International Agora Paleobotanica Meeting

Liège, October 21st- 23rd, 2021

In Honor of Philippe Gerrienne.

Programme

October 21st

12:00 – 14:00 Welcoming of the participants.

Paleozoic session (I)

Chair:

14:00 – 14:30 **A tribute to Philippe Gerrienne: a mentor, a colleague, a friend.**

Cyrille Prestianni

14:30 – 14:50 **New insights into the *Horneophyton* spore morphology.**

Borja Cascales-Miñana, Thomas Servais, Eliott Capel, Phillippe Steemans

14:50 – 15:10 **Preliminary data on the Givetian flora of Oum El Jerane (Anti-Atlas, Morocco).**

Candys Bert, Brigitte Meyer-Berthaud, Anne-Laure Decombeix

15:10 – 15:30 ***Attritasporites* and *Virgatasporites*: the oldest land-plant derived spores, cryptospores or acritarchs?**

Thomas Servais, Philippe Steemans

15:30 – 15:50 **Silurian-Devonian plant diversity patterns: biological signal, sampling bias or both?**

Eliott Capel, Christopher J. Cleal, Jinzhuang Xue, Claude Monnet, Thomas Servais, Borja Cascales-Miñana

15:50 – 16:15 **Paleobotany in Liège, lets dig into the past…**

Cyrille Prestianni, Annick Anceau, Julien Denayer

October 22nd

9:00 – 9:30 Welcoming of participants.

Paleozoic session (II)

Chair: Carla Harper

9:30 – 9:50 **The role of geological bias into our perception of Silurian-Devonian plant dynamics: insights from the North American fossil record**

Eliott Capel, Claude Monnet, Thomas Servais, Borja Cascales-Miñana

9:50 – 10:10 **A new phylogeny of the cladoxylopsid plexus - contribution of an early cladoxylopsid from the Lower Devonian (Emsian) of Québec**

Thibault Durieux, Madeleine A. Lopez, Allison W. Bronson, Alexandru M.F. Tomescu

10:10 – 10:30 **Plant diversity after the Devonian-Carboniferous boundary: new data from the Tournaisian of Montagne Noire, France**

Anne-Laure Decombeix, Brigitte Meyer-Berthaud, Maddalena Passelergue, Aixa Tosal, Catherine Girard.

10:30 – 10:50 **First record of silicified woods in the Late Carboniferous basins of the Pyrenees**

Aixa Tosal, Anne-Laure Decombeix, Brigitte Meyer-Berthaud, Jean Galtier, Carles Martín-Closas

---

10:50 – 11:20 Coffee Break

Paleozoic and Mesozoic session

Chair: Anaïs Boura

11:20 – 11:40 **Evolutionary floras and Palaeozoic vegetation history**

Christopher J. Cleal, Borja Cascales-Miñana

11:40 – 12:00 **Climate-driven palaeofloral fluctuations on a volcanic slope from the low latitudes of the Palaeotethys(early Permian, West Sumatra)**

Isabel Van Waveren, Menno Booi, Han Van Konijnenburg-Van Cittert, Mike Crow.

12:00 – 12:20 ***Saportaea* Fontaine et White 1880 –An enigmatic, long-ranging, widely distributed but rare type of late Paleozoic and early Mesozoic foliage**

Hans Kerp, Patrick Blomenkemper, Abdalla Abu Hamad, Benjamin Bomfleur

12:20 – 12:40 **Les bois fossiles du synclinal d'Anoual (Jurassique, Maroc) : description et identification**

Lydéric Portailler, Anaïs Boura

12:40 – 13:00 **Pinaceae diversity from the Lower Cretaceous of Belgium**

Léa De Brito, Valentin Fischer, Cyrille Prestianni

13:00 – 14:20 Dinner

Cretaceous and Paleogene session

Chair: Aixa Tosal

14:20 – 14:40 **A new bioprovince for Barremian-Aptian charophytes in the Cretaceous Tethyan Archipelago**

Josep Sanjuan, Carles Martín-Closas, Alba Vicente, Jordi Pérez-Cano.

14:40 – 15:00 **Highly diverse saproxylic assemblage from the Mzamba Formation (Late Cretaceous, South-Africa)**
Marion Bamford, Stephen McLoughlin, André Nel, Christine Strullu-Derrien, Frédéric Thévenard, Marc Philippe

15:00 – 15:20 **Blue stain fungi infecting an 84 million year old conifer from South Africa**

Christine Strullu-Derrien, Marc Philippe, Paul Kenrick, Robert A. Blanchette

15:20 – 15:40 **L'étude du bois fossile pour mieux comprendre l'évolution du climat et de la végétation en Asie du Sud-Est au cours du Cénozoïque**

Nicolas Gentis, Anaïs Boura, Dario De Franceschi, Alexis Licht, Zaw Win Et Day Wa Aung

15:40 – 16:00 **Assessing the diversity of insects damage traces in the fossil flora of Gelinden (Limburg, Belgium)**

Raphaël Zambon, Julien Denayer, Cyrille Prestianni

16:00 – 16:20 **Fruits of *Firmiana* and *Craigia* (Malvaceae) from the Eocene of the Central Tibetan Plateau with emphasis on biogeographic history**

Cédric Del Rio, Teng-Xiang Wang, Shu-Feng Li, Lin-Bo Jia, Pei-Rong Chen, Robert A. Spicer, Fei-Xiang Wu, Tao Su

---

16:50 Appointment at the Opera for a visit of the city and "Fossiles en ville" animation.

19:30 up to the end of the night!

Meeting Dinner

at

Maccheroni.
tratt•ria

Rue de la Poule 9, 4000 Liège

Chair: Cédric Del Rio

10:00 – 10:20 **Palaeoclimatic analysis of the Tortonian flora from la Cerdanya (Eastern Pyrenees). Palaeoaltitudinal implications.**

Carles Martín-Closas, Aixa Tosal, Oscar Verduzco

10:20 – 10:40 **Deux nouvelles fleurs de la famille des Commelinaceae dans l'ambre miocène de Zhangpu (Chine)**

Simon Beurel, Julien Bachelier, Christopher R. Hardy, Jörg U. Hammel, Gongle Shi, Eva-Maria Sadowski

10:40 – 11:00 **Cryptogams from Miocene Ethiopian amber**

Valentine Bouju, Kathrin Feldberg, Ulla Kaasalainen, Alfons Schäfer-Verwimp, Lars Hedenäs, William R. Buck, Wang Bo, Vincent Perrichot, Alexander R. Schmidt

11:00 – 11:20 **A new climate model for the Pleistocene or how the earth used to breath in pre-industrial time.**

Isabel Van Waveren

11:20 – 11:40 **Are morphological characters of litter's leaves enough to characterize local environmental parameters?**
Camille Henriet, Dario De Franceschi

11:40 – 12:00 Coffee break

12:00 – 13:00 General Assembly and end of the meeting.

Highly diverse saproxylic assemblage from the Mzamba Formation (Late Cretaceous, South-Africa).

Marion BAMFORD[1], Stephen MCLOUGHLIN[2], André NEL[3], Christine STRULLU-DERRIEN, Frédérix THÉVENARD[5], Marc PHILIPPE[6]

*1. Witwatersrand University, Johannesburg, South-*Africa (*marion.bamford@wits.ac.za*)
2. Swedish Museum of Natural History, Stockholm, Sweden (Steve.Mcloughlin@nrm.se)
3. Muséum national d'histoire naturelle, Paris, France (andre.nel@mnhn.fr)
4. Muséum national d'histoire naturelle, Paris, France and Natural History Museum, London, UK (c.strullu-derrien@nhm.ac.uk)
5. Univ Lyon, Université Claude Bernard Lyon 1, CNRS, ENTPE, UMR 5023 LEHNA, Lyon, France (frederic.thévenard@univ-lyon1.fr)
6. Univ Lyon, Université Claude Bernard Lyon 1, CNRS, ENTPE, UMR 5023 LEHNA, Lyon, France (marc.philippe@univ-lyon1.fr)

Saproxylic communities are major contributors to the recycling of terrestrial organic matter as more than 60% of the current global biomass is composed of wood. The energy and minerals released in the breakdown of wood fuel woodland biotas along with various ecosystems where wood is exported, e.g., as driftwood in streams and coastal areas or as sunken wood in the deep sea. Saproxylic communities are based on microbial life comprising archaea, bacteria and fungi. Microbial attack is enhanced by various wood borers (either terrestrial or freshwater, such as 'woodworms', or marine, such as 'shipworms') resulting in simple to complex arrays of ecological relationships, from phoresy to endosymbiosis.

As secondary xylem consists mostly of dead cells, saproxylic communities can develop inside living trees. The development of saproxylic communities is limited by the capacity of plants to counter their attacks, so the plant biomass at any given time reflects the balance between the capacity of plants to produce and maintain wood and that of saproxylic communities to degrade it. An evolutionary approach is essential to the understanding of this dynamic equilibrium. The wood of living trees, dead stumps and fallen logs are all key habitats for saproxylic species.

The fossil record of wood decay is meagre even though permineralized woods are common. While the first records of trace feeding of arthropods on plants are Silurian, the earliest evidence of wood decay has been reported from a Late Devonian permineralized wood, but it might have occurred earlier as wood evolved in Early Devonian plants. Although most of the studies of wood degradation have focused only on fossil fungal occurrences, a few have paid attention to saproxylic biocoenoses, leading to a sporadic fossil record of such ecological communities for most periods (especially for the Mesozoic). Very few studies have documented bacterial communities in fossil wood and, as for modern woods, much remains under explored concerning their identity, ecology and their interactions with other saproxylic organisms.

Here we report a remarkably diverse saproxylic community from the early Santonian (Late Cretaceous) of southeast Africa, based on150 thin-sections containing wood remains kept in a cabinet for more than half a century, at the Senckenberg Institut (Kräusel collection, Frankfurt-am-Main, Germany). It includes evidence of several types of bacteria, fungi, nematodes, oribatid mites, other arthropods, and bivalves. We show that this community developed through several stages, originating in terrestrial settings when the tree was still alive, continuing in coastal driftwood assemblages, and culminating in burial within submarine mass flow deposits.

