m thick) lacks foraminifera that are younger then the lowermost Changhsingian / Dorashamian stage (upper Late Permian; depth 5645-5650 m). Above this hiatus, the succession passes upwards into ~ 40 m interval (5645 – 5603 m) that a contain Lower Triassic palynomorphs assemblage dominated by the *Densoisporites* group, *D. playfordii* associated with *Krauselisporites, Aratrisporites* and *Lunatisporites*, and also with common marine acritatchs. The co-appearance of *Protohaploxypinus*, *Potoniesporites novices* and *Luekisporites verkkiae*, and the appearance at the top of the interval of a Lower Triassic foraminifer *Meandrospira pussila* mixed with reworked fusulinids (at 5603 m depth) indicates Permian sediment reworking at the onset of the Triassic sedimentary system.

The P/T transition lies at the bottom of this reworked interval. No exposure features or sedimentary breakup are recognized. The carbonate microfacies contain bivalve and gastropod shells (lacustrine belt), ooids, foraminifera, algae, *tubiphytes* (marine belt) mixed/exchange with siliciclasts (coarse and fine sand, silt, clay) indicating sea level change, nearshore to inner ramp facies shifts, and climate fluctuations. These fluctuations control the siliciclastic supply that probably suppressed the carbonate factory and might increase its sensitivity to the turnover of the ecological conditions a few Myr before the P/T crisis striked.

This perturbed 40 m interval (about 8 Myr time span) represents the Permo-Triassic transition recording the ecosystem's decadence at the upper Late Permian and the renewal at the Early Triassic.

Multidiscipline study of the Lower Permian deposits in the Most Section (Central Urals)

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The confirmation of GSSP for the Cisuralian stage boundaries stimulated the investigation aimed also to their definition by other criteria. Most key section situated along the Kosva River embraced Asselian–Artinskian carbonate deposits of inner, mid- and outer ramp. Revised biostratigraphic data and $\delta^{13}C/\delta^{18}O$ results are summarized. Lowermost part of the section is characterized by packstone containing an assemblage of small foraminifers. It seems to be the most controversial part of the section referred to the Shikhanian or uppermost Kholodnologian. Corals are represented by fasciculate *Ferganophyllum* and first *Protowentzelella* cerioid colonies. The Shikhanian boundary is traced out by *Sphaeroschwagerina sphaerica* and *Tschussovskenia captiosa* appearance. *Sakmarella moelleri* is the index species of the Tastubian. *Kleopatrina (K.) magnifica* – the Lower Sakmarian key form occurred in this section well above the boundary. The transient cerioid – asteroid colonies appeared slightly below *Schwagerina uralica–Verneuilites verneuili* Zone (Sterlitamakian). *Protolonsdaleiastraea* was found in the middle of the Sterlitamakian. The lower boundary of this substage is confirmed by the occurrence *of Verneuilites urdalensis.* The origination of morphological innovations in *Protowentzelella – Permastraea* lineage took place in the progressively changing environments. The Artinskian boundary coincides with first *Concavutella concavutas* occurrence. The abrupt deepening, accumulation of spiculites, biotic change, formation of the distal tempestites is characteristic for the Sargian Substage. 46 samples were processed to obtain the stable isotope data. The average meaning of $\delta\ ^{13}C$ along the section is estimated at 4- 5‰. The maximal above 5 ‰ is found in the middle of Shikhanian and corresponded approximately to the first appearance of bioherms. The end of the Early Artinskian coincides with the minimum value of both ^{13}C and ^{18}O mirroring the Late Sakmarian deglaciation.

Main transformation in reef biota composition (Permian, East European Platform)

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Late Artinskian–Kungurian cooling is considered as event reflected the total replacement of the reef biota. The typical pre-crisis Photozoan biota was widespread along the Urals, Northern Timan, Kolguev Island and Petchora Sea. The heterochronity is found by the comparison of the gradual replacement of Photozoan biota by Heterozoan in studied area and the Sverdrup basin (Reid et al., 2007). The typical reef constructers included *Tubiphytes, Archaeolithoporella*, *Palaeoaplysina*, and massive colonial Kleopatrinidae. The Upper Asselian-Sakmarian outer ramp deposits of Tra-Tau, Shakh-Tau and Urak-Tau (the Urals) demonstrates mosaic distribution of biota and variety of framestone and bindstone. The inner ramp microfacies are represented by fusulinids or bryozoan packstone with a lot of colonial coral fragments. There is the systematical and possibly ecological variations among the coral associations inhabited different types of build-ups. The abrupt transgression and possible cooling effect trigged the disappearance of Photozoan biota and replacement of the skeletal constructions by mud-mounts where biocementation was of crucial value. The Late Artinskian Heterozoan assemblages included frame-building sponges, bryozoans and associated ostracods and small foraminifers. Mud-mounts of Divia Mountain demonstrates the microfacies succession reflecting the transgressive – regressive cycle. The bioclasts include fenestellid bryozoans and silicisponges affected by *Microcodium* (Early Kungurian). The post–Artinskian cool climate, regression and spreading of the evaporite facies blocked the reef development. The terminal Early Kazanian mud-mounds are developed in the central part of the East European Platform. Mud-mounts are surrounded by oncoid shoals consisting of micritized oncoid-foraminiferal rudstone, with *Parachaetetes* (red-algae) fragments. Microfacies are represented by bryozoan boundstone, *Tubiphytes–Palaeonubecularia* floatstone, foraminiferal wackstone. Appearance of *Microcodium* in the uppermost part of the mud-mound corresponds to subaerial exposure.

The Devonian/Carboniferous boundary in the Moravian-Silesian Basin (Central Europe, Czech Republic) in the light of the high-resolution stratigraphy

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The transitional Devonian/Carboniferous (D/C) strata in southern part of the Moravian-Silesian Basin important by co-occurrence of conodonts and foraminifers provide unique opportunity for correlation between shallow and deep water successions. Lithological, biostratigraphical, petrophysical (γ-ray spectrometry – GRS and magnetic susceptibility – MS) and $\delta 13C_{carb}$ changes during the D/C boundary interval are studied in the Moravian Karst (Lesni lom Quarry and Krtiny Quarry). Lithological changes and biostratigraphy in the Lesni lom calciturbidite and hemipelagite section reveals a characteristic and relatively continuous development below and above the global Hangenberg Event. On the other hand, the hemipelagites in the Krtiny Quarry are monotonous in terms of facies, but with stratigraphic gaps at or near the H. Event level. GRS and MS data reveals changes of the petrophysical curves trends at the H. Event level, together with positive and negative peaks of $\delta 13C_{carb}$. The positive peak occurs in the Lesni lom Quarry in the Middle praesulcata conodont Zone, and is synchronous with the peak from Carnic Alps, reported by Kaiser et al. (2006). The H. Event in the Moravian Karst is associated with relatively low K and Th concentrations (GRS), while the MS curves failed to show correlatable patterns. The negative δ13Ccarb peak in the Upper preaesulcata Zone provides a good correlative link between both the Lesni lom and Krtiny sections. In both sections, it is associated with increased concentrations of K and Th and moderately high values of bulk MS. The lowermost Carboniferous patterns are difficult to correlate due to the stratigraphic gap near the D/C boundary in the Krtiny section. Appearance of the basal Carboniferous index conodot Siphonodella cf. sulcata underneath the H. Event in the Lesni lom Quarry and continuation of Devonian foraminiferal genus Quasiendothyra to the Carboniferous highlight problems connected with current definition of D/C boundary.

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Peculiarities of Permian – Triassic palynological records

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A severe biotic crisis occurred on land at the end of the Permian which is reflected not only by a major (micro)floral turnover but also by palynological peculiarities that characterize the Permian-Triassic (P-Tr) pollen and spore records in many parts of the world. Two of them will be discussed in this presentation. The first one is an acme of filamentous organic-walled microfossils assigned to *Reduviasporonites* Wilson 1962, which is the senior synonym of *Chordecysta* Foster 1979 and *Tympanicysta* Balme 1980. Although they have been persistently described from many P-Tr boundary sections, their biological affinity and their ecological role in an end-Permian extinction scenario is still controversially discussed. Based on morphological features they have been interpreted as saprophytic fungal remains that thrived on the mass of dead wood (Visscher et al. 1996, Elsik 1999). But their fungal affinity has been refuted (Foster et al., 2002) because of their organic-geochemical composition and C-isotopic signature. Foster and co-workers, as well as Afonin (2001), favoured an algal origin. Freshwater green algae of the Zygnemataceae are regarded as their nearest living relatives. Because the significance of the organic geochemical data as evidence for either an algal or fungal origin has been questioned (Sephton et al, 2009), the morphology of *Reduviasporonites* has been restudied in a recent paper (Visscher et al, in press). They show a close morphological similarity with resting structures of soil born filamentous fungi. These modern relatives include abundant plant pathogens. In analogy to their role in modern ecosystems they may have played a significant role as a cause for the widespread demise of the arboreal vegetation during the end-Permian biotic crisis.

Another peculiarity of end-Permian palynological records is the increased abundance of abnormal gymnosperm pollen (Foster and Afonin, 2005) and lycophyte spore tetrads (Visscher et al., 2004). Both features have been interpreted as evidence for environmental mutagenesis in response to enhanced levels of UV-B radiation.

The age and palaeoenvironmental conditions spanning the Permian/Triassic boundary in the northern onshore Perth Basin by using biomarker distributions and stable isotopes (C, H)

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The Perth Basin petroleum system has been intermittently explored for the last few decades, resulting in the production of gas and oil from several onshore fields. The effective source rock for petroleum in the Perth Basin is the marine Kockatea Shale, with the hydrogen-richest interval being the Sapropelic Unit of the Hovea Member. The Perth Basin in southwest Western Australia (WA) is a deep, north to south trending basin. The Perth Basin sediments comprise of rocks of Permian−Early Cretaceous in age. The current perception is that the area is gas prone and has been challenged with the recent discovery of the near-shore Cliff Head oil field. The Dongara gas field in the onshore Perth Basin contains more than half the oil and gas reserves. The Perth Basin sediments used in this study are from the Senecio-1 core which is located approximately 15.5 km from the north of Dongara. Stable carbon and hydrogen isotopic composition of biomarkers measured by compound specific isotopic analysis (CSIA) has been shown to be an effective tool for establishing biogeochemical changes in the Early Triassic. In the present study bulk geochemical, biomarker and CSIA of biomarkers are used to restrain the age and palaeoenvironmental conditions spanning the Triassic in the northern onshore Perth Basin and to compare these results with the Hovea-3 drill core 'type-section' (Grice et al., 2005a). For this purpose 31 samples from the Senecio-1 cored at 1 m spacing were selected. The ages of the samples have been determined by conodont biostratigraphy (Metcalf, these proceedings). Rock-Eval & TOC analyses have been performed to identify the type and maturity of organic matter and to evaluate the petroleum potential of these samples. The samples were analysed following the methodology of Grice et al. (2005b). Each sample was ground to a fine powder and extracted using an Accelerated solvent extractor. The extracts were separated into 6 fractions by liquid chromatography.

Saturate and aromatic hydrocarbon fractions were characterised by GC-MS. The saturated hydrocarbon fractions were separated from branched and cyclic hydrocarbons by treating with 5A molecular sieves and CSIA of biomarkers was performed for these fractions. Bulk stable isotopic compositions were measured on the kerogens isolated from the extracted powders. The data is consistent with Hovea-3 for both Rock-Eval and kerogen type. δ13C of the bulk organic matter is consistent with land plant derived material and phytoplanktonic, the change in stable isotopes is not as abrupt as shown in Hovea-3.

Understanding the volcanism-extinction link: Emeishan LIP and the Middle Permian mass extinction case study

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The Emeishan Large Igneous Province (LIP) was erupted onto Middle Permian Maokou Limestone of platform settings in SW China and has been proposed as a trigger for the “end-Guadalupian” mass extinction. In order to decipher the causal and temporal links between the Emeishan volcanism and Middle Permian biocrisis, we have conducted a multi-disciplinary research on both the Emeishan basalts and the Maokou Limestone over the entire LIP terrain. Our results suggest that the mafic volaniclastic deposits were commonly seen in the basal and upper part of the volcanic succession, indicating fierce, explosive interaction when lavas contacted the sea water. This explosive eruptional pattern amplified volcanic lethality against the biosphere, which in turn explained why a relatively small LIP had such big impact on marine biotas. The conodont data obtained from Maokou limestone directly underlying and intercalated Emeishan Basalt suggests the initial eruptions were in the *Jinogondolella altudanensis* zone of the Middle Capitanian Stage with more extensive eruptions developed in the *J. xuanhanensis* zone of the later Capitanian in most localities. The extinction of the distinctive keriotheca-walled Schwagerinidae and Neoschwagerinidae fusulinids and species-level turnover amongst calcareous algae in South China coincides with the initial Emeishan eruptions suggesting a cause-and-effect scenario. The extinction/eruptions also coincide with a major perturbation of the global C cycle as shown by a major δ13C decline of 5-6‰ in the platform carbonate record. This fluctuation was too large for the volcanism itself and may potentially imply the input of light carbon released from thermogenic sources. Specific climate effects triggered by Emeishan volcanism have not yet been determined.

Uppermost Permian to Early Triassic Conodonts at Bianyang Section, Great Bank of Guizhou, South China

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Detailed conodont biostratigraphic investigation has been carried out on Uppermost Permian to Lower Triassic at Bianyang Section, Great Bank of Guizhou. Eight conodont zones are recognized in ascending order: *Hindeodus changxingensis* Zone; *Hindeodus parvus* Zone; *Neospathodus kummeli* Zone; *Neospathodus dieneri* Zone; *Neospathodus cristagalli* Zone; *Neospathodus pakistanensis* Zone; *Pachycladina-Parachirognathus* Assemblage Zone; *Neospathodus homeri* Zone. Moreover, most of conodont zones are correlated finely with the conodont sequences in other areas of China and the world. The Permian-Triassic boundary is defined at the base of Bed 7 by the first occurrence of *Hindeodus parvus* and the Permian-Triassic extinction event occurred at the bottom of Bed 4 according to the first occurrence of *Hindeodus changxingensis*. Combining the correlation of *N. pakistanensis, N. novaehollandiae* and *N. waageni* in the high-resolution conodont biostratigraphy of some typical sections around the world as well as Guandao section with the conodont evolution lineage, it is argued that *N. novaehollandiae* could be used as one reference criteria to define Induan-Olenkian boundary under the circumstance of no *N. waageni* being identified. Therefore, Induan-Olenkian boundary is placed at at the first occurrence of *N. novaehollandiae* , which is about 126.3m above the base Permian-Triassic Boundary at Bianyang section.

The Current State and Future of Stratigraphy

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Stratigraphy consists of a broad association of loosely-linked, stand-alone subdisciplines (biostratigraphy, lithostratigraphy, chemostratigraphy, geochronology, sedimentology, paleogeomorphology, paleoceanography, among others) covering the gamut of the sedimentary crust. Until recently, research has tended to focus on these individual components of stratigraphy rather than blending them into broader synthetic stratigraphic analyses (e.g., basin analysis and paleogeomorphic synthesis) that produce important results for societal and human value. As a result, stratigraphy is not faring well in the competition for national funding resources with its scientific equivalents (i.e., tectonics, structural geology, seismology, geophysics, surface processes, volcanology, geochemistry, hydrology, geomorphology). Yet, stratigraphy provides the scientific framework so critical to understanding the architecture and history of the sedimentary crust, and the evolution of life. If stratigraphy is to survive and thrive, it must realign its focus away from internal scientific house-keeping; consolidate its disparate intellectual parts under one umbrella; and address larger societal and human issues relating to the sedimentary crust and deep time. This more unified approach can produce the state-of-the-art projects that promise to advance the frontiers of stratigraphy and provide the scientific wherewithal to compete and communicate with scientifically equivalent fields. A greater effort in the areas of outreach and educational thrusts to better inform the public is requisite.

Depositional Analogues for Permian Fluvial-deltaic reservoirs of Eastern Australia

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The Permian coal measures of Eastern Australia (Bowen-Sydney-Cooper-Galillee basin system) were deposited in a vast foreland and intracratonic basin setting in a cool-temperate paleoclimate that steadlily warmed through the late Permian, terminating at the Permo-Triassic boundary. Significant hydrocarbon resources (mostly gas) are reservoired in fluvial channel belt and crevasse splay sandstones, as well peri-glacial fluvial outwash plains. Seals include extensive lacustrine and floodplain intervals in the Cooper Basin, passing into more marine shales in the Bowen-Sydney basins. To further understand reservoir geometry, interconnectivity, and relationship with the coal, useful insights can be gained from modern analogues, including the modern rivers of sub-arctic to cool-temperate Canada, Alaska, and especially Siberia. The West Siberian lowlands contain the world's most extensive cool temperate to sub-arctic peat mires. The Ob River that traverses most of lowlands flows north and west for over 4000km from the headwaters in the Altai Mountains. The gradient is mostly very low, with the last 2900 km of the Ob River dropping only 91 m, where it is dominantly meandering and anastomosing in the middle reaches, with splay belts in the lower reaches. The Ob River is frozen much of the year, but thaws in May and June resulting in extensive flooding in the lower reaches, usually accompanied by ice jams and strong currents associated with confined underflows. The Western Siberian Lowland is an intracratonic basin with more than 1000 m of Cainozoic cover overlying several thousand meters of Mesozoic and Paleozoic rocks. Basement structure controls the present day channel belt orientation, and the peat mires become more extensive on the interfluves where peat mires develop directly on sandy, Pleistocene fluvio-glacial outwash. Drilling in the middle Ob shows an extensive sheet of amalgamated multivalley fluvial channel belt sands over 100m thick, extending up to 100km wide, overlying extensive lacustrine sediments. Estuarine and deltaic deposits occur in the lower reaches within a broad incised multivalley complex, part of huge delta complex at the head of the Gulf of Ob. Peats mainly form as raised mires (up to 40m above the river) but also infill abandoned channels along with organic silts, providing analogues for stratigraphic traps. The sand-prone Ob River meander belt, floodplain and peat mires along the drainage divide between the Ob and the Arctic offer useful analogues for comparison with Permian coal measures of Eastern Australia, with implications for reservoir geometry, connectivity and especially stratigraphic traps. Examples used from Permian oil and gas fields are supported by 3D amplitude maps and well correlations from the subsurface, whereas examples from the Bowen Basin are based on extensive coal-mine outcrops and borehole datasets.

Facies Architecture and evolution of the Late Carboniferous–Permian Pha Nok Khao Platform, Loei–Phetchabun Foldbelt, Northeast Thailand

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Late Carboniferous to Early Permian carbonate and siliciclastic rocks are well exposed in the Loei Syncline area in the Loei–Phetchabun Foldbelt and represent an important outcrop analogue for the Phu Horm giant gas-field and nearby fields in the Khorat Plateau Basin to the east. Approximately 30 carbonate facies and six siliciclastic facies have been identified and grouped into facies associations. Inner platform associations are widely developed. Subtidal to intertidal restricted inner platform facies associations are composed of skeletal floatstones–rudstones, calcisphere packstones–wackestones and fenestral limestones with partial to pervasive dolomitisation. Open marine subtidal inner platform to platform margin associations feature diverse skeletal grains including fusulinid foraminfera, calcareous algae and crinoids with small phylloid algal mounds. Widespread dolomitisation of shallow subtidal bioclastic facies is most notable in hinge zones of major folds, forming thick interval of vuggy dolostone, and associated with faults. Oncoid rudstone and cross-laminated ooid grainstone arranged in metre-scale shallowing-upward cycles record local platform-margin shoals. Large (~10 metre) phylloid algal–microbial mounds are locally associated with platform margin facies. Middle to upper slope facies associations are composed of normally graded intraclastic-skeletal rudstones–floatstones, crinoidal packstones–wackestones and laminated wackestones–mudstones. Carbonate breccias and skeletal rudstones, with small phylloid algal-microbial mounds, are rare. Fine quartz sandstones, mudstones and spicular mudstones with minor bedded chert represent the lower slope.

The distribution of inner platform to platform margin facies associations and coarse carbonate slope facies associations in the study area suggests that the windward margin was located along the (present-day) northern and western parts of the platform and is consistent with location of more restricted inner platform associations to the southeast. Fusulinid and brachiopod biostratigraphy, coupled with distribution of corals, indicates major carbonate accumulation had begun in the early Late Carboniferous (Moscovian-Bashkirian) in the northern part of the study area whereas in the southern part of the study area, major carbonate accumulation began in the Early Permian (~Asselian). Cessation of Pha Nok Khao Platform deposition by drowning in the ?Middle Permian is best preserved in the southern part of the study area where the platform is overlain by calcareous to siliciclastic turbidites.

Palaeobiogeographical interpretations of *Kaninospirifer* Kulikov and Stepanov in Stepanov et al., 1975 and *Fasciculatia* Waterhouse, 2004 (Neospiriferinae, Brachiopoda)

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The morphology and systematic position of a Permian neospiriferin brachiopod, *Kaninospirifer* Kulikov and Stepanov *in* Stepanov et al., 1975, appears to have been misinterpreted and/or misunderstood in the literature for a long time. The misunderstanding has led to discrete diagnoses of the genus by different researchers, resulting in the placement in this genus of morphologically very different species. Furthermore, the greatly varied interpretations of the genus by different authors have also caused some ambiguity in understanding the biogeographic distribution of *Kaninospirifer*. For example, did the genus attain a genuine antitropical distribution pattern during the Permian?

This study amends *Kaninospirifer* especially in relation to *Fasciculatia* Waterhouse, 2004, a close-related genus. It has been based on large collections from Spitsbergen, Arctic Canada, and Inner Mongolia, as well as on results from a critical review of all relevant literature. According to our reassessment of all species of these two genera, all relevant species appear to have been confined to the Boreal Realm during the Permian. Interestingly, some morphological characteristics, represented by both *Kaninospirifer* and *Fasciculatia*, are quite similar to those of a few other neospiriferin genera that were restricted to the Gondwanan Realm. These morphological similarities superficially may suggest a pattern of antitropicality in biogeographic distribution for the neospiriferin brachiopod group. However, the suspected case of antitropicality is different from other reported examples of antitropical distribution, as in the latter cases antitropically distributed taxa belong to the same brachiopod genera. In our view, the morphological similarities between *Kaninospirifer* and *Fasciculatia* and other neospiriferin genera from Gondwana might have resulted from parallel evolution of a common distant ancestor (presumably *Neospirifer*), rather than from dispersal mechanisms which were mostly favoured by other interpretations for the antitrophicality of Permian marine faunas.

Preliminary data on the pre-*sagittalis* interval from the Kasimovsky Quarry Section (Ryazan District, Russia)

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Recent studies of the transitional Moscovian-Kasimovian (in its traditional use) deposits were carried out in the Oka-Klyazma uplift situated east of Moscow. The Kasimov quarry is located on the left bank of the Oka River 8 km upstream from the town of Kasimov (Ryazan district). The exposed section is composed of rhythmic alternation of carbonate deposits and clay, where frequent paleokarst and erosion surfaces mark formation boundaries. The lowermost part of the section is represented by fusulinoid grain- and packstones with solitary *Bothrophyllum* and fasciculate *Fomichevella*. The presence of Chaetetidae in the lower part of the section allows the provisional assignment to the Korobcheevo Fm (Myachkovian, Moscovian). The Domodedovo Fm consists of ooid grainstone and ooid-peletal packstone resembling microfacies of the type area, and the uppermost part consists of algal–ooid–foraminiferal packstone changing into weakly cemented grainstone. The Korobcheevo(?) and Domodedovo Fm interval is dated by the first occurrence of *Idiognathodus delicatus*. The upper boundary of the Domodedovo Fm. is marked by an erosional surface with vertical burrows and limestone with wackstone pebbles. The lower part of the Peski Fm consists of ooid packstone with graded lamination. The distinctive level in its middle part shows sub-aerial exposure with abundant well-preserved *Microcodium*. The basal Kasimovian Suvorovo Fm unconformably overlay the Peski Fm. The formation consists of wavy-bedded brachiopod-crinoid grainstones intercalated with mudstone. The deposits are strongly bioturbated. The age of the Suvorovo Fm is determined by the appearance of *Streptognathodus subexcelsus*. *Swadelina makhlina* occurs in the middle part of the Voskresensk Fm.

37 bulk samples were processed to obtain the $\delta^{18}O/\delta^{13}C$ data. The highest $\delta^{18}O$ value at about 3 ‰ characterizes the middle part of the Peski Fm followed by a decrease to -4 ‰. The minimum value found in the middle part of the Peski Fm is similar to a negative shift recoded in the type area of the Moscovian stage making it useful for correlation and climate interpretation. An extreme positive change at the *Microcodium* level is considered artificial.

Depositional environments of the Permo-Carboniferous Taiyuan Formation from the southern piedmont of the Taihang Mountain, North China

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The Permo-Carboniferous Taiyuan Formation, widely distributed thousands of kilometers cross the North China block, yields abundant coals and is one of the most important energy source rocks in China. This formation therefore is economically very important in North China and attracts much attention from coal and petroleum exploration geologists in this region. It is generally believed that the Taiyuan Formation was deposited in the sea-land transitional environmental settings in many areas of the North China block during the latest Carboniferous to Early Permian. However, little has been published on depositional environmental changes through this economically important formation in the Taihong Mountains area, where the formation succession is proving to be very complete and several giant coal mines have begun operating. Thus, this paper aims to document the depositional environments of the Taiyuan Formation in the Taihong Mountains area, and thus enhance our understanding of coal's distributions and formation mechanisms in Taihong Mountain areas, offering useful information for future energy exploration in this vast region.

The Taiyuan Formation exposed at the Taihong Mountains areas comprises fine sandstone, siltstone, calcareous mudstone, carbonaceous mudstone and limestone. Of these, limestone beds are usually less weathered in comparison with fine sandstone and mudstone, and thus are conspicuous and become reliable marker beds in the field. There are seven limestone beds, between which coal seams are very common. Moreover, these limestone beds are usually highly fossiliferous and yields fusulinid foraminifera, conodonts, brachiopods, bivalves, bryozoans, corals, while sandstone and mudstone beds yield plants, spores, and pollen. Trace fossils are also abundant and diverse throughout the formation. Like the Carboniferous-Permian boundary in many areas of China, this boundary is placed at the base of fusulinid *Pseudoschwagerina* Zone, which is located at the 2nd limestone bed. Accordingly, most of parts of the Taiyuan formation are assignable to the Lower Permian except for the lowest beds that are uppermost Carboniferous.

Based on detailed field logging and indoor petrographic studies, we have undertaken microfacies analysis and attempted to reconstruct depositional environmental changes of the Taiyuan Formation. We conclude that most limestone beds were deposited in normal epicontinental sea settings, while the siliciclastics between limestone beds represent the sedimentation of coastal lagoon-swamp environment. The former units indicate transgression, while the latter represent regression in the Carboniferous-Permian basins of North China.

Temporal-spatial-geochemical features and magmatic dynamics of the Permian large igneous province in Tarim Basin of NW China

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The Tarim Large Igneous Province (TLIP) covers an area of ca. 250,000 sq km in the Tarim Basin in northwestern China. The temporal relations of different types of the rocks in the TLIP are built mainly using lithologically spatial distribution and precised zircon U-Pb dating, which show basaltic lavas (285-290 Ma), and layered intrusive rock, diabase and quartz syenite (274-284 Ma). Three compositional groups for the TLIP basalts from the outcropping sections and drill holes could be identified. The Groups 1 and 2 basalts are clearly differentiated based on different Nb/Y values, with two subgroups (Group 1a, 1b) identified based on distinct P_2O_5 vs. Mg# trends. All the basalts have high LILE and LREE/HREE and no Nb-Ta anomalies. The basalts have εNd(t) = 0~-5.17, $Sr_i(t)$ = 0.704986~0.708347, $^{206}Pb/^{204}Pb$ = 17.72~18.86, and $^{176}Hf/^{177}Hf$ = 0.282584~0.282837. A systematic study of platinum-group elements (PGE) shows that the Tarim basalts contain relatively low PGE abundances and Pd/Ir ratios, high Cu/Pd ratios and a distinctive bell-shaped PGE pattern, suggesting that the basalts might have experienced sulfur saturation with the removal of the PGE during sulfide segregation, and a multi-stage mixing process was proposed. For the Tarim basalts, the OIB-like source, yet distinct input from an enriched continental lithosphere mantle are comparable to those of the Permian Emeishan and Siberian LIP, suggesting a plume origin. We suggest that plume melts penetrated into the Tarim continental lithospheric mantle, and that mixing of plume-derived melt with melts from the enriched lithospheric mantle generated the Group-1 lavas. Subsequent higher degree of decompressional melting in the plume mantle as the plume-head ascended further produced the Group-2 basalts.

