the wireline log data. A sub-set of these samples was then taken for quantitative palynofacies. Aspects that were of particular interest were the exact character of the D3B transgression and the speed and symmetry of its development. Does its presence reflect a transgression or is it, in fact, a response to the regression that created the sands of the Jauf Reservoir? In addition to palynofacies a number of analyses were also carried out including atomic H/C ratio of the kerogen and a limited programme of stable isotope determinations in the organic matter. These results will help determine the magnitude of this transgression and whether it can be related to a named 'global' Devonian event.

AL-HAJRI, S. A., FILATOFF, J., WENDER, L. E. & NORTON, A. K. 1999. Stratigraphy and operational palynology of the Devonian system in Saudi Arabia. **GeoArabia**, 4: 53-68.

Late Devonian and early Carboniferous miospore assemblages from Saudi Arabia

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Famennian (Late Devonian) and Tournaisian (Early Carboniferous) miospore assemblages are described from two exploration wells in Saudi Arabia; one located offshore in the Arabian Gulf, the other drilled east of the Ghawar Oilfield, *c.* 300 km east of Riyadh. The latter section includes assemblages dominated by *Retispora lepidophyta*, the disappearance of which coincides with the Devonian / Carboniferous boundary. However, overlying strata spanning the system boundary have been removed by erosion. Diverse assemblages from the Arabian Gulf well include typical Famennian and Tournaisian miospore taxa. However, *R. lepidophyta* has only been recorded from this well section as recycled specimens in assemblages that are clearly Carboniferous in age, so it appears that latest Devonian rocks have not been preserved. Extensive reworking has led to difficulty in interpreting the age of some of the lower intervals in this section.

Vallatisporites and related Cingulizonate genera from the Late Carboniferous–Early Permian of Saudi Arabia and South America

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Knowledge of Late Carboniferous and Early Permian Gondwanan microfloras has expanded significantly during the past five years as a result of detailed investigations in Saudi Arabia, Oman, Argentina and Brazil (STEPHENSON & FILATOFF, 2000; STEPHENSON et al., 2003; DI PASQUO, 2003; DI PASQUO et al., 2003 a, b). Correlation of the Early Permian sequences between the two regions is presently afforded by a small number of well illustrated spore taxa such as *Converrucosisporites confluens* (Archangelsky & Gamerro) Playford & Dino but many other morphotypes are similar in the two regions, particularly within the cingulizonate group. These spores are, however, complex and poorly illustrated so that comparative taxonomy is difficult. This contribution attempts to present a comparison between species of the genus *Vallatisporites* and other related cingulizonate genera including *Cristatisporites crassilabratus* Archangelsky & Gamerro, which are extensively recorded in the Late Carboniferous – Early Permian assemblages in Saudi Arabia, Oman and Argentina in order to reassess the outline correlations recently proposed by STEPHENSON & FILATOFF (2000).

Data from Saudi Arabia and Oman are derived from the subsurface glacigene Jawb (Unayzah B) and Al Khlata formations or the surface equivalent Juwayl Formation whilst those from South America were mainly recorded from the Machareti and Mandiyuti Groups in the Tarija Basin as well as from the Paganzo Basin in Argentina and from the Itarare Subgroup in the Paraná Basin of Brazil. The assemblages typically contain variable frequencies of spores and pollen grains (monosaccate, bisaccate and taeniate) from both the Late Carboniferous and Early Permian intervals and represent a predominantly gymnospermous (cordaitalean and coniferalean) vegetation but with significant contributions from lower vascular plants, notably pteridophytes, sphenophylls and lycopods. Taeniate pollen grains which become increasingly prominent in the Early Permian are derived from a glossopterid source.

Species such as *Vallatisporites arcuatus* (Marques Toigo) Archangelsky & Gamerro, *Cristatisporites menendezii* (Menéndez & Azcuy) Playford, *C. inordinatus* (Menéndez & Azcuy) Playford, and *C. crassilabratus* Archangelsky & Gamerro were recorded in both regions and are here critically re-examined in order to confirm both specific and stratigraphic assignments. Other species appear to remain endemic to both regions.