Deux nouvelles fleurs de la famille des Commelinaceae dans l'ambre miocène de Zhangpu (Chine)

Simon BEUREL[1], Julien BACHELIER[2], Christopher R. HARDY[3,4], Jörg U. HAMMEL[5], Gongle SHI[6], Eva-Maria SADOWSKI[1]

1. *Museum für Naturkunde, Leibniz Institute for Evolution and Biodiversity Science, Invalidenstraße 43, 10115 Berlin, Allemagne (Simon.Beurel@mfn.berlin, Eva-Maria.Sadowski@mfn.berlin)*
2. *Freie Universität Berlin, Institut for Biologie, Altensteinstr. 6, 14195 Berlin, Allemagne (julien.bachelier@fu-berlin.de)*
3. *James C. Parks Herbarium, Department of Biology, Millersville University, PO Box 1002, Millersville, PA 17551-0302, États-Unis (Christopher.Hardy@millersville.edu)*
4. *Department of Botany, MRC-166, National Museum of Natural History, Smithsonian Institution, PO Box 37012, Washington, DC 20013-7012, États-Unis*
5. *Institute of Materials Research, Helmholtz-Zentrum Geesthacht, Max-Planck-Str. 1, 21502 Geesthacht, Allemagne (joerg.hammel@hzg.de)*
6. *State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology and Center for Excellence in Life and Paleoenvironment, Chinese Academy of Sciences, Nanjing 210008, Chine (glshi@nigpas.ac.cn)*

L'ambre miocène de Zhangpu (province du Fujian, Chine) a depuis peu dévoilé une importante paléobiodiversité avec de nombreuses inclusions d'insectes, de plantes, de fungi, de gastéropodes et même de plumes (Wang et al., 2021). Ces organismes ainsi que les végétaux fossiles présents dans le registre sédimentaire du site attestent d'un climat chaud et humide durant l'optimum climatique du Miocène moyen, il y a 14,7 Ma. Les familles de ces plantes en compression sont encore aujourd'hui retrouvées dans les forêts tropicales d'Asie du sud-est. L'analyse des composés organiques de l'ambre a de même permis d'identifier l'arbre producteur de résine comme appartenant à la famille des Dipterocarpaceae (Shi et al., 2014). Cependant, aucune plante n'a pour l'heure été décrite et identifiée dans cet ambre.

Pour la première fois, deux inclusions de fleurs ont été étudiées dans l'ambre de Zhangpu à l'aide de la microtomographie synchrotron (SRµCT). Cette technologie permet d'observer les inclusions de manière non-destructive et, grâce à leur reconstruction en 3D à l'aide du logiciel VG studio Max, d'étudier non seulement leur surface mais aussi leur structure interne.

Nos résultats montrent que les fleurs sont trimères avec un périanthe différencié en trois sépales et trois pétales, six étamines et trois carpelles formant un ovaire syncarpique et supérieur. La structure de ces fleurs permet leur affiliation aux monocotylédones de l'ordre des Commelinales et se rapproche le plus de la famille des Commelinaceae. Cette dernière est aujourd'hui distribuée dans le monde entier avec 42 genres et 650 espèces et est particulièrement diversifiée sous les tropiques et dans les régions chaudes et tempérées d'Amérique, d'Afrique, d'Asie et d'Australie (Faden, 1998).

Nos fossiles se distinguent toutefois des membres actuels de la famille par la présence d'une bractée florale et d'une paire de bractéoles sous tendant chacune un bourgeon floral, ainsi que par la fusion des bases des sépales et de celles des étamines. Cette étude est la première description de fleurs dans l'ambre de Chine et la première occurrence fossile des Commelinaceae en Asie. Même si nos fossiles représentent un nouveau genre potentiellement éteint, ils enrichissent la paléoflore de la forêt fossile de Zhangpu grâce à la préservation exceptionnelle de ces plantes dans l'ambre.

Références :

Faden, R. B., 1998. Commelinaceae. In: Kubitzki, K. (Ed.), The Families and Genera of Vascular Plants, vol. 4. Springer, Berlin, 109-128.

Shi, G. Dutta, S. Paul, S. Wang, B. & Jacques F. M. B., 2014. Terpenoid Compositions and Botanical Origins of Late Cretaceous and Miocene Amber from China. PLoS ONE, 9(10), e111303.

Wang, B. Shi, G. Xu, C. Spicer, R. A. Perrichot, V. Schmidt, A. R. Feldberg, K. Heinrichs, J. Chény, C. Pang, H. Liu, X. Gao, T. Wang, Z. Ślipiński, A. Solórzano-Kraemer, M. M. Heads, S. W. Thomas, M. J. Sadowski, E.-M. Szwedo, J. Azar, D. Nel, A. Liu, Y. Chen, J. Zhang, Q. Zhang, Q. Luo, C. Yu, T. Zheng, D. Zhang, H. & Engel, M. S., 2021. The mid-Miocene Zhangpu biota reveals an outstandingly rich rainforest biome in East Asia. Science Advances, 7, eabg0625.

Cryptogams from Miocene Ethiopian amber

Valentine BOUJU[1*], Kathrin FELDBERG[2], Ulla KAASALAINEN[2], Alfons SCHÄFER-VERWIMP[3], Lars HEDENÄS[4], William R. BUCK[5], Wang BO[6], Vincent PERRICHOT[1], Alexander R. SCHMIDT[2]

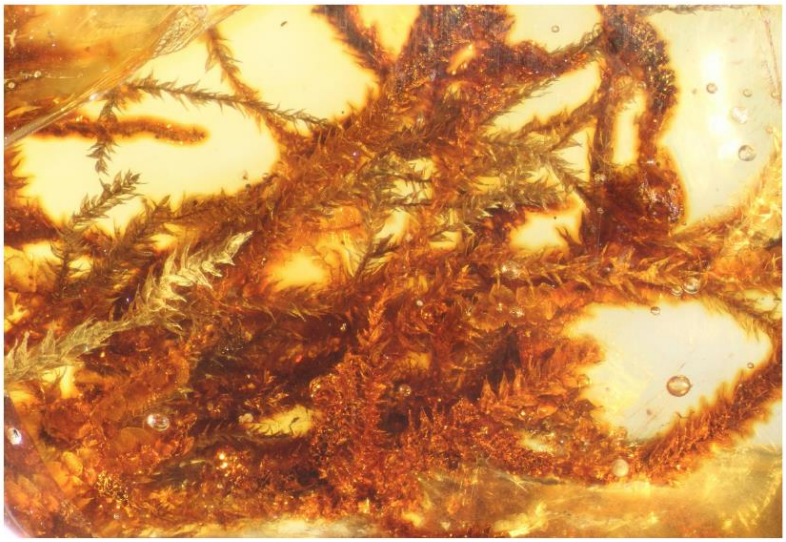
1. *Univ Rennes, CNRS, Géosciences Rennes, UMR 6118, Rennes, France (valentine.bouju@gmail.com)*
2. *Department of Geobiology, University of Göttingen, Göttingen, Germany*
3. *Mittlere Letten 11, Herdwangen-Schönach, Germany*
4. *Swedish Museum of Natural History, Department of Botany, Stockholm, Sweden*
5. *Institute of Systematic Botany, The New York Botanical Garden, New York, U.S.A.*
6. *State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology and Center for Excellence in Life and Palaeoenvironment, Chinese Academy of Sciences, Nanjing, China*

Fossiliferous amber deposits are relatively common in the Northern Hemisphere but are much scanter in ancient Gondwanan territories. The first African fossiliferous outcrop was reported in 2010 in Ethiopia. Field observations and palynological studies suggest a lower Miocene dating of the deposit and in the last decade, this amber has revealed numerous plants, fungi, and arthropods inclusions. Ethiopian amber represents a new, invaluable source to fill an important gap in the fossil record of Gondwanan terrestrial palaeoecosystems and to better apprehend the biogeographical history of organisms.

Ethiopian amber contains abundant and diverse remains of cryptogams that are exquisitely preserved. These cryptogam fossils include new Miocene species of leafy liverworts (Marchantiophyta) assignable to the extant genera *Thysananthus, Lejeunea* (Lejeuneaceae) and *Frullania* (Frullaniaceae); pleurocarpous mosses of the genus *Isopterygium* (Pylaisiadelphaceae), and a fragment of a lichen belonging to the Lecanorales. These new discoveries are the only bryophytes and lichens known to date from the African fossil record.

This cryptogam assemblage provides a new glimpse into a Miocene Ethiopian ecosystem, supporting a resin-producing forest under (sub)tropical conditions. A similarity is noticeable with the liverwort biodiversity from lower Miocene Dominican amber. A comparison between both deposits may further corroborate the already suspected Gondwanan origin of some of the American ecosystem.

Figure



Silurian-Devonian plant diversity patterns: biological signal, sampling bias or both?

Eliott CAPEL [1]*, Christopher J. CLEAL [2], Jinzhuang XUE [3], Claude MONNET [1], Thomas SERVAIS [4], Borja CASCALES-MIÑANA [4]

1. *Univ. Lille, CNRS, UMR 8198 – Evo-Eco-Paleo, F-59000 Lille, France*
2. *School of Earth Sciences, University of Bristol, Life Sciences Building, Tyndall Avenue, Bristol, BS8 1TQ, UK*
3. *The Key Laboratory of Orogenic Belts and Crustal Evolution, School of Earth and Space Sciences, Peking University, Beijing 100871, PR China*
4. *CNRS, Univ. Lille, UMR 8198 – Evo-Eco-Paleo, F-59000 Lille, France*

*Corresponding author (eliott.capel@univ-lille.fr)

In this communication, we present an in-depth characterization of tempo and mode of the early evolution of vascular plants (tracheophytes). This analysis is based on a recently constructed megafossil-based dataset of plant genera that captures a comprehensive view of Silurian–Devonian floras. Results reveal important fluctuations of diversity and evolutionary rates linked to the early diversification and demise of different tracheophyte groups. Overall, despite an overall increase of taxonomic richness over the course of the Silurian–Devonian period, we identify several stepwise origination/extinction patterns. Such patterns describe the diversity changes over time from both lineages and major morphological (taxonomical) groups. However, it is well-known that observed diversity patterns are distorted by inherent sampling bias to the fossil record, and plants are no exception. Thus, we have compared, for the first time, the global diversity pattern of early land plants to sampling signal, by taking plant-bearing localities as proxy. As expected, results show a significant correlation between both patterns. But interestingly, results further show no homogenous sampling effect. This suggests that some apparent fluctuations of plant diversity would have a biological explanation. For instance, the corrected standing diversity pattern suggests solid diversity increases in the Pragian and Givetian, which are linked to the expansion of early land floras and the initial diversification of forested ecosystems. The role of biotic/abiotic parameters in explaining the observed patterns are also discussed. Finally, a few perspectives for future diversity studies on early land plant diversification are provided.

The role of geological bias into our perception of Silurian-Devonian plant dynamics: insights from the North American fossil record

Eliott CAPEL [1*], Claude MONNET [1], Thomas SERVAIS [2], Borja CASCALES-MIÑANA [2]

1. *Univ. Lille, CNRS, UMR 8198 - Evo-Eco-Paleo, F-59000 Lille, France*
2. *CNRS, Univ. Lille, UMR 8198 - Evo-Eco-Paleo, F-59000 Lille, France*

*Corresponding author (eliott.capel@univ-lille.fr)

Since the pioneering work of Raup (1972), it is now widely accepted that the amount of preserved rock volume through time has a strong influence on diversity patterns. In a landmark study, Knoll et al. (1979) first pointed out an important correlation in North America between the extent of terrestrial outcrop area with plant fossil diversity. Subsequently, difficulties in obtaining accurate quantifications of rock volume through time has hampered further assessment of geological biases on plant diversity patterns. The Macrostrat database now allows testing the impact of rock volume on observed plant diversity dynamics using an Silurian–Devonian occurrence-based dataset. During the period, plants underwent an apparent radiation during their progressive colonisation of the continents. However, it has been suggested that several geological biases may highly distort the observed diversification patterns (e.g., lack of terrestrial sediments in Pre–Devonian times). Results first show that Silurian–Devonian North American plant diversity displays fairly dissimilar patterns to what is observed globally. Results further show a substantial correlation between sampled-in bin diversity and amount of terrestrial rock volume, indicating a strong control of this factor on stage to stage diversity fluctuations. Furthermore, the lack of terrestrial sediments before the Emsian severely diminishes diversity counts, implying that this is an important element in obscuring our understanding of earliest land plant history. Finally, two different corrections methods for sampling are used and compared (SQS and residuals diversity estimates using rock volume as a proxy), in an attempt of obtaining a more reliable biological signal.