Paleoclimatic evolution of Southwestern Gondwana during the Late Paleozoic: A record from ice-house to green-house conditions

C.Limarino, L.Spalletti, J.Isbell, S.Césari & S.Geuna

The complex paleoclimatic history of the late Paleozoic has captured the attention of geologists since the end of the XIX century when glacial deposits were reported from distant areas of Gondwana. However, other paleoclima`tic conditions also hold a far deeper influence on Carboniferous and Permian stratigraphy. Indeed, the late Paleozoic is unique in Earth history in that a long-term transition from icehouse to greenhouse conditions was preserved on a global-scale. In this paper we divide the stratigraphic record of the icehouse-greenhouse transition in South America into four major stages: 1. Late Visean-Early Bashkirian (icehouse), 2. Late Bashkirian-Early Cisuralian (terminal icehouse) 3. Late Cisuralian-Guadalupian (transition from humid to semiarid conditions) and 4. Lopingian (greenhouse). The Late Visean-Early Bashkirian (icehouse, stage 1) is well recorded along the western margin of Gondwana in Argentina (Guandacol, Hoyada Verde and Agua de Jagüel Formations), Bolivia (Tupambi Formation) and Brazil (Poti Formation). Radiometric U/Pb ages indicate that the glacial event ended in the Andean region not later than 319.57 Ma (Late Serpukhovian). To the east, glacial conditions persisted in the Paraná and Tarija basins until the Late Pennsylvanian. The end of glaciation across most of South America took place during the Late Bashkirian-Early Cisuralian (stage 2). Glacial diamictites were covered by transgressive shales in the Itararé Group (Lagoa Azul Formation, Brazil), Lower San Gregorio Formation (Uruguay) and Tupambi Formation (Bolivia and Argentina). In the Andean region, coal-bearing fluvial deposits containing the NBG fossil flora prevailed. Climatic conditions were markedly different in the western (Andean) and eastern (pericratonic) South American basins from the Late Cisuralian to the Guadalupian (stage 3). These differences likely resulted from initiation of Choiyoi volcanism in the Andean region, which influenced local- and regional-scale climactic conditions. While eolian deposits, alternating with fluvial red beds and playa lake successions, appeared in the western Andean basins (Patquía and De La Cuesta Formations), fluvial and estuarine coal beds occurred in the Paraná Basin (Lower part of the Río Bonito Formation). Finally, extremely arid greenhouse conditions(stage 4),dominated during the Lopingian when thick red bed-bearing ephemeral river, evaporite, and eolian successions were deposited in various places in South America (Talampaya, Chutani, Vitiacua Formations).

Permian Mantle-Originated Hydrothermal Exhalative Sedimentary Rocks in San-Tang-Hu Basin and regional parallel analysis, Xinjiang, NW China

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The Santang- hu region in NW China was located in a within-plate, post-orogenic extensional environment during the Middle Permian (~270-260.4Ma), which had developed an undercompensation elongate rift lake basin with oriented NW to SE. The section and well drilling imply the mafic magmatism and hydrothermal activities, which occurring in the deposition of Middle Permian Lucaogou Formation and Tiaohu Formation, concentrated in the southern basin, with a linear distribution. The Lucaogou Formation contains significant source rocks in northern Xinjiang, which distributed widely and fairly good contrasted. The strata thickness changed from more than 1000m to 200m from Tianchi-Wulumuqi to Santanghu area. The sediments include thick dark colored mudstones bedded microcrystalline dolostone, microcrystalline dolomitic limestone and oil shale with abundant fossils such as Turpan-cod , Ostracoda, Gastropoda, bivalve and so on.

The new research results indicate that laminated rocks with 0.1-1cm bedding thickness consist of black and white smokers produced by explosive flows of mantle-derived, multi-component hydrothermal fluids. White smokers are marked by deposition of microcrystalline analcime dolostone, dolostone and chert, black smokers are consisted of pyrite and carbon, as well as relicts analcime-rich phonolite, carbon-rich lava, trachyte, welded tuff are easily observed in mantle-originated hydrothermal exhalative sedimentary rocks. The same rocks have been found in the south of Bogeda mountains in the eastern Mulumuqi.

Finally, Tiaohu (Santanghu area) magmatic rocks overlie the exhalative rocks in Lucaogou, consist of 2000m dolerite, basalt, diabase, and a handful of peridotite, andesite, which is extremely different from Hongyanchi(Wulumuqi area). Electron spectrum analysis of three peridotites shows a composition of 37-39% MgO, 20-22% FeO, and 36-38% SiO_2, whole-rock strontium isotope analysis of 13 dolostones exhibits a $(^{87}Sr/^{86}Sr)_s$ ratio of 0.704570–0.706339, indicating a mixture of hydrothermal and lake water. More contrasts between Tiaohu Formation and the Hongyanchi Formation are being studied.

Grazing/gnawing traces from the Lower Triassic Kockatea Shale Formation, northern Perth Basin, Western Australia: Taphonomy, palaeoecology and implications for the bioerosion ichnofacies model

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The Lower Triassic Kockatea Shale Formation of the northern Perth Basin, Western Australia yields extremely abundant trace fossils and thus provides the only window to insight into marine ecosystem collapse and rebuilding during the Permian-Triassic transition. Of these trace fossils, grazing/gnawing traces belonging to *Gnathichnus* Bromley, 1975 and *Radulichnus* Voigt, 1977 of the bioerosion ichnofacies are particularly abundant, including two new ichnotaxa.

Since *Gnathichnus* was proposed by Bromley (1975) this ichnogenus has been reported worldwide from hardground or shellground substrates of Middle to LateTriassic and younger ages, including the present-day oceans. Accordingly, the new *Gnathichnus* traces from the Smithian strata represent the oldest forms of *Gnathichnus*. *Radulichnus* has a much broader stratigraphic distribution, appearing in the Ediacaran-early Cambrian and Jurassic-present intervals. This ichnogenus is also reported for the first time from the Early Triassic, which therefore is a critical period for the evolution of grazing/gnawing traces. The Lower Triassic records the youngest known softground substratum-attaching grazing/gnawing traces. Since then, grazing/gnawing traces have become much smaller and the tracemakers inhabited hard bottom substrates such as shells, pebbles and limestone cliffs. Taphnomic study indicates that abundant microbes in sea water are crucial for the exceptional preservation of these scratches, especially through the role of microbial mats (Seilacher, 2008). Microbes sealed rapidly onto the traces and generated microbial coats. The microbial envelopes functioned as a sole veneer in early diagenesis. The death mask that arose from bacterial precipitation may have smothered decaying microbial mats and these fine scratches. The bloom of microbes in Early Triassic oceans are also reinforced by the common occurrence of microbial mats and wrinkle structures associated with these trace fossils at the study section. Finally, the preservation of the Early Triassic grazing/gnawing traces on siltstone and silty mudstone suggests that the tracemakers may have lived on matgrounds during the Early Triassic. Previously, the *Gnathichnus* ichnofacies only includes these grazing/gnawing traces recorded on hardgrounds or shellgrounds. The new material from the Lower Triassic broadens the *Gnathichnus* ichnofacies to include the grazing/gnawing traces preserved on the softgrounds, like these reported from the Ediacaran and early Cambrian before the Cambrian substrate evolution.

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Late Permian-Early Triassic palynology of the Bowen and Sydney basins: results and implications of new CA-IDTIMS isotopic ages

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Palynology is the principal biostratigraphic tool employed to correlate among the thick fluvial to shallow marine successions of the Permian-Early Triassic of the Bowen and Sydney basins of eastern Australia. The regional palynofloras can be utilised for intra-continental comparisons but are only broadly correlative across Gondwana and rarely applicable as stage or sub-stage level global tie-points. High precision CA-IDTIMS dating of Middle Permian-Early Triassic ashfall tuffs in these basins has provided a unique opportunity to confidently tie the endemic fossil biota to the international timescale. Carbonaceous siltstones and coals bracketing the tuff beds have been processed for their palynological content thus enabling precise chronometric ages to be ascribed to the fossil biotas. Tying these biozones to the internationally accepted Geologic Timescale will greatly enhance the event and biozonation correlation to areas outside Australia. Chronometric tie-points can now be attached to the Early Triassic *Aratrisporites tenuispinosus* Zone and the Late Permian *Dulhuntyispora parvithola*, and *Praecolpatites sinuosus* zones. Initial results suggest significant modifications to the ages currently assigned to some of these zones; in particular the tops of the *Dulhuntyispora parvithola* and *Praecolpatites sinuosus* zones are younger than currently accepted.

The Early Permian glaciation of the Canning Basin, NW Australia: a sedimentological/provenance analysis

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Lower Permian glacial deposits in the Canning Basin belong entirely within the 800-m thick Grant Group, but interpreting the glaciogenic nature of this succession is difficult due to the complexity of many glacial depositional environments, limited outcrop and subsurface data and the lack of detailed biostratigraphy. Nevertheless, detailed facies analysis of the Grant Group integrated with evidence from a new detrital zircon dataset provides new data on the provenance of glacially derived clastic grains, with significant implications for models of regional scale evolution of the late Paleozoic ice age.

Eight facies associations are interpreted within a single depositional sequence that records the evolution from glacial maxima (erosion and ice-contact to proglacial fluvial sedimentation) through deglacial (marine flooding) to post-glacial (delta progradation) environmental conditions. This is analogous with late Cenozoic sequences documented from Antarctic and other high latitude epicontinental environments. The suite of sedimentary facies from the Grant Group indicates deposition within an epicontinental shelf surrounded by glaciated cratonic uplands, and an interplay between high sediment supply and fluctuations in glacioeustatic relative sea-level. The group contains sediment sourced from cratonic areas to the south and east of the basin. Based on current knowledge of the Pre-Permian geology of Australia some of the zircons, especially those that are close to the depositional age of the Grant Group that are unlikely to have been recycled, could have been derived from eastern Australia but whether transportation was entirely by ice is uncertain.

The Lower Permian of East Timor: a possible distal expression of the west Australian Gondwanan Lower Permian tripartite successions

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An impressive 600 m Lower Permian marine succession outcropping in central East Timor shows many characteristics of a typical Gondwanan Lower Permian tripartite succession. However due to the distal depositional setting along with poor age control correlation to these typical successions remains ambiguous.

The lowermost package of a typical tripartite succession comprises the coarsest grained sediment deposited as a lowstand systems tract (LST), often clearly glaciogene in origin, followed by a mudstone-dominated interval comprising the transgressive systems tract (TST) and the early highstand systems tract (HST). The succession is capped by a prograding package deposited during the mid to late HST. The Timor succession can be divided into three lithostratigraphic units, Units A-C, that show many similarities to the typical tripartite succession and may be correlatable to the Bonaparte Basin succession comprising the Kurrippi Formation, the Treachery Shale and the Keyling Formation respectively.

Alternatively given the distal depositional setting of Unit B this may represent a condensed TST to late HST. In such a scenario the tripartite succession would comprise Unit A and B only. If so Unit C would instead be correlated to the Fossil Head Formation of the Bonaparte Basin which overlies the Keyling Formation. Such an interpretation is within the bounds of the sparse age control which is limited to *Vjalovognathus australis* and *Mesogondolella bisseli* at the base of Unit C. Based on the stratigraphic ranges of these species an age anywhere from the late Sakmarian to late Artinskian is likely. The first occurrence of the bivalve *Atomodesma exarata* near the base of Unit C may support such an interpretation as this species first occurs in Western Australia within the Nookanbah Formation of the Canning Basin, thought to be coeval with the Fossil Head Formation.

Unlike the tripartite succession in west Australian basins, no direct sedimentary evidence for glacial influence is evident within the East Timor succession. This may be explained by the amelioration of the climate at the leading edge of northeastern Gondwana during the Lower Permian. Alternatively it may reflect oceanic currents diverting calved icebergs away from the depositional site of these strata now outcropping in Timor.

Biomarkers and stable isotopes of euxinia and their role in fossil preservation

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The Gogo Formation, located in the Canning Basin, north-western Western Australia, shows remarkable preservation of a Late Devonian (380 MYA) reef fauna. The exceptional preservation, including original bone and mineralized soft tissues, has resulted from a combination of rapid burial and cementation within a relatively tectonically stable environment. Soft-tissues have been identified and described in vertebrate an invertebrate fauna from the Gogo. However, the exact mode of preservation is yet to be determined.

To establish the palaeoenvironmental conditions that resulted in the exceptional preservation of the "Gogo" Formation an invertebrate fossil, containing soft tissue, and the carbonate nodule were investigated for the presence of biomarkers.
The nodule was divided in two with only one half used for the experiments described below. The fossil was extracted and separated into different fractions. Dominant n-alkanes ranging from C_{15} to C_{32} (maximizing at n-C_{18} and n-C_{25}) were identified. Their $\delta^{13}C$ (-34 ‰ to -40 ‰) values are consistent with a source from chemotrophic sulfate reducing bacteria. In addition, the fossilised matrix was dominated by cholestane (with a $\delta^{13}C$ value of -30.5 ‰) bearing the 22R isomer (biological stereoisomer, reflecting an immature signal) and high relative amounts of phytane (δ13C value of -34 ‰) probably derived from sterols and chlorophyll of phytoplankton, respectively in the upper water column on which the crustacean used for its diet.

The desulfurised polar fraction (using Raney Nickel) yielded a similar distribution of biomarkers to those found in the free bitumen fraction. This observation is remarkable for a sample 380 million years old. This data supports rapid burial and preservation through sulfurisation during the early stages of diagenesis.

Consistent with this hypothesis is the presence of abundant Chlorobi biomarkers present in both the free bitumen and sulfurised polar fraction. Markers of Chlorobi, like isorenieratane and derivatives therefrom, globally identified across Permian/Triassic mass extinction boundary, have also been identified here also supporting photic zone euxinic conditions (H_2S and light) in the water column. These results also support a recent study which has demonstrated that the Gogo Formation, Western Australia, and the equivalent aged - Duvernay Formation, western Canada (and their associated oils) were deposited under highly euxinic conditions based on the presence of biomarkers associated with Chlorobi.

New Middle Permian - Early Triassic U-Pb zircon CA-IDTIMS isotopic ages of tuffs in the Sydney Basin, Australia: International calibration of stratigraphy and biostratigraphy

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The Middle Permian-Early Triassic (MP-ET) of Eastern Australia contains a predominantly endemic biota precluding precise correlation with standard international biozones and System/Stage boundaries. The Permian-Triassic boundary, other MP-ET stage boundary levels, and the major end-Guadalupian and end-Permian mass extinction levels in Australia remain poorly constrained. Attempts to calibrate the MP-ET of Australia using Sensitive High Resolution Ion Microprobe techniques have resulted in controversial radioisotopic ages with percent-level uncertainty and compromised accuracy due to the use of an unsuitable standard. We here report eighteen new high-precision (<±0.05 my) U-Pb CA-IDTIMS ages for tuffs in the Sydney Basin based on isotopic dating of chemically abraded individual zircons. These dates provide vital international timescale tie points for the MP-ET of Australia. The youngest samples from the Garie Fm (c. 247.7 Ma, c. 248.0 Ma) give a late Early Triassic (late Spathian) age. The youngest Permian age is c. 252.6 Ma from the Mannering Park Tuff. Two samples from the prominent Awaba Tuff are tightly grouped at c.253 Ma. An age of c.253 Ma for the Nalleen Tuff confirms the previous stratigraphic and geochemical correlation with the Awaba Tuff. The prominent Nobbys Tuff in the Newcastle Coal Measures, is dated as c. 255 Ma which is latest Wuchiapingian. The oldest dates obtained are c. 263.4 Ma from the Broughton Fm and c. 271.4 Ma for the Rowan Fm, both older than the Guadalupian–Lopingian boundary of c. 260 Ma. Implications of these ages for calibration of stratigraphy and biostratigraphy, intra and inter basin correlations, placement of mass extinction levels, sedimentation rates, dating of environmental and climate change (including glaciation) and the degree of intensity of volcanism in the late Permian of the Sydney Basin are presented.

Late Permian U-Pb CA-IDTIMS isotope geochronology of the Bowen Basin, Eastern Australia

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High-resolution geochronology with an age resolution at the permil or sub-permil levels has the potential to internationally calibrate Late Permian peri-Gondwanan sequences in the Bowen Basin. Previous attempts at such calibration have relied on carbon-isotope records and very tenuous biostratigraphic and lithostratigraphic correlations here deemed unsuitable for a high-resolution chronostratigraphic framework for the basin. Existing SHRIMP U-Pb ages for some tuffs in the basin have been compromised by inaccuracy and low precision when compared to the CA-IDTIMS method. High-precision CA-IDTIMS ages also allow us to correlate individual tuff beds across the basin, to estimate sedimentation rates of packages of strata, and to estimate rates of climatic and biotic change between the late Guadalupian and late Changhsingian major Permian mass extinctions. We here report seven new U-Pb CA-IDTIMS ages for ash-fall tuffs in the Late Permian of the Bowen Basin. Our youngest age, c.252.2 Ma from the top of the Bandanna Formation essentially equates with the Permian-Triassic boundary. Our oldest date so far, c.257.3 Ma, from the Ingelara Formation, equates with the early Wuchiapingian Stage. The major northern marker Platypus Tuff has been dated at c. 256.6 Ma indicating a mid-Wuchiapingian age, and a date of c. 256.4 Ma from a 1 meter thick tuff in the Wallabella Coal Member of the Tinowon Formation in the south confirms previous suggestions that these tuffs are equivalents. Our preliminary date of c. 254 Ma for a tuff near the base of the Black Alley Shale approximately equates with the base of the Changhsingian Stage. Our new CA-IDTIMS ages indicate that the Late Palaeozoic glaciation period (top of P4) may be earliest Changhsingian in age dating the last glacial event and the transition from "Icehouse" to Greenhouse" conditions in eastern Gondwana to be younger than previously interpreted.

The Induan-Olenekian boundary in Western Australia: Conodont biostratigraphy, carbon isotopes and constraints on post mass extinction anoxia

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Ocean anoxia was widespread in the latest Permian and continued episodically into the Early Triassic. These episodes of anoxia have been interpreted to be due to upward rise(s) of the chemocline, oceanic overturn(s) and/or major climatic perturbations. A significant anoxic event is recorded in the Kockatea Shale of the lower part of the Senecio-1 borehole core from the northern Perth Basin, Australia. We here present new biostratigraphic and chemostratigraphic data constraining the age of this anoxic event. The Early Triassic Induan-Olenkian Stage boundary (Dienerian-Smithian Sub-Stage boundary) has been identified in the Senecio-1 Well. This is the first international Triassic stage boundary to be unequivocally placed in Australia. Relatively abundant conodont faunas (1,000+ elements) represent three conodont zones in ascending order, the *Clarkina carinata - Neospathodus dieneri* Zone, the *Neospathodus waageni eowaageni* Zone and the *Neospathodus waageni waageni* Zone. In addition, a *Neospathodus waageni* subsp. nov. subzone is recognised in the upper part of the the *Neospathodus waageni waageni* Zone. The Induan-Olenekian (Dienerian-Smithian) boundary is placed at the base of the *Neospathodus waageni eowaageni* Zone equivalent to the first appearance of *Neospathodus* ex. gr. *waageni* utilised elsewhere and adopted by the International Union of Geological Sciences International Commission on Stratigraphy Triassic Subcommission to define the base of the Olenekian. Bulk kerogen $\delta^{13}C$ carbon isotopes define a positive peak of c. 4 per mille that essentially coincides with the Induan-Olenekian boundary and correlates with the Dienerian-Smithian carbon isotope positive anomaly reported from Pakistan, North India, South China, Japan and Italy. The upper limit of the anoxic zone recognised in the lower part of the Senecio-1 core is dated as latest Dienerian. This correlates with the late Dienerian anoxic event recognised globally indicating that this global anoxic event occurs in high-latitude Western Australia and is temporally coincident.

Late Permian (Changhsingian) and Early Triassic (Induan) conodonts and the Permian-Triassic boundary in central Peninsular Malaysia

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The Permian-Triassic boundary (PTB) is defined in the GSSP section at Meishan, China at the base of Bed 27c and is recognised by the first appearance of the conodont *Hindeodus parvus*. The PTB is dated at 252.3 Ma by bracketing tuff CA-IDTIMS ages and is slightly younger than the main "end" Permian (late Changhsingian) mass extinction. Despite decades of searching, the PTB has not been located precisely to date in Malaysia and it is still unclear if a stratigraphic break occurs at the boundary. In central Peninsular Malaysia, there are three mogote hill limestone sections, Gua Panjang, Gua Bama and Gua Sei, that have yielded biostratigraphic data indicating the probable presence of the PTB. The Late Permian foraminifers *Palaeofusulina* and *Colaniella*, which indicate a probable Changhsingian (but not latest Changhsingian) age have been reported from the lower parts of Gua Panjang and Gua Sei. Changhsingian conodonts including *Clarkina* spp., *Hindeodus julfensis* and *Hindeodus typicalis*, occur in the lower part of Gua Panjang but the presence of the Early Triassic has not yet been confirmed. Early Induan (Griesbachian) conodonts including *Hindeodus parvus* and *Isarcicella staeschei* (*Isarcicella staeschei* Zone) are known from the upper part of Gua Sei indicating that the PTB lies between this conodont-bearing horizon and the lower level with *Colaniella*. The lower part of Gua Bama comprising bedded tuffaceous limestones, dolomitic limestones and tuffs have yielded Changhsingian conodonts including species of *Clarkina*, *Hindeodus julfensis* and *Iranognathus movschovitschi*. Colaniellid foraminifers and brachiopods including the rare genus *Dongpanoproductus*, known elsewhere only from the upper Changhsingian of South China, have also been reported from near the base of Gua Bama. The Triassic nautiloid *Sibyllonautilus bamaensis* was recently reported from the top of Gua Bama, confirming the presence of the Triassic. The Gua Bama sequence therefore must include the PTB transition. However, basal Induan and topmost Changhsingian strata are yet to be identified in the studied sequences. This is partly due to difficulties of sampling largely inaccessible critical levels in these limestone hill sections.

Permian middle-high latitude Gondwana palaeoenvironment stable isotope records from West Australia

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We have analyzed 57 Western Australian (WAU) Permian fossil brachiopod samples from the Canning and Carnarvon basins, to study the middle-high latitude palaeoenvironment in the Permian. All samples, originally collected by officers of the former Australian Bureau of Mineral Resources (now Geosciences Australia), were thin sectioned and examined under the petrographic and cathodoluminescence microscopes for evaluating shell preservation. A total of 214 isotopic analyses and 185 electron probe micro-analyses were performed. There were 161 isotopic analyses from the most well preserved portion (non-luminescent; NL) for inferring the palaeoenvironment.

Average carbon isotope values of NL shells were 4.3 ± 0.6‰ (N = 85), 3.7 ± 0.3‰ (N = 2), 4.2 ± 0.6‰ (N = 36), 4.2 ± 0.3‰ (N = 14), 5.1 ± 0.3‰ (N = 9) , 5.1 ± 1.1‰ (N = 11) , and 4.8 ± 0.6‰ (N = 4) for the Callytharra Formation (Sakmarian), Jimba Jimba Calcarenite (early Artinskian), Madeline and Coyrie Formations (middle Artinskian), Wandagee Formation (Kungurian), Quinnanie Shale/Cundlego Fm. (Kungurian), Noonkanbah Fm. (late Artinskian-Kungurian), and Hardman Formation (Wuchiapingian), respectively. Within the uncertainty of the stratigraphical correlation, $\delta^{13}C$ values and trend of WAU are comparable to those of low latitude Urals from Late Sakmarian to Late Artinskian, whereas are overall less than those of the southern Sydney Basin (SB).

Average oxygen isotope values of NL shells were -0.1 ± 0.5‰, -0.7 ± 0.0‰, 0.0 ± 0.5‰, -0.6 ± 0.8‰, -0.1 ± 0.4‰, 0.1 ± 0.4‰, and -0.1 ± 0.4‰ for the Callytharra Formation, Jimba Jimba Calcarenite , Madeline/Coyris Formation, Wandagee Formation, Quinnanie Shale/ Cundlego Formation, Noonkanbah Formation, and Hardman Formation, respectively. These $\delta^{18}O$ values are greater than the coeval values reported for lower latitude regions, and are surprisingly even greater than those from the higher latitude southern Sydney Basin succession. Based on palaeolatitudes, biogeographic data, and Na/Ca and S/Ca ratios (1.7 and 12.6 mmol/mol greater than those of SB, respectively), and the overall higher oxygen isotope values in WAU compared to those of SB may indicate a higher salinity environment for Western Australia.

Climate-forcing feedbacks in the Carboniferous

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Evaluating climate forcing-feedbacks in the deep-time requires reconstructing marine-terrestrial linkages between atmospheric composition, the regional hydroclimate expression of mean climate change, ice sheets, and sea-level. Here we present a chronostratigraphic comparison of the late Mississippian through Pennsylvanian relative sea-level history, recently defined for the Donets Basin and correlated - in part - to the mid-continent cyclothemic succession, with published and new brachiopod oxygen isotope compositions from Tethyan and Panthalassan successions, estimated atmospheric pCO_2 inferred from soil-formed minerals, and ice sheet variations constrained by the distribution of high-latitude Gondwanan glacial deposits and paleoclimate simulations. This comparison indicates strong correlation between these climate parameters lending further support to the hypothesis of a dynamic late Paleozoic icehouse characterized by 1 to 6 million-year glaciations and intermittent periods of waning ice sheets, inferred higher surface temperatures, and decreased precipitation.
Maximum sea-level lowstands and inferred ice sheet growth across the mid-Carboniferous boundary (323.5-322 Ma) and in the early to middle Moscovian (314-311 Ma) are coincident with highest brachiopod $\delta^{18}O$ values and present-day to lower paleo-atmospheric pCO_2. Peak sea-level highstands coincide with decreased inferred ice volume and overall lower brachiopod $\delta^{18}O$ values, including a late middle to early late Pennsylvanian $\delta^{18}O$ minima defined by Tethyan brachiopods that is synchronous with a protracted (~8 myr duration), stepped sea-level rise. Paleoatmospheric pCO_2 for the late-middle through late Pennsylvanian interval, estimated using the $\delta^{13}C$ values of pedogenic carbonates, coal macerals, discrete plant matter from Illinois and Appalachian basin cyclothems, covaries with sea-level rises (CO_2 contents of 600 to 900 ppmv ±500) and falls (200 to 400 ppmv) of intermediate duration (10^4- to 10^6-year) superimposed on the overall protracted sea-level rise. Overall increasing CO_2 levels throughout this interval were accompanied by substantially decreased effective moisture throughout much of paleotropical Pangaea as indicated by the widespread occurrence of sabkha deposits and associated evaporates. Fully coupled ocean-atmosphere-ice sheet climate simulations for the Carboniferous support a similar range of CO_2 variation between glacial minima and maxima inferred from the reconstructed geographic extent of well-constrained glacigenic deposits in Southern Gondwana. The possibly CO_2-forced period of waning continental ice sheets and sea-level highstand encompassed a large-scale floral turnover across the mid-to-late Pennyslvanian boundary and the onset of the demise of paleotropical rainforests across much of Pangaea.