DI PASQUO, M.M., 2003. Avances sobre palinología, bioestratigrafía y correlación de las asociaciones presentes en los Grupos Macharetí y Mandiyutí, Neopaleozoico de la Cuenca Tarija, provincia de Salta, Argentina. **Ameghiniana** 40: 3-32.

DI PASQUO, M.M., AZCUY, C.A., SOUZA, P.A., 2003a. Palinología del Carbonífero Superior del Subgrupo Itararé en Itaporanga, Cuenca Paraná, Estado de São Paulo, Brasil. Parte 1: sistemática de esporas y paleofitoplancton. **Ameghiniana** 40: 277-296.

DI PASQUO, M.M., AZCUY, C.A., SOUZA, P.A., 2003b. Palinología del Carbonífero Superior del Subgrupo Itararé en Itaporanga, Cuenca Paraná, Estado de São Paulo, Brasil. Parte 2: sistemática de polen y significado paleoambiental y estratigráfico. **Ameghiniana** 40: 297-313.

STEPHENSON, M., FILATOFF, J., 2000. Correlation of Carboniferous - Permian palynological assemblages from Oman and Saudi Arabia. In: AL-HAJRI, S., OWENS, B. (Eds.), **Stratigraphic Palynology of the Palaeozoic of Saudi Arabia**. pp. 168-191. GeoArabia Spec. Public. 1. Gulf PetroLink, Bahrain.

STEPHENSON, M., OSTERLOFF, P.L., FILATOFF, J., 2003. Palynological biozonation of the Permian of Oman and Saudi Arabia: progress and challenges. **GeoArabia** 8: 467-496.

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MESOZOIC PALYNOLOGY

Palynology and paleoenvironment of the Gulailah and Hamlah formations (Triassic) in Qatar, Arabian Gulf

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Palynological and total organic carbon (TOC) analyses have been conducted on core samples recovered from the Gulailah and Hamlah formations of two wells drilled in the Dukhan oil field, western Qatar. Analysis of $^{87}Sr/^{86}Sr$ ratio of the studied succession give a chronostratigraphic range of Middle to Late Triassic (Ladinian-Carnian) for the Gulailah and Hamlah formations respectively. Palynological analysis has yielded a rich and fairly well preserved assemblage. Sixty-one palynomorph species have been identified. The assemblages are dominated by monosaccate, bisaccate and Circumpolles pollen. Three palynomorph assemblage zones have been established in the following ascending order: Zone I (Microcachrydites doubingeri - M. fastidiosus - Enzonalasporites vigens - Duplicisporites granulatus Assemblage Zone) dated as late Ladinian, Zone II (Patinasporites densus-Partitisporites maljawkinae Assemblage Zone) of Carnian age and Zone III (Corollina meyeriana–Eucommiidites major–

Ovalipollis pseudoalatus Assemblage Zone) assigned as early Norian. These Triassic palynofloras show a remarkable similarity to the Laurasian palynoflora and a lesser resemblance to the Gondwanan palynofloras. Deposition of the upper Gulailah and lower Hamlah formations took place in a lacustrine environment. The middle Hamlah Formation may have been deposited in a shallow, near-shore, normal marine environment, whilst deposition of the upper part took place in a drastic hypersaline marine environment. Humid, temperate climatic conditions alternating with arid to semiarid conditions prevailed during the sedimentation of the upper Gulailah and Hamlah formations in Qatar. Mixture of kerogen type II and III, oil and gas-prone material are inferred for the carbonates of the upper Gulailah-basal Hamlah formations (TOC higher than 0.3%), while, kerogen type IV, inert material is suggested for the upper Hamlah Formation (TOC less than 0.3%). The spore colour indicates that the upper Gulailah and basal Hamlah formations are thermally mature. The thermal alteration index (TAI) ranges from 3- to 3, which is interpreted as peak oil to onset gas generation.

Aspects of Late Triassic Palynology 5: Palynology of the Late Norian (Sevatian)–Rhaetian Zlambach marls in the Northern Calcareous Alps (Austria)

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The present contribution provides preliminary results of a quantitative and qualitative palynological study