References

Knoll, A.H., Niklas, K.J., & Tiffney, B.H., 1979. Phanerozoic land-plant diversity in North America. Science 206, 1400–1402.

Raup, D.M., 1972. Taxonomic diversity during the Phanerozoic. Science 177, 1065–1071.

New insights into the *Horneophyton* spore morphology

Borja CASCALES-MIÑANA [1*], Thomas SERVAIS [1], Eliott CAPEL [2], Phillippe STEEMANS[3]

1. *CNRS, Univ. Lille, UMR 8198 - Evo-Eco-Paleo, F-59000 Lille, France*
2. *Univ. Lille, CNRS, UMR 8198 - Evo-Eco-Paleo, F-59000 Lille, France*
3. *EDDy Lab/Palaeobotany and Palaeopalynology, Univ. Liège, 4000, Liège, Belgium*

[*]Corresponding author (borja.cascales-minana@univ-lille.fr)

The Rhynie chert (Aberdeenshire, Scotland, UK) plant *Horneophyton lignieri* is likely one of the most studied elements of Lower Devonian floras considering both macro and microremains. Intriguingly, while larger plant fragments are exceptionally fossilized, *in situ* spores are not necessarily well-preserved in the chert: they are dark brown and intensively torn overall. However, spore masses are often dominated by single spores, which can be taxonomically attributed. Mainly, *Horneophyton* spores have been described as belonging to *Apiculiretusispora* type and *Emphanisporites* cf. *decoratus*, this last one being currently accepted in general. Here, we document new *Horneophyton* spore morphologies, that are sometimes quite different. Such morphologies include, but are not restricted to, *Ambitisporites*, *Dibolisporites* or *Retusotriletes*. All these observed spore morphotypes belong to the same palaeobiological entity, as they have been found in the same parent plant. These findings show that the sporangia of a same plant species may deliver diverse taxa of coeval isolated spores. But most importantly, if these spores are found in sediments, they would most probably be identified as different dispersed miospore taxa. This highlights that caution is needed when comparing plant diversity with the dispersed spore fossil record. Moreover, we confirm the presence of *Emphanisporites decoratus* inside most of the sporangia of *Horneophyton lignieri*, and its high morphological variability. We further discuss the role of the different states of maturation and preservation, as well as taphonomy-induced features, on observed spore diversity.

Evolutionary floras and Palaeozoic vegetation history

Christopher J. CLEAL [1], Borja CASCALES-MIÑANA [2*]

1. School of Earth Science, University of Bristol, Life Sciences Building, Tyndall Avenue, Bristol, BS8 1TQ, UK
2. CNRS, Univ. Lille, UMR 8198 - Evo-Eco-Paleo, F-59000 Lille, France

[*]Corresponding author (borja.cascales-minana@univ-lille.fr)

The overarching trajectory of Palaeozoic vegetation history can be interpreted as the sequential replacement of the Eotracheophytic, Eophytic, Palaeophytic and Mesophytic evolutionary floras. Each evolutionary flora was characterised by a group of co-existing supra-generic plant taxa (families and orders) that formed relatively coherent communities in time and space. In most cases, the transition between floras was relatively brief and usually reflected the appearance of evolutionary adaptations (e.g. seeds, robust steles) that favoured the plants of the new flora. The main exception was the diachronous appearance of the Mesophytic Flora during the late Carboniferous and Permian, apparently the result of the invasion by upland or extra-basinal vegetation pre-adapted to the drier substrates that were developing then in the lowlands. The mass extinctions that had such a major effect on Sepkoski's evolutionary faunas had little effect on the dynamics of the evolutionary floras.

Pinaceae diversity from the Lower Cretaceous of Belgium

Léa DE BRITO[1,2], Valentin FISCHER[1], Cyrille PRESTIANNI[1,2]

1. Evolution & Diversity Dynamics Lab, UR Geology, Université de Liège, Belgium (l.debrito@uliege.be, v.fischer@uliege.be, cyrille.prestianni@uliege.be)
2. Royal Belgian Institute of Natural Sciences, Brussels, Belgium

The expansion of Pinaceae during the Cretaceous is exemplified by the numerous ovulate cone taxa found in Western Europe and North America. The Belgian Wealden facies deposits (Barremian-Albian, 125.0 – 100.5 My) have delivered hundreds of exceptionally well-preserved, yet isolated, pinaceous ovulate cones; these cones were placed by convention in form-genera (Alvin 1953; Alvin 1957; Alvin 1960). A total of 10 species has been described in Belgium, representing about 33% of the known fossil cone species of this period.

However, the validity of these taxa is questionable as their intra- and interspecific variabilities have never been studied. The review of the material led to the identification of delimitation problems between species. In a previous study, we showed that the morphological disparity within species was overestimated, the number of Pinaceae species in Belgium has to be re-evaluated upwards (De Brito and Prestianni 2021). In addition, research in the collections built up at the end of the 19th century by C. Bommer has led to the rediscovery of unstudied material, which may provide crucial new information on the evolution of the early Pinaceae (Bommer 1892). During recent excavations in the Wealden facies, new coniferous fossils have also been discovered. Moreover, the exceptional diversity of this fossil record is not limited to specific diversity, as probable traces of Lower Cretaceous Pinaceae/animal interactions have been revealed.

We present here these unpublished results in a preliminary study on the re-evaluation of the diversity of the Lower Cretaceous Pinaceae. This work demonstrates that a reassessment of the ovulate cone species described in the 20th Century is finally revealing the diversity of early Pinaceae and the shape of their radiation.

References

Alvin KL 1953 Three abietaceous cones from the Wealden of Belgium. Mémoires l'Institut R des Sci Nat Belgique 125:1–42.

——— 1957 On the two cones Pseudoaraucaria heeri (Coemans) nov. comb. and Pityostrobus villerotensis nov. sp. from the Wealden of Belgium. Mémoires l'Institut R des Sci Nat Belgique 135:1–27.

——— 1960 Further conifers of the Pinaceae from the Wealden formation of Belgium. Mémoires l'Institut R des Sci Nat Belgique 146:1–39.

Bommer C 1892 Un nouveau gîte à végétaux découvert dans l'argile wealdienne de Bracquegnies. Bull la société Belge Géologie 6.

De Brito L, C Prestianni 2021 Pityostrobus andraei (Pinaceae) from the Barremian (Lower Cretaceous) of Belgium: A Morphometric Revision. Int J Plant Sci 182:174–184.

Plant diversity after the Devonian-Carboniferous boundary: new data from the Tournaisian of Montagne Noire, France.

Anne-Laure DECOMBEIX[1], Brigitte MEYER-BERTHAUD[1], Maddalena PASSELERGUE[1], Aixa TOSAL[2], Catherine GIRARD[3].

1. *UMR AMAP, Univ. Montpellier, CNRS, CIRAD, INRA, IRD, Montpellier, France (anne-laure.decombeix@cirad.fr;meyerberthaud@cirad.fr;maddalena.passelergue@etu.umontpellier.fr)*
2. *Departament de Dinàmica de la Terra i de l'Oceà, Facultat de Ciències de la Terra, Institut de Recerca de la Biodiversitat (IRBio), Universitat de Barcelona-UB, 08028 Barcelona, Catalonia, Spain (aixatosal@gmail.com)*
3. *UMR ISEM, Univ Montpellier, CNRS, EPHE, IRD, Montpellier, France (catherine.girard@umontpellier.fr)*

The Devonian-Carboniferous boundary (359 Ma) is now recognized as a period of major environmental changes, affecting both marine and terrestrial ecosystems. However, the impact of this event on plants remains controversial, notably because of the scarcity of macrofloral data in the earliest Carboniferous. In this context, we are currently focusing on the diversity and biology of fossil plants from the Tournaisian Lydienne Formation in the Montagne Noire, Southern France (Galtier et al. 1988).

A first source of information is the (re)investigation of specimens kept in the Université de Montpellier collections. This allows us to better understand plant systematic and functional diversity, and to compare the assemblage to Late Devonian floras from around the world. We will present some recent work on two key anatomically preserved taxa: (1) *Cladoxylon*, the youngest representative of the cladoxylopsids and the only one to date in which the production of periderm is documented (Decombeix & Galtier, 2021; Fig 1a), (2) large bisporangiate lycopsid cones originally described as *Lepidostrobus* (Zeiller, 1911; Böhm, 1935; Genson, 1941; Fig 1b)

In addition to collection material, new trenches cutting through the Lydienne Formation at the locality of La Serre (Fig 1c) have allowed us to collect new specimens, mostly preserved as adpressions. Although most of them are very fragmentary (1-2 cm), they are important as they provide crucial information on small structures that are less represented in the anatomically preserved material, such as seeds and foliage.

In the coming years, the combination of paleobotanical studies in the Montagne Noire with work conducted in parallel on the vertebrate fossil record is expected to provide a better insight on ecosystem recovery patterns following the D-C boundary.

References

Böhm, R., 1935. Etude sur la flore de l'horizon à lydiennes de la base du Carbonifère de la Montagne Noire. - 2ème thèse, Impr. de la Charité [ed.], Montpellier, France.

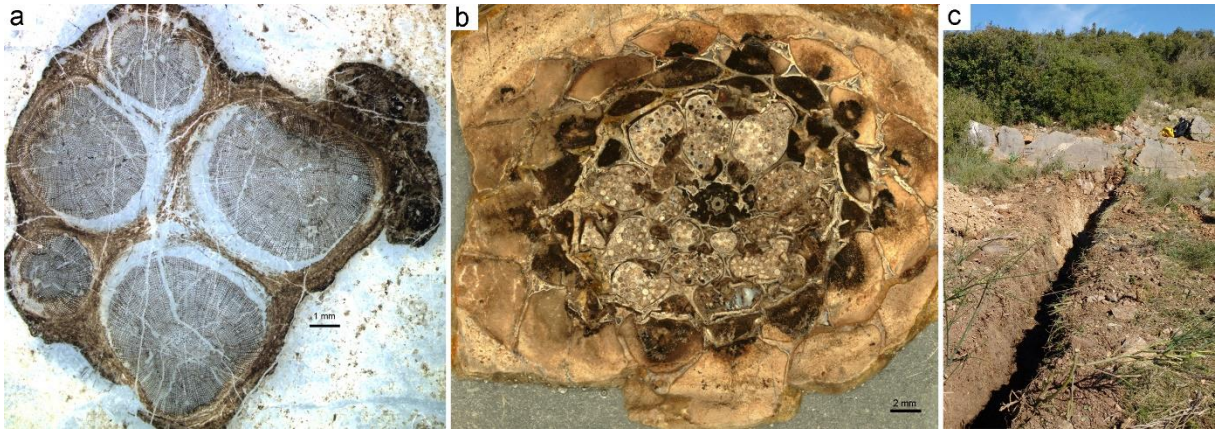
Decombeix, A-L., Galtier, J., 2021. Periderm production in the Mississippian cladoxylopsid *Cladoxylon taeniatum* and a review of periderm occurrence in Paleozoic plants. *International Journal of Plant Sciences* 182, 430-444

Galtier, J., Meyer-Berthaud, B., Rowe, N.P., 1988. Tournaisian plants from the ‘‘Lydiennes’’ Formation of the Montagne Noire (France). *Courier Forschungsinstitut Senckenberg*, 100, 109-117.