Unusal skip marks from the early Viséan Molignée Formation (Mississippian) of southern Belgium

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The early Viséan-aged Molignée Formation occurs in the Namur-Dinant Basin (Belgium) where it is developed only in the central part of the Dinant sedimentation area (DSA) between a prograding platform to the north and a Waulsortian complex running along the border between the DSA and the Avesnois sedimentation area to the south. This lithostratigraphic unit (*c.* 60 m in thickness) consists of a succession of thin-bedded, commonly laminated black limestones that alternate with thick-bedded, dark-grey limestones. Some levels of black limestone included in the Molignée Formation were extensively and manually quarried at the end of the 19^{th} century and at the beginning of the 20^{th} century for the production of ornamental stone, well-known as the 'black marble' of Denée. These levels have yielded remarkably preserved but rare fossils such as giant echinoderms, dendroid graptolites and fishes. Besides these exceptional macrofossils, several types of skip marks produced by broken shells of molluscs have been also recovered as well as ichnofossils (e.g. *Zoophycos*, meandering pascichnia). The first type, which is preserved as skip mark moulds, probably results from the repeated impact of a shell bearing large tubercles which are a reminiscent of those occurring in the gastropod genus *Porcellia*. The second type corresponds to a skip mark mould which is repeated four times over a distance of more than one metre and which has been produced by the shell cut in half of a large-sized cephalopod reaching about 18 cm in diameter. The third type corresponds to a series of three identical horseshoe-shaped skip marks which are deeply engraved in a lime mudstone that was most likely endowed with some plasticity at the origin. The fourth type, probably the most spectacular, corresponds to the repetition over a distance exceeding three metres of a pattern which is composed of three different skip mark moulds produced by the saltation of a mollusc shell. Moreover, the interpretation of several skip marks is still dubious as the objects which produced them are still unidentified. However, the presence of skip marks confirms the existence of bottom currents strong enough to move large fragments of shell and corroborate the turbiditic origin of some deposits of the Molignée Formation.

Late Pennsylvanian to Middle Permian reef succession on Panthalassan oceanic atolls

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The Carboniferous-Permian atoll carbonates in the Akiyoshi accretionary complex of SW Japan contain a continuous record of the evolution of Panthalassan reefs. Throughout this interval, the earth system experienced global cooling from the Pennsylvanian to the earliest Permian, and warming in the remaining Early and Middle Permian. These climatic changes are thought to have strongly influenced the prosperity and turnover of the Panthalassan reef community. We here report on Late Pennsylvanian to Middle Permian reef communities from the Panthalassan Akiyoshi and Taishaku limestones.

Palaeoaplysina flourished as the main reef-builder on the mid-Panthalassan Akiyoshi atolls during Gzhelian–Asselian time, acting as a frame-builder in a high-energy, reef-core environment. *Palaeoaplysina* was associated with abundant binders, including *Tubiphytes*, *Archaeolithoporella*, micrite crust-forming microbes, and cystoporate bryozoans. Fenestrate and cryptostomate bryozoans were sediment-bafflers and sediment-producers, but also acted as a frame-builder (as well as *Palaeoaplysina*) in association with microencrusters.

The biotic succession since the Sakmarian is still less clearly constrained, but sponge–microencruster boundstones, which include sphinctozoan and inozoan sponges, *Tubipytes*, and microbes forming micrite crusts, have been reported from a Murgabian to Midian back-reef succession of the Akiyoshi Limestone (Nakazawa et al., 2009). Although more detailed examination is necessary, the *Palaeoaplysina*–microencruster community was possibly turned over by the sponge–microencruster community on the Akiyoshi atolls during Sakmarian to Bolorian time.

Paleogeographically, *Palaeoaplysina* is well-known as a boreal element and was distributed mainly along the northern margin of Pangea. The global cooling during Gzhelian-Asselian time probably contributed to its migration to the tropical or subtropical Akiyoshi atolls of the mid-Panthalassa Ocean. The *Palaeoaplysina*–microencruster community was succeeded by the sponge–microencruster community in the late Early Permian. This biotic turnover corresponds in timing to a change of climate regime from icehouse to greenhouse conditions, and also coincides with a superplume activity (Ichiyama et al., 2008) beneath the mid-Panthalassa Ocean.

Permian conodont biostratigraphy of Australia and New Zealand

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Earlier reports on the Permian conodont biostratigraphy of Western Australia have documented faunas from the Canning Basin (Noonkanbah Formation) and Carnarvon Basin (Callytharra, Coyrie, Wandagee and Coolkylia formations) that ranged in age from the Late Sakmarian to the Roadian. New studies have now documented additional Permian conodont faunas from the Perth Basin (Beekeeper Formation, and a single specimen of *Clarkina jolfensis* from the basal Kockatea Shale) and from the Canning Basin (Nura Nura Member of the Poole Formation, from throughout the Noonkanbah Formation, in the Lightjack Formation and from the Kirkby Range and Cherrabun Members of the Hardman Formation). These faunas range in age from the Late Sakmarian to the Wuchiapingian and possibly Changhsingian. This study has been able to recognize a total of 9 species of the Genus *Vjalovognathus* based on prominent morphologic trends. Unfortunately several of the key taxa have yet to be recognised in localities outside Australia.

New Zealand Permian conodont biostratigraphy is limited to the single recovery of *Mesogondolella idahoensis* fauna from a locality Nokomai in the Caples Terrane, southern South Island. This fauna is suggested to be of Kungurian age. A fauna thought to contain *M. bisselli* from the Meyers Pass locality in the Torlesse Terrane has been re-identified and is now thought to be of Carboniferous age. The New Zealand material is part of the accreted terrane complex of New Zealand and was not at its present location at the time of deposition.

In the high latitude faunas of the Western Australian basins the conodont fauna has been dominated by the genus *Vjalovognathus* with only occasional occurrences of the genera *Hindeodus* and *Mesogondolella* and only a single occurrence of the genus *Sweetognathodus* in the Nura Nura Member of the Poole Formation. In the lower latitude conodont faunas from Timor, Pakistan, Tajikistan and Nepal/Tibet, the generic and species diversity of the conodont faunas is greater and this has been attributed to warmer water temperatures.

New U-Pb CA-IDTIMS isotopic age tie points for the Lightjack Formation, Canning Basin, Western Australia

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Ash-fall tuffs are extremely rare in the Permian of Western Australia, but recent coal exploration boreholes in the Fitzroy Trough of the Canning Basin have intersected several in the ~30–300 m thick Lightjack Formation. We here report four high-precision U–Pb zircon CA-IDTIMS ages of these tuffs. The formation contains marine to non-marine facies, and extends along the major depocentre of the Canning Basin (Fitzroy Trough – Gregory Sub-basin) and its margins, where it is sporadically exposed at localities including Lightjack Hill (type section), the Noonkanbah area, Liveringa Ridge and in Shore Range. The formation is dominated by siltstone and calcareous to ferruginous sandstone, with minor coal and fossiliferous beds near its base. It has previously been assigned a Roadian–Wordian age based on ammonoids (*Daubichites goochi* and *Bamyaniceras australe*) and brachiopods (*Neochonites* (*Sommeriella*) *afanasyevae* Zone), whereas palynomorphs (*Dulhuntyispora granulata* to *D. parvithola* Zones) indicate a slightly younger age for the upper part of the formation. Rare *Vjalovognathus* sp. nov. is the only conodont recovered from calcareous facies. Two closely spaced tuffs at ~58 m depth in exploration corehole Rey-D16C1 southeast of Duchess Ridge have isotopic ages of 268.86 Ma and 269.10 Ma with per mil and sub-per mil uncertainties. These ages indicate an early Wordian age (currently dated internationally at ~266–270 Ma). A third tuff sample from ~70 m in a nearby corehole (Rey-LR12C) also yielded an early Wordian age of 268.63 Ma. The fourth tuff sample from 210 m in Blackfin Liveringa P01 (drilled next to Petaluma 1, and 64 m above the base of the formation) is dated at c. 270.14 Ma, essentially at the Roadian–Wordian boundary.

Carboniferous conodont faunas in Australia and New Zealand

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Mississippian and Pennsylvanian conodonts are known from both eastern and Western Australia (WA), but only Pennsylvanian faunas are found in New Zealand (NZ). Mississippian faunas are widely distributed in WA in the Carnarvon, Canning and Bonaparte basins as well as from marine facies in New South Wales and Queensland. Pennsylvanian conodont localities in Australia and NZ are rare. In WA Pennsylvanian conodonts are known from only a single locality in the offshore Bonaparte Basin. A more diverse fauna has been described from near Murgon in southeast Queensland. In NZ Pennsylvanian conodonts have been found within the Torlesse Terrane (Rakaia Sub-terrane) Complex.

In WA Tournaisian and Visean faunas are dominated by shallow water species, such as *Bispathodus, Clydagnathus, Polygnathus* and *Pseudopolygnathus* with *Siphonodella* and *Gnathodus* as rare components. *Mestognathus beckmanni* is present higher in the sequence. In the Carnarvon Basin *Synclydognathus* cf. *S.geminus* in the Yindagindy Formation probably indicate a Visean age. Eastern Australian Tournaisian and Visean faunas represent a deeper water and more diverse faunas than those of WA. Genera include *Adetognathus, Bispathodus, Capricornognathus, Cavusgnathus, Clydagnathus, Gnathodus, Mestognathus, Montognathus, Patrognathus, Polygnathus, Pseudopolygnathus*, and *Siphonodella*. *Montognathus* is endemic to eastern Australia except for an occurrence in Malaysia on the Sibumasu Terrane which was attached to NW Australia in the Visean.

In Australia, Pennsylvanian conodonts are known only from the Early Bashkirian *Declinognathus noduliferus – Idiognathoides corrugatus* Zone level in the Bonaparte Basin and from near Murgon in southeastern Queensland. This may reflect the early onset of glaciation at this time in the southern hemisphere. In NZ Pennsylvanian conodonts occur at Meyers Pass, Kakahu and Conical Peak, all in the Rakaia Terrane. Preservation is poor and only generic level identification of *Gondolella, Idiognathodus* and *Streptognathodus* is possible. The faunas could be as old as Bashkirian or as young as Gzhelian.

Mid-Carboniferous boundary beds in the Muradymovo section (South Urals, Russia)

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In the South Urals, the Mississippian-Pennsylvanian boundary (MCB) is examined in facially different sections in the western and eastern tectonic sectors. At the end of the Mississippian the western, paleocontinental sector consisted of a shallow shelf of the continental margin of Baltica and a marginal trough (Zilair Megasynclinorium (ZM)). The eastern, paleooceanic sector contained an accretionary uplift and a marine basin with a series of deep and shallow zones. The Muradymovo Section is in the western sector (in ZM) and displays carbonate-siliciclastic deep water facies of the Bukharcha Formation, which is partly Serpukhovian (Kosogorskian, Khudolazovian and Yuldybaevian) and partly Bashkirian (Syuranian, including Bogdanovskian and Kamennogorian). The lower part of the formation is argillaceous carbonates, whereas the upper part is mostly clean limestone (interbedded calcarenites and calcilutites) with cherty interbeds. In the north of the ZM, the formation mainly consists of limestone. In the south, it contains some beds of shale, siltstone, and shale, sometimes clastic limestones and limestone breccia. The total thickness of the formation is 250-300 m. The beds are in places folded but the succession contains no identifiable gaps in the MCB portion. The Muradymovo is mainly limestone: micritic and fine-grained, argillaceous, cherty, in places bioclastic, with well-preserved fossil remains. The MCB beds contain a succession of foraminiferal, ostracode, conodonts, and ammonoid zones. The upper Serpukhovian (Yuldybaevian, ca. 13 m) contains the foraminiferal *Monotaxinoides transitorius* Zone, the conodont *Gnathodus postbilineatus* Zone, the ostracode *Pseudoparaparchites celsus* Beds, and the ammonoid *Fayettevillea-Delepinoceras* Genozone (= E2). The MCB coincides with the base of the Bogdanovskian and is defined by the entry of *D. noduliferus.* The same level and one 6 m above contain ammonoids *Proshumardites delepinei.* Beds above MCB contain: at 4.5 m ostracodes of the *Fellerites gratus* Beds, at 6 m foraminifers of the *Plectostaffella varvariensis* Zone, at 11 m foraminifers of the *Pl. bogdanovkensis* Zone. The *D. noduliferus* Zone is ca. 18 m thick. The upper Bogdanovskian begins with the entry of the conodonts *Idiognathoides sinuatus*, foraminifers *Semistaffella minuscilaria*, ostracodes *Limnoprimitia* cf. *arcuata,* and ammonoids *Ramosites sp.* An ammonoid assemblage with *Isohomoceras* sp., *Ramosites ramosus*, and *Homoceras haugi astrictum* (= H2 Zone) is located 18 m above the base of the *I. sinuatus* Zone.

Summary of Research at the Verkhnyaya Kardailovka section (South Urals) - a candidate for the Viséan-Serpukhovian boundary GSSP

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Sampling of the siliciclastic and carbonate succession spanning the Upper Viséan to Bashkirian along the Ural River by the village of Verkhnyaya Kardailovka (South Urals, Bashkortostan, Russia) confirmed the ammonoid, foraminiferal and conodont zones that allow reliable correlation of the Upper Viséan to Lowermost Bashkirian deposits in the Northern Hemisphere. The FAD of *L. ziegleri* is confirmed in the lower part of the section, with the basal Serpukhovian foraminifers and ammonoids entering nearby. New trenches were excavated to expose more adequately the lower and upper segments of the section. Approximately 50, five-centimeter-long, consecutively numbered aluminum pins, recording the metreage, were glued into holes drilled at 1 meter intervals across the section, marking it for comprehensive sampling. The lower 12 to 13 m (Traverse 1) of the section, comprise multiple, laminated to massive, volcanic-ash beds and laminae intercalated with tuffaceous shale and mudstone containing microfossils, scattered plant remains, and corals. The siliciclastics and volcanics unconformably overlie a paleosol developed on shallow-marine Viséan platform carbonates with *G. texanus*, *M. beckmanni*, and *L.* aff. *commutata-cracoviensis* (Sample VK 1 and VK3). So far no conodonts have been extracted from the previously unexposed tuffaceous beds.

Middle to upper parts of the section are dominantly fine-grained, massive to nodular and planar-laminated, basinal carbonates. The upper part of the section preserves somewhat coarser-grained flanking facies of a prominent, nearby, deep-water, carbonate mud mound. The paleosol and overlying fine-grained siliciclastics and volcanics of the lower part of the section represent an early terrestrial to shoreline setting transgressed by neritic to deep-basin waters. These lower deposits also record rapid and considerable subsidence and water deepening subsequent to an episode of Viséan subaerial exposure and pedogenesis. The overlying upper Viséan to lower Bashkirian carbonate succession is a shallowing and coarsening-upward succession. The multiple ash layers will allow precise radiometric dating immediately below the Viséan-Serpukhovian boundary, thereby confirming the status of the Verkhnyaya Kardailovka section as an excellent GSSP candidate for the Viséan-Serpukhovian Stage boundary.

Recognition of the Guadalupian–Lopingian boundary in a chert sequence in Japan with conodont and radiolarian biostratigraphy: Special reference on a carbon isotope stratigraphy across the boundary

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The terminal Guadalupian (the Middle Permian) is marked by one of the most significant biotic crises of the Phanerozoic. Pelagic Guadalupian–Lopingian (G–L) sedimentary rocks are widely distributed in accretionary complexes in Japan, but the boundary between the two series has not been well documented from these pelagic sediments. To identify the G–L boundary, we examined the conodont biostratigraphy in a pelagic chert sequence in the Gujo-hachiman section, Gifu, southwest Japan. Age-diagnostic conodonts, including *Clarkina postbitteri postbitteri*, were found in this section. The biostratigraphic occurrences of these age-diagnostic conodonts can pinpoint the "G–L transitional zone" in the Gujo-hachiman section, in comparison with the well-studied sections from South China, including the GSSP section. The transitional zone was recognized by the first occurrence horizons of both *Clarkina postrbitteri hongshuiensis* and *C. p. postbitteri*. The G–L boundary has been placed at the base or above the first occurrence horizon of radiolarian *Albaillella yamakitai* or *Albaillella cavitata* in previous studies in South China and Japan. The first occurrence horizon of *Albaillella yamakitai* is detected below the base of the "G–L transitional zone," but, this first occurrence may be even lower in the section. Our conodont biostratigraphy is consistent with the radiolarian biostratigraphy in this section, which can be correlated to relevant sections in South China. This result can be confirmed with the stable carbon isotope stratigraphy in the same section. Two negative shifts of $\delta^{13}C$ values of kerogen were recognized in the lower part of the section. In the upper part of the section, $\delta^{13}C$ values are relatively unchanged. The first negative shift, a 1.1‰ drop from –29.0 to –30.1‰, in the "G–L transitional zone", is comparable with the negative shift of carbonate-carbon isotope ratio at the G–L boundary at the Penglaitan section (GSSP section), South China. This negative shift of the Gujo-Hachiman section might be also correlative with that in the Kamura section where the G–L boundary is placed in the seamount-limestone sequence. The second negative shift, a 1.8‰ drop from –28.9 to –30.7‰, occurred above the "G–L transitional zone" in the study section. Although this negative shift is detected at the beginning of the Lopingian, such feature is not detected in either the Penglaitan or Kamura sections. The biostratigraphic data from each section indicates that the Penglatian and Kamura sections do not extend far enough into the Lopingian to capture the second negative carbon-isotope shift.

Permian Fusulinids and the paleobiogeography of southern Qinghai, NW China

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The Qamdo Block, of southern Qinghai, China, is on the boundary between Gondwana and Eurasia, and its tectonic affiliation is still controversial. The determination of the northern boundary of Gondwana can be recognized from the palaeobiogeography of the Qamdo Block. Fusulinids, a benthic fauna, can be used to define the palaeobiogeography. During Early Permian, fusulinids from southern Qinghai are dominated by *Robustoschwagerina*, *Sphaeroschwagerina*, *Misellina*, which shows similarities to assemblages found in the areas to the east of Jinshajiang Suture Zone, such as western Sichuan and eastern Tibet, western Qinling and South China. The *Misellina* fauna are not found in regions south of the Lungmu Co-Shuanghu -Lantsangjiang Suture Zone, and are easily distinguished from the fusulinid *Monodiexodina* Fauna that are characterized by cold-water biota in southern Qiangtang Block. By the Middle Permian, the *Neoschwagerina* fauna comes across the Lungmu Co-Shuanghu-Lantsangjiang Suture Zone in the south. But in species composition and dominant groups, the faunas of southern Qinghai and Xainza still exhibit significant differences. The documented distribution of *Gallowayinella* and *Palaeofusulina*, two representative genera of South China Subprovince, part of the Tethyan Realm in the Late Permian, indicate that they are only present to the east of the Lungmu Co- Shuanghu-Lantsangjiang Suture Zone.

This paper argues that the Permian fusulinid fauna in Qamdo Block have always been the warm Tethyan type, and show more similarity with South China, and are unrelated to Gondwana. So, Qamdo Block should belong to South China Subprovince, Cathaysian- Tethyan Province, Tethyan Realm in palaeobiogeographic affiliation. The Lungmu Co-Shuanghu- Lantsangjiang Suture Zone in the Early Permian was the southern boundary of the Cathaysian-Tethyan Province (warm-type) in the Tibetan Plateau. This marks the boundary of both the South China Subprovince and the northern Tibet Subprovince, characterized by mixed warm and cold biota, as well as the division boundary of Tethyan Realm and Gondwana Realm. After Middle Permian times, this suture zone no longer forms the boundary of any faunal realm, but is still useful in determining the province boundary during Middle to Late Permian. Whereas the evident similarity of fauna between both sides of Jinshajiang Suture, the north border of Qamdo Block, show it was not the barrier to the free migration of benthic biota and has no significance in palaeogeographic division.

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Foraminiferal Biostratigraphy of the Upper Carboniferous to Middle Permian Deposits in the Karavanke Mts. and Julian Alps (Southern Alps, Slovenia)

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A review of the rich fusulinoidean foraminiferal fauna described from the Southern Alps in Slovenia (Karavanke Mts. and Julian Alps) has been made. To demonstrate the whole range from the earliest late- to post-Variscan (Pennsylvanian) to the latest Middle Permian fusulinoidean taxa, the more recent studies of the Gzhelian to Artinskian biostratigraphy are complemented with the material published earlier.

Upper Carboniferous to Lower Permian rocks in the Karavanke Mountains have been subdivided traditionally into beds of Gzhelian, "Orenburgian", and Asselian to Artinskian age. A re-examination of the sedimentary succession along the Dovžanova soteska near the town of Tržič, that represents the most complete section of Late Paleozoic beds in the Karavanke Mts., together with comparative studies of some other sections, described in literature (Košutnik river and Javorniški Rovt), led to a refined biostratigraphic zonation.

Nine local fusulinoidean zones were recognized in the upper Pennsylvanian (Kasimovian and Gzhelian) and seven zones in the Lower Permian (Asselian to Kungurian). The oldest fusulinid fauna in the Pennsylvanian molasse-type deposits that unconformably overlie the Variscan flysch and other older basement rocks is early Kasimovian (Krevyakinian). The youngest Late Permian fusulinid fauna of the late Artinskian to Kungurian age, characterised by the first appearance of predecessors and first representatives of the Verbeekinidae family, was identified only recently in tectonically isolated outcrops between Kranjska Gora and Javorniški Rovt. The westernmost occurrences of the youngest Neoschwagerinid and Verbeekinid fauna (early Capitanian, Middle Permian) in the Southern Alps were described from the Lake Bled region of the eastern Julian Alps.

Local fusulinoidean zones were correlated with standard regional biozonation in the better exposed and more complete sections in the Carnic Alps (Austria/Italy) and with stratotype sections in Central Asia and Southern Urals.

Foraminiferal biostratigraphy of the Permian succession in Israel – new data

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The Permian succession in Israel is found at the bottom of very few boreholes. The succession presents deposition in proximal, sandy, fluvial-deltaic belt environments (Sa'ad Fm) during the Middle Permian, with increasing marine influence in the Upper Permian ('Arqov Fm.). Their spatial appearance along a depositional transect from the south to the west (proximal Pleshet 1 and Gevim 1 boreholes) and northward (distal David 1 borehole) exhibit increasing marine influence northward, coinciding with an apparent increase of grain size to clay-level percentage. In this work we present the results of the recovery and occurrence of foraminifera in the three boreholes and establish three assemblages **(A)** in the Permian:
A1 "*Pseudodunbarula arpaensis*" contains *Agathammina pusilla, Ogbinella ogbiensis*, *Shubertella* sp., *Pseudodunbarula arpaensis*, *P. minuta*, *Yangahienia* cf *hainanica*. The last strongly supports a Capitanian / Midian age. The zone is attributed to the Late Capitanian / Midian of the Middle Permian.
A2 *"Codonofusiella kwangsiana",* contains *Baisalina pulchra*, *Codonofusiella kwangsiana*, *Midiella irregulariformis*, *Ogbinella plata* (?), *Shubertella sp*. This assemblage of foraminifera correlates with the earliest of the Dzhulfian Stage (Tethyan) or the lower part of the Wuchiapingian (Global Permian Scale).
A3 "*Reichelina media*" contains *Colaniella* sp., *Nodosaria doraschamensis*, *N. dzhulfensis*, *Reichellina leveni*, *R. media*. The assemblage correlates with the uppermost Wuchiapingian / Dzhulfian and lowermost Changhsingian / Dorashamian, upper Late Permian.

The Middle – lower Late Permian fusulinids of Israel (**A1** and **A2)** were found to be eurybiontic (*Pseudodunbarula, Ogbinella*, *Codonofusiella, Shubertella*). A low diverse highly dense population of fusilinids characterizes the more proximal paleoenvironment (Pleshet 1 and Gevim 1 boreholes), while in a distally marine influenced environment (David 1 borehole), the fusulinids reduced population density and other foraminifera show a diversity increase at the same time (e.g. abundance of *Hemigordius*, *Neoendothyra*?, *Globivalvulina*, *Nodosaria*). During **A3** (upper Late Permian), dominated by non-eurybiontic fusilinids with low population density, and highly diversified other foraminifera (presence of *Hemigordius admirabilis*, *H. discoides*, *Midiella zaninettiae*, *Reichellina pulchra*, *Urushtennella* cf. *latebrosa* and others) indicating a regional transsgressive event. These changes not concur with the absence of Permian fauna younger than the lowermost Changhsingian / Dorashamian, leading up to the Permo-Triassic transition.

Late Carboniferous Onlap Curve, Donets Basin, Ukraine

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Mixed siliciclastic-carbonate cyclothems of the Donets Basin, eastern Ukraine, exhibit extraordinary lateral continuity along a dip-oriented transect within an aulocogenic setting. Stratigraphic data from >80 core logs and 20 outcrops were correlated for distances up to 250 km along the basin axis using laterally extensive coals and limestones as near-isochronous timelines. Eleven high precision U-Pb dates add numerical ages to the time control. The correlated cyclothems show distinctive facies that mark 1) the estimated lowstand position of the shoreline (fluvial sandstones), 2) the location of the subsequent transgressive shoreline (marine barrier sandstones) and 3) the minimum extent of transgressive onlap (marine limestones). The time-distance relationship of these 'pinning points' was used to construct an onlap curve for the Late Carboniferous of the Donets Basin. Near one-to-one correlation of the Donets onlap history with that from the US Midcontinent cyclothemic succession strongly suggests that the sea level fluctuations that controlled the onlap history during the Late Carboniferous were eustatic rather than tectonic. Furthermore, prolonged episodes of offlap and sea-level lowstands correspond with glacial maxima defined from high-latitude Gondwanan basins. In similar fashion, extended phases of onlap and sea-level highstand coincide with glacial minima. Our conclusions are that cyclothems from the Donets (and likely from the US Midcontinent) are glacio-eustatic in origin, an interpretation that dates back to the mid-20th century, but that has never been confirmed to this degree of precision.

Deep time paleoclimate reconstruction using carbonate clumped isotope thermometry: A status report

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Carbonate clumped isotope thermometry holds great promise for addressing questions in Paleozoic paleoclimate and paleoceanography because of its ability to simultaneously record temperature and fluid $\delta^{18}O$. Here we review recent developments in the method related to 1) temperature calibration in biogenic carbonates; 2) scenarios where original clumped isotope signals are likely to be preserved or altered; and 3) applications of the method to Paleozoic paleoclimates. Most biogenic carbonates (including foraminifera, corals, otoliths, mammalian bioapatite) conform to a single temperature calibration curve. Mollusks deviate from this calibration, showing a slightly lower temperature sensitivity that is similar to the theoretical temperature sensitivity of the thermometer. The origin of the difference between mollusks and other biogenic carbonates is unclear and stands as an important mystery to solve because it bears on proper selection of paleotemperature equations for fossil biogenic carbonates. A detailed calibration is lacking for brachiopods. The question of preservation is addressed by ongoing experimental and empirical observations. Experiments are aimed at determining Arrhenius parameters for rates of solid-state ^{13}C-^{18}O bond reordering that will allow prediction of temperature-time combinations of elevated heating (for example, as experienced by a fossil during burial) resulting in measurable reordering of C-O bonds (and hence, alteration of the clumped isotope signal). Published and unpublished data provide examples of nominally-pristine Paleozoic brachiopods that preserve both 'plausible' (for example, less than ~35°C) and 'implausible' (up to ~180°C) clumped isotope temperatures, and the difference in many cases can be related to inferred burial depth. Published applications of the method have addressed glaciation during the Ordovician/Silurian, and coupling between temperature and inferred CO_2 levels during Silurian and Pennsylvanian. A notable emerging conclusion from these studies and our own analyses of Carboniferous brachiopods is that there is little support for models of low seawater $\delta^{18}O$ (< - 3‰ SMOW) during the Paleozoic.

Application of palynostratigraphy to petroleum bearing Permo-Carboniferous sediments – a case study from Oman's Haushi Group

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A review of the palynostratigraphy in over 1000 wells penetrating Oman's Permo-Carboniferous Haushi Group has enabled high resolution reservoir-scale subdivision of this interval. The Haushi Group comprises the glacially influenced Al Khlata Formation and the overlying marine to fluvial Gharif Formation. These are respectively the second and most prolific petroleum reservoirs in Oman.

Oman-wide mapping of the palynologically-constrained unit thicknesses of the Al Khlata Formation and lower member of the Gharif Formation appear to display considerable influence of both basement faulting and halokinesis from the Late Pre-Cambrian Ara Group Salt. This has resulted in a series of depocentres developing at different times when salt dissolution created accommodation space, which was rapidly filled by sediment.

Palynostratigraphy within the Al Khlata has identified at least 7 palynozone-based lithostratigraphic intervals which can be mapped across the region. A number of structural features appear to control the extent of certain intervals including the Rahab Shale Member, which is thought to represent the last major melt-out of the Gondwana glaciation.

The overlying pre-marine and transgressive marine Lower Gharif interval can be resolved into at least 4 palynozones which reflect changing palaeoenvironments. Palynostratigraphy has facilitated the mapping of the both the pre-marine and marine units including a ravinement surface, which precedes the development of the high-stand carbonate facies of the Haushi Limestone in Northern and Central Oman.

After the deposition of the Haushi Limestone a regression occurred and associated palynofloras suggest aridity, supported by the predominance of terrestrial redbeds, which include fluvial and fluvio-lacustrine deposits. This is followed by a mostly palynologically barren interval dominated by palaeosols formed in fluvial and flood plain environments. Low yields of palynomorphs from the upper part of this succession suggest the presence of possible disconformities prior to the marine transgression represented by the overlying Khuff Formation.

Foraminiferal "microbuildups" in a condensed section of the Zechstein Limestone, western Poland

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Encrusting foraminifers are common constituent of various facies of the Zechstein Limestone (basal Zechstein) of western Poland. Previous studies (Peryt & Ważny, 1980; *Contr. Sedimentology*, 9: 279-306) indicated that in the basinal location do occur thin sections of the Zechstein Limestone which are developed as fossiliferous micrites to sparse biomicrites, with foraminifers *(Agathammina, Ammodiscus, Nodosaria,* encrusting foraminifers), bryozoans and shell fragments, rare nautiloids and echinoids, and locally with big (up to 10 mm in diameter) intraclasts (fragments of foraminiferal-cyanobacterial encrustations developed on shells, and fragments of neomorphised stromatolites) and sporadically radial ooids. Commonly, these sections are developed as grained rocks: in the dolomitic matrix of somewhat pelmicritic appearance skeletal fragments (foraminifers — *Nodosaria, Earlandia, Ammodiscus,* spiral and encrusting foraminifera, ostracods, echinoids, molluscs) and grains of variable size and origin occur. Skeletal grains are typically accompanied by individual big (up to 4 mm) recrystallized grains encrusted by sessile tubular foraminifera in the bottom, and in the middle part of the Zechstein Limestone recrystallized oncoids occur. In the top of the Zechstein Limestone radial ooids occur that contain foraminiferal overgrowths. In one borehole section (Radlin 60) located NE of the Brandenburg-Wolsztyn Ridge (western Poland), the Zechstein Limestone (1.1 m thick, limestones with rare dolomitic portions) contains in its lower part bioclastic packstone with abundant fauna (crinoids, gastropods, bivalves, spiral and uniserial foraminifers, echinoids, bryozoans, brachiopods and ostracods) and quartz grains that is associated with numerous small, pillar-like microbuildups (which often are merged by subsequent generations of overgrowths, forming thus one body composed of many individual pillars); the structure of those foraminiferal microbuildups shows a great similarity to "reefs" built of sessile foraminifers (mostly *Tolypammina gregaria*) occurring in the Carnian of the Northern Calcareous Alps and described by Wendt (1969; *Paläont. Z.*, 43: 177-193). Like their younger equivalent, the Zechstein foraminiferal microbuildups are related to the condensed section that has originated in the hungry basin conditions.

Carbon and oxygen isotopic composition of basal Zechstein (Upper Permian) rocks in northern Poland: implications for seawater chemistry and temperature

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The lithological succession of the basal Zechstein strata was previously interpreted as reflecting the transition, after the euxinic deposition of the Kupferschiefer, to normal marine conditions with elevated water salinity in which the Zechstein Limestone deposits have originated. However, in the basinal facies the Zechstein Limestone is a dark, laminated, marly micritic limestone what suggests that the environmental change could be minor. We have studied a representative section in the basin location (more than 50 km from the seaward margin of carbonate platform during the Zechstein Limestone sedimentation) in northern Poland. This section is composed entirely of oncoid packstones that are accompanied by stromatolites in the upper part of the Zechstein Limestone. The deposition occurred in persistently subtidal environments, above the storm wave base, in mostly dysoxic conditions, and thus they did not differ essentially from those characteristic of the Kupferschiefer. The Ni/Co, Ni/V, V/(V+Ni) and (Cu+Mo)/Zn ratios that are commonly regarded as indicators of anoxic environment, show remarkably similar values for the Kupferschiefer and the Zechstein Limestone. The fauna restriction and the dwarfed forms suggest elevated salinity of seawater; during the deposition of the topmost part of the Zechstein Limestone section in response to the shallowing and the better water circulation the ecological conditions improved what finds its expression in richer fauna assemblages. The average $\delta^{13}C$ and $\delta^{18}O$ values are +5.1± 0.6‰ and -0.5±0.7‰, accordingly. In the section, a clearly upward increase of $\delta^{13}C$ values is noticed, from about +4.4‰ at the base of the unit to ca. +5.8‰ at its top. The $\delta^{18}O$ values of calcite throughout the Zechstein Limestone remain quite stable (although they show a slight increase upsection, from about -0.6‰ to about -0.3‰). There are several distinct deviations from those trends of $\delta^{13}C$ and $\delta^{18}O$ values. The calculated palaeotemperature of seawater was within the range of 23 to 33°C (or more), the higher values being more appropriate, and slightly (by ca. 1.5°C) decreased at the end of the Zechstein Limestone deposition.

Upper Permian reef complex in the basinal facies of the Zechstein Limestone (Ca1), western Poland

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Stromatolite and bryozoan build-ups from the Werra Cycle (Zechstein) of the Southern Permian Basin of Europe meet all definitions given by various authors for reefs and they commonly occur at the shelf edge. In a few places, including western Poland, they are also recorded in the basinal facies. In the lower part of those isolated reefs common are beds with brachiopod shells. The main part of the reef is formed by fragmented bryozoan zoaria. The reef biota are typical bryonoderm association indicating cool-water and cold-water environments. A characteristic feature is a large amount of fragmented skeletal remains of small resistance. The main part of reefs is built of rudstones, and only stromatolitic crusts form massive construction. Astonishing is the mechanism of origin of clearly separated morphologically reef constructions from remains of relatively low potential of fossilization. Zones built of crushed remains clearly dominate over parts representing massive constructions (bafflestone and bindstone). The colonization of the substrate began very early as indicated by the interbedding of breccia (with clasts being often overgrown by bryozoans) and bioclastic carbonates in the lowermost part of the Zechstein Limestone in some reef sections. The Zechstein Limestone reefs of western Poland abound in the hemispheroid aragonitic cement what is otherwise common for the reefs elsewhere in the Zechstein basin as well in other Permian basins. The abundance of the cement recorded in Permian reefs is interpreted as the result of an unusually high saturation state of surface seawater because of number of factors, including prolific carbonate precipitation due to occasional upwelling of warmer saline waters on shelf environments in the stratified Zechstein basin. The origin of a system of reefs within the Zechstein Limestone basin was a bio-sedimentary event that was geologically isochronous, and the pervasive carbonate precipitation contrasts with a restricted carbonate precipitation in the adjoining basin. The reefs show variable diagenetic alterations including dolomitization and dedolomitization, multiphase carbonate (calcite and dolomite) and/or anhydrite cementation and recrystallization.

The Permo-Carboniferous glaciation of Gondwana: its legacy in Western Australia

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Large areas of the Gondwana supercontinent, comprising Australia, Antarctica, India, and parts of southern Africa and South America, were subjected to repeated glaciations during the Late Carboniferous and Early Permian. The whole of Western Australia was covered by ice, probably up to five kilometres thick, which moved steadily away from the Permo-Carboniferous South Pole. Rock debris, ranging in size from large boulders to fine 'rock flour', was frozen into the basal ice, planing down the underlying rocks as the ice moved steadily away from the pole. The resulting level surface is reflected in the flat landscapes that are so characteristic of Western Australia today.

Some of the best examples of grooved, striated, and polished glacial pavements are in the Pilbara district, east of Marble Bar. They are also displayed clearly at other locations around the State, notably east of Geraldton, near Lyons River, and east of Fitzroy Crossing

Ice at the base of the ice cap was melted by geothermal heat, forming subglacial lakes and channels in some areas. Boulder deposits, resulting from the melting of ice that transported the boulders are common in Permian deposits in many parts of Western Australia. Glacial boulders are not always angular; many were rounded while being transported by flowing water in channels below the continental ice sheet.

In Devonian limestone of the Canning Basin the subglacial water carved deep channels and formed solution dolines and cave systems. Subglacial channels localized some of Western Australia's existing rivers and paleo-river systems, and the subglacial water played an important role in localizing supergene mineral deposits.

Belgian substages as a basis for an international chronostratigraphic division of the Tournaisian and Viséan

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The Tournaisian and the Viséan were formerly considered as series and were divided in Belgium by Conil et al. (1977), respectively in Hastarian and Ivorian and in Moliniacian, Livian and Warnantian stages. These stages were based mainly on shallow-water deposits which give the advantage to correspond to thick and relatively complete sedimentary successions, rich in fossils comprising foraminifera, conodonts, corals and brachiopods. Now these divisions are considered as substages, the Tournaisian and the Viséan being redefined as stages by the IUGS Subcommission on Carboniferous Stratigraphy (Heckel, 2004). In the last years, the boundaries, the biostratigraphy (mainly foraminifers and rugose corals) and the sequence stratigraphy of these substages were emended and clearly defined in several papers. For example, now the base of the Moliniacian corresponds to the base of the Viséan stage (first appearance of *Eoparastaffella simplex* from *E. rotunda*). The up-to-date chronostratigraphic subdivision of the Tournaisian and Viséan is not limited to Belgium and the surrounding areas, but it can be applied through Eurasia, as it did successfully as far as South China. It could be the base for a future international division of the Tournaisian in two parts (Hastarian and Ivorian) and of the Viséan in three parts (Moliniacian, Livian and Warnantian), corresponding to time intervals of about 5 to 8 Ma.

Bio- and sequence stratigraphic correlations between Western Europe and South China: to a global model of the eustatic variations during the Mississippian

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The biostratigraphy (mainly based on foraminifers and rugose corals) and the third-order sequence stratigraphy of the European Mississippian have been recently revised (Hance et al., 2001; Poty et al., 2006). Both were defined in Western Europe and were later extended to Poland and South China. In South China, several sections in Hunan, Guanxhi and Guiyang were investigated or revised in the last years and provide a complete composite Mississippian section. They allowed to check, by comparison with Europe, what were local or global sea-level variations and to extend the biostratigraphic zonations. Among the sequences, some correspond to sea-level changes larger than the others and/or can be correlated with major changes in marine faunas. The highstand systems tracts (HST) of sequence 1 (following the D/C boundary extinction event) and sequence 3 (base of Upper Tournaisian) are characterized by a widespread of corals in Eurasia. The latest Tournaisian sequence is characterized by a very high HST and a flooding of lowlands previously emerged (« Avins event », Poty, 2007). This very high-sea level caused good connections between marine basins and thus to the widespread of foraminifers, brachiopods and corals, through Australia, Japan, China, and the rest of Eurasia. Its falling stage systems tract is characterized by a very strong fall in the sea-level and is considered as a heralding change to the Carboniferous climate with glaciations and the development of an ice-cap. This low sea-level persisted during the earliest Viséan, and the third-order sequence 5 never reached the shallow marine platforms previously covered by the latest Tournaisian sea. It is from the base of this sequence that a marked four and/or five-order cyclicity developed. A strong fall of the sea-level occurred at the end of the Viséan and caused, like at the end of the Tournaisian, the emergence of many carbonate platforms. These were affected by an intense karstification probably due to the replacement of the relatively dry Viséan climate by the Serpukhovian wet climate. That is considered as corresponding to an enhancement of the ice-caps and the starting of the upper Carboniferous glaciations.

Preliminary report on the earliest callipterid assignable to the morphogenus Rhachiphyllum Kerp from the late Moscovian (Asturian) Farmington Shale (Illinois Basin, USA)

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Callipterids are among the longest studied groups of plants in palaeobotanical history, dating back to the first half of the 18th century. We report a recent discovery from the Illinois Basin, USA (in estuarine deposits in roof of the Danville Coal), pushing the range of callipterids back into the Moscovian. Fossils were collected in the UMI West 61 Mine (United Minerals, Inc.), in Warrick County, the SW part of the Illinois Basin, Indiana, USA. Fossils were recovered from the Farmington Shale, which overlies the Danville Coal Member of the Shelburn Formation. This laminated dark-gray shale contains scattered remains of drifted flora preserved as compressions/impressions. The new fossil plant has the characteristics of a callipterid and is assignable to the morphogenus *Rhachiphyllum* Kerp. The new callipterid species is accompanied by *Macroneuropteris macrophylla* (Brongniart) Cleal, *Linopteris obliqua* (Bunbury) Zeiller, unidentified axes or stems, a small oviform reproductive organ of uncertain systematic affinity, *Lobatopteris saraeofolia* (Bertrand) nov. comb., *Pecopteris* cf. *polypodioides,* fragments of calamitalean axes and unclassified macroalgals. In addition, pectenoid bivalves and *Lingula* are present.

The stratigraphic position of the uppermost Moscovian spore assemblage of the Danville Coal is near the top of the traditional Westphalian, below the Westphalian-Stephanian (W/S) boundary. The Danville Coal spore assemblage corresponds to the lower part of GD (*Lycospora granulata-Cappasporites distortus*) palynozone in Indiana, USA (Shaver et al. 1970) and OT (*Thymospora thiessenii-Thymospora obscura*) palynozone in western Europe palynozonation (Clayton et al. 1977). The Danville Coal resides in the upper part of the Desmoinesian Series (uppermost Moscovian) and the age is confirmed by fusulinids (Douglass 1987) and conodonts (Brown and Rexroad 2009) from limestone units that bracket the Danville Coal. Peppers (1996) placed the Westphalian-Stephanian boundary above the Farmington Shale.

Finding of the oldest known remains of callipterid plant in the western equatorial Pangea agrees with onset of gradually increasing aridity in the Late Pennsylvanian in this area. At this time a belt of tropical humid climate became narrower and disappeared completely, being replaced by seasonal climate in the early Permian. We speculate that conditions for development of callipterids were more suitable here than in other parts of equatorial Pangea.

New progress on the study of conodonts from candidate GSSPs for the bases of Carboniferous stages in South China

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Carboniferous marine sediments are widely distributed in Guizhou, South China. Of these, several important boundary successions such as the Visean-Serpukhovian (V-S), Bashkirian-Moscovian (B-M), Moscovian-Kasimovian (M-K), and Kasimovian-Gzhelian (K-G) boundaries are best exposed at the Naqing (Nashui) section of Luodian County, Guizhou. Here, the relatively deep carbonate ramp facies carbonates characterize the entire Carboniferous succession. Abundant conodonts across these boundaries from Naqing allow better definitions of these stage boundaries. The Naqing section therefore is the important candidates for the GSSPs for the bases of the Serpukhovian, Moscovian, Kasimovian and Gzhelian stages.

Four conodont zones have been established from a 40-m-thick interval across the VSB: the *Gnathodus bilineatus*, *Lochriea nodosa*, *L. ziegleri* and *L. cruciformis* zones. The first occurrence (FO) of *L. ziegleri* in the *L. nodosa-L. ziegleri* evolutionary lineage has been updated from Naqing. The V-S conodont zones are well-correlated with the same zones reported elsewhere in Eurasia and are also possible to correlate with coeval zones recognized from North America. *Eolasiodiscus* cf. *donbassicus*, a previous marker of the base of the Serpukhovian, is found in a slightly higher horizon than the FO of *L. ziegleri* at Naqing. The study on the B-M conodonts indicates that rapid morphologic evolution in P1 elements of the *Streptognathodus expansus* and *S. suberectus* groups permits the recognition of a new biostratigraphic boundary for the base of the Moscovian Stage. Barrick et al. (2010) restudied conodonts across the M-K and K-G boundaries at Naqing and established relatively continuous conodont zone successions for these boundaries. All lines of evidence indicate that the Naqing section is the ideal candidate for the GSSP for these several important Carboniferous stages.

Conodont biostratigraphy of Tournaisian shallow water carbonates in central Guangxi, South China

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The conodont fauna of the Tournaisian shallow water carbonates from South China are described mainly for biostratigraphy purposes. A complete series of samples was collected from the Long'an section, which consists of Long'an Formation and Du'an Formation characterized by skeletal and peloidal wackestone, packstone and grainstone with typical shallow water biota. In all, these samples produced 809 indentifiable Pl elements, belonging to 50 species in 11 genera, of which 2 species and 2 subspecies are new.

The fauna enables us to establish seven biozones, in ascending order, these are the *Polygnathus spicatus* Zone, the *Siphonodella homosimplex* Zone, the *Si. sinensis* Zone, the *Si. dasaibaensis* Zone, *Polygnathus communis carina* Acme Zone, *Gnathodus cuneiformis* Zone and *Po. communis longanensis* sp. nov. Local-range Zone.

The *Po. spicatus* Zone is recognized thanks to the recovery of *Polygnathus spicatus* in bed 5, which co-occure with *Si. sulcata*, *Bispathodus aculeatus plumulus*, *Bi.ac. aculeatus*, *Clydagnathus gilwernensis* and *Cl. unicornis*. The *Si. homosimplex* Zone, the *Si. sinensis* Zone and the *Si. dasaibaensis* Zone are established by the first appearance of the zonal name-bearing species, and were proposed as shallow water *Siphonodella* Zones in South China, and they together could correspond to the *P. inornatus*-*Siphonodella* Local-range Zone in the British Isles due to the occurrences of abundant *P. inornatus* at the base of the *Si. homosimplex* Zone and advanced Siphonodellids such as *S. obsoleta* in the middle part of the *Si. dasaibaensis* Zone. The *Po. c. carina* Acme Zone, identified by the abundant occurrences of the eponymous species in this succession, has been found in Belgium and the British Isles. The lower limit of the *G. cuneiformis* Zone is marked by the incoming of the eponymous species, which is also a good marker for the *G. typicus* Zone worldwide. The *Po. c. longanensis* Zone, containing many endemic species, occupies the uppermost part of Long'an Formaiton and the lowermost part of Du'an Formation and corresponds roughly to the *Scaliognathus anchoralis* Zone.

Most of the conodont zones of the Tournaisian Shallow water carbonates in South China correlate well with their counterparts recognized in Great Britain and Ireland, which may be of greater significance in stratigraphic correlation than previous thought.

Carbon and oxygen isotopic records of Lower Carboniferous brachiopod shells from Southern Guizhou, South China

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Carbon and oxygen isotopes of brachiopod shells from Lower Carboniferous sections (Baihupo, Yangfengxiang and Baijin sections) in Guizhou were produced to investigate the carbon isotopic compositions and palaotemperature in Paleotythyan region during that time. 62 specimens were examined under transmitted light and cathodoluminescence microscopes, and of which 39 were selected for the analyses of trace element to evaluate the preservation. In total, 176 powders were drilled from brachiopod shells and associated matrix or cements for stable isotopic analyses.

The Early Carboniferous $\delta^{13}C$ and $\delta^{18}O$ values of nonluminescent (NL) and slightly luminescent (SL) shells from open sea range from -0.3 to 6.6‰ and from -5.2 to -2.7‰, respectively.

The carbon isotope trend begins with values of around 0‰ in the early Tournaisian, increase to a maximum of 6.5‰ in late Tournaisian. This peak has also been found in micritic limestone of Nevada U.S.A.) and brachiopod shells of the U.S. Midcontinent, and may represent one of the largest global carbon isotope events in the Phanerozoic. The $\delta^{13}C$ values show homogenous values of around 5.3‰ with minor exception in early Visean; decrease to a minimum of 1.6‰ in the middle Visean; rise to a peak of 6.6‰ in the late Visean. Following this peak, $\delta^{13}C$ values fall back to 2.4‰ before rising up above 5‰ in the Serpukhovian.

The oxygen isotopes range from -5.2 to -4.4‰ in early Tournaisian. The first major increase of $\delta^{18}O$ values from the early Tournaisian to early Visean (-4.0‰), associated with the major sea level fall during the Tournaisian/Visean transitional time interval, indicate that climatic cooling may have occurred in late Tournaisian. The $\delta^{18}O$ values of Visean brachiopod shells preserved in similar depositional environment fluctuated between -4.9 and -3.1‰, probably reflecting the seasonality changes of paleotemperature. The $\delta^{18}O$ values in the late Visean-Serpukhovian generally increase upward, shifting from -3.8 to -2.7‰. This positive shift coincides with the shallowing upward successions in South China, glacio-eustasy sequences in North America, and extensively distributed glacial deposits, marking the onset of Permo-Carboniferous Glacial Maximum.

The Late Carboniferous basal Grant Group unconformity, Canning Basin, Australia: a complex surface recording glacial, tectonic and halotectonic processes

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The glacial origin of the Permo-Carboniferous siliciclastic succession in the Canning Basin is widely supported by both subsurface data and outcrop studies. The cored interval within the Hoya Formation of the Grant Group consists of diamictite, sandstone, conglomerate, breccias and mudstone, within facies associations that strongly suggest a glacial influence.

The angular unconformity at the base of Grant Group forms a distinctive surface evident both at outcrop and in the subsurface on seismic and well logs. The processes controlling the formation and morphology of this surface are complex, and cannot be ascribed to glacial erosion alone. Detailed analysis of an extensive 2D seismic dataset, integrated with available well data, suggests the mechanisms that produced and deform this surface can be subdivided into three categories based on their timing: either pre-, syn- or post-Grant Group deposition. Processes that were active pre-and syn-Grant deposition have major impact on the thickness and facies distribution of the Grant Group.

Pre-Grant deformation induced changes in topographic relief, associated either with tectonic activity during the Middle to Upper Devonian (Pillara Extensional Movement) or the Mid- to Late Carboniferous (Meda Transpressional Movement). This resulted in reactivation of older normal faults and generation of small en echelon anticlines.

Syn-Grant processes include the development of localised subsidence and accommodation associated with asynchronous salt dissolution, which produced significant local thickening of the Grant Group. Later salt dissolution resulted in development of "turtle type" mounded structures identifiable on seismic and locally called "Worral Sombreros". The dominant syn-Grant process producing relief on the Grant Group unconformity was the erosion of large valleys observed in the study area. These vary significantly in size, ranging up to 4 km wide and 400m deep. The degree of erosion is partly controlled by the nature of the substrate, which in turn is related to pre Grant inversion associated with movements of the Dummer Range Fault. There is significant facies variation in valley infill observed on seismic, from low amplitude chaotic reflectors interpreted as sandstone, conglomerate or diamictites, to high amplitude reflector typical of mudrocks. These features are interpreted, based on morphology and context, to be glacially eroded valleys, either sub glacial or outwash valley systems.

The most significant tectonic movement responsible for Post Grant deformation is the Late Triassic to Early Jurassic Fitzroy Transpressional Movement. This resulted in fault reactivation and development of a series of en-echelon anticlines.

This study unravels the complex nature of the Base Grant unconformity. Better understanding of the unconformity surface will aid prediction of sedimentation and improve models for hydrocarbon reservoir, source, seal facies and timing of charge versus trap formation.

Global Correlations and the Viséan-Serpukhovian Stage Boundary

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Since inception in 2002, the Viséan-Serpukhovian Boundary task group of the ICS Subcommission on Carboniferous Stratigraphy has progressed substantially toward selecting a GSSP for the boundary. Their work is focused on strata containing the *Lochriea nodosa - Lochriea ziegleri* conodont lineage, not yet recognized in North America. The first appearance datum (FAD) of *L. ziegleri* in the *L. nodosa - L. ziegleri* lineage presents the best potential for defining the Viséan-Serpukhovian Boundary GSSP. The FAD of *L. ziegleri* is in the upper Brigantian Substage, a position slightly below the type Serpukhovian in Russia. The lineage, best documented from deep-water carbonates, has been identified in numerous Eurasian sections. One of the best European localities is the Millaró section (by village of Millaró) in the Cantabrian Mountains of Spain. At Millaró well-preserved conodonts within the *L. nodosa - L. ziegleri* lineage are abundant in the Alba Formation and the FAD of *L. ziegleri* located with moderate precision. In basin to lower-slope carbonates of the Nashui section in Guizhou Province, China the FAD of *L. ziegleri* is precisely located. The FAD of *L. ziegleri* has also been carefully located in basinal carbonates by the Ural River at Verkhnyaya Kardailovka village, Russia. A major biostratigraphic advantage of the Millaró and V. Kardailovka sections is the abundant ammonoids. Elements transitional between *L. nodosa* and *L. ziegler*i are plentiful at Nashui and V. Kardailovka, and oldest representatives of *L. ziegleri* can be distinguished from transitional *L. nodosa*. Although the *L. nodosa - L. ziegleri* lineage has not been located in North America, *L. ziegleri* has been found in the Barnett Formation of Texas. Establishment of chemostratigraphic and sequence-stratigraphic trends across the boundary in several sections and intensive study of foraminifers associated with the *Lochriea* lineage at Nashui and other Chinese sections should lead to a good correlation with North America at the proposed level. Study of ammonoids occurring with the *Lochriea* lineage at V. Kardailovka and nearby sections combined with work on Viséan-Serpukhovian ammonoids in Western Europe and Chainman Shale of the USA will facilitate Global boundary correlations. The task group is studying corals and microfaunas in carbonates spanning the boundary in the Etherington Formation of western Canada in an attempt to obtain a good correlation with Eurasian sections containing the FAD of *L. ziegleri*. The best GSSP candidates are the V. Kardailovka and Nashui sections. The Millaró section has potential rivaling that of the others.

The Carboniferous World: Assembly of Pangea and Onset of late Paleozoic Glaciations

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The Carboniferous (359.2 - 299.0 Ma), comprising the Mississippian (Tournaisian, Viséan and Serpukhovian) and Pennsylvanian (Bashkirian, Moscovian, Kasimovian and Gzhelian), was a period of profound change. Continents were assembled forming Pangea with continent-continent collisions and subduction causing magmatism, volcanism and emplacement of base-metal orebodies. After the latest Famennian glaciation, greenhouse conditions predominated until the late Viséan onset of high-frequency glaciations and interglacials on southern Gondwana that continued into the Permian. Carbonates formed on ramps and less commonly platforms with shelf-margin reefs. Shallow-marine, deltaic and coastal-plain successions are conspicuously cyclic. Pre-late Viséan low- to mid-latitude sequences were largely controlled by tectonism, are frequently carbonate dominant and autocyclic, lack high-frequency regionally developed subaerial unconformities and commonly include extensive cyclic carbonate tidal-flat facies. Post-middle Viséan, low- to mid-latitude sequences typically resulted from glacially controlled sea-level changes superimposed on tectonic cycles. The latter sequences, resulting from interaction of periodically varying orbital parameters of the Earth's orbit (Milankovitch cycles) on climate and sedimentation, are allocyclic and high frequency, show regionally developed high-frequency subaerial unconformities on supratidal to neritic lithofacies, and comprise either mixed-carbonate-siliciclastic facies or coal-bearing siliciclastics. Chert-dominated successions formed in basin to slope settings at subtropical to mid-latitudes, whereas glacial and related siliciclastics were deposited at high-latitudes on Gondwana. Establishment of anoxic bottom-waters during major transgressions produced hydrocarbon source rocks comprising black shale. After the Late Devonian extinctions, invertebrate groups recovered substantially and crinoid abundance peaked, contributing vast amounts of debris. Stromatoporoids never recovered but new reef builders evolved and, along with submarine cements, constructed mounds and shallow-water reefs. Biostromes, constructed by communities resembling those of the reefs were common. Fusulinids appeared and became major components of Pennsylvanian carbonates. Biotic changes on land included the appearance of abundant amphibians and winged insects, formation of coal swamps dominated by seedless vascular plants, and establishment of upland gymnosperm forests. The evolution of reptiles from amphibians permitted vertebrates to colonize dry land.