Genson, E., 1941. Nouvelles découvertes dans l’horizon à Lydiennes de la base du Carbonifère de la région de Concous. Imprimé par l’auteur, Béziers, France.

Zeiller, R., 1911. Etude sur le *Lepidostrosbus Brownii* (Unger) Schimper. *Mémoires de l'Académie des Sciences*, 52, 1-67

Figure 1.



Fruits of *Firmiana* and *Craigia* (Malvaceae) from the Eocene of the Central Tibetan Plateau with emphasis on biogeographic history

Cédric DEL RIO[1,2], Teng-Xiang WANG[1,3], Shu-Feng LI[1,2], Lin-Bo JIA[4], Pei-Rong CHEN[1,3], Robert A. SPICER[1,2,5], Fei-Xiang WU[6], Tao SU[1,2]

1. CAS Key Laboratory of Tropical Forest Ecology, Chinese Academy of Sciences, Mengla, Yunnan 666303, China

2. Center of Plant Ecology, Core Botanical Gardens, Chinese Academy of Sciences, Mengla 666303, China

3. University of Chinese Academy of Sciences, Beijing 100049, China

4. CAS Key Laboratory for Plant Diversity and Biogeography of East Asia, Kunming Institute of Botany, Chinese Academy of Sciences, Kunming 650204, China

5. School of Environmental, Earth and Ecosystem Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, U.K.

6. Key Laboratory of Vertebrate Evolution and Human Origins, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, 100044 Beijing, China

Malvaceae Juss. is a widely dispersed family occurring today in warm regions of all vegetated continents. The fossil record emphasizes an old origin and diversification of Malvaceae in the Northern Hemisphere. What is now the central Tibetan Plateau was at a low elevation with monsoon influence during the Eocene, allowing the development of a subtropical flora containing Malvaceae. Despite recent intensive paleobotanical research on the Tibetan Plateau, the taxonomic study of fossils from there dating from the Eocene is still ongoing.

Malvaceae fossils from the Eocene Jianglang flora in central Tibet, are attributed to sub-families Tilioideae and Sterculioideae, and are compared with modern species. Paleoclimatic parameters were reconstructed based on climatic preferences of modern species. A new species, *Firmiana zhekunii* sp. nov. C. Del Rio & T. Su is described based on a fruit valve. This fruit is foliaceous, dehiscent with a distal end constricted and acute, and seed scars at the proximal part of the ventral suture. *F. zhekunii* represent the earliest occurrence of the genus so far and the only reliable Eocene occurrence. A new occurrence of *Craigia* is also reported based on fruit capsules with a prominent fusiform locular area crossed by the median suture and with a straight, radiated venation.

Based on the fossil record of *Firmiana* and its modern distribution, we infer that the genus may have originated in East Asia and subsequently diversified in South China and Southeast Asia. The new occurrence of *Craigia* indicates that the genus was distributed in humid areas in South and North China during the Eocene. Both fossil records suggest the important role that the Tibetan region played in the diversification of plants in East and Southeast Asia. Moreover, the occurrence of *Firmiana* supports existing interpretations that the Jianglang flora grew under a subtropical climate at a relatively low elevation.

A new phylogeny of the cladoxylopsid plexus – contribution of an early cladoxylopsid from the Lower Devonian (Emsian) of Quebec

Thibault DURIEUX [1], Madeleine A. LOPEZ [2], Allison W. BRONSON [2], Alexandru M.F. TOMESCU [2]

1. *Trinity College Dublin, Dublin, Ireland (durieuxt@tcd.ie)*
2. *Humboldt State University, Arcata, USA (mihai@humboldt.edu)*

Cladoxylopsids represent one of the two main groups of euphyllophytes recognized in the Devonian based on xylem architecture – the moniliformopsids (Kenrick and Crane, 1997, Gerrienne et al., 2016). Cladoxylopsids formed earth's earliest forests and are thought to have given rise to sphenopsids and ferns (Stewart and Rothwell, 1993; Soria and Meyer-Berthaud, 2004). Emsian strata of the Battery Point Formation on the Gaspe Peninsula (Quebec, Canada) (Hoffman and Tomescu, 2013) contain anatomically preserved cladoxylopsids. We describe a new cladoxylopsid from this unit and we evaluate the phylogenetic position of this plant.

The phylogenetic study also addresses broader questions of cladoxylopsid systematics and evolution. The new plant is preserved anatomically and consists of small actinostelic axes bearing dichotomously-branched, helically-arranged ultimate appendages and fusiform sporangia. This plant provides the oldest evidence of cladoxylopsid anatomy, including ultimate appendages and sporangia.

To evaluate phylogenetic relationships we use a dataset of 36 new morphological characters and 31 species in parsimony-constrained analyses. In agreement with non-phylogenetic classification schemes, our analysis resolves a basal grade of iridopterids and a clade of cladoxylopsids s.s., which includes a pseudosporochnalean cladoxylopsid clade and a cladoxylalean cladoxylopsid clade.

The new plant is resolved as part of the cladoxylopsid s.s. clade. Our phylogenetic analysis illuminates aspects of tempo and mode of evolution in the cladoxylopsid plexus. Originating prior to the Emsian, cladoxylopsids reached global distribution by the Frasnian. Iridopterids and cladoxylopsids s.s. radiated in the Emsian-Eifelian (cf Figure 1). The sequence of character changes recovered by our phylogeny supports a transition from actinostelic protosteles to dissected steles, associated with an increase in xylem rib number and medullation generating a central parenchymatous area.

References

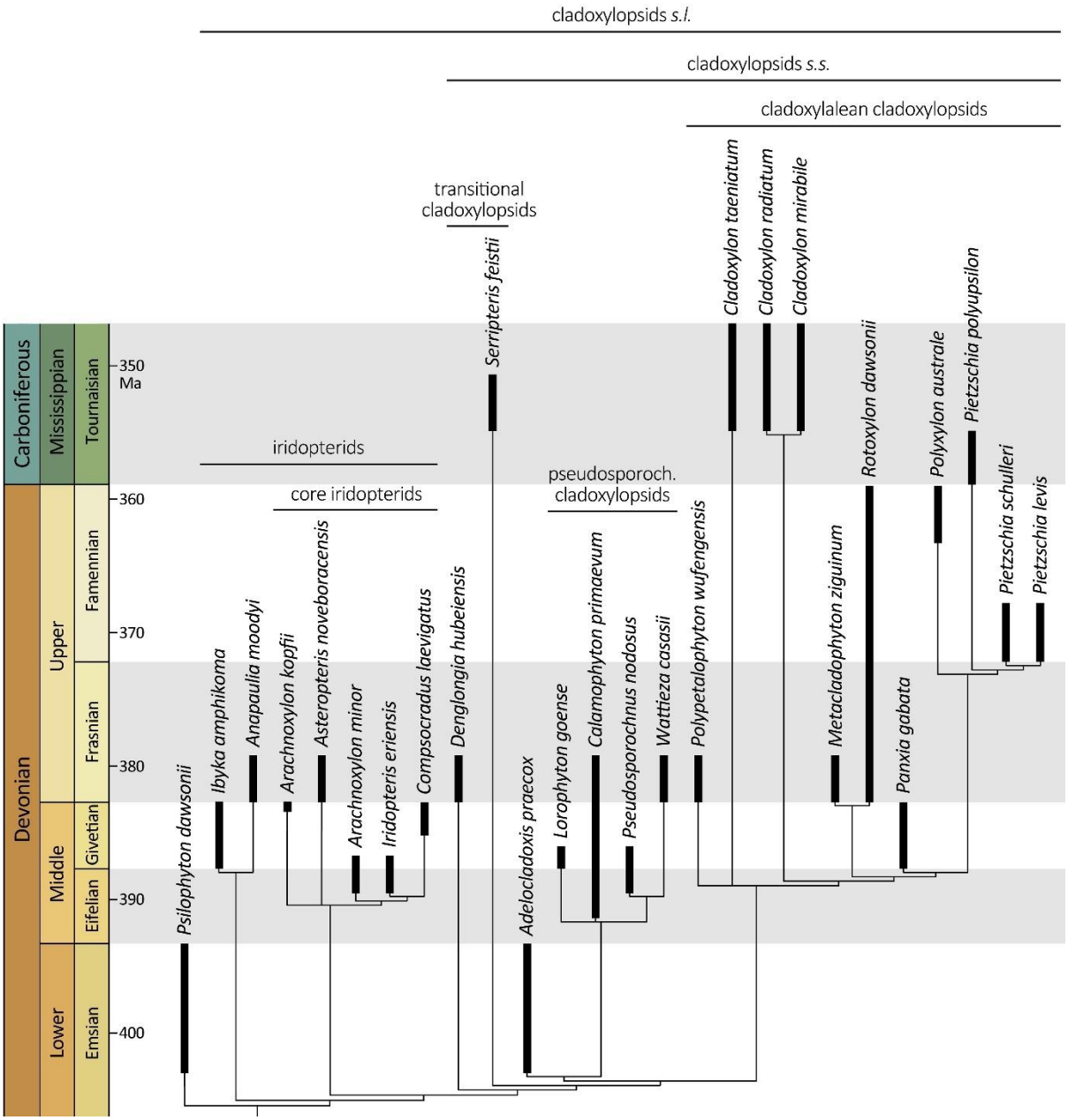
Gerrienne, P. Servais, T. & Vecoli, M, 2016. Plant evolution and terrestrialization during Palaeozoic times - the phylogenetic context. Review of Palaeobotany and Palynology 227: 4–18.

Hoffman, L. A. & Tomescu, A. M. F, 2013. An early origin of secondary growth: Franhueberia gerriennei gen. et sp. nov. from the Lower Devonian of Gaspé (Quebec, Canada). American Journal of Botany 100: 754–763

Kenrick, P. & Crane, P. R, 1997. The origin and early evolution of plants on land. Smithsonian Institution Press, Washington, DC, USA.