Ocean redox history during the Early Triassic

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The greatest mass extinction occurred at the end of the Permian. A meaningful biotic recovery was delayed until the end of the Early Triassic, which lasted about 5 million years. This was an extraordinary long delay for biotic recovery after a mass extinction, the Early Triassic therefore has often been considered as an interval when global conditions repeated opposed to life. Several euxinic phases during Early Triassic have been reported. However, ocean redox history of whole Early Triassic has not yet clarified. Here we show euxinic conditions gradually became much stronger toward the end of the Early Triassic and the most severe condition occurred just before the recovery in eastern equatorial Paleotethys sea (South China). This condition suddenly disappeared and dissolved oxygen levels abruptly increased in the Middle Triassic. This phenomenon coincides with the biotic recovery in the Middle Triassic. Dibenzothiophenes and arylisoprenoids are detected which provide unequivocal evidences for depositional environment euxinia and photic zone euxinia at ~80 m water depth, respectively. These biomarkers became more abundant toward the end of the Early Triassic. Noteworthy detection is Okenane, a biomarker for photic zone euxinia at ~20 m water depth, from the top of the Lower Triassic. The detection of okenane is the first time in Phanerozoic. Moreover, crocetane which is a biomarker for anaerobic methanotrophic Euryarchaeota (ANME) is detected from the upper part of the Lower Triassic. Crocetane indicates existence of methane in the late Early Triassic sea. This methane might be derived from methane hydrates. One of the concentration of crocetane coincides with the okenane concentration. The most severe euxinic condition at the end of the Early Triassic was possibly caused by anaerobic oxidation of methane triggered by melting methane hydrates. This is a model case that melting methane hydrates is not only a driver of global warming but also a driver of ocean euxinia.

A terrestrial vegetation turnover in the middle of the Early Triassic

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Land-plant productivity was greatly reduced after the end-Permian mass extinction, causing a pronounced "coal gap" during the Early Triassic worldwide. Newly obtained organic geochemistry data from the Chaohu area, south China, indicated an abrupt and profound terrestrial vegetation change over the middle part of the Early Triassic Smithian–Spathian (S–S) interval. Herbaceous lycopsids and/or bryophytes dominated terrestrial vegetation through Griesbachian to Smithian times. The terrestrial ecosystem underwent an abrupt change, and woody conifers became dominant over the S–S interval. Several important biomarkers, namely retene, simonellite, and dehydroabietan (with multiple sources: conifer, lycopsid, and/or herbaceous bryophyte), were relatively abundant during Griesbachian, Dienerian, and Smithian times. The relatively low C/N ratio values during the Griesbachian–Smithian interval indicate that these biomarkers were likely sourced from herbaceous lycopsids and/or bryophytes. The extremely abundant conifer-sourced pimanthrene, combined with relatively high C/N ratio values, suggested the recovery of woody conifers after the S–S boundary. The new data revealed that the switch from herbaceous vegetation to woody coniferous vegetation marked a terrestrial plant recovery, which occurred globally within 3 million years after the end-Permian crisis rather than at a later date estimated in previous studies. In Chaohu, the S-S terrestrial event was marked by a positive δ^{13}C excursion, a reappearance of woody vegetation, an increase in ichnodiversity, trace complexity, burrow size, infaunal tiering level, and bioturbation level, and a possible deep-ocean upwelling event indicated by the extended tricyclic terpane ratios (ETR). Coeval vegetation changes with comparable patterns have also been documented in Europe and Pakistan based on palynologic studies. They are associated with a positive δ^{13}C excursion, the rebound of woody vegetation, a turnover of ammonoid faunas, and possible global climate cooling. This is the first study to document the S-S event using biomarkers and C/N ratios.

Correlation of the base of the Serpukhovian Stage in Northwest Europe and North America

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The Task Group charged with proposing a GSSP for the base of the Serpukhovian, the third stage of the Mississippian (Lower Carboniferous), has been examining the utility of a biostratigraphical tool – the First Appearance Datum (FAD) of the conodont *Lochriea ziegleri* in the lineage *Lochriea nodosa*-*L. ziegleri* – for the definition and subsequent correlation of the base of the stage. It is important to establish that the first occurrence of *L. ziegleri* is isochronous. In many evolutionary lineages, an ancestral taxon does not become extinct at the inception of its daughter taxon, and the two taxa may co-exist for some time. This can lead to a situation in which the FAD of the daughter taxon is not its evolutionary earliest occurrence, even where an evolutionary lineage has been demonstrated. Ammonoids provide high resolution biostratigraphy in the late Mississippian but their use for international correlation is limited by provincialism. However, it is possible to assess the levels of diachronism of the FAD of *L. ziegleri* in sections in northwest Europe, using the high resolution ammonoid biozonal scheme common to these areas. In NW Ireland, *L. nodosa* and *L. ziegleri* both first occur in the *Lusitanoceras granosus* ammonoid Biozone (P_{2a} zone of the British scheme). In the Yoredale facies of northern England, the FAD of *L. ziegleri* is high in the P_{1d} zone; and in the Craven Basin it is at least as old as the P_2 zone. Published compilations of conodont distribution in the Rhenish Slate Mountains of Germany, show the first occurrence of *L. ziegleri* in the *Emstites novalis* Biozone (upper part of the P_{2c} zone). However, in the original description of *L. ziegleri*, it is reported as occurring in the *Neoglyphioceras spirale* ammonoid Biozone (P_{1d} zone). Thus, it seems likely that the true first occurrence of *L. ziegleri* in northwest Europe is high in the P_{1d} Biozone of the British ammonoid scheme. This correlation is consistent with the situation in one of the leading candidate sections for the GSSP, the Verkhnyaya Kardailovka section, Bashkortostan, Russian Federation, where conodonts and ammonoids occur together. The other leading candidate section, the Nashui section, Guizhou Province, China has not yielded ammonoids.
Correlation of the base of the Serpukhovian to sections in North America, from whichever GSSP is selected, will have to rely on auxiliary biostratigraphical tools. At present, foraminiferans offer the best possibility, particularly the first occurrence of *Asteroarchaediscus postrugosus*.

Evolution of a latest Devonian–Early Carboniferous mixed carbonate–siliciclastic ramp (Fairfield Group) Canning Basin, northwestern Australia

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Detailed sedimentological analysis of core from 40 wells on the northwestern Lennard Shelf, northern Canning Basin, was undertaken to interpret the depositional history of the latest Devonian–Early Carboniferous carbonate-siliciclastic Fairfield Group within a sequence–stratigraphic framework. Fourteen facies associations are identified from core. The majority of associations (FA1-FA9) were deposited on a broad inner ramp with open marine to restricted shallow subtidal–supratidal conditions. Shallow subtidal–intertidal fenestral microbial mats and bioclastic facies were widely developed on the platform and are typically dolomitised. Sandstones and siltstones represent deposition on tidal flats and in open marine areas. Protected and restricted shallow subtidal areas on the platform are typically fine-grained carbonate facies. Bioclastic facies were deposited in high energy zones as shoals. Two facies associations represent the middle to outer ramp and are characterized by distal carbonate mudstone and proximal bioclastic sandstones (FA10-FA11). Three outer ramp to slope facies associations are composed of turbiditic sandstones and limestones (FA12-FA14).

A distally steepened ramp morphology for the Fairfield Group identified from seismic data is supported by extensive peritidal platform facies and turbiditic facies of the outer ramp. The Fairfield ramp evolved from the underlying Famennian platform topography as a result of the global loss of reef-builders during extinction events in the Late Devonian, ongoing tectonic activity associated with the Fitzroy Trough and relative sea-level changes. The initial Fairfield carbonate-dominated ramp evolved to be a siliciclastic-dominated ramp in the Early Carboniferous.

The Fairfield Group is subdivided into five regional stratal packages and two local packages that represent four third-order sequences (S1-S4). The sequences are bounded by flooding surfaces and include transgressive system tracts composed of mid to outer ramp facies associations and capping highstand system tracts composed of inner ramp facies associations. Lowstand system tracts, identified in S2 and S3, are characterised by siliciclastic wedges deposited on the outer ramp. Overall, the Fairfield Group was largely deposited during sea-level highstands characterized by progradational trends and dominant shallow subtidal inner ramp facies associations. Reservoir development resulted from dolomitisation of coarse carbonate facies of the highstand system tracts on the distal inner ramp.

The end-Permian mass extinction: a single- or two (multiple)-phase extinction?

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The end-Permian (end-Changhsingian) mass extinction has been unanimously documented as the largest extinction during the Phanerozoic. However, the extinction pattern and cause remain controversial. One of key issues to unravel the causes is to figure out the extinction pattern based on not only single section, but also multiple sections spanning a large palaoegeographic area with different sedimentary settings. In South China, two major different extinction patterns have been documented recently. One suggests that the extinction happened in a short time less than half mys; and the other favors a stepwise pattern that occurred in two or multiple episodes. However, our studies suggest the two (multiple)-phase extinction pattern based on stratigraphic ranges of different fossil groups from different sections in South China actually occur in different levels and the step-wise extinction patterns are largely due to the Signor-Lipps Effect or facies changes or bed-by-bed fossil collecting bias. The extinction has a continuously accelerating disappearance process with no distinct diversity punctation within the short extinction interval if considering the Signor-Lipps Effect and using confidence interval approach to re-locate the last appearances of all recorded species. The end-Permian extinction pattern is very different from the two-phase model of the end-Ordovician mass extinction that was intervened by an invasion of the new distinct Hirnantian Fauna associated with a glacial pulse. Our analyses using both range data and CONOP9 approach based on a large data set from different paleoenvironmental settings demonstrate that the extinction pattern is consistently happened within a short interval.

Lopingian (Late Permian) biostratigraphy, chemostratigraphy and correlation between South China and Iran

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The Lopingian Series represents the last epoch of the Palaeozoic Era and recorded two severe biotic mass extinctions associated with severe environmental changes. South China and Iran are two of the very few places in the world with well-preserved marine Lopingian deposits and have become the most extensively studied areas. In this report, we use a sample-population approach, to develop a high-resolution conodont biostratigraphic framework for the Lopingian of South China and Iran. Seven Wuchiapingian conodont zones and five Changhsingian conodont zones in South China are integrated based on our new collections and previously published materials. The high-resolution Lopingian conodont zonation in Iran is closely correlative with its counterpart in South China. However, slightly different evolutionary trends in *Clarkina* populations existed at the very end of the Changhsingian between Iran and South China. This reflects a geographical cline and/or facies dependence in *Clarkina* populations rather than stratigraphic incompleteness of sections in either Iran or South China. Carbon isotope chemostratigraphy and magenetostratigraphy provide other supporting evidence for the biostrtigraphical correlation between South China and Iran. Our studies indicate different taxonomic philosophies of condonts may produce very different correlation and high-resolution calibration is essential to understand the model of the Earth's largest biotic extinction at the end of Permian.

Permian sequences and faunas in the peri-Gondwanan region and their palaeogeographical and tectonic implications

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The rifting and drifting of different tectonic blocks in the peri-Gondwanan region has long been one of the most hotly-discussed issues among geoscientists. Extensive investigations during the past decade indicate that numerous sections with carbonate and clastic deposits containing abundant Permian faunas are distributed in the Himalayan region and the Indus-Tsangbo Suture Zone in southern Tibet. A detailed comparison of faunal affinities among different tectonic blocks in different stages in the Permian Period suggests that nearly all blocks in the peri-Gondwanan region including the Qiangtang, Baoshan, Tengchong, Lasha and the Himalaya Tethys Zone are characterized by containing diamictites and typical cold-water faunas in the pre-Artinskian time, therefore were probably in a relatively high-latitude area and attached to the northern margin of Gondwanaland. By the end of late Sakmarian or early Artinskian time, warm-water faunas first occur in the Baoshan and Tengchong blocks in western Yunnan, which probably implies that those blocks began to drift away from the peri-Gondwanan margin and they moved to a relatively warm temperate zone in the Late Guadalupian (Middle Permian), as indicated by widespread distribution of warm-water faunas and carbonate deposits. The earliest warm-water faunas occurred in the Midian in the Lasha Block, which suggest a slightly later rifting and/or climatic amelioration than the Tengchong and Baoshan blocks. Numerous exotic blocks between the Lasha Block and the Himalaya Tethys Zone containing abundant Middle Permian fusuline faunas and compound rugose corals also indicate a different palaeontological content and palaeobiogeographical affinity between the Lasha Block in the north and the Himalaya Tethys Zone in the south. By the Late Permian (Lopingian) time, these palaeontological and palaeobiogeographical disparities became more evident, therefore strongly suggest that the Lasha Block probably rifted away from the peri-Gondwanan region in the early Middle Permian, a much earlier opening of the Neotethys – not Triassic as previously suggested.

Where worlds collide: Permian analogues of Wallacea

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On a global scale, the provinciality of biotas at any given time is in part a function of the number, size, spatial position and orientation of continental masses. Therefore, when lithospheric plates move about, global continental configuration changes as a consequence, which in turn renders Earth's provincialism waning and waxing over time. This generalised tectono-biogeographical model is best manifested by the concepts of the Wallace Line and Wallacea, first recognised by Alfred Russell Wallace over 150 years ago as a demarcation boundary across the Indonesian archipelagos that divide the present-day Australian biogeographic region from its neighbouring Asian biogeographic region. Subsequent further research on the biogeography of the SW Pacific and SE Asia revealed that the Wallace Line may not be as abrupt as Wallace originally conceived. In fact, many biogeographers now accept that the divide between the Australian and Oriental regions is better to be portrayed as a biogeographic mixed (or transitional) zone, whose origin has generally been attributed to the tectonic collision of the Australian plate with the Eurasian plate in the Miocene.

In this presentation it is suggested that the model that accounts for the genesis of 'Wallacea' could also explain, to a large extent, the evolution of the Permian provincialism in two separate geologic domains of the present-day Asia-Pacific region. During the Permian, East Asia was located at the inter-junction between two large palaeo-plates (Cathaysialand and Angaraland) and three large palaeo-oceans (Palaeotethys, palaeo-Arctic and Panthalassa). As such, the Permian palaeogeography of East Asia was characterised by a complex pattern of ocean-to-continent and ocean-to-arc subduction systems, giving rise to a highly varied and dynamic tectonic landscape of continents, marginal basins, magmatic arcs, ocean-born island arcs, as well as back-arc and intra-arc basins. This complexity of Permian palaeogeography and tectonism of East Asia was also well reflected in the 'deep-time' historical biogeography of its Permian biotas. It is suggested that tectonic motions involving both large continental plates and smaller terranes, coupled with a mid-latitude setting and a 'gateway' palaeoceanographic position analogous to Wallacea, were primarily responsible for the transformation of East Asia from an early Permian 'dual-biotic-provinciality' stage (with both Boreal and Cathaysian provinces present) to a mixed biota stage in the Middle and Late Permian. Interestingly, many features of the Permian palaeogeography and biogeography of East Asia outlined above may be compared with that of southwestern China (southern and central Tibet, West Yunnan), southeast Asia and, to some extent, southeastern Gondwana (eastern Australia, New Zealand and New Caledonia). This comparison would demand a more generic geodynamic model that can explain apparently synchronised global tectonic, environmental and biotic changes for the Permian world.

Argentinean-Siberian Late Palaeozoic marine biogeographic links: implications for Permian global marine biogeography and climate change

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Strong antitropicality has been noted in the global distribution patterns of Late Palaeozoic biotas, for both animal and plant fossil records. However, just as there has been an extensive debate surrounding the origin of the modern biotic antitropicality, palaeobiogeographers are also deeply divided with regard to the initiation, dynamic development and underlying control mechanisms of this phenomenon in the fossil record. Existing models relevant to antitropicality in 'deep time' tends to emphasise the role of tectonic vicariance events, surface ocean currents, palaeogeography and suitable climatic conditions in the long-distance dispersal of antitropical taxa. Other alternative models are available but limited.

The present study is built on recent new discoveries of well preserved Carboniferous-Permian antitropical brachiopod taxa from Argentina. These new reports not only have confirmed the presence of Late Palaeozoic biotic antitropicality between Gondwana and the Arctic, but have also allowed us to reassess the relative strength of the various existing scenarios invoked to explain the origin and development of this remarkable Late Palaeozoic biogeographical phenomenon. As an alternative interpretation, here we propose a new scenario based on our detailed taxonomic study of two separate, but morphologically similar, lineages of Late Palaeozoic productoid brachiopods. It appears plausible that the morphological similarities between a lineage of Late Palaeozoic Argentinean brachiopod genera, ranging from *Lanipustula* (Viséan) through *Verchojania* (Moscovian-Kasimovian) to *Jakutoproductus* (Asselian-Artinskian), and that of the same lineage from Siberia (Verchoyansk Mountains), could be a consequence of parallel evolution, although trans-oceanic dispersal as a mechanism of initiating and sustaining Late Palaeozoic antitropicality remains a viable scenario. If parallel evolution was indeed the mechanism for initiating Late Palaeozoic antitropicality between Argentina and Siberia, it must have commenced during the late Viséan at a time when the Earth was experiencing a global cooling phase allowing the trans-oceanic and global dispersal of some cool-water brachiopod genera (e.g. *Absenticosta*, interpreted as the ancestral stock of the parallel lineages) from lower to higher latitudes. It is interesting to note that the parallel lineage thus far has only been noted to be shared between Argentina and Siberia. The reason for this remains little understood, although several possibilities could be discussed. Obviously, the role of Antarctica is critical in this discussion due to its close position to Patagonia and between South America and Australia during the Late Palaeozoic; however, the scarcity of Late Palaeozoic marine fossils found in Antarctica presents a great challenge for any further studies in this regard.

Fusulinids in the Dianqiangui Basin during Early and Middle Permian, South China: pattern and causes of their diversification

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Animal's diversification is a comprehensive story of life interacted with natural environment. The diversity pattern of fusulinid from the Dianqiangui Basin in South China during Early and Middle Permian has been explored and analysed to reveal the major fusulinid bio-events and their inherent causes.

A fusulinid dataset from 27 sections of the Dianqiangui Basin was compiled, and changes of several diversity indices, including the apparent diversity, speciation rate and extinction rate, from the Late Carboniferous to Middle Permian were pursued. Results show that there are two climaxes in specific diversity respectively in the Asselian Stage, Early Permian, and the Wordian Stage, Middle Permian. In detail, species diversity in the Asselian Stage is rather higher, resulted from the overall higher speciation rate of the Early Permian fusulinids, while the genus replacement rate in the Wordian Stage is quite faster, benefitted from high genus production and extinction rate.

As to the causes of the high speciation rate in the Asselian Stage, the first is probably good adaptation ability of Schwagerininae. Schwagerininae is the major taxon of Asselian fauna, does have a much higher speciation rate compared with the second major taxon, Pseudoschwagerininae, as well as all major taxa of Wordian fauna, i.e. Neoschwagerininae, Summatrininae, Schwagerininae, and Verbeekininae. Major genera of Schwagerininae, such as *Triticites*, *Pseudofusulina* and *Schwagerina*, are all cosmopolitan, which means they could live under all kinds of climate, whereas the Pseudoschwagerininae, Neoschwagerininae, Summatrininae and Verbeekininae are mainly restricted in tropical areas. Moreover, some important genera of Pseudoschwagerininae, such as *Sphaeroschwagerina* and *Robustoschwagerina*, only thrived in certain carbonate facies even in tropical areas (Zhang et al., 1988).

Schwagerininae fusulinids have fusiform shell and simple inner structure, and are believed to be the benthic in the shallow sea. Their great adaptation to all kinds of climate and sedimentary facies, and slow movement capability may lead to high speciation rate.

Secondly, different rate of the sea level change could be responsible for different speciation rate. Sea level change curve in the Dianqiangui Basin during Carboniferous and Permian shows that the eustatic change is rather gradual in the Asselian Stage while considerably rapid in the Wordian. Varied niches could form during the gradual sea rise in the Asselian Stage and therefore gave rise to the quick speciation of Schwagerininae or Pseudoschwagerininae. However during the Wordian, rapid sea level rise and fall could be the reason of low speciation rate and fast genus replacement.

Early Triassic Griesbachian Anachronistic World after the P-T Mass Extinction in Upper Yangzi Area, Southwest China – is the Gaia Theory applicable?

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Here we describe two major stratigraphic PTB sections plus several minor sections in the Upper Yangzi area(SW China). Particular attention was payed to the succession of earliest Triassic marine carbonates that formed in an oceanic setting but under rather anomalous conditions. The anomalous carbonates of the Lowest Triassic were divided into three main groups by genesis: Group A-biogenic, Group B-abiogenetic (chemical and hydrodynamic) and Group C-multi-genesis anachronistic carbonates. Specific lithological members of the anachronisitc carbonate succession are: (i) microbiolite, (ii) vermiculate limestone -category A, B and C, (iii) laminated limestone and argillaceous limestone, (iv) limestone breccia and flat-pebble conglomerates, (v) ribbon limestone and (vi) mottled limestone. In the Shuijingping section the Lower Triassic mottled limestone interpreted by us as the incipient hydrochemical change of the Tethys Ocean at the PTB.

Our sedimentological and isotopic data suggest that the anachronistic carbonate facies can be interpreted as the result of both, the extreme oceanic environment and climatic conditions at the PTB. In the course of the P-T mass extinction, benthonic animals went almost completely extinct, while the surface layer of the sea experienced storms. Subsequent to the mass extinction (especially during the Later Griesbachian substage), the seafloor was affected by frequent cyclonic storms that stirred up the unconsolidated carbonate ooze, which resulted in accumulation of syngenetic calcirudites in the sections of NW Sichuan. The Upper Griesbachian limestone breccia in the Shangsi Section (SBB) probably indicates the start of an extremely turbulent paleoclimate. Moreover, we interpret the ribbon limestone developed in Chongqing area as the result of the regular alternation between the processes of clastic sediments and chemical sediments.

The Gaia theory describes the life–environment system of the Earth as stable and self-regulating (Lovelock, 1995; Free and Barton, 2007). Does the Gaia theory still hold for major extinction events in the earth history like the P-T Mass Extinction? In the sedimentological/paleoenvironmental model suggested via our sedimentological analysis from NW Sichuan, some abiotic environmental feedback mechanisms are evident. Biological feedback and stabilizing mechanisms were severely weakened subsequent to the P-T mass extinction, favoring development of extreme environmental conditions that in turn delayed the biotic recovery of the earth system significantly.

Middle Pennsylvanian Bohemian and Poland corditaleans and their dispersed cuticles

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Cordaitaleans belong to common elements of the Euramerican Pennsylvanian Flora. Their lanceolate, or ribbon-shape leaves with parallel venation are difficult to classify, namely from fragments. Venation itself is not sufficient for species determination, because leaves with similar venation patterns can have different cuticular types (Šimůnek, 2007). Dispersed cuticles were obtained from coal samples from the Upper Silesian Basin (Poland; 90 *Cordaites* cuticles and about 12 species) and the Intrasudetic Basin (Bohemia; 120 *Cordaites* cuticles and about 5 species). In contrast to roof rock "in situ" cordaitalean cuticles, they bear much more papillae on ordinary epidermal cells (palaeoecological bias?). The principal features of cordaitalean cuticle are parallel oriented cells and stomata in rows or bands. The problem is how to name dispersed cuticles in the artificial system. Meyen (1966) suggested creating generic name with suffix *–stomites,* Roselt and Schneider (1969) with suffix *–cutis.* We were not named dispersed cordaitalean cuticles yet.

Polish and Bohemian cordaitalean samples are of the Westphalian age and a distinct stomatal type similar to the Bolsovian *Cordaites borassifolius* from the Radnice Basin (Bohemia, Šimůnek, 2007) has been found in the dispersed spectra: transverse crypt with two papillae covering the outer stomatal chamber. The dispersed cuticles are more papillate. We call them *Cordaites borassifolius*-type, because other information is not known.

In the type area of *Cordaites schatzlarensis* Šimůnek et Libertín, 2006 (Duckmantian, Intrasudetic Basin, Bohemia), the comparable dispersed abaxial and adaxial cuticles from a coal sample were called by the same name. The other cuticles, that probably do not have equivalent among "in situ" cuticles, are necessary to evaluate. This is a preliminary research, but we hope that it will contribute to stratigraphy and palaeoecology of the Carboniferous.

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An Algal Bloom (green algae of zygnematalean affinity) from the Gechang Formation (Lower Permian) of Spiti Basin, NW Himalaya, India

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Reduviasporonites Wilson 1962, a senior synonym of *Chordecysta* Foster 1979 and *Tympanicysta* is a genus of filamentous microfossils. The natural affinities of the specimens described under these taxa are uncertain and they have been interpreted either as being of fungal origin or of possible algal origin. Abnormal frequency of this taxon at the P/T boundary is known from the Junggar Basin, Northern Xinjiang, China; Russia; Greenland, United Kingdom, Austria, Southern Arabia and Australia. In the present study, *Reduviasporonites*, has been recorded for the first time from India along with other forms of zygnematalean affinity in the Gechang Fm that ranges from Asselian to Sakmarian in age on the basis of *Eurydesma* reported from the lower part of this Formation and the presence of *Waagenophyllum* in the upper part. In the study material, pollen grains of *Scheuringipollenites* have also been found in the assemblage. The present work proves that *Reduviasporonites* is not only restricted to a narrow span of time at the Permian-Triassic Boundary, but it also lived beyond the postulated time of mass-extinction at the P/T boundary. In the present study, fragments of filaments, dispersed cells and zygospores are recorded. The filaments are slender with cylindrical cells having signatures of chloroplasts. Dispersed cells are barrel shaped with smooth and folded transverse septa. *Spirogyra* filaments are also present. The microfossils assigned to *Reduviasporonites/Chordecysta/Tympanicysta* are more closely related to the Zygnematalean algae of the Order Cladophorales/Zygnematales.

Biodiversity of the Palaeozoic rocks in the North West Himalaya, India -A Review

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The Indian sub-continent consists of a peninsular region and the extra-peninsular Himalayan region. Himalayan region again consists of the Lesser Himalayan zone and the Tethyan Himalayan zone. The Peninsula is completely devoid of the rocks of Ordovician to Carboniferous ages. The oldest Palaeozoic sediments here belong to earliest Permian Talchir Formation (Asselian-Sakmarian). Further sedimentation during the Late Palaeozoic Period in the Peninsula occurred under fluvio-lacustrine conditions and belongs to Karharbari Fm. (Artinskian), Barakar Fm. (Kungurian), Barren Measures Fm. (Guadalupian) and the uppermost Raniganj Fm. (Lopingian). All these formations are basically continental in nature and store all the Gondwana coals.

The Lesser Himalaya is also devoid of Early Palaeozoic rocks and the late Palaeozoic sedimentation in this zone occurred during Early Permian. In contrast to the Peninsula and the Lesser Himalaya, an almost complete Palaeozoic succession is developed in Kashmir and the Spiti areas of the Tethyan Himalaya.

A few palaeobotanical investigations were carried out in India on the rocks of Ordovician to Carboniferous ages as compared to the enormous work done on the Gondwana deposits of Peninsular India. Sir Henry Hayden discovered the Pre-Gondwana flora from Po and Tabo villages of Spiti area in 1904. Gothan and Sahni (1937) described this collection and identified the first ever *Rhacopteris* flora of Lower Carboniferous age in India. Later on Sahni (1953) described *Hostinella* and *Psilophyton* like axes from the Silurian rocks in the Spiti area. Hoeg et al., 1957 and Dhar et al., 1980 also reported some more Lower Carboniferous fossils from Spiti region.

In contrast to the Spiti region, Kashmir has better developed Palaeozoic sequences represented by Aishmuqam Formation, Syringothyris Limestone Fm., Fenestella Shale Fm., Agglomeratic Slate, Nishatbagh Fm., Panjal Volcanics, Mamal Fm. and Zewan Formation that range in age from Upper Devonian to Upper Permian in ascending order of succession. The Devonian, Carboniferous and the Permian floras of Kashmir have been recorded from more than 30 localities by a number of workers. The floras of Silurian, Devonian and Carboniferous ages in Kashmir and Spiti regions consist of around 42 species belonging to 21 form genera, and the Permian floras of Kashmir area consist of 60 species belonging to 29 genera.