Soria, A. & Meyer-Berthaud, B, 2004. Tree fern growth strategy in the Late Devonian cladoxylopsid species Pietzschia levis from the study of its stem and root system. American Journal of Botany 91: 10–23

Stewart, W. N. & Rothwell, G. W, 1993. Paleobotany and the evolution of plants. Cambridge University Press, Cambridge, UK.


cladoxylopsids s.l.
cladoxylopsids s.s.
cladoxylalean cladoxylopsids
transitional cladoxylopsids
iridopterids
core iridopterids
pseudosporoch. cladoxylopsids
Carboniferous
Devonian
Mississippian
Lower
Middle
Upper
Tournaisian
Famennian
Frasnian
Givetian
Eifelian
Emsian
350 Ma
360
370
380
390
400
Psilophyton dawsonii
Ibyka amphikoma
Anapaulia moodyi
Arachnoxylon kopfii
Asteropteris noveboracensis
Arachnoxylon minor
Iridopteris eriensis
Compsocradus laevigatus
Denglongia hubeiensis
Serripteris feistii
Adelocladoxis praecox
Lorophyton goense
Calamophyton primaevum
Pseudosporochnus nodosus
Wattieza casasii
Polypetalophyton wufengensis
Cladoxylon taeniatum
Cladoxylon radiatum
Cladoxylon mirabile
Metacladophyton ziguinum
Rotoxylon dawsonii
Panxia gabata
Polyxylon australe
Pietzschia polyupsilon
Pietzschia schulleri
Pietzschia levis

Fossil wood: a key to understand paleoenvironmental and biogeographic evolutions in South and Southeast Asia.

Nicolas GENTIS[1], Anaïs BOURA[1], Dario DE FRANCESCHI[1], Alexis LICHT[2], Zaw Win[3] et Day Wa Aung[4]

1. CR2P, UMR7207, MNHN, Sorbonne Université, CNRS, Paris, France (nicolas.gentis@edu.mnhn.fr) (dario.de-franceschi@mnhn.fr) (anais.boura@mnhn.fr)
2. CEREGE, UMR CNRS 7330, Aix-en-Provence, France (licht@cerege.fr)
3. Geology Department, Shwe Bo University, Sagaing Region, Myanmar (zawwin87@gmail.com)
4. Geology Department, University of Yangon, Yangon, Myanmar (daywaaung.geol@gmail.com)

Monsoons are the defining climatic phenomenon of South and Southeast Asia. Monsoons are primarily controlled by topographic effects caused by Asian uplifts such as the Tibetan Plateau, the Himalayas or the Indo-Burman Ranges; their establishment during the Cenozoic and their evolution are yet not fully understood. Myanmar stands along the Bengal Bay, in the core engine of the South Asian monsoon, and is thus a relevant area of investigation. The country is separated today from India by the Indo-Burman Ranges. Fossil wood specimens from Myanmar offers the opportunity to follow the local evolution of the ecosystems and the biogeographical evolution of some taxa. A first comparison between the Pondaung (late Middle Eocene) and Natma (late Lower Miocene to early Middle Miocene) Formations allows us to identify long-term floristic changes. Eocene forest assemblages present taxa affiliated with modern analogues of dry dipterocarp forests (such as Sal, *Shorea robusta* C.F. Gaertn.). By contrast, Miocene forests are more analogous to modern tropical rainforests dominated by dipterocarps adapted to wetter conditions. These changes could first indicate a stronger monsoon regime during the Miocene than the Eocene, potentially due to regional uplift. From a biogeographical standpoint, these results support an emergence of the Dipterocarpaceae family in a dry seasonal climate, followed by a diversification and spreading toward everwet tropical zones. We also identify species similar to those of modern mangroves in both formations, confirming the continuous presence of this ecosystem in South Asia since at least since the middle Eocene. The expansion of the study to other geological units of Myanmar dating from the Paleocene, the Eocene, the Oligocene and the Miocene offers the possibility to draw up a more global overview of the climatic and biogeographic evolution of South Asia.

References

Gentis, N., Licht, A., Boura, A., De Franceschi, D., Zaw Win, Day Wa Aung & Dupont-Nivet, G., (under review). Fossil woods from the lower Miocene of Myanmar (Natma Formation): paleoenvironmental and biogeographic implications. *Geodiversitas*.

Licht, A., Boura, A., De Franceschi, D., Utescher, T., & Jaeger, J.-J, 2015. Late middle Eocene fossil wood of Myanmar: Implications for the landscape and the climate of the Eocene Bengal Bay. *Review of Palaeobotany and Palynology*, 216: 44–54. https://doi.org/10.1016/j.revpalbo.2015.01.010

Licht, A., Boura, A., De Franceschi, D., Ducrocq, S., Aung Naing Soe & Jaeger, J.-J, 2014. Fossil woods from the late middle Eocene Pondaung Formation, Myanmar. *Review of Palaeobotany and Palynology*, 202: 29–46. https://doi.org/10.1016/j.revpalbo.2013.12.002

Figure

Up: Badland of the Natma formation from the lower middle Miocene, Myanmar. Credit: Alexis Licht. **Down**: *Cynometroxylon holdeniae* Prakash & Bande from the Natma formation, related to modern *Cynometra* L. growing in back-mangroves.

Are morphological characters of litter's leaves enough to characterize local environmental parameters?

Camille HENRIET[1], Dario DE FRANCESCHI[1]

1. *CR2P (Centre de Recherche en Paléontologie – Paris), MNHN – CNRS – Sorbonne Université, Paris, France (camille.henriet@edu.mnhn.fr, dario.de-franceschi@mnhn.fr).*

In paleobotany, fossil leaves are frequently studied in order to estimate the environmental parameters (temperature, precipitation…) contemporaneous to their formation thanks to LA, LMA and CLAMP methods. Fossil leaf assemblages often correspond to litter deposited in diverse sediments, mainly in aquatic environments. In order to test if small amounts of leaves allow the determination the local climatic parameters, we decided to use a well known forest environment in its floristic composition and local climate parameters. We used litter's leaves of Uppangala forest (Western Ghâts, India) collected on one square meter, in an homogeneous plot of the forest, already studied for dynamic monitoring. The forest type corresponds to DKH (Dipterocarpus indicus Bedd., Kingiodendron pinnatum (Roxb. Ex DC.) Harms, Humboldtia brunonis Wall.). The sample used here allowed us to test the reliability of methods using leaf characters by a comparison between measured and estimated environmental parameter values. The scans of all leaves of the year (undecayed mesophyll) were used to obtain several observations and measurements (leaf area, leaf margin, leaf perimeter, circularity, angles of base and apex, …). The morphology and venation were used to distinguish the 664 leaves in 20 species for the analyses. The main obtained result is the estimated MAT and MAP with the leaf margin and leaf area methods which is compatible, including the standard error, with the measured parameters obtained locally with meteorological compiled data. Interestingly, the obtained values are included in the range were the forest type growth in the western Ghâts ($2000 \leq MAP \leq 6000$ et $25 \leq MAT \leq 31$). This work shows that this environment can be globally characterized by the study of a limited amount of leaves and tend to validate these classical methods used in paleobotany.

Saportaea Fontaine et White 1880 – An enigmatic, long-ranging, widely distributed but rare type of late Paleozoic and early Mesozoic foliage

Hans KERP[1], Patrick BLOMENKEMPER[1], Abdalla ABU HAMAD[2], Benjamin BOMFLEUR[1]

1. *Palaeobotany Research Group, Institute of Geology and Palaeontology, Westfälische Wilhelms-Universität, Münster, Germany (kerp@uni-muenster.de; p.blomenkemper@uni-muenster.de; bbomfleur@uni-muenster.de)*
2. *Department of Applied and Environmental Geology, The University of Jordan, Amman, Jordan (abdalla80@hotmail.com)*

New material of the enigmatic plant *Saportaea salisburioides* Fontaine et White 1880 is reported from three localities in the late Permian Umm Irna Formation from the Dead Sea region, Jordan. The preservation and the sedimentology indicate that remains from all three localities were transported over a very short distance. In one of the localities the rich leaf association exclusively comprises *Saportaea* remains, which show a remarkably large morphological variation. They occur together with a coaly axis with attached petioles and several isolated petioles. The specimens apparently belonged to a single monospecific stand, or maybe even a single plant. Another locality yielded a large leaf portion showing the leaf architecture. Our material leads to the conclusion that *Saportaea grandifolia* Fontaine et White 1880 and *Baiera virginiana* Fontaine et White 1880 are to be regarded as synonyms of *S. salisburioides*. In one locality *Saportaea* foliage was found in close association with *Nystroemia* sp., which might suggest that this fructification belongs to *Saportaea*. *Saportaea* is a long-ranging, geographically widely distributed but very rare genus that first appears in the Westphalian D (Moscovian, Pennsylvanian) and has its last occurrence in the Carnian (Late Triassic).

Palaeoclimatic analysis of the Tortonian flora from la Cerdanya (Eastern Pyrenees). Palaeoaltitudinal implications

Carles MARTÍN-CLOSAS [1], Aixa TOSAL [1], Oscar VERDUZCO [2]

1. *Departament de Dinàmica de la Terra i de l'Oceà, Institut de Recerca de la Biodiversitat (IRBio),Facultat de Ciències de la Terra, Barcelona, Catalonia (Spain) (atosal@ub.edu, cmartinclosas@ub.edu .*
2. *Departamento de Licenciatura en Educación Secundaria, Instituto Superior de Educación Normal de Colima Profesor Gregorio Torres Quintero, Colima, México (osverto@hotmail.com)*

The late Miocene (early Tortonian) climate of the La Cerdanya Basin (Catalonia, Spain) has been analysed using the Climate Leaf Analysis Multivariate Program (CLAMP) based on an assemblage comprising twenty-nine dicot leaf taxa (Tosal et al., 2021). Results show a mean annual temperature of 11.4 ± 2.1ºC. The coldest mean monthly temperature was 1.8 ± 3.4º C while the warmest was 21.6 ± 2.5º C. Growing season was 6.8 ± 1.1 months in duration. Precipitation during this period was 1082 ± 317 mm, reaching 661 ± 38 mm in the three wettest consecutive months, while in the three driest months it was 194 ± 229 mm. These results indicate a permanently humid temperate climate, with warm and wet summers.

Compared with published palaeoclimatic results obtained using the Coexistence Approach method, our CLAMP analysis indicates lower temperatures and higher rainfall during the driest month. The climatic parameters are consistent with the occurrence of a temperate mixed evergreen and broadleaf deciduous fossil assemblage in the late Miocene of the La Cerdanya Basin. The assemblage contains more taxa in common with coeval localities from northern and central Europe than with Mediterranean sites; its closest modern analogue is with the montane flora from Honshu Island (Japan). This suggests that the palaeoaltitude of La Cerdanya Basin was higher than that of other coeval floras known from the Tortonian of the Mediterranean area.

Palaeoaltitudinal estimation using the terrestrial lapse rate method suggests that the La Cerdanya Basin was positioned at 1100–1550 m during early Tortonian times. This result challenges previous palynological and isotopic studies that inferred a palaeoaltitude of c. 600 m in early Tortonian-Messinian times and a Quaternary rise of the Pyrenean chain. In contrast, our results suggest that the present-day altitude of the La Cerdanya Basin (1100-1400 m a.b.s.l.) was similar to today's one, at least since the late Miocene.

References

Tosal, A. Verduzco, O. Martín-Closas, C., 2021. CLAMP-based palaeoclimatic analysis of the late Miocene (Tortonian) flora from La Cerdanya Basin of Catalonia, Spain, and an estimation of the palaeoaltitude of the eastern Pyrenees. Palaeogeography, Palaeoclimatology, Palaeoecology, 564, 110186.

Preliminary data on the Givetian flora of Oum el Jerane (Anti-Atlas, Morocco)

Candys BERT[1], Brigitte MEYER-BERTHAUD[2], Anne-Laure DECOMBEIX[3]

1. *UMR AMAP, Univ. Montpellier, CNRS, CIRAD, INRA, IRD, Montpellier, France (candys.bert@etu.umontpellier.fr)*
2. *UMR AMAP, Univ. Montpellier, CNRS, CIRAD, INRA, IRD, Montpellier, France (meyerberthaud@cirad.fr)*
3. *UMR AMAP, Univ. Montpellier, CNRS, CIRAD, INRA, IRD, Montpellier, France (anne-laure.decombeix@cirad.fr)*

This communication presents a preliminary analysis of an unpublished fossil plant assemblage from the marine deposits of Oum El Jerane in Tafilalt (Southeastern Morocco). These fossils were collected during a geological field-trip conducted in 2013 by Profs. El Hassani, Becker and Tahiri as part of the International Field Symposium "The Devonian and Lower Carboniferous of Gondwana". The plant remains are dated of the upper Givetian (Middle Devonian) by the associated fauna (Becker et al. 2013). They represent the oldest assemblage of anatomically preserved plants in Morocco. The specimens are anatomically preserved in a limonitic matrix. About 30 small axes measuring between 4 and 14 mm wide and preserved over a length not exceeding 30 mm were collected. Wafers were prepared in cross-section, and longitudinally when the axis length allowed it. The described specimens are assignable to the Iridopteridales, pseudosporochnalean-type Cladoxylopsida and Aneurophytalean progymnosperms. The Oum El Jerane assemblage shows affinities with contemporaneous plant assemblages from the eastern USA, suggesting floristic exchanges with the paleocontinent Laurussia.

Reference

Becker R., Aboussalam, Z., Hartenfels, S., El Hassani, A., Fischer, T., 2013. The Givetian - Famennian at Oum El Jerane (Amessoui Syncline , Southern Tafilalt). In : International Field Symposium "The Devonian and Lower Carboniferous of Northern Gondwana" Field Guidebook. Documents de l'Institut Scientifique, Rabat, 27, 61–71.

Les bois fossiles du synclinal d'Anoual (Jurassique, Maroc) : description et identification

Lydéric PORTAILLER[1], Anaïs BOURA[2]

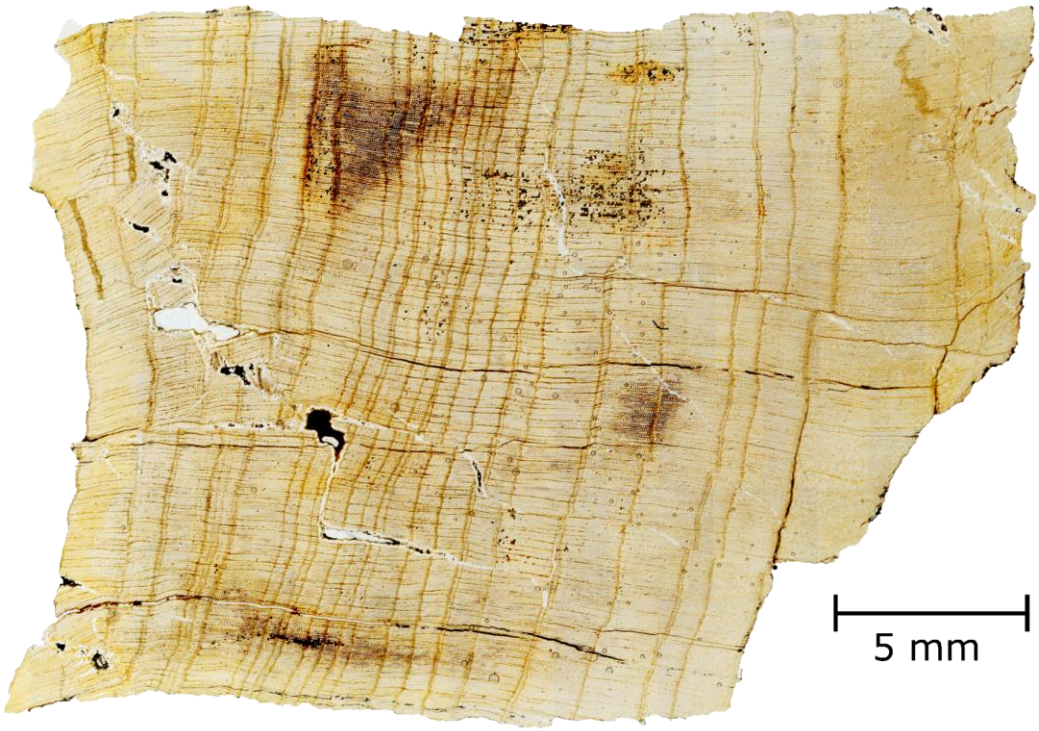
1. *Centre de recherche en Paléontologie – Paris – CP 40 - 53 rue Cuvier – 75231 Paris Cedex 5 – France – lyderic.portailler@edu.mnhn.fr*
2. *Centre de recherche en Paléontologie – Paris – CP 40 - 53 rue Cuvier – 75231 Paris Cedex 5 – France – anais.boura@sorbonne-universite.fr*

Les « Couches Rouges » du synclinal d'Anoual (Tithonien-Berriasien, Formations de Ksar Metlili, Anoual et Dekkar), dans l'est-Atlas marocain, ont livré une quantité importante de fossiles d'animaux, de pollen, de spores, et de troncs ou de fragments de bois silicifiés. Depuis le début du XXème siècle, une nomenclature commune et des outils sont développés afin d'identifier les bois fossiles. Cependant, beaucoup de lacunes doivent encore être comblées, notamment pour l'identification des bois mésozoïques du Gondwana.

Ainsi, le premier objectif de notre étude a été de référencer les espèces fossiles jurassiques d'Afrique du Nord et du Portugal à partir de la littérature. Une base de connaissance Xper3 (Vigne-Lebbe *et al.*, 2015).) a ensuite été créée à partir des 18 espèces inventoriées. La base comprend 37 descripteurs microscopiques utilisés dans les diagnoses, descriptions et images des publications originales. Cet outil a ensuite été utilisé afin d'identifier deux échantillons particulièrement bien conservés parmi les 54 disponibles provenant du site d'étude. Bien qu'encore incomplète la base de connaissance s'est révélée suffisante pour aiguiller les recherches de façon efficace et simple. À l'avenir, il sera nécessaire d'achever les descriptions et les identifications de tous les échantillons disponibles provenant du Synclinal d'Anoual et de les comparer entre eux et avec les espèces précédemment décrites grâce notamment à la base. Enfin, une attention particulière devra être portée aux nombreux cernes/faux cernes très fréquents au sein de la structure de nombreux échantillons.

References

Vignes Lebbe R, et al.. 2015. « Xper3: new tools for collaborating, training and transmitting knowledge on botanical phenotypes ». *Rakotoarisoa NR, Blackmore S, Riéra B (Eds) Botanists of the 21st century*, 11 pp. [ISBN 978-92-3-100120-8].



Photographie d'An4 observé au microscope optique en coupe transversale.

A new bioprovince for Barremian-Aptian charophytes in the Cretaceous Tethyan Archipelago

Josep SANJUAN [1], Carles MARTÍN-CLOSAS [1], Alba VICENTE [1, 2], Jordi PÉREZ-CANO [1]

1. *Departament de Dinàmica de la Terra i de l'Oceà, Institut de Recerca de la Biodiversitat (IRBio),Facultat de Ciències de la Terra, Universitat de Barcelona-UB, Barcelona, Catalonia (Spain) (cmartinclosas@ub.edu, josepsanjuan@ub.edu, jordi_perez-cano@ub.edu)*
2. *Estación Regional del Noroeste, Instituto de Geología, Universidad Nacional Autónoma de México-UNAM, Blvd. Luis Donaldo Colosio S/N Campus UNISON, Hermosillo, Sonora, México (albavr@geologia.unam.mx)*

Clavatoraceae was a charophyte family that dominated tropical and subtropical charophyte floras from Northern Hemisphere during the Early Cretaceous. The maximum diversity of the group was reached during the Barremian in the islands of the Central Tethyan Cretaceous Archipelago (present-day Europe, North Africa, and Middle East). As to present knowledge, Iberia was the island were clavatoraceans were more diverse (Peréz-Cano et al., 2020).

In order to characterize the palaeobiogeographic distribution of this family (17 taxa) during the Barremian, a statistical cluster analysis has been performed using the software Palaeontological Statistics (PAST). Results allow distinguishing a charophyte bioprovince within the Central Tethyan Archipelago. Some species were unique to the whole area (e.g., *Globator maillardii*). Other taxa were particular of specific island groups, such as Moecia-Dacia in Rumania (e.g., *Clavator ampullaceus* var. *latibracteatus*), or *Ascidiella triquetra* in islands of present day Europe and North Africa (Sanjuan et al. 2021). Only one species, *Pseudoglobator fourcadei*, is endemic from the Iberian island. Moreover, up to 6 species that had their origin in the archipelago were capable of expanding its biogeographic range outside and reached sub-cosmopolitan to cosmopolitan ranges (e.g., *Clavator calcitrapus* and *C. harrisii* respectively), the latter extending in a near-continuous area from East Asia to North and South America (Martín-Closas 2015).

The analysis reveals a further grouping within the Central Tethyan Archipelago consisting in two subbioprovinces following a latitudinal distribution: 1) North Central Tethyan subbioprovince including six islands (Brabant-Bohemian island, British island, Central Massif, Moecia-Dacia, Iberia, and North Africa) and 2) South Central Tethyan subbioprovince which comprises the equatorial Levantine island and East Gondwana´s continental margin.

Results suggest that the flux of species between islands of the archipelago was strong enough to maintain its homogeneity and to limit the island endemisms to the minimum. The frequent sea-level changes during the Barremian and Aptian probably helped the migration of these plants from one island to the other. The separation of the two subbioprovinces (North and South) would be climatically controlled. The extension of these bioprovinces to other groups of coeval vascular plants, such as ferns, conifers or early angiosperms is explored.

Acknowledgement. This study is a contribution and has been financed by project PID2020-113912GB-100

References

Martín-Closas, C. 2015. Cosmopolitanism in Northern Hemisphere Cretaceous Charophyta (Clavatoroidae). Palaeogeography, Palaeoclimatology, Palaeoecology, 438:9-23.

Pérez-Cano, J., Bover-Arnal, T., Martín-Closas, C. 2021. Barremian Charophytes from the Maestrat Basin. Cretaceous Research, 115:104544.

Sanjuan, J., Vicente, A., Pérez-Cano, J., Stoica, M., Martín-Closas, C. 2021. Early Cretaceous charophytes from South Dobrogea (Romania). Biostratigraphy and palaeobiogeography. Cretaceous Research 122: 104762.

Attritasporites and Virgatasporites: the oldest land-plant derived spores, cryptospores or acritarchs?