The present paper provides an updated account of the previous and recently published megafloral assemblages reported from the Silurian, Devonian, Carboniferous and the Permian sediments exposed at a number of localities across Kashmir and Spiti regions. This review work also deals in the regional geology and the depositional environment of the fossil sites. We also compare the present floras with the known contemporary floras across the world.

Reef complex of Carboniferous deposits of the central part of the Volga-Ural province

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Carboniferous sediments of the central part of the Volga-Ural province were formed in the changing paleogeographic conditions. This is due to geodynamic differentiation of its main structural and tectonic elements - a system of uplifts of the Tatar arch and its surrounding rift zones. One of the major rift zones - Kama-Kinel system, the major development of which is related to the Carboniferous period of tectonic activation of the Russian plate. This basin is characterized by a complex shape and associated with adaptation of dynamic active sites in the region to have already formed and stable domes systems of the Tatar arch.

Studies of the complex coal deposits that form this rift system indicate landmark expansion of the system in Carboniferous period due to the formation of structural terraces. There took place formation and development of reef complexes that traced structural terraces of the Kama-Kinel rift. Lithological study of these reef complexes allows us to establish the sequence of their development from the Tournaisian to Bashkirian time.

In the Tournaisian time these reef complexes are typical organogenic, micrite-organogenic and ballstone. At the time of Visean carbonate sedimentation of these complexes is replaced by terrigenous. In the Bashkir time once again replaced by carbonate. However, due to aridization of paleoclimate regime in the development of reef complexes the major role goes to sulfate and carbonate-sulfate sedimentation associated with increased salinity. That's why sediments are gypsified a lot.

In the Volga-Ural province with the studied reef complexes associated numerous deposits of hydrocarbons, characterized by multi-storey structure. Reservoir rock is usually located at the base of reef structures, and their higher plastered horizons are confining beds.

A detailed study of the lithology and mineralogy of reef complexes of the Kama-Kinel system allows not only restore the Carboniferous paleoclimatic characteristics, but also to forecast the oil content of individual reef arrays of this system.

Mississippian microbial mounds and coral reefs from Central Morocco

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Mississippian microbial mounds occur in the southern Azrou-Khenifra Basin, west of Khenifra, Central Morocco. The Tabainout mound lies directly on Ordovician sandstones. Basal Carboniferous deposits are polymictic conglomerates and sandy limestones, succeeded by bedded bioclastic limestones of upper Viséan (Asbian) age, containing a rich and diverse assemblage of solitary and colonial rugose corals. The overlying massive fine-grained limestones with stromatactoid cavities represent the core facies of the mounds, and show rare solitary corals (*Amplexus* and *Axophyllum*). The upper part of the mounds and flank beds are composed of coquinas with abundant crinoids and goniatites, and locally rich Brigantian corals, including rare *Kizilia*. Shales with *Cyathaxonia*-fauna corals succeed the mounds. Similar late Viséan rmounds are recorded from the northern part of the Azrou-Khenifra Basin at Adarouch, as well as at Jerada in NE Morocco, and in the eastern Anti-Atlas near Erfoud.

A Mississippian fringing reef with a coral framework is located at Tiouinine, south of Khenifra. The reefal facies rest directly on Devonian sandstones. There is a complete zonation from near-shore deposits to reefal talus. The near-shore deposits (sandy packstones) occur in a narrow band and pass transitionally, through coral biostromes with coral patches, to reef core facies. The latter is composed of fasciculate and massive corals reinforced by algal masses around corals and microbial micropeloidal mudstone/ wackestone coating the corals and algae. The spaces between corals and algae are infilled by crinoidal and coral grainstone. Dominant reef-building corals include *Siphonodendron, Lithostrotion, Diphyphyllum, Tizraia*, and *Michelinia*. The fore reef facies contains bioclastic limestones with fragments of colonial corals and crinoids, with scour channels and reworked debris. The Upper Viséan (Brigantian) aged Tiouinine reef is unique in Morocco and has the highest number of rugose genera and species for a single locality.

Serpukhovian foraminiferal markers from Central Morocco

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A continuous Upper Viséan to Bashkirian sequence is recorded in the Adarouch area of Central Morocco. The succession is composed mainly of limestone and shale with red bed siliciclastic rocks at the top. The base of the Serpukhovian is marked by the first appearance of *Eostaffellina decurta, Eostaffellina* spp*., Eostaffella pseudostruvei, Loeblichia ukrainica* and *Archaediscus* at *tenuis* stage, as well as unusual and rare *Zellerinella*, and *Endothyranopsis plana*.

Late Serpukhovian taxa include *Brenckleina rugosa*, *Eosigmoilina robertsoni*, *Loeblichia minima*, *Bradyina cribrostomata, Plectostaffella* spp., *Eostaffellina protvae, Eostaffellina paraprotvae,* and *Monotaxinoides* spp., together with the zonal conodont *Gnathodus bilineatus bollandensis*. Higher in the late Serpukhovian is recorded *E. postmosquensis* and *Globoomphalotis.*

The Serpukhovian/Bashkirian (Mississippian/Pennsylvanian) boundary at Adarouch is marked by the first occurrence of rare *Globivalvulina bulloides*, *Seminovella elegantula,* and *Novella*? The base of the Bashkirian is marked by the zonal conodont *Declinognathodus noduliferus.*

Although the Adarouch Serpukhovian succession formed at the northern margin of Gondwanaland, it shows all the characteristic taxa of western Palaeotethyan basins, including the Donets, Moscow Basin and the Urals, and also shows some affinities with North American successions.

Large Seawater Sulfur Isotope Perturbations During the Early Mesozoic

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The end-Permian mass extinction was the largest biotic crisis in the Phanerozoic record, with global loss of marine species estimated at ~90%. Low-diversity marine ecosystems, extensive and persistent marine anoxia, and large and frequent shifts in the marine carbonate C-isotope record indicate that Early Triassic marine conditions were unstable and deleterious to marine fauna. Studies of carbonate-associated-sulfate (CAS) and pyrite $\delta^{34}S$ document a major perturbation of the global sulfur cycle in conjunction with the end-Permian mass extinction. S-isotopic variation in shallow-marine settings has been attributed to deepwater anoxia and strong bacterial sulfate reduction (BSR) followed by upwelling and partial oxidation of deepwater hydrogen sulfide. However, there has been less effort on investigating sulfur isotopic evolution in the aftermath of the extinction. Sporadic evaporite $\delta^{34}S$ data document a positive shift during the Early Triassic, but most of the existing evaporite $\delta^{34}S$ data are from late Early Triassic and the exact age of the shift is poorly constrained.

Here, we report a series of $\delta^{34}S_{CAS}$ data sampled in high resolution from the uppermost Permian to the Middle Triassic at the Great Bank of Guizhou in southern Guizhou Province, Southwest China. The results show that the S isotopic composition of seawater sulfate underwent significant excursions throughout the Early Triassic, with fluctuations of 10 to 20‰ at timescales of a few hundred thousand years. CAS $\delta^{34}S$ rose irregularly during the Griesbachian and Dienerian substages to a peak value of ~+35‰, fell during the Smithian substage to a minimum of ~+15‰, and then underwent another excursion to ~+30‰ during the Spathian before stabilizing at ~+18‰ during the Middle Triassic. These variations in CAS $\delta^{34}S$ probably record the influence of intense BSR in deep water and drawdown of seawater sulfate concentrations during intervals of rising CAS $\delta^{34}S$, and the influence of enhanced vertical mixing and oxidation of hydrogen sulfide in the surface watermass during intervals of falling CAS $\delta^{34}S$. Thus, perturbations of $\delta^{34}S_{CAS}$ compositions in the aftermath of the end-Permian mass extinction imply the existence of a stratified ocean that was subject to episodic vertical mixing events, which brought toxic sulfidic deepwaters into shallow-marine settings and produced unstable environmental conditions that delayed the recovery of marine biotas during the Early Triassic.

Development and diversification of *Glossopteris* flora in Early Permian sequence of Indian Gondwana

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The Permian Gondwana sequence of India shows well preserved assemblages of the *Glossopteris* flora. The study suggests that flora developed, diversified and settled during the Early Permian successions of Talchir, Karharbari and Lower Barakar formations and all the elements of the flora belonging to Lycophytes, Pteridophytes, Glossopterids, Coniferales and Ginkgoales had their emergence and manifestation.

The record of palynogical assemblages from the glacial tillites and boulder bed of Talchir Formation indicates that *Glossopteris* flora had its existence even before Permian in Indian Gondwana . The onslaught of Late Carboniferous or Early Permian glaciation forced the flora to survive in hospitable pockets with the limited presence of *Noeggerathiopsis*, *Gangamopteris*, *Arberia* and *Paranocladus*. The flora developed and diversified during Karharbari Formation with the new forms of *Euryphyllum*, *Rubidgea,Botrychiopsis, Phyllotheca*, *Schizoneura*, *Neomariopteris, Buriadia, Cordaites* and species of *Gangamopteris* , *Noeggerathiopsis* and *Glossopteris* increased substantially. The diversity and proliferation of the flora continued during Lower Barakar Formation with the addition of *Cyclodendron, Lelstotheca*, *Barakaria*, *Gondwanophyllites*, *Palaeovittaria*, *Maheshwariphyllum*, *Ottokaria, Scutum*, *Partha*, *Plumsteadia* , *Walkomiella, Cordaites, Cheirophyllum*, *Kwaziophyllum, Rhipidopsis, Psygmophyllum, Ginkgophyllum,* during this phase the species of *Gangamopteris* and *Glossopteris* increased further to attain the maturity. By the time of Late Permian the flora of Upper Barakar shows the extermination of many forms and dominance of *Glossopteris*. The similar impoverish nature of flora continued in Barren Measures but in Late Permian stage of Raniganj Formation flora rejuvenated itself with the number of species of glossopterid and pteridophytes.

The distribution and succession of plant fossils in different geologic formations of Permian Gondwana specify that the elements of *Glossopteris* flora survived the severity of Late Carboniferous or Early Permian glaciation and during Talchir and Karharbari formations flora developed successively with the emergence of new forms. The extermination of many forms and homogeneity of the flora with the species of *Glossopteris* during Late Permian upper Barakar suggest a climatic shift from warm-humid to dry condition. The aridity became more apparent in Upper Permian Barren Measures when flora reduced substantially, however, it emerged to its full strength as vengeance in Late Permian Raniganj Formation under favourable warm moist conditions.

Palynostratigraphic significance of *Pyramidosporites* Segroves 1967 in Permian strata of eastern Gondwana

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Only two species are assigned to the genus *Pyramidosporites* Segroves 1967, namely *Pyramidosporites cyathodes* Segroves 1967 and *Pyramidosporites racemosus* Balme 1970. Because of its size of around 70 µm, its tetrahedral form, and its dark brown colour *Pyramidosporites* is easily identified. *P. cyathodes* was originally described as 'an obligate tetrahedral tetrad with no clear evidence of a germinal structure'. *P. racemosus* has 'four spheroidal, spore-like bodies occurring as obligate, tetrahedral tetrads and no tetrad scar or germinal structure apparent'. *P. cyathodes* and *P. racemosus* are probably synonyms and are grouped together for stratigraphic purposes. *P. cyathodes* occurs in Southeast Turkey in the Kas Formation and lower parts of the Gomaniibrik Formation. It has its oldest occurrence in the 'Basal Khuff Clastics' in central Saudi Arabia, and it was reported from the Chia Zairi Formation in Iraq from a depth of 2,730.1 m in the Mityaha-1 well. *P. racemosus* was described from the Amb Formation of the Salt Range, West Pakistan, at a level just below the Wargal Limestone. Today, the upper Amb Formation is considered to be late Wordian. The 'Basal Khuff Clastics', and the Chia Zairi and Kas formations are also dated as Wordian to early Capitanian. *P. cyathodes* was also originally described from Western Australia from the Wagina Sandstone of the Perth Basin, and also occurs in upper Collie Coal Measures. Both records can now be considered Wordian to Capitanian in age. *Pyramidosporites* shows a nearly coincident stratigraphic appearance in the Permian of eastern Gondwana, and is therefore an excellent index fossil for correlation and dating.

First documented palynological record from Kasimovian deposits of the Zonguldak Coal Basin, NW Turkey

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Drill core material from the AK-10 well from Amasra, part of the Zonguldak Coal Basin in NW Turkey, contains organic matter rich clay- and siltstones. These rocks are part of the Çapakdere Formation, in which sandstones are commonly more represented than in the underlying, coal seam bearing Karadon Formation. The Pennsylvanian from the Amasra area has ever since been assigned to the European regional stages, principally to the Westphalian. In this study, the palynological record from AK-10 is related to the ICS international stages with reference to the microfloral zonation of 'A Geological Time Scale 2004', and to the stratigraphic framework of Heckel and Clayton from 2006. A Kasimovian age is considered for part of the AK-10 well at a depth of 637.1 – 637.6 m, based on the presence of the taxon Angulisporites splendidus in dark claystones. Although A. splendidus seems to show facies dependant occurrences along the sequence, the spore species is a valuable key stratigraphic marker for the ST Zone. Accompanying species such as Cirratriradites saturnii and Florinites spp., and the absence of Vestispora costata and Cingulizonates loricatus, which occur in older Zonguldak deposits, support the age assessment. The investigated well section shows close comparison to deposits of the Çapakdere Formation, and palynomorphs of a Kasimovian age are presented for the first time from the Zonguldak Basin.

Understanding the conodont biostratigraphy of Emeishan Large Igneous Province and its bearing on mid-Permian biocrisis

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The Permian Emeishan Large Igneous Province (LIP) was a relatively small LIP that erupted on marine setting during its early stage. This unique setting enables us to conduct comprehensive conodont biostratigraphic and facies analysis studies on Maokou Limestones that were underlying and/or intercalated the initial lava flows. The studies sections span the localities from the LIP central area via LIP periphery to several hundred kilometers beyond the LIP margin. The results suggested the initial onset of the Emeishan volcanism was probably around middle Capitanian *Jinogondolella altudaensis* conodont zone, which was seen at Xiong Jia Chang and Pingdi sections of Guizhou Province. The large scale eruption only occurred later around *J. xuanhanensis* zone, which was seen at six sections of Sichuan and Yunnan Province. This phenomenon is also observed in other LIP (e.g. Paraná-Etendeka) where the initial eruptions were small and increased in extent and volume with time. The onset of Emeishan volcanism coincided with -5~-6% negative shift of carbonate carbon isotope around *J. altudaensis* zone, the extinction of keriotheca-walled fusulinaceans (e.g., Neoschwagerinidae), and the changeover of calcareous algae.

Together with former studies, we conclude that the initial and main stages of Emeishan volcanism were within the Capitanian (~263 Ma) rather than around the Gaudalupingian-Lopingian boundary (~259 Ma). Our conodont data provide not only important constraints on biostratigraphic controls of Emeishan volcanism, but also the correlation criteria for further studies.

The stage boundaries of the Middle and Upper Carboniferous based on conodonts in the Volga Region

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The boundaries of stages of the Middle and Upper Carboniferous in the Volga region are marked by changing of the conodont assemblages.

1. In the Serpukhovian-Bashkirian boundary there is considerable renewal in the conodont assemblages. The genera *Cavusgathus, Gnathodus* disappear and several new genera: *Declinognathodus, Idiognathodus, Idiognathoides*, *Neognathodus* appear at this boundary.
2. A great variety of conodonts are found at the Bashkirian-Moscovian boundary. This boundary in the Volga region is defined by the first occurrence of *Declinognathodus donetzianus* Nemirovskaya. In addition, species *Diplognathodus orphanus* Merrill and *Idiognathoides postsulcatus* Nemirovskaya appear near the lower boundary of the Moscovian Stages.
3. Important changes in conodont assemblages occur at the Moscowian-Kasimovian boundary. Many *Streptognathodus subexcelsus* Alekseev & Goreva are found there. The first appearance of this species in the Volga region is restricted to the lower part of the Kasimovian Stage.
4. Conodont assemblages at the Kasimovian-Gzhelian boundary include several species, such as: *Idiognathodus simulator* (Ellison), *Streptognathodus eccentricus* Ellison, *S. alekseevi* Barskov, Isakova & Stshastlivzeva.
5. Only a few conodont species: *Adetognathus lautus* (Gunnell) and *A. paralautus* Orchard, are found at the Carboniferous-Permian boundary.

Euxinic maximum coinciding with the end-Permian mass extinction following progressive euxinia development inferred from trace elements and sulphide sulphur isotope

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The end-Permian mass extinction was the greatest paleontological event of the Phanerozoic. We here describes the variations of trace-elemental compositions that took place in the paleo-super-ocean "Panthalassa" during the end-Permian mass extinction, based on the sedimentary rock samples from one of the most continuous Permian-Triassic boundary section of pelagic deep-sea, exposed in the northeastern Japan area (Akkamori section-2; Takahashi et al., 2009). Our measurement shows high concentrations of chalcophile elements (Zn, Ni, Co, Cu, Mo, and Pb) and redox-sensitive elements (V and Cr) are present in Upper Permian to end-Permian strata in the Am-2 section. The high concentrations of these elements developed in a distinct succession. First, V (probably in the first reduced state, which requires at least weakly reducing sea-water) shows a peak in the Changhsingian chert beds, and is followed by Zn, Ni, Co, and Cu, which have peaks in the overlying siliceous claystone beds. Finally, Mo, Pb, and V (probably in the second reduced state, which requires strongly reducing sea-water) show high concentrations at the base of the black claystone. These elemental uptake in sediment suggest reduced sea-water condition (e.g. Algeo and Maynard 2004). Especially, co-occurrence of high concentrations in Mo, Pb, and V imply water-column euxinia above the bottom water (Algeo and Maynard, 2004). Therefore, this succession of changes in element concentrations indicates a progressive development of euxinic water-mass in the central Panthalassa, and was probably associated with upward expansion of the euxinic deep-water pool and radiolarian demise. The sharp decrease in $\delta^{34}S_{sulfide}$ and the Mo and Pb precipitations are accompanied by a sudden lack of radiolarian fossils and a carbon isotopic excursion signal coinciding with the mass extinction (Takahashi et al., 2010). A possible explanation for these coincidental changes is that euxinic deep-water development caused the chemocline to rise to a shallow water depth at the central Panthalassa, resulting in the acceleration of oxidation and re-reduction of sulfide (isotopically light) and a collapse in radiolarian productivity. Such expanded euxinic deep waters might represent an important causal factor in the end-Permian mass extinction in central Panthalassa.

Induan (lowest Triassic) radiolarians from Arrow Rocks, New Zealand, and the radiolarian faunal transition above the P/T boundary

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Radiolaria is a principal plankton fossil group in Late Paleozoic and Early Mesozoic. The biggest change of radiolarian faunas occurred around the P/T boundary, where most of Paleozoic radiolarian species seems to go extinct near the boundary. The detail of this faunal change, however, was obscured because of the scarcity of our knowledge about Early Triassic radiolarian fauna. Recently, Induan (Lowest Triassic) radiolarians were reported from Arrow Rocks (Oruatemanu Island), a small islet in New Zealand, and it was clarified that many Permian radiolarians survived across the P/T boundary (Takemura et al., 2007).

Permian to Triassic ocean floor sequence, named as the Oruatemanu Formation, crops out on Arrow Rocks. This formation is composed of basalt with limestone lenses, bedded chert and siliceous mudstone, and divided into 9 lithologic units, Units 1, 2a, 2b and 3 to 8. The geologic age of this formation was determined mostly by conodonts (Yamakita et al., 2007). While the bedded cherts and mudstones of Unit 2a is Middle to Late Permian in age, Units 2b to 7 were determined as Early to Middle Triassic.

Many Triassic conodonts were reported from Units 2b and 3 of the formation, which is composed mostly of bedded cherts. They include *Ng. carinata*, *Ns. kummeli*, *Ns. dieneri* and *Ns. cristagalli*, and the age of Unit 2b and 3 is assigned as Induan, Earliest Triassic. At present, Induan cherts are not reported from other localities in the world, except Waiheke Island near Auckland, New Zealand, where lowest Induan chert exists at the base of the sequence (Hori et al., 2011).

Relatively well-preserved radiolarians were obtained from 17 horizons in Griesbachian and lower Dienerian interval within the formation. In this study, we report the occurrence of more than 30 species in this interval, many of which are Permian-type, including genera *Albaillella, Follicucullus, Entactinia, Entactinosphaera, Copicyntra, Copicyntroides, Hegleria, Cauletella* and *Quadriremis*. The Induan radiolarian fauna changes gradually upward. Griesbachian fauna shows larger similarity to Permian, whereas some Permian genera disappeared in lower Dienerian. Genus *Oruatemanua*, descendant of Late Paleozoic Latentifistularia, is peculiar to this interval. Some nassellarians occur in middle Dienerian, which are the almost oldest Nassellaria, characteristic of Mesozoic and Cenozoic radiolarian faunas.

Gondwana megaspores of India – architectural radiation, distribution, evolutionary and biostratigraphic significance

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Megaspores-the female reproductive units of heterosporous, early land plants, when found as fossils are significant indicators for the presence of land plants, especially lycopsids a group otherwise scarce in the Indian Gondwana succession. Megaspores are a significant biostratigraphic tool since some are restricted to a particular horizon, while others are widely distributed. In India, dispersed fossil megaspores are present in the Early Permian Talchir Formation, extend through the Karharbari, diversify through the Barakar Formation and reach a peak in the Late Permian Raniganj Formation and display a distinct evolution in morphology. However, this evolutionary trend is not so distinct in the Mesozoic.

Megaspores demonstrate a well defined range of shape, exosporium characters like presence and absence of tri-radiate and contact ridges, ornamentation, and the nature of the mesosporium/inner layer, which may display or lack cushions. The exosporium ornamentation displays a marked variance from Early Permian to Early Cretaceous, reflecting the diversity of the parent plants. The Early Permian megaspores exhibit a wide variety of ornamentation including laevigate and micropitted/granulate; those of the Late Permian are by and large spinate and show various types of straight, hooked, stout, simple, bifurcate and multifurcate spines. Some of these sculptures indicate aquatic and sub-aquatic environments. Additionally, the presence of the alete, spinate taxon Kamthispora–a seed megaspore and a marker for the Raniganj Formation probably indicates an intermediate stage between a megaspore and a seed. Some Mesozoic megaspores show reticulate exosporia, which are not recorded from the Permian. Evidently, the outer layers of megaspores exhibit a distinct evolutionary trend. In most Mesozoic megaspores, though the exosporium/exine/outer wall layer is well known, the mesosporium /intine/inner body/inner wall layer has either not been studied or is not well documented because it involves time-consuming destructive maceration. This trend has seriously affected the complete and comprehensive knowledge of megaspores and ultimately reflects on the study of their evolutionary pattern. A careful, detailed study of morphological characters will result in a detailed understanding of evolutionary trends in megaspores that will lead to information on the evolution of their parent plants.

Development of oolites in the aftermath of the end-Permian mass extinction

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Following the end-Permian extinction event, a delayed interval of unusual deposition occurred in the Early Triassic reflected by microbialites, wrinkle structures, seafloor precipitated carbonate fans, and flat pebble conglomerates. Oolitic limestone, another sedimentary response, is one kind of common rocks in the uppermost Permian and Lower Triassic strata in the Paleotethys realm. However, it attracts much less attentions.

Our study focuses on the temporal and spatial distribution of oolitic limestone during the Permian-Triassic interval. Oolitic limestone occurred suddenly in the end-Permian and became rich in the Early Triassic. The Permian-Triassic boundary oolitic limestone beds, being characterized by small and simple coated grains, have been found in Europe, South China, and Vietnam while Permian-Triassic boundary oolitic limestone only occurred in South China. Induan oolites, known as "Giant Ooid", are marked by big sizes and complex structures and have been found in South China. Olenekian oolites, appearing in South China and America, are much smaller than Induan oolites, and even smaller than the uppermost Permian oolites.

Generally, oolitic sediments occurred at the eve of the end-Permian extinction event and disappeared in the begging of Middle Triassic. The coincidence between oolitic sediments and end-Permian extinction and subsequent delayed biotic recovery suggests that oolitic limestone is a significant sedimentary response to the end-Permian crisis.

High-frequency cyclicity recorded in the aftermath of the end-Permian mass extinction: Case study of the Lower Triassic Yinkeng Formation at the Meishan section, South China

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As consequence of the most devastated biotic crisis of Earth life at the end of the Permian, the Early Triassic marine fauna fossils appeared very rare worldwide. The depauperate nature of marine faunas suggests a rather low bioturbation level, which enables the excellent preservation of very fine rhythmic cyclicity in the Early Triassic sediments. The well-preserved rhythmic sediments are characteristics of the Lower Triassic successions worldwide. Here, we present a case study of the lowest Triassic Yinkeng Formation exposed at the well-know Meishan Section, South China, the GSSP for the P-Tr boundary (Yin et al., 2001).

In Meishan the Lower Triassic successions comprises the Yinkeng and Helongshan Formations, which overly above the platform facies carbonates of the latest Permian Changhsing Formation. The early-middle Griesbachian Yinkeng Formation, ~14 m thick, is composed of 70 decimeter-scale rhythmic alternations, which comprises seven lithofacies: claystone, black shale/mudstone, calcareous mudstone, marlstone, muddy limestone, and limestone.

We utilized high-resolution time series of carbonate content as numerical proxy to reconstruct high-frequency rhythmic cyclicity and further probe into their possible climate-driving mechanism. Spectral analysis indicates these very fine rhythms can be grouped into the 6th-, 5th-, 4th- and 3rd-orders cycles, implying that they were likely astronomically controlled with eccentricity as the dominant orbital parameter. Furthermore, the astronomical duration of the sedimentation of the Yinkeng Formation can be determined by multiplying the number of eccentricity cycles with the corresponding period from the latest astronomical solution. These are reinforced by the high-frequency cycle analysis using the modified Fischer plot methods.

Age dating of the Araguainha impact crater and implications for the Permo-Triassic carbon isotope record

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The end-Permian mass extinction witnessed the largest reduction in biodiversity in Earth history, but the cause(s) of this catastrophe remain controversial. Chemostratigraphic studies of P-T sections worldwide have demonstrated a global excursion towards negative delta 13C, although the cause of this isotopic shift is unknown. In this contribution, we demonstrate the potential for the massive release of isotopically light carbon from the Araguainha impact crater, located in the northern Paraná Basin of central Brazil. A multi-isotope study of the shocked minerals and melt rocks from the impact crater yield an age that is essentially synchronous with the known age of the mass extinction and the carbon isotope excursion. We present several lines of geological evidence from the Paraná Basin demonstrating that the seismic effects of the Araguainha crater caused the release of isotopically light carbon at the time of the impact. These results demonstrate the potential for an extraterrestrial trigger for some of the events of end-Permian times.

Magnetostratigraphic and geochronological age constraints on the lowermost Beaufort Group, Karoo Basin

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The Karoo Basin of South Africa is a classic foreland basin sequence, with sedimentation putatively linked to Gondwanide orogenesis in the Cape Fold Belt. Biostratigraphic data for the fluvial to lacustrine sediments of this basin provide good regional correlations, but uncertain absolute age assignments. A recent magnetostratigraphic and geochronological study undertaken on the lowermost Beaufort Group of South Africa provides new, unambiguous age information for depositional age of these rocks. Volcanic zircons from various tuffaceous horizons were analyzed for U-Pb age by SHRIMP. The youngest population of late Permian zircons are interpreted as the age of volcanic ashfall and sedimentation, with inheritance from pre-existing crust recognized from the presence of 500 Ma and 1000-1100 Ma zircons. Magnetostratigraphic sampling was carried out in two separate sedimentary profiles,180 m and 500 m thick, that are separated by roughly 50 km. Diagnostic patterns of normal and reversed magnetozones allow for the close correlation of these two sections. This pattern, anchored by the U-Pb zircon ages, can be correlated to the Global Polarity Timescale of Ogg et al. (2008), and supports a late Guadalupian age for these sediments.