Thomas SERVAIS[1], Philippe STEEMANS[2]

1. CNRS, Univ. Lille, UMR 8198 - Evo-Eco-Paleo, F-59000 Lille, France
2. FNRS, Univ. Liège, Evolution and diversity dynamics lab, Allée du 6 Août, B18, 4000 Liège, Belgium

Combaz (1967) published the two new genera *Attritasporites* and *Virgatasporites*, under the heading *Anteturma Sporites* H. Potonié 1893, *Turma incertae sedis*, thus considering the taxa described as spores of unknown biological affinity. The diagnosis of *Attritasporites* includes the term miospore, and mentions a possible trilete mark. The type species *Attritasporites messaoudensis* (correction from *A. messaoudi*) is described as a '(?) trilete spore' and is compared by Combaz (1967) with *Crassispora*, and with *Densisporites* from the Carboniferous. Similarly, the diagnosis of *Virgatasporites* mentions a spore-like aspect, with a questionable trilete mark, and clear radial stratiation. The type-species *Virgatasporites rudii* (corrected from *V. rudi*) is also described as a 'miospore' and compared with *Emphanisporites* by Combaz (1967), but it also resembles the cryptospore *Artemopyra*. However, the main problem with both genera, that have subsequently been described from many localities of the Gondwanan margin, is the fact that they occur in the Early Ordovician, long before the first occurrence of cryptospores (*sensu* Steemans, 2000) or miospores, with or without trilete marks.

Several authors considered the two taxa as spore-like organisms, and they have sometimes been placed in the grouping of the cryptospores. Other authors consider them as acritarchs, i.e. organic-walled microfossils of unknown biological affinity.
Here, we revise the different concepts, and we revisit the cryptospore-acritarch question.

References:

Combaz, A., 1967. Un microbios du Trémadocien dans un sondage d'Hassi-Messaoud. *Actes de la Société linéenne de Bordeaux*, sér. B. 29, v. 104, 1–26.

Steemans, P., 2000. Miospore evolution from the Ordovician to the Silurian. *Review of Palaeobotany and Palynology*, v. 113(1-3), 189-196.

Blue stain fungi infecting an 84-million-year-old conifer from South Africa

Christine STRULLU-DERRIEN[1,2*], Marc PHILIPPE[3], Paul KENRICK[2], Robert A. BLANCHETTE[4]

1. *Institut Systématique Evolution Biodiversité, Muséum national d'Histoire naturelle, CNRS, Sorbonne Université, Paris, France.* c.strullu-derrien@nhm.ac.uk
2. *Department of Earth Sciences, The Natural History Museum, Cromwell Road, London, U.K.* p.Kenrick@nhm.ac.uk
3. *Univ Lyon, Université Claude Bernard Lyon 1, CNRS, ENTPE, UMR 5023 LEHNA, Villeurbanne, France.* marc.philippe@univ-lyon1.fr
4. *Department of Plant Pathology, University of Minnesota, St. Paul, Minnesota, U.S.A. robertb@umn.edu*

Blue stain fungi are a polyphyletic assemblage of parasitic and saprotrophic ascomycetes that typically infect living woods colonised by bark beetles (Scolytinae) as well as by other insects. These eponymous fungi generate melanin as they grow that imparts a blue, grey, or black pigmentation to the wood. We investigated fossil fungi preserved within silicified wood attributable to the fossil taxon *Agathoxylon* (Araucariaceae) from the Upper Cretaceous (ca 84 Ma) of KwaZulu Natal, South Africa. We compared the fossils to blue stain fungi infecting modern *Pinus strobus* (Pinaceae). Our results indicate significant similarities, including wood discoloration, septate hyphae with dark and thick walls suggestive of pigmentation, preferential colonization of ray parenchyma, and passage of hyphae through plant cells without disruption or degradation of their cell walls. The South African fossils represent the first documented occurrence of blue stain fungi in the geological record. We further suggest that an ecological association between blue stain fungi and bark beetles originated during the latter part of the Mesozoic Era. Our results highlight the value of collections of petrified woods that are available in museums worldwide as a new source of information on the fossil record of wood colonizing fungi.

First record of silicified woods in the Late Carboniferous basins of the Pyrenees

Aixa TOSAL[1], Anne-Laure DECOMBEIX[2], Brigitte MEYER-BERTHAUD[2], Jean GALTIER[2], Carles MARTÍN-CLOSAS[1]

1. *Departament de Dinàmica de la Terra i de l'Oceà, Facultat de Ciències de la Terra, Institut de Recerca de la Biodiversitat (IRBio), Universitat de Barcelona-UB, 08028 Barcelona, Catalonia, Spain. e-mails: aixatosal@gmail.com (A. Tosal); cmartinclosas@ub.edu (C. Martín-Closas)*

2. *AMAP, Université de Montpellier, CIRAD, CNRS, INRA, IRD, Montpellier, France. e-mails: anne-laure.decombeix@cirad.fr (A.L. Decombeix); brigitte.meyer-berthaud@cirad.fr (B. Meyer-Berthaud); galtierjean@wanadoo.fr (J. Galtier).*

The Upper Carboniferous intramontane basins from the Pyrenees are rich in fossil plant adpressions but generally devoid of permineralized remains. Recently, well-preserved specimens of silicified wood were found in the Stephanian C of the Erillcastell Basin (Central Pyrenees, Catalonia, Spain) and are studied here from the anatomical and taxonomical viewpoint. These specimens correspond to the secondary xylem of a Calamitale and a Cordaitale.

The Calamitalean specimen shows two types of medullar rays i.e., large and narrow, both displaying a fusiform shape in tangential section. They are composed of parenchyma cells that have a square to rectangular shape in transverse section, with conspicuous uniseriate or multiseriate simple pits. These pits are spaced and located near the transversal walls and occasionally in the tangential walls. Often, brownish dark rounded organic content that could correspond to fungi are observed within the ray cells. The rays separate tracheids that show variable lumen sizes but a constant wall thickness in transverse section. The radial section of the wood shows long tracheids with scalariform-bordered pits. Cross-field areas show crowded multiseriate pits with an elongated and sub-rounded irregular shape. These features are consistent with the anatomy of the genus *Arthropitys*. Comparison with similar wood from coeval plant localities suggests that the *Arthropitys* from Erillcastell is most similar to *A. medullata* and *A. ezonata*.

The Cordaitalean specimen has uniseriate to rarely biseriate rays in transverse section. Occasionally, pale brown spherical organic content occur within the ray cells and may corresponds to fungal hyphae. Rays separate rows of tracheids with a square to rectangular shape. The tangential sections of the xylem show long tracheids and fusiform-shaped rays. The radial section shows araucarian pitting on the tracheid walls, with a uni-to triseriate arrangement. The pits are circular or oval, with a spindle-shaped aperture. Locally, some tracheids are filled with an ochre-orange content with polygonal shapes that likely corresponds to a late stage of tylose formation. Cross-fields show crowded uni- or biseriate circular small pits with a spindle-shaped aperture. These features are consistent with the genus *Dadoxylon*. Comparison with other late Palaeozoic cordaitalean silicified woods from southwest Europe, i.e., Graissessac-Lodève and Autun (Central Massif, France) and Arnao (Cantabrian Mountains, NW Iberian Peninsula), shows well-marked differences in the pitting patterns. Despite the good preservation of anatomical characters in *Dadoxylon* from Erillcastell, the primary xylem remains unknown, hindering its taxonomic assignment to the species level.

Anatomical features of the specimens here studied provide complementary information about the environment where these plants grew. For instance, *Arthropitys* with tracheids showing variable lumen size and constant wall thickness may indicate changes in growth linked to environmental factors such as drought, volcanic activity, or seasonality. Tyloses in *Dadoxylon* could also be linked to environmental conditions such as high temperatures or severe drought. However, a larger sample would be necessary to verify this hypothesis.

Acknowledgements. This project was funded by Fundació Universitària Agustí Pedro i Pons and is a contribution to project SGR2017-824 from the AGAUR (Catalan Research Agency)

A new climate model for the Pleistocene or how the earth used to breath in pre-industrial time

Isabel VAN WAVEREN[1]

1. *Naturalis Biodiversity Centre, Postbus 9517, 2300 RA, Leiden, the Netherlands*

E-mail address: Isabel.VanWaveren@naturalis.nl (I.M. van Waveren)

In the Palaeozoic temperature is found to be dependent on CO_2 concentration, driven by photosynthesis and modulated by orbital forcing. Considering carbon gets entombed in sediment sinks, a different reservoir for new CO_2 must exist and a process different from photosynthesis must be conceived for the replenishment of CO_2 in the atmosphere. The present and the Pleistocene are considered here to identify both this reservoir and this process. In the present, oceans are important CO_2 reservoirs and in the Pleistocene ash and dust (aerosols) precede degassing events. Various recent studies indicate that particulate matter composed of dust, ash, charcoal, soot, fungi spores, bacteria and larger molecules represent crystallisation cores for cirrus clouds and induce optical forcing. It is demonstrated here that glacial periods are gradually becoming colder, oxygen rich and fire prone, which induces a dense and low cirrus deck, that is retaining a large portion of the heat that reaches the troposphere. At the glacial maximum the oceanic system is demonstrated to momentarily switch from a chiefly buffering to a chiefly degassing system. The period of degassing ends through the expansion of the troposphere when the cirrus deck melts, climbs in altitude, and becomes fragmented, allowing the excess heat to leave the troposphere again. This happens when the excess heat due to light bouncing into greenhouse molecules is equal to the heat that escapes the troposphere which under natural circumstances always is at approximately 300 ppm. This new model for system earth is verified in the present where it explains the longitudinal migration of the Wallace line. The most important implication of this new model is that particulates drive warming and photosynthesis drives cooling. Orbital forcing modulates photosynthesis, rather than drives it and triggers rather than causes degassing, chiefly through the intermediary of CO_2. Present model resembles the Gaia model of Lovelock in the sense that particulate matter (and not dimethyl sulphides), plays a role as crystallisation (and not condensation) cores of water, but its response displays no homeostasis and is intermittent. It is demonstrated that during warm periods condensation clouds dominate over crystallisation clouds and force cooling, while during cold periods crystallisation clouds dominate over condensation clouds and force warming. The mix between earth's natural CO_2 reservoirs and industrial emission needs a re-assessment, in particular with respect to the fate of the chlorophyll front in the Northern Pacific and eutrophication. It is stressed that dust in the stratosphere drives warming, and consequently that geoengineering with any type of dust is not recommendable.

Climate-driven palaeofloral fluctuations on a volcanic slope from the low latitudes of the Palaeotethys (early Permian, West Sumatra)

Isabel VAN WAVEREN[1], Menno BOOI[2], Han VAN KONIJNENBURG-VAN CITTERT[1], Mike CROW[2]

1. *Naturalis Biodiversity Centre, Postbus 9517, 2300 RA, Leiden, the Netherlands*

2. *28A Lenton Road, The Park, Nottingham NG7 1DT, UK*

E-mail address: Isabel.VanWaveren@naturalis.nl (I.M. van Waveren), Menno4@gmail.com (M. Booi), Jtvk@kgk.nl (J.H.A. van Konijnenburg-van Cittert), Mcrow73517@aol.com (M.J. Crow).