Evidence for the Triassic Recovery in South China

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The great Paleozoic-Mesozoic transition is not only characterized by the biggest Phanerozoic mass extinction but also by the delayed recovery in the aftermath of extinction. The elongated Triassic recovery even produced more evidence for a better understanding of the great transition. South China has not only excellent Permian-Triassic boundary geological records for defining the boundary GSSP and studying the end-Permian mass extinction events, but also continuous Lower-Middle Triassic sequences covering various paleogeographic lithofacies for understanding the characteristic recovery and succeeding radiation. Evidence from South China indicates that the recovery of benthic community clearly speeded up at the beginning of the Anisian but radiated in the mid-late Anisian. Though the Permian-Triassic transition resulted in the replacement of the Brachiopoda by Bivalvia in marine invertebrate communities, the Brachiopoda still were the main group in the Anisian recovered and radiated benthic communities. However, the full recovery and radiation of marine ecosystems happened with the appearance of carnivorous reptiles in the late Spathian in terms of ecosystem structure and food-chain composition although some links in the food chain might not be recorded in body fossils but trace fossils during the time. Moreover, the primary consumers such as foraminifers show an earlier speeding of recovery in the early Olenekian. But the environmental markers such as carbon isotopes suggest that the intense fluctuation of marine conditions would persist till the end of the Early Triassic.

The Moscovian-Kasimovian and Kasimovian-Gzhelian boundaries – an overview and progress report

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The Task Group to establish the Moscovian-Kasimovian and Kasimovian-Gzhelian boundaries in SCCS deals with establishing the two stage-base boundaries of the Late Pennsylvanian. In this presentation, a general view of the boundaries and current progress of the boundary work are briefly introduced.

The traditional base of the Kasimovian Stage was put within the fusuline *Protriticites* genus-range zone of the Moscow Basin, but this level was not easy for precise correlation both interregionally and globally. Recently the Task Group agreed to focus their further study on two conodont species, *Idiognathodus sagittalis* and *I. turbatus*, as the potential biostratigraphic marker by which the level of the base of the Kasimovian Stage can be selected and correlated globally. They occur in the North American Midcontinent and some Eurasian basins. Their first occurrence level is approximately one-stage higher than the traditional base of the Kasimovian at the base of the Krevyakinian Substage, but it would facilitate global correlation. Moreover, this level is close to the first occurrence level of the fusuline *Montiparus*, which is known to occur in wider areas of Eurasia. Now Task Group members continue studying relevant sections in the Moscow Basin and Urals (Russia), Donets Basin (Ukraine), Cantabrian Mountains (Spain), Guizhou (China), Midcontinent Basin (USA), and others, from which both or either conodont species are documented. Due to observed high provincialism of marine biota during this time interval, our task work of fixing the marker taxon and then settling the GSSP has still run into difficulties until now. But we are in the process of determining the direction toward choosing the marker event as a first step.

For the Kasimovian-Gzhelian boundary, the conodont *Idiognathodus simulator* (s.s.) was formally selected as the event marker. The fusuline *Rauserites rossicus*, which widely occurs in Eurasian basins, can be served as a potentially auxiliary taxon for the base of the Gzhelian. As a step of settling the GSSP, the Usolka section of the South Urals and the historical Gzhel Quarry section of the Moscow Basin were proposed as potential GSSP candidates until now. Recently, our Chinese colleagues, in collaboration with international specialists, work on the Nashui section of southern Guizhou, South China. It is a typical slope section with rich conodonts, including *I. simulator*, and fusuline-bearing beds at the base of some coarse-grained turbidites. After completing the detailed taxonomic work, this section would also be nominated as a potential GSSP candidate of the base-Gzhelian. Moreover, colleagues from Moscow recently started investigating a new section at the Yablonevyy Ovrag Quarry in Samarskaya Luka (Samara, Russia). It exhibits a continuous succession and bears various kinds of fossils (including *I. simulator*). We await their detailed work.

Carbonoschwagerina-mimics from the Zongdi section of South China: new relatives or homeomorphic strangers?

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Carbonoschwagerina is a schwagerinid fusuline genus, which has peculiarly inflated shells like Permian *Pseudoschwagerina* and is known as a good marker of the Gzhelian in the Panthalassa and Eastern Tethys. *Carbonoschwagerina* clearly shows a successive inflation of shell in their evolution and based on this feature, their phylogeny and biostratigraphic value are well understood. Until now, however, this genus has not been reported from South China. We newly found interesting inflated schwagerinids that can be closely compared morphologically with *Carbonoschwagerina* but could be disparate from it (thus we call them here *Carbonoschwagerina*-mimics) from the Zongdi section of southern Guizhou, South China.

The Zongdi section is one of shallow-marine successions on the Yangtze Carbonate Platform, which developed on the South China Craton during Late Paleozoic time. In the measured interval of about 150 m thick spanning from the late Moscovian to the Asselian, we recognized a total of 26 depositional sequences (DS1~DS26), which are bounded by major subaerial exposures (sequence boundaries). Fusulines are abundant in especially lower and upper portions of the sequences, which are generally represented by peritidal-facies deposits. We found three forms of *Carbonoschwagerina*-mimics from the upper part of DS13 and the lower part of DS14.

Fusulines are characterized by advanced *Protriticites* and *Quasifusulinoides* in DS11, by *Montiparus* in DS12, and by abundant *Triticites* and rare *Quasifusulina* in DS13. The base of DS14 corresponds to the first occurrence level of the genus *Rauserites* in this section and bears *Rauserites* ex gr. *rossicus, Triticites* sp., *Quasifusulina* sp., and others. This fusuline succession clearly demonstrates that DS11~DS13 is referable to the Kasimovian and the base of DS14 coincides with the base-Gzhelian. Form A of *Carbonoschwagerina*-mimics was found in the upper part of DS13, whereas Forms B and C occur in the lower part of DS14. Morphologically, Form B somewhat resembles *C. morikawai*, which has a moderately inflated shell and occurs in the early Gzhelian. Form C has a well-inflated shell and is very similar to *C. minatoi*, which is known as the direct descendant of *C. morikawai* and clearly indicates a late Gzhelian age.

The *Carbonoschwagerina*-mimics from the Zongdi section look like genuine *Carbonoschwagerina*, and particularly Form C is indeed similar to *C. minatoi* in gross shell morphology. Because they occur from obviously different chronostratigraphic intervals and seemingly have different ancestors, however, we conclude that they highly probably represent different lineages in inflated schwagerinids. They are not directly related phylogenetically and thus can be better interpreted as merely homeomorphic strangers.

Strato-systematics: A new technique for refining marker taxa

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Current biostratigraphic calibration involves identifying marker species that have been defined through traditional taxonomic methods. Developments in systematics over the last 40 years allows for existing taxonomies to be tested for natural groupings, meaning that it is possible to refine and re-diagnose genera. These natural groups may be able to help stratigraphers and taxonomists alike, allowing for taxonomic reinterpretations of fossil marker species, which could create a refined and more accurate stratigraphic column. As a tool for biostratigraphy, 'strato-systematics' may become highly advantageous as will be shown in several examples using trilobites. In addition, several problematic Carboniferous trilobite taxa of Eastern Australia will be flagged for revision.

Early Triassic foraminifers from the Gorny Mangyshlak and Caucasus to the Alps: new and published data

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The Early Triassic foraminifer assemblages of Caucasus area and Gorny Mangyshlak have some typical features: nodosariids are very diverse, attached and primitive agglutinated foraminifers are diverse and dominant. The late Olenekian assemblage of the Gorny Mangyshlak is similar to those present in the Western Caucasus and Eastern Precaucasus, but they are more diverse. *Ammodiscus minutus* and *Meandrospira pusilla* assemblages occurs in the Olenekian of the Eastern Precaucasus, the first also in uppermost Induan and lower Olenekian of the Western Caucasus. Foraminifer assemblage of the uppermost Induan to the lower part of the upper Olenekian of Crimea consists of diverse nodosariids, attached and primitive agglutinated foraminifers and *Meandrospira*. The taxonomic composition of the Early Triassic foraminifer assemblages from these regions make them close to the coeval foraminifer assemblages from parts of the Carpathians and Balkans.

In North Italy (Dolomites) and Hungary (Transdanubian Mid-Mountains) there are two "foraminiferal beds": *Cyclogyra – Rectocornuspira* beds contain index foraminifers only, and they are presented in the upper part of lower Induan – lower part of upper Induan; and *Meandrospira pusilla* beds, which usually occurs from middle part of upper Olenekian. Moreover in North Italy the last assemblage is known from the upper Induan of the Werfen Formation of the Western Dolomites and different levels of the Werfen Formation (Induan - Olenekian) of the Trentino-Alto Adige. In Lombardian Alps *Meandrospira pusilla* assemblage is reported upper from the Olenekian of Servino Fm. Moreover, *Cyclogyra* sp. and *Rectocornuspira* sp. are reported from Induan of this formation. So, in North Italy the foraminifers occur from the Induan to Olenekian. *Meandrospira pusilla* assemblage is typical for upper Induan to the Lower and Middle Anisian.

New investigation in the Lombardian Alps allowed us to find the *Meandrospira* assemblage in the new outcrops of the Servino Fm. (Gastropod Oolite and *Myophoria* beds). So, foraminifers were found in the known and new stratigraphic levels of the Lombardy.

The existence in the Early Triassic of the similar coeval foraminifer assemblages from Europe to Asia allows us to mark that the paleobasins of these territories were probably connected and the foraminifers migrated over considerable regions. The Olenekian transgression makes the more favorable conditions for foraminifers and to cultivate the similar communities on the discussed territories.

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Compound-specific hydrogen and carbon isotopic evidence for the origin of the pristane abundance anomaly around the Permian-Triassic boundary (GSSP at Meishan, China)

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Biomarker compositions of the Permian–Triassic boundary (PTB) strata at the Meishan section (GSSP) are characterized by higher Pristane/Phytane (Pr/Ph) values (ca. 1.5–4.7, with an average of 3.0) and high Pristane/nC_{17} (ca. 0.6–2.6, with an average of 1.8), which usually indicate oxic sedimentary conditions. However, this is conflicted with the fact that some intervals in the PTB strata are relatively rich in Chlorobiaceae-derived aryl isoprenoid hydrocarbons diagnostic for photic zone euxinic conditions (Grice et al., 2005). The high Pr/Ph values at Meishan PTB could have been caused by abnormal accumulation and preservation of pristane-rich lipids and metabolites from some marine animals, under some special conditions such as the catastrophic death of animals and anoxic water column (Wang et al., 2005). However, this explanation has not been supported by other studies. Here, we provide the compound-specific hydrogen and carbon isotopic data for the Meishan section, which may help to understand more about the origin of the Pr/Ph value anomaly.

The results show that δD_{Pr} and δD_{Ph} values of the Beds 23–32 vary from -136‰ to -89‰ and from -198‰ to -110‰, respectively, indicating that phytane is strongly D-deleted compared with pristane and n-alkanes. The ΔD (δD_{Pr}-δD_{Ph}) values change from 6‰ to 73‰ with an average of 28‰, accompanying with the higher Pr/Ph values and showing some co-variation with ΔC (δC_{Pr}-δC_{Ph}) in these intervals. It is very important that the δD_{Pr} value varies negatively with δD_{Ph} value, indicating that a strong hydrogen isotopic fractionation occurred between pristane and phytane. This scenario has not been found in other geological records and could not be caused by terrigenous organic matter input, diagenesis or thermal maturation. Thus, animal metabolism processes is proposed to have caused this hydrogen isotopic fractionation. If so, the compound-specific H and C-isotopic data may support the pristane enrichment mechanism (Wang et al., 2005) and provide valuable information about the marine ecosystem during Permian-Triassic transition.

The Carboniferous and Lower Permian of South China, sedimentologic cycles and biotic events

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The Carboniferous and Permian of South China is recorded by characteristic Paleo-Tethyan biota and depositional types. The base of the Carboniferous is characterized by microbial sediments that indicate the beginning of transgression after the Hangenberg extinction event of the upper Devonian. The Lower Carboniferous lithology is diverse, ranging from basinal and shelf carbonate rocks to coal measures and continental clastics, which consists of several major sedimentary cycles. The Upper Carboniferous and Lower Permian, however, are composed mostly of shallow-marine carbonates, which consist of remarkable, high frequency sedimentary cycles that were highlighted by as many as more than 25 subaerial exposures.

A decrease in the diversity of benthic fauna occurred in the Serpukhovian, followed by a change in the composition of fossil assemblages at the Mid-Carboniferous Serpukhovian—Bashkirian boundary. This compositional change was associated with a regressive event, recognized by the absence of upper Serpukhovian strata in many places and by several erosional surfaces in carbonate sequences in South China. This regressive event was probably caused by an episode of glaciation in Gondwana. Subsequent transgression occurred in South China during the early Bashkirian, where a wide, uniform shallow-water platform developed in South China, on which were deposited tidal-flat dolostone and pure limestone containing new faunal assemblages.

Another major change in the faunal assemblages, at the Sakmarian-Artinskian boundary, resulted in the absence from the Artinskian of representatives of typical Pennsylvanian and Earliest Permian families of rugose corals and fusulinids. Families uniquely typical of the Kungurian and mid Permian, characterized by rugose coral Waagenophyllidae and Kepingophyllidae, as well as by fusulinid Verbeekinidae dominate post-Sakmarian strata. This faunal change may be related to a major, worldwide regression, recognized at the end of the Sakmarian.

Earliest Triassic anachronistic carbonates in NW Sichuan, China: implications for the turbulent evolution of the Earth system after the P-T mass extinction

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Anachronistic carbonates, e.g. flat-pebble conglomerate, are widely found in the Lowest Triassic Griesbachian 1st member of Feixianguan Formation of NW Sichuan, China. Here we describe an important stratigraphic section at Shangsi plus another section at Dagouli, in which typical Permian-Triassic boundary (PTB) is exposed. The intact Griesbachian sedimentary succession of Shangsi Section records the lithological change from normal bedded carbonates to the anachronistic sediments, along with the synchronous paleontological change from fossiliferous limestone to nearly unfossiliferous massive limestone breccia and bedded flat-pebble conglomerates, indicating the turbulent evolution history of the Earth system shortly after the end-Permian mass extinction.

A distinct erosion surface was developed at the bottom of the upper Griesbachian limestone breccia which was named Shangsi Breccia Bed (SBB). Flat-pebbles, 15-20 centimeters in length (a-axis), were found in the breccia. Laterally, limestone breccia transformed to flat-pebble conglomerates in Shangsi Section. The flat-pebbles, generally 0.5-3 centimeters in length (a-axis), were developed in the conglomerates. Sedimentary structures of storm deposit including chrysanthemum-shaped pebble, hummocky cross-bedding etc. are seen in the flat-pebble carbonates. Thus it is inferred that the flat-pebbles in the limestone breccia to a certain extent was storm-generated. However, the meter-sized clasts in the limestone breccia, which was interpreted as gravity flow sediment by Zhao et al. (1994), along with the distinct erosion surface, should imply a tectonic movement. It is therefore concluded that the enigmatic limestone breccia in NW Sichuan is the result of tectonic processes and cyclonic storms (generating in situ brecciation). Based on the lithological, paleontological and stratigraphical analysis, we postulate that the storms were triggered by the Griesbachian tectonic movement and the cyclonic storm was a major cause for the Early Triassic delayed recovery from the end-Permian mass extinction.

It is indicated in the thin sections and via X-ray analysis that the clay mineral content maintains a higher value in the limestone breccia, flat-pebble conglomerates and the interlaid lime mudstones than in the carbonate sediments below the SBB. The increased clay mineral contents along with the synchronous rampaging storms imply that rapid weathering (causing a massive terrestrial influx of sediment to shallow marine) was more or less affected by the inordinate atmospheric conditions. To summarize, our sedimentological and paleontological data in NW Sichuan suggest the following scenario for the Griesbachian: a tectonic movement drove a turbulent atmospheric circulation and the resulting storms facilitated the deposition of the anachronistic carbonates. Rapid terrestrial weathering being related to the tectonic movement and cyclonic storms caused a massive influx of clay to shallow marine and all the hostile environmental conditions resulted in the delayed recovery of the Early Triassic ecosystem.

Recent progress on the Upper Permian boultoniids: their biostratigraphy and palaeogeography

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The Upper Permian in South China has been extensively studied since 1960's. The boultoniid genus *Palaeofusulina* has long been regarded as the index fossil for the Changhsingian. In recent studies we found the early Wuchiapingian *Palaeofusulina* fauna at the Penglaitan section, the GSSP for the base-Wuchiapingian, in Guangxi Province, southwestern South China. This fauna is dominated by large-sized and longfusiform *Palaeofusulina* with subordinate *Gallowayinella* and *Tewoella*. The primitive form, *Palaeofusulina minima*, is rare in number. Both the elongated *Palaeofusulina* and *Gallowayinella* show close similarities in their shell size, shape, wall structure and the coiling pattern of the inner volutions. It is highly possible that the elongated *Palaeofusulina* was derived from *Gallowayinella*. This *Palaeofusulina* fauna disappeared about 11 meters above, and has not been found in any other Wuchiapingian strata at the section. More investigations are necessary to demonstrate the biostratigrphic distribution of this genus.

The genus *Palaeofusulina* also provides reliable palaeogeographic constraints on the East and Southeast Asian Terranes of the latest Permian. The Gyanyima Limestone from southern Tibet, with the absence of *Palaeofusulina* and presence of a newly-established boultoniid genus *Dilatofusulina*, proved to be located at lower latitudes in the Neotethys. The genus *Dilatofusulina* is found for the first time in southern Tibet. It is recognized as the terminal genus in the lineage of *Dunbarula*-*Nanlingella*- *Parananlingella*- *Dilatofusulina*. A new foraminiferan zone, the *Reichelina pulchra*-*Colaniella parva*-*Dilatofusulina orthogonios* Zone, was proposed to represent the last abundant phase of foraminiferans just before the end-Permian mass extinction. This zone can be correlated broadly with the middle to upper parts of the *Palaeofusulina sinensis* Zone in the Eastern Tethys based on advanced features observed in major elements of the fauna.

Nature and timing of Late Mississippian to Mid Pennsylvanian glacio-eustatic sea-level changes of the Pennine Basin, UK

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The palaeo-equatorial Pennine Basin of northern England contains a comparatively complete Serpukhovian to Moscovian succession characterised by high-resolution ammonoid zonation and cyclic paralic sedimentation (expressed as marine bands and typically upward-coarsening deltaic cycles). Two new high-precision ID-TIMS ages on zircons from biostratigraphically well-constrained ash beds deposited during the Arnsbergian (mid-Serpukhovian stage) and earliest Bolsovian (early Moscovian stage) regional substages have been determined. The weighted mean $^{206}Pb/^{238}U$ dates of 328.34 ± 0.55 and 314.37 ± 0.53 Ma (total uncertainty), respectively, require modification of the current timescale for the Western Europe regional chronostratigraphy. These dates, combined with analyses of existing bio- and lithostratigraphic datasets, are used to constrain the temporal development of this succession with a focus upon constraining the absolute age of key biostratigraphic intervals and assessing the periodicity (magnitude and consistency) of cyclic forcing.

The areal extent of acme ammonoid facies within 47 discrete marine intervals have been determined from surface and borehole sections and used as a proxy for the magnitude of these flooding events. The recognition of 17 incised valleys, and the number of cycles removed by these major sequence boundaries, is used as a proxy for the magnitude of sea-level falls. The frequency of these events, in the light of the new radiometric dating, indicates:

1 Distinct peak flooding surfaces within Namurian strata, and those associated with ammonoid-bearing marine bands in the Westphalian succession, have an average frequency of c. 400 kyr, reflecting a long-duration eccentricity modulation;

2 Average durations of marine band cycles during the Pendleian–early Arnsbergian and Chokierian–Bolsovian, of 105 kyr and 153 kyr, respectively, may reflect a short-duration eccentricity component;

3 Multiple flooding surfaces associated with the same ammonoid assemblages in the Namurian may equate with sub-100 ka precession or obliquity frequencies;

4 Close comparisons occur between periods of increased numbers of sequence boundaries in the Pennine Basin during the late Pendleian–early Arnsbergian, late Arnsbergian–Chokierian, late Kinderscoutian–early Langsettian age and Duckmantian–early Bolsovian and the recognition of major glaciations in Gondwana.

Application of trace element geochemistry to ancient limestones: palaeoceanography, palaeogeography and palaeoecology

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The trace element geochemistry of limestone is growing in utility for understanding Earth history as mass spectrometry has become more sophisticated. Trace elements, (e.g., rare earth elements - REEs, Ba, Th, Zr) preserved in carbonate skeletons, microbialites and cements potentially provide information about water chemistry, bathymetry, proximity to hydrothermal or terrigenous sources, palaeogeography and palaeoproductivity. In general, limestones contain four major sources of trace elements, which are: 1) elements incorporated into precipitates directly from the ambient water body; 2) biologically-enriched elements accumulated by organisms or within organic matter or biofilms either enzymatically or incidentally; 3) elements associated with trapped and bound detrital siliciclastic sediment; and 4) elements deposited from younger diagenetic fluids. The first group of elements reflect the chemistry of the ambient water body and may be incorporated directly into growing mineral precipitates in ratios that reflect their occurrence in ambient fluid, thus forming proxies for the geochemistry of the water body and informing interpretations of depositional environments. The second category includes elements that are concentrated in the biominerals or organic matter of organisms or biofilms, thus serving as potential biosignatures. The third group of elements occur in transported detrital sediment and commonly represent significant sources of contamination owing to their high concentrations relative to those in limestones. The final category of elements includes those that may be introduced with diagenetic fluids. Deep basinal brines may carry elements in high concentrations (e.g., mineralizing fluids) that could overprint original geochemical signatures. Diagenetic fluids also may mobilize and remove elements from original precipitates, thus altering initial-depositional elemental distributions. The REEs have been found to be preserved in the same ratios as they occur in ambient seawater in microbialites, ooids, some, but not all skeletons (e.g., crinoids and stromatoporoids) and marine cements. As each of these types of marine carbonate are abundant through in late Palaeozoic carbonate platforms and reefs, aspects of global marine chemistry may be reconstructed through that interval on the basis of analyses of Panthalassan limestones, such as the Akiyoshi Limestone of Japan, and more continent-margin and epicontinental carbonate platforms around Pangaea.

Paleo-environmental Analysis of the Attargoo Permo-Triassic Section: A Neo-Tethyan Permo-Triassic Section

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The Attargoo Permian-Triassic boundary (PTB) section is representative of the Neo-Tethyan marine environment during the end-Permian extinction. This section is currently located in present-day Spiti Valley, Himachal Pradesh, India. In Spiti Valley, PTB sections such as Attargoo are exposed by a thin (~ 2cm) ferruginous layer separating the Permian black shale from Triassic Limestone. The $\delta^{13}C$, litho- and biostratigraphy of these PTB sections in Spiti Valley are well studied but the chemostratigraphy is not well known. Energy Dispersive X-ray fluorescence (ED-XRF), Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES), Inductively Coupled Plasma Mass Spectrometer (ICP-MS) and Loss on Ignition (LOI) were used to gather major, minor and trace elements, along with organic and inorganic carbon values for the Attargoo PTB section. Using multivariate chemometric techniques (e.g., Principal Component Analysis and Cluster Analysis) we identified variance in the geochemical record of the original detrital and depositional conditions. We also identified 4 beds within the Gungri that mark "depositional events" which may correlate to those identified in other PT sections (e.g., Guryul Ravine, Kashmir). The Attargoo section records a sequence of discrete events including transient iron-enrichments and Ce-anomaly variations associated with pulsed transgression-regression towards the uppermost Permian. The Fe, P, C_{org} from LOI, Sc/Th values suggest that the ferruginous layer represents a non-depositional event possibly of sub-aerial origin. REEs values suggest that the sub-aerial exposure might have been caused by an enriched europium source possibly due to volcanism.

Carboniferous-Permian boundary recorded in North China Block: An operational approach

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The first appearance of the conodont *Strepnathodus isolatus* has been formally selected as the global standard marker for the Carboniferous-Permian boundary by the International Commission on Stratigraphy. This boundary is usually defined by two schemes: (1) fusulinids *Pseudoschwagerina*-*Zellia* Zone or *Sphaeroschwagerina* Zone and conodonts *Neogondolella bisselli*, *Streptognathodus elongatus*-*S. simplex*, or *S. longatus* Zones characterize the topmost of the Carboniferous; (2) fusulinid *Pseudoschwagerina* Zone (or the interzone of this genus) and conodont *Streptognathodus elongates* Zone define the base of the Permian. In North China, fusulinid foraminifers are considerably abundant, while conodonts are relatively rare. In particular, the elements of the Fusuliniina are very abundant and diverse, exhibiting complete evolutionary lineages. They therefore are powerful in defining the Carboniferous-Permian boundary. The lower part of the Pseudoschwagerina (s.s) Zone marks the lowest Permian. In the case that *Pseudoschwagerina* is absent in some areas, the first appearance of either *Pseudofusulina* or *Chalaroschwagerina* elements can define the base of the Permian. The present stratigraphic subdivision scheme is the closest to the world standard than any of the previous proposals for the Carboniferous-Permian boundary in the North China block.

Lithostratigraphy and conodont biostratigraphy of Upper Permian to Lower Triassic ocean floor sequences in Japan and New Zealand, originally deposited in low and southern middle latitudes in Panthalassa

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We have reported ocean floor sediments recording Permian / Triassic boundary events and their recovery processes from Japan and New Zealand (NZ), which were deposited in low and southern middle latitudes in Panthalassa and accreted in Jurassic and Triassic age respectively. In this presentation we summarize the lithostratigraphy and conodont biostratigraphy of the Upper Permian to Lower Triassic sequences in the two areas and compare them.

In Japan, Changhsingian to Smithian sequence can be observed only in a few sections, because detachment faults were formed around these horizons when they accreted. Although most of them are incomplete, the stratigraphy is summarized as follows, 1) Changhsingian chert and siliceous claystone, 2) Griesbachian to lower Smithian black claystone, and 3) Smithian siliceous claystone. Spathian siliceous claystone similar to the Smithian one is widely recognized beneath Anisian chert in Jurassic accretionary complexes in Japan. But we have found no continuous sections through Smithian to Spathian. Black claystone similar to the Griesbachian to lower Smithian one is observed overlying the Smithian siliceous claystone and underlying the Spathian one. Therefore this is probably another black claystone occurring near Smithian / Spathian boundary or in lower Spathian.

In NZ, we found Changhsingian to Anisian sequences in two localities, Arrow rocks and Waiheke, although the latter lacks upper Dienerian and Smithian. The stratigraphy is summarized as follows, 1) Changhsingian tuffaceous chert and mudstone, 2) Griesbachian black and gray chert, 3) lower Dienerian gray and red chert, 4) upper Dienerian gray and black chert, 5) upper Dienerian to Smithian red chert, lower Spathian gray and black chert, and 6) upper Spathian to lower Anisian red chert and red mudstone, in ascending order. Gray and black chert with no red chert occurs in three intervals, lower Griesbachian, upper Dienerian and lower Spathian..

The lower two and the upper one intervals of gray and black chert in NZ roughly correspond to the two intervals of black claystone in Japan, although the lower one in Japan is split into two and its total net period is much shorter in NZ. They must represent global changes of oceanic environment. Including these periods, deposition of chert continued through Early Triassic in southern middle latitudes, while it stopped in low latitudes. The environmental changes in the former were much more moderate than the latter.

Revised geochronology, cyclostratigraphy, and paleoclimatic conditions of an uppermost Carboniferous-Lower Triassic terrestrial record of mid-latitude NE Pangea, Southern Bogda Mountains, NW China

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Eleven sections of Uppermost Carboniferous-Lower Triassic fluvial-lacustrine deposits in the Tarlong-Taodonggou half-graben, southern Bogda Mountains, NW China, comprise a 1834-m-thick sedimentary and paleoclimatic record of the east coast of mid-latitude NE Pangea. This succession represents the first continental deposit on Junggar microplate in the easternmost Central Asia tectonic belt. Three orders (high, intermediate, and low) of sedimentary cycles are identified. High-order cycles (HCs) have five basic types including fluvial and lacustrine cycles recording repetitive environmental changes. HCs are grouped into intermediate-order cycles (ICs) on the basis of systematic changes of thickness, type, and component lithofacies of HCs. Nine low-order cycles (LCs) are demarcated by graben-wide surfaces across which significant long-term environmental changes occurred. The cyclostratigraphic framework provides a foundation for future studies of terrestrial climate, tectonics, and paleontology in mid-latitude NE Pangea.

15 U-Pb zircon ages obtained through IDTIMS, SHRIMP, and Ar/Ar geochronological analyses significantly improve the poorly-constrained Carboniferous-Triassic chronostratigraphy in the study area and, potentially, the greater Turpan-Junggar basin. For example, the base of previously-assigned Kungurian Daheyan Formation is lowered to 301.61 Ma and the top of previously-assigned Wordian Hongyanchi Formation to 281.42 Ma. As a result, the age of Kungurian-Wordian strata shifts to early Gzhelian to Artinskian; and the unconformity between Hongyanchi and overlying Capitanian (?) Quanzijie formations could span up to 16 Ma.

Climate variabilities at the intra-HC, HC, IC, and LC scales were interpreted from sedimentary and paleosol evidence. Four prominent climatic shifts include: 1) from humid-subhumid to highly-variable subhumid-semiarid conditions at the beginning of Sakamarian; 2) from highly-variable subhumid-semiarid to humid-subhumid conditions across the Artinskian-Capitanian unconformity; 3) from humid-subhumid to highly-variable subhumid-semiarid conditions at early Induan; and 4) from the highly-variable subhumid-semiarid to humid-subhumid conditions across the Olenekian-Anisian unconformity. The stable humid-subhumid condition from Lopingian to early Induan implies that paleoclimate change may not have been the cause of end-Permian terrestrial mass extinction. A close documentation of the pace and timing of the extinction and exploration of other causes are needed. Finally, the semiarid-subhumid conditions from Sakamarian to Artinskian-Kungurian (?) and from middle Induan to end of Olenekian are in conflict with modern mid-latitude east-coast meso- and macrothermal humid climate. Extreme continentality, regional orographic effect, and/or abnormal circulation of Paleo-Tethys may be the causes.

Early Permian hydrothermal cherts from North China and Yangtze Blocks, eastern Palaeo-Tethys

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Our geological investigation reveals that nodular cherts are considerably abundant in limestones of the Taiyuan Formation, North China Block and the Chihsia Formation, Yangtze Block. Palaeogeographically, both the North China and Yangtze blocks were situated at eastern part of the Palaeo-Tethys during the Permian times. Both the Taiyuan and Chihsia Formations are constrained as a Kungrian age (Early Permian) by abundant fusulinid foraminifer and conodont zones. Previously, the Early Permian cherts were believed to be biogenic or volcanogenic or silicationgenic or hydrothermal in genesis. Petrographic study shows that the cherts from the Taiyuan Formation (TC) contain some fluid-transported hydrothermal sediments. The contact between cherts and their hosting rocks and syndepositional structures are conspicuous in outcrops. Conducting elements and isotopes abundance test, we detect TC are enriched in Fe, Mn, Cu, impoverished in Al, Ti, very low value of w(∑REE) and LREE>HREE, apparently negative Ce anomaly, δ^{30}Si is similar to that of hydrothermal quartz and δ^{18}O geothermometer indicates the paleotemperature of the seawater was higher than normal level. Testing the composition and homogenization temperature of TC's fluid inclusions, we found the fluid sediments possess hydrothermal characteristics with considerably high homogenization temperature. TC therefore likely belongs to hydrothermal chert. Its silica was probably derived from the colloidal silicon dioxide of mid-ocean ridge outpouring in the Paleo-Tethys. Research about the characteristics and genetic type of Qixia formation cherts (QC) is extensive and controversial. We suggest QC could also be hydrothermal cherts and the silica source may be the same as that of TC. By the comparison of TC and QC, we expect to set up the evolutional mode of the specific mid-ocean ridge activity during Carboniferous-Permian.

Global plate motion models and paleogeography of the Permian and Carboniferous

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Global plate motion models covering the Mesozoic and Cenozoic have successfully shown how past positions of continents can be reconstructed by using seafloor spreading histories. Published plate reconstructions that extend as far back as the Paleozoic are less well constrained and are typically presented as instantaneous snapshots of plate configurations in tens of millions of year increments at best, thus limiting their use for studies of plate motions and paleogeography.

We present a new and unique method, based on open-source and cross-platform interactive GPlates software (www.gplates.org), allowing us to combine and constrain plate motions and continental fits with cookie-cut raster, vector and point data. In this way we can link, visualize and interactively reconstruct fossil, sedimentary and potential field data in order to better constrain the origin and fate of continental blocks in the absence of preserved seafloor. Our method can also be used as a 4D (space and time) framework for hydrocarbon and mineral exploration as it can uncover previously obscure spatio-temporal relationships of tectonic activity with particular rocks in regions of interest.

Based on this approach we have imported a published global plate motion model for the Permian and Carboniferous into GPlates. The model has been updated with more recently published geological and paleomagnetic data, focusing on the geometry and evolution of the Rheic and Palaeotethys oceans, thus providing an improved framework to study the development of basins and orogens. We have cookie-cut and rotated filtered global free-air gravity and magnetic anomalies using our plate motion model to study the Gondwanan pre-break up fit and subsequent separation.

We have studied the tectonic fabric and inheritance of Pangea-derived continental blocks. In addition, an extensive fossil database containing the age and position of each specimen has been linked to study biologic provenance, and in turn tectonic affinities between continental blocks that presently reside in very different regions of the world. The assembly and dispersal of the Pangea supercontinent has dominated the tectonic evolution of our region – dictating changes in climate, sea levels, basin evolution, accumulation of economic resources and contemporary natural hazards.

Multiple original microspherules from the Permian-Triassic boundary event beds in South China

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60 samples from 35 layers at 12 sections in China were collected and analysed for searching microspherules to study possible evidence of extraterrestrial impact or volcanic eruptions. Detailed SEM observations of surface and internal structures and chemical analyses indicate that microspherules from the Hongshuihe section in Laibin, Guangxi and the Huangshi section in Hubei, South China consist of five different groups in terms of their chemical compositions. They are namely iron, ferruginous, Fe-rich and Fe-poor silicate and calcareous microspherules. Most of them are modern fly ashes based on external characters and chemical compositions.

Microspherules have also been found from boundary beds at Meishan sections. A careful study on the shapes, microstructure, and chemical composition of these microspherules indicate that they have different origins. The iron microspherules are most likely of terrestrial origin rather than cosmic dusts. Abundant pyrite microspherule and framboidal pyrites are also present at Meishan sections. They are apparently of depositional or diagenetic origins. Calcareous microspherules and hollow organic microspherules are also present and they are clearly of biological origin. The soil samples near the P/T boundary layers at Meishan sections also contain abundant fly ashes. Therefore, most of microspherules previously-figured in these sections are possibly from modern contamination.

By contrast, microspherules are not found in the hard tuff layers of the Permian-Triassic boundary at the Xiaochehe Section in Guiyang, the deeply-evacuated samples near the P/T boundary at the Shangsi Section in Sichuan, and the caliche Bed at the Selong Xishan section in Tibet and the mudstone beds in the Dalongkou Section in Xinjiang province which are far from the industrial areas.

Based on a study of microspherules from the P/T boundary beds in South China, neither microspherules of impact origin nor accompanying minerals with impact planar deformation features were found. The microspherules from the P/T boundary beds are of multiple origins. Among them, most of iron and Fe-rich microspherules previously reported are modern fly ashes. The pyrite microspherules and framboidal pyrite are of depositional, biological or/and diagenetic origins. The calcareous microspherules and the hollow organic microspherules are of biological origin.

A Middle Permian seamount from the Xiahe area, Gansu Province, northwestern China: Zircon U-Pb age, biostratigraphy and tectonic implications

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The well-preserved seamount buildups are documented from the northwestern Qinling orogenic belts, northwest China. The study sections are located at the Ganjia area of the Xiahe County, Gansu Province. The dark basalt and overlying massive reef carbonate characterize the Xiahe seamount buildup. Basalts are dominated by the olivine type of rocks and bear distinct porphyritic textures, and fumarole and amygdaloidal structures. The basalts are dominated by ω(SiO2)/% (up to 48.49-52.29%) followed by $\omega(Na_2O + K_2O)$ (3.80-4.96%) and $\omega(TiO_2)$ (2.04-2.52%). They are featured by considerably high content of Ti. The tholeiite-series rocks dominate the basalts, while calc-alkali-series rocks are also present. The REE of the basalts shows the LREE-enrichment type with distinct Eu+ abnormity. The race elements of the basalts are characterized by the lack of P and high content of Ti. These geochemical signals suggest that the Xiahe basalts were formed in an ocean-island setting. The Laser ICP-MS Zircon U-Pb age of the basalts is 267.6 ± 5 Ma, which is reinforced the presence of the fusulinid *Neoschwagerina* Zone of the Wordian (Middle Permian) in the limestone interbeds of the basalts. Integration of petrologic and geochemical studies of seamount basalts and lateral correlation of seamount buildups reveals that the Qinling-Qilian-Kunlun orogenic belts were probably the archipelagic oceans during the Permian times.

The study of Pennsylvanian reefal microbial carbonates in South Guizhou, China

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Microbialites were widespread in Precambrian and Phanerozoic deposits worldwide. The microbialite-/or calcimicrobe-dominated reefs proliferated mainly in the aftermath of major biotic crisis during the Phanerozoic. Here, we document a microbialite-dominated reef from the Carboniferous of South China. The studied microbial reefs crop out at the Bianping Village, 4 km west of Houchang town of Ziyun County, Guizhou, Southwest China. These reefs are preserved in massive limestones of the Gzhelian Maping Formation and are constrained by the fusulinid Tricitites Zone. The study area was located on the platform margins with strong hydrodynamic condition and many small-scale biodetritus banks, mounds, phylloid algae reefs, and coral reefs were built during the Pennsylvanian times. The substrate of microbial reefs consists of bioclastic grainstone and packstone. Unlike these post-extinction microbial reefs, the Carboniferous reefs contain crinoids, brachiopods, gastropods, corals and tubular organisms except for microbes. Microbes encrusted on the hard substrate and bound the sediments; their growth model is the same as that of stromatolites. Microbialite contains clusters of tubes, which are cylindrical, gently curved to sinuous, and lack internal structures. Microbial reefs vary in sizes from 2 to 40 m in height and 10 to 50 m in width. They appear isolated, lens-like or dome-shaped in geometry. These microbial reefs also occasionally form complex reef bodies together with coral reef. Thus, microbial reefs were coeval with coral and phylloid algal reefs in South Guizhou during the Late Carboniferous. It should be noted that calcimicrobes generally grow under oligotrophic conditions, ranging from above wave base euphotic settings to deeper poorly illuminated environments. Microbes building these Carboniferous reefs in South China, presumably belonging to photosynthetic organisms, are associated with colonial corals, crinoids, brachiopods and fusulinids. They therefore may have grown in the photic zone of a shallow-marine setting.

Comparative Mineralogy of Volcanic Influenced Coal Seams in the Songzao Coalfield, China and the Sydney Basin, Australia

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The mineralogy of coal plies and non-coal (claystone) intra-seam bands in coal seams of the Songzao coalfield, China and the Great Northern seam of the Sydney Basin, Australia have been evaluated. The analytical techniques include low-temperature oxygen plasma ashing, Rietveld-based X-ray diffraction, and optical and scanning electron microscopy. Oriented aggregates of the clay fraction of the coal LTAs and the non-coal samples were also analyzed.

The minerals in the Songzao coals are mainly kaolinite, pyrite, interstratified I/S and quartz, with minor amounts of feldspar (albite), carbonates and anatase. The mineralogy of the Great Northern seam is dominated by kaolinite with minor quartz and carbonates, and in some cases minor phosphates and anatase.

The claystone bands in the Songzao coals were identified as tonsteins; as observed under the optical microscope and SEM they contain altered biotite and altered glass shards, which indicate a volcanic origin.

There is also evidence for a contribution from volcanic sources to the peat swamp when the Great Northern seam was forming. Anorthoclase-sanidine and graupen to vermicular kaolinite is commonly present in the upper two non-coal partings. Fine grains of anatase as inclusions in vermicular kaolinite and in cracks of the kaolinite matrix in partings are interpreted as reprecipitation products from the original volcanic ash material. A mixed epigenetic and pyroclastic source is suggested for the Great Northern partings, based on the additional presence of detrital orthoclase.

Although altered volcanic ash has contributed to the partings of both coal seams, the clay fraction of the partings in the Great Northern seam consists entirely kaolinite while that of the Songzao partings is dominated by I/S. This may be attributed to the marine influence during the Songzao coal peat accumulation, allowing the volcanic ash form smectite or I/S in the marine environment.

The tonstein layers have an impact on the mineralogy of the adjacent coal plies. Hydrous REE carbonates and monazite are present in the Songzao coals. The REE carbonate veins crystallized from ascending hydrothermal fluids carrying high REE concentrations, while authigenic monazite in kaolinite-filled cracks may be crystallization products of REE-rich leachates from the overlying tonstein layers.

Seawater rare-earth element patterns preserved in conodonts document intensified chemical weathering and marine anoxia during the latest Permian mass extinction

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The latest Permian mass extinction (LPME) killed ~90% of skeletonized marine species, suggesting a severe catastrophe. Whatever its origin, the disaster triggered major changes in oceanic biochemical conditions that may have been a factor in the demise of most marine organisms at the latest Permian. Thus, an understanding of contemporaneous changes in seawater chemistry are crucial in probing the cause of this crisis. Changes in paleomarine environmental conditions can be assessed using rare-earth elements (REEs). The latter can provide information regarding the influence of weathering fluxes and hydrothermal inputs on seawater chemistry as well as processes that fractionate REEs between solid and aqueous phases. Redox-related changes in cerium (Ce) distributions may provide information about variations in dissolved oxygen in seawater. REE patterns preserved in biogenic apatite (i.e. conodonts) are ideal proxies for revealing original seawater chemistry. Here, we present REE results from analysis of conodonts in two Permian-Triassic boundary (PTB) sections in South China. REE profiles for two PTB sections (Meishan and Daxiakou) in South China document major changes in chemical weathering fluxes and seawater redox conditions during the LPME. A transient sharp increase in total REE concentrations as well as a sustained shift toward low Eu/Eu* ratios at the LPME reflect increased fluxes of solutes from volcanic sources to the latest Permian ocean. These changes immediately below the LPME horizon, suggesting that increasing volcanic activity and continental weathering fluxes slightly preceded and, thus, potentially served as a trigger for the biotic crisis. A shift toward higher Ce/Ce* ratios occurred at the level of the LPME, indicating that the onset of more reducing seawater conditions was concurrent with and, thus, potentially a direct cause of the extinction event. These inferences are consistent with the hypothesis that increasing volcanic activity in the latest Permian devastated terrestrial ecosystems, leading to enhanced fluxes of particulates that were harmful to marine benthos and of nutrients that stimulated marine productivity, leading to expanded water-column anoxia.

Geological events and their geochemical responses at the Permian-Triassic boundary, Huaying Mountain, Eastern Sichuan, SW China

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In the past decades geologists have paid great attention to the Permian-Triassic boundary (PTB) and have made great achievements, but there are still several problems unsolved. Two different types and layers of PTB, biostratigraphical PTB and lithostratigraphical PTB, are identified from Jianshuigou PTB Section on Huaying Mountain, near Huaying City, Eastern Sichuan in the present study. The distance is 4.56m between the biostratigraphical PTB and the lithostratigraphical PTB in this section. All of the complex geological events occurred between the two types of Permian-Triassic boundaries, such as regression, biotic mass extinctions, volcanic eruptions and the upsection change of Sr content (from normal to abnormal (higher) Sr content) in the ocean, etc.. Evolution curves of Fe, Mn, Sr content, $\delta^{13}C$, $\delta^{16}O$ are established at the Jianshuigou PTB Section, indicating the regular biostratigraphical and lithostratigraphical changes are tightly bounded with the listed geological events.

Timing of opening and subduction of the paleo-Tethys at Jinshajiang (SW China): perspectives from zircon U-Pb and Hf-O systematics of ophiolitic plagiogranites

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Paleogeographic reconstruction suggests that the late Paleozoic to early Mesozoic paleo-Tethys in SE Asia was characterized by an archipelago of arcs or continental ribbons separating multiple paleo-Tethyan seaways, a configuration analogous to the present-day SW Pacific. The ophiolite-decorated Jinshajiang belt and the Ailaoshan belt to the south are among multiple paleo-Tethys suture zones that are well developed and preserved in southwestern China, representative of a remnant of the eastern paleo-Tethys ocean. Field relationships, geochronological and geochemical study have identified two distinct suites of plagiogranites within the ophiolite reflecting contrasting rift and subduction settings related to opening and closing of the ocean. SHRIMP U-Pb analysis on zircons extracted from the Dongzhulin plagiogranite yield a mean $^{206}Pb/^{238}U$ age of 347 ± 7 Ma (n=11, MSWD=0.99). REE and isotopic characteristics suggest an origin from partial melting of a basaltic protolith within the garnet-absent field. The low-Ti tholeiitic rocks (metamorphosed to amphibolite) that were emplaced during a preceding rift magmatic episode occur as xenoliths within the ophiolitic assemblage and constitute a plausible source for the Dongzhulin plagiogranite. Highly variable Hf isotopic compositions (εHf(t)=+18 to -18.6) for zircons from this plagiogranite indicate a heterogenous source involving both depleted and enriched components. This, together with the E-MORB signature of the Jinshajiang ophiolite, suggests formation at the inception of ocean spreading in a continent-ocean transition setting. The Jiyidu plagiogranite has a U-Pb zircon crystallization age of 283 ± 3 Ma (n=10, MSWD=1.03), and geochemical data indicates unequivocal adakitic signatures, i.e., high Sr/Y, $(La/Yb)_N$ and low Y, and marked heavy REE depletion. These signatures argue for derivation from low degree partial melting of subducted oceanic crust at pressure high enough to stabilize garnet and/or amphibole. A slab-melt origin is also supported by the zircon *in situ* Hf and O data (εHf(t)=+11 to -4.5; $\delta^{18}O$=6.06 to 6.80 ‰(VSMOW)) that show isotopic compositions comparable with typical altered oceanic crust. Thus, the crystallization age of the Jiyidu adakitic plagiogranite provides a constraint for the intra-oceanic subduction of the Jinshajiang ocean floor beneath the Qamdo-Simao terrane. The rift-related Dongzhulin plagiogranite and subduction-related Jiyidu plagiogranite constrain the timing and setting of opening and closing of this segment of the paleo-Tethys ocean.

Patterns in Early Triassic infaunal recovery in northwestern Pangaea in the aftermath of the end-Permian extinction event

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The end Permian biotic crisis had a profound effect on the abundance and diversity of infaunal and epifaunal marine organisms and in most parts of the world the marine recovery was delayed for several millions of years. On the northwestern coastline of Pangea trace and body fossil records provide evidence of complex recovery patterns that span the Lower Triassic, with widespread recovery delayed until the Anisian. Persistent anoxic to dysoxic oceanic conditions contributed to delayed recovery. The presence of high-diversity pockets is best explained by the Habitable Zone concept.

Paleolatitudinal trends in trace fossil distribution have been observed in NW Pangea. In higher paleolatitudes numerous environmental refugia - characterized by diverse trace fossil assemblages - have been identified, yet more commonly lower Triassic successions are characterized by very low diversity ichnocoenoses, laminated sediments and rare body fossils. Bacterially modified facies, such as wrinkle structures and microbial laminae, are common features of shoreface successions in lower paleolatitude regions. Greater storm frequency and sedimentation rates likely mitigated low oxygen conditions at higher paleolatitudes.

Temporally, biotic recovery appears to have occurred in a series of fits and starts, with spikes in trace and/or body fossil diversity occurring locally in late Induan to late Olenekian sections. These recovery spikes are followed by a subsequent drop-off suggesting that adverse environmental conditions were geographically and temporally variable and not indicative of sustainable large-scale, recovery until the latest Olenekian; although some of these spikes may have occurred regionally (e.g. Induan-Olenekian boundary). With the exception of ocean fringe habitable zones, east Panthalassan oceanic water remained inimical to life until the late Olenekian when oxygenation approached pre-extinction levels.

Once persistent oxic conditions prevailed, repopulation of marine environments from localized refugia was rapid and long lived. On the northwestern coastline of Pangaea this occurred in the Middle Triassic. Significantly, diversity levels in both trace fossils and body fossils in Middle Triassic shallow marine successions exceeds that reported for Late Paleozoic and later Triassic, Jurassic and Cretaceous successions in western Canada.

New time constraints on illite authigenesis processes in Permian Rotliegend reservoirs of Northern Germany

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The southern Permian gas province extends from southern North Sea to Poland and represents a major subsidence structure of the West European Craton. The lower units of the Rotliegend facies of Permian age comprise numerous clastic continental rock units that host important gas reservoirs. Illitization of these porous clastic units has been extensively studied and described because of its possible influence on the reservoir characteristics of the rocks and impact of their economic potential. It has been widely demonstrated that filamentous, pore-bridging illite has a particularly deleterious effect on reservoir permeability. It is therefore of importance to understand the conditions prevailing during illitization for both gas exploration and production.

In Northern Germany, gas is mainly sourced from Upper Carboniferous Coal Measures that underlie the Rotliegend sediment series, while the seals of the reservoirs are the Upper Zechstein evaporates. Diagenetic alteration and hydrothermal overprints were reported to be of variable strength, inducing significant changes in the reservoir qualities depending among others on the extent of illitization. The regional tectonic activity contributed also to the reservoir properties with a system of NW-SE striking horst and graben structures that impacted the Rotliegend paleogeography. Reservoir qualities of the Rotliegend sandstone units result from a combination of facies distribution and diagenetic-to-hydrothermal alteration. We present an integrated petrographic and geochemical study that comprises new and existing K-Ar illite age data. The K-Ar data fit a regional model of recurrent thermal activity with the oldest occurrence being located in the eastern area of the Rotliegend province and a trend of the activity towards ages as young as about 150 Ma in the direction of either W or NE. Previous results from northern and central Netherlands as well as from southern North Sea complete the model with an initial activity at the same 200-Ma period in the western off shore and central Netherlands and an activity trend towards E.

Permian rugose corals from southern Shan State, Myanmar: associated microfossils and paleogeographic implications

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The Permian carbonate successions are widely distributed in the Shan State of eastern Myanmar. Their counterparts are also exposed in adjacent Thailand, Malaysia, West Yuannan, and Central Tibet regions. This paper aims to document the Thitsipin Limestone of the "Plateau Limestone Group" and its rugose coral faunas. These successions were logged at the Thayetpya-In-Petlet, Thayetpya-Namplan and Thayetpya-Bawsaing sections of the Thayetpya area. Coral *Thomasiphyllum-Laophyllum* and *Ipciphyllum-Waagenophyllum* Assemblages are defined in Thayetpya. The former is constrained as an Early Permian age by its associated fusulinid *Pseudoschwagerina* Zone. The latter is incorporating with Murgabian (Middle Permian) fusulinids. The Taungni section yields corals of three assemblages. The *Thomasiphyllum-Laophyllum-Wentzellophyllum* and *Ipciphyllum-Waagenophyllum kueichoensis* Assemblages are similar to these two coral assemblages of the Thayetpya section except for the presence of *Wentzellophyllum densicolumnatum* in Taungni. The third assemblage contains *Waagenophyllum virgalense*, *W. fontainei*, and *Pavastehphyllym carcinophylloides* in association with fusuline *Sumatrina* which belongs to the *Yabeina* Zone of Midian age. The Murgabian colonial rugose coral *Yatsengia* is recorded from the Kyauk ku pyin, Ye-ngan Township. The rugose coral fauna is composed of typical Tethyan elements with strong affinities with the coeval faunas from the Cimmerian Province, Inner Mongolia-North China, Japan, West Sumatra, Peninsular Thailand, Peninsular Malaysia, Vietnam, Central Tibet, and Iran. Rugose corals from this region clearly indicate a warm water setting during the late Early Permian times and they continued to flourish in the Shan Plateau, forming reefs and carbonate build-ups during the Middle Permian (Murgabian) and carbonate sedimentation continued into the early Late Permian (Midian). The above faunas and their hosting carbonates are very different from the underlying glacial deposits and faunal assemblages.

The boundary between the Sakmarian and younger Permian stages marks the switch from cold-water siliciclastic glacio-marine deposits to entirely tropical carbonate shelf deposits of the Thitisipin Limestone. The boundary therefore clearly represents a distinctive stratigraphic discontinuity, indicating the rapid northward migration of the Shan-Thai terrane from low latitude cold-temperate Australian-Gondwanan conditions to the subtropical and tropical regions. The timing of this event is bracketed by the youngest cold-water deposits (Sakmarian) and the first occurrence of warm water carbonates in late Artinskian.

Late Palaeozoic regolith and palaeo-landscape features in southeastern Australia

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Late Palaeozoic landscape features have endured up to 400 million years of denundation and exhumation. This preservation is supported both in the sedimentary record and by dating techniques such as palaeomagnetic and K-Ar dating and apatite fission track thermochronology. The relationship between the sedimentary record and landscape evolution are derived from sediment lithologies and mineralogy as well as stratigraphy. Late Palaeozoic landforms and sediments such as tillites, lake deposits and outwash gravels are all indicators to the landscape during the Late Palaeozoic in southeastern Australia.

Relic landforms such as ice-scoured channels, U-shaped valleys and striated pavements present in Victoria, South Australia and some parts of New South Wales are indicative of continental ice sheets that once covered much of Australia. In close vicinity to these landforms are sediments that indicate the climate, depositional and landscape setting that contributed to the development of the landforms.

The nature of preservation of Late Palaeozoic landforms and sediments can be attributed to the burial and exhumation of these landforms. These landforms would not have been preserved had they been exposed at the surface since their formation. The preservation of landforms such as glacial pavements, like those seen at Hallett Cove and Christmas Cove in South Australia, can be attributed to their burial by younger sediments. Late Palaeozoic sediments are also within sedimentary basins. The basins are often poorly constrained, as they are depocentres for Late Palaeozoic glacial sediments and not necessarily basins in the traditional sense. These glacial sediments have also been preserved by burial, with only small parts of these basin sediments having been exhumed, such as within the Arckaringa Basin, South Australia. Most Late Palaeozoic landforms across southeastern Australia are at or near the modern day surface, this suggests that the modern land surface is very similar of that during the Late Palaeozoic and hence has experienced very little change. The close association between the present-day landscape and that during the Late Palaeozoic allows for accurate palaeogeographical reconstructions, which include palaeolandscapes and palaeoclimates reconstructions.

Analytical expression of the Golovkinskyi law of facies relationships of Upper Permian deposits (east part of Russian Plate)

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The main feature of the Upper Permian deposits of the eastern Russian Plate is the development of two major megaformations represented by typical marine and lagoonal-marine sediments and the complex of red clastic rocks. The relationship of these formations was the basis of N.A. Golovkinskyi's studies (Golovkinskyi, 1869) made in order to establish laws of facies relationships of the rocks. Our work has been done to identify the analytical dependencies of the relations of certain types of rocks for an east-west geological profile crossing in the eastern part of the Russian Plate from the Volga River to the Urals region over a distance of 400km. The results of these studies indicate that the percentages of Upper Permian rocks are exposed to wide range of fluctuations. But amid these fluctuations is allocated a certain tendency, which allows us to describe changes in the contents of typical rock types at the transition from the grey marine formations to the red-coloured sediments. This descrition can be carried out using a differential equation:

$$dy = -kydx$$

where y = profile distance & x = percentage of rock.

Thus the change in the percentage of species in the transition from the gray formation to the red-colored sediments will be described by an exponential dependence. The obtained pattern is naturally complicated by the random component determined by local conditions of sedimentation at a certain profile point. A detailed study of well sections and relations of different rock types let stand out from the established patterns changes in the relations of the lithological types of rocks in the sequence of individual wells. It is possible to identify the certain patterns associated with the eustatic level of the Kazan Basin. They clearly correspond to the sequence-stratigraphic scale established for the Permian period by Ross and Ross (1985). These variations have previously been identified by Noinskyi as stratigraphic subdivisions of Lower and the Upper Kazanian deposits (Noinskyi, 1989, 1924), which clearly correspond to the eustatic level of Permian marine basin.

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