The present paper focuses on plant diversity fluctuations within three ecosystems from a volcanic slope in the sequence analytical context of three superimposed cyclicities. This analysis was possible thanks to the isotopic age evaluation of the volcanic Merangin section that bracketed the Mengkarang Formation on West Sumatra between 296.77 ± 0.04 and 296.14 ± 0.09 Ma (Asselian, Lower Permian). The Merangin section consists of a 490-meter-long fining and thinning tuffaceous aggregational sequence composed of eight short-eccentricity fining and thinning upwards parasequences. The palaeoflora along the sequence varies from tropical wet taxa, comprising cordaitalean and ferns, to mesic-xeric taxa, typified by seed ferns and early conifers. Herein the palaeofloral content of 14 consecutive lahars from a single volcanic accretion wedge in the seventh parasequence is described in detail. It displays a gradual increase in the ratios of (seed) ferns (*Macralethopteris hallei*, *Sphenopteris* sp. and gigantopterids) and early conifers (*Dicranophyllum molle*, *Tobleria bicuspis*), reaching ~~a~~ 100 % in the 6th bed, and returning to 100% cordaitalean and ferns. The high ratio of seed ferns and early conifers in the 6th lahar is interpreted as reflecting a temporary lowering of the tree line caused by a glacial maximum from a high order cycle (obliquity or precession), superimposed on a short-eccentricity cycle, which in turn is superimposed on our third-order cycle palaeofloral transition described earlier for the whole sequence. Along this lower Permian section from the low latitudes from the Palaeotethys, glacial-interglacial cycles are seen to affect the fluctuations of the vegetation line in a chiefly similar way as during the Quaternary. The diversity fluctuations for three ecosystems (wetlands, lower and upper slope) are modelled for two of the three or more superimposed cycles. Emphasis is put on the appearance of a glacial palaeoflora on top of the sequence.

Assessing the diversity of insects damage traces in the fossil flora of Gelinden (Limburg, Belgium).

Raphaël ZAMBON [1], Julien DENAYER[2], Cyrille PRESTIANNI [1,3]

1. *Evolution and Diversity Dynamics Lab, Université de Liège, Liège, Belgium (*raphael.zambon@student.uliege.be*, cyrille.prestianni@uliege.be)*
2. *D*
3. *OD Earth and Life Directory, Royal Belgian Institute of Natural Sciences, Bruxelles, Belgium (cprestianni@naturalsciences.be)*

Plants and insects are two of the most important clades of multicellular organisms, both in terms of diversity and in abundance. They are relatively ancient groups, appearing in the Late Ordovician according to molecular clocks (Sanderson et al., 2004, Misof et al., 2014). Indeed, it is the colonisation of the continents by the plants that allowed the insects to develop on land (Labandeira, 2005). Therefore, these two groups have shared a long history of coevolution, developing a wide diversity of complex interactions, whose oldest examples are described as early as the Late Silurian (Labandeira, 2006). These interactions range from mutualist relations, such as pollination, to more predatory forms, such as herbivory and parasitism. The latter can be particularly evident in the fossil record thanks to the traces they left on the host plants, which are often more abundant, older and more informative than the remains of their perpetrator (Labandeira, 2007).

The study of these interactions in the fossil record is of great importance, as it not only gives us a better understanding of the evolution of such relations, through time and space (Labandeira, 1998, 2006), but also provides us with crucial information on the mechanics of these associations, which are still relevant in present time (Liu et al., 2015). Indeed, interactions are at the direct basis of the food chain, of the associated ecosystems (Labandeira, 2006). The study of their evolution through time notable allows to understand the reaction of such interactions to environmental change (Wilf & Labandeira, 1999).

The Palaeocene is a particularly interesting period from this point of view, as it directly follows the cataclysmic event of the K-T extinction and ends with the sudden warming of the Palaeocene-Eocene Thermal Maximum, changes which reflect on plant-insects associations (Currano et al., 2010, Tanrattana et al., 2020). While Palaeocene plant-insect associations have already received a certain interest with the development of the wider discipline in the last 30 years, most of these studies have focused on North American floras (Currano et al., 2008, Wilf et al., 2006, Wilf, 2008), in no part due to the relative rarity of European Palaeocene sites in comparison (Kvaček, 2010). However, up to now, the only similar study on a European site, at Menat of Selandian (Middle Palaeocene) age (Tanrattana et al., 2020), has revealed some interesting dynamics in comparison to its American equivalents, in particular when it comes to the diversity of insect-mediated damages (Wappler et al., 2009), making the study of other European floras all the more interesting.

In such a context, this study aims at investigating the multiple traces of damages present in the Selandian flora of Gelinden, in Belgium (Saporta, 1873, Saporta & Marion,

1878), in particular from the point of view of damage diversity. The point is to provide a basis of data usable for comparison of sites of similar age and nature, and therefore lead to a better understanding of the dynamics of plant-insect interactions during the Palaeocene of Europe, and in relation with the rest of the world.

References

Currano, E.D., Wilf, P., Wing, S.L., Labandeira, C.C., Lovelock, E.C. & Royer, D.L., 2008. Sharply increased insect herbivory during the Paleocene-Eocene Thermal Maximum. Proceedings of the National Academy of Sciences, 105(6), 1960-4.

Currano, E.D., Labandeira, C.C. & Wilf, P., 2010. Fossil insect folivory tracks paleotemperature for six million years. Ecological Monographs, 80(4), 547-67.

Kvaček, Z., 2010. Forest flora and vegetation of the European early Palaeogene – a review. Bulletin of Geosciences, 85(1), 63-76.

Labandeira, C.C., 1998. Early history of arthropod and vascular plant associations. Annual Review of Earth and Planetary Sciences, 26, 329-77.

Labandeira, C.C., 2005. Invasion of the continents: cyanobacterial crusts to tree-inhabiting arthropods. Trends in Ecology & Evolution, 20(5), 253-62.

Labandeira, C.C., 2006. The four phases of plant-arthropod associations in deep time. Geologica Acta, 4(4), 409-38.

Labandeira, C.C., 2007. Assessing the fossil record of plant-insect associations: Ichnodata versus body-fossil data. SEPM Special Publications, 88, 9-26.

Liu, W.H., Dai, X.H. & Xu, J.S., 2015. Influences of leaf-mining insects on their host plants: A review. Collectanea Botanica, 34, e005.

Misof, B., Liu, S., Meusemann, K., Peters, R.S., Donath, A., Mayer C, et al., 2014. Phylogenomics resolves the timing and pattern of insect evolution. Science, 346(6210), 763-7.

Sanderson, M.J., Thorne, J.L., Wikström, N. & Bremer, K., 2004. Molecular evidence on plant divergence times. American Journal of Botany, 91(10), 1656-65.

Saporta, G. de, 1873. Essai sur l'état de la végétation à l'époque des marnes heersiennes de Gelinden, 112 p.

Saporta, G. de, Marion, A.F. 1878. Révision de la flore heersienne de Gelinden: d'après une collection appartenant au comte G. de Looz. Académie royale des sciences, des lettres et des beaux-arts de Belgique, 154 p.

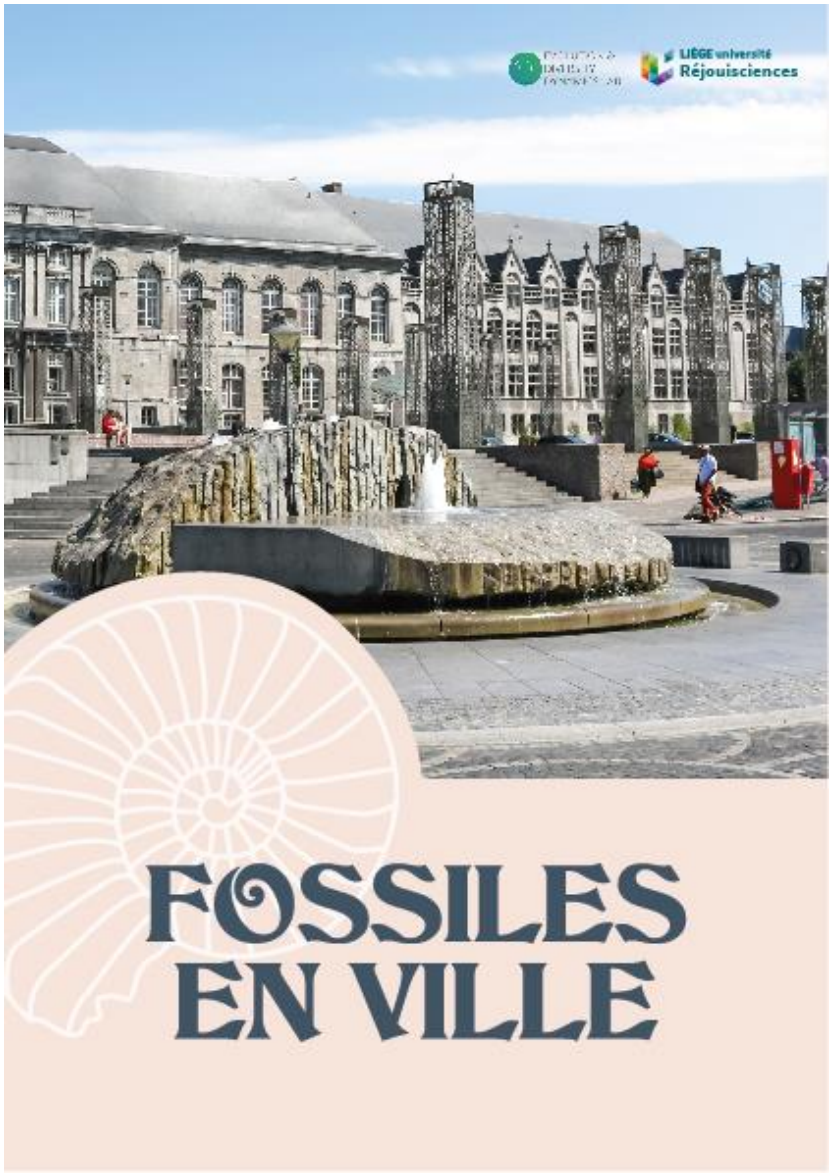
Tanrattana, M., Boura, A., Jacques, F.M.B., Villier, L., Fournier, F., Enguehard, A., Cardonnet, S., Voland, G., Garcia, A., Chaouch, S. & Franceschi, D.D., 2020. Climatic evolution in Western Europe during the Cenozoic: insights from historical collections using leaf physiognomy. Geodiversitas, 42(11), 151-74.

Wappler, T., Currano, E.D., Wilf, P., Rust, J., Labandeira C.C., 2009. No post-Cretaceous ecosystem depression in European forests? Rich insect-feeding damage on diverse middle Palaeocene plants, Menat, France. Proceedings of the Royal Society B: Biological Sciences, 276(1677), 4271-7.

Wilf, P. & Labandeira, C.C., 1999. Response of plant-insect associations to paleocene-eocene warming. Science, 284(5423), 2153-6.

Wilf, P., Labandeira, C.C., Johnson, K.R. & Ellis, B., 2006. Decoupled Plant and Insect Diversity After the End-Cretaceous Extinction. Science, 313(5790), 1112-5.

Wilf, P., 2008. Insect-damaged fossil leaves record food web response to ancient climate change and extinction. New Phytologist, 178(3), 486-502.



For more information on this project:

https://www.rejouisciences.uliege.be/cms/c_14099439/fr/rejouisciences-fossiles-en-ville-les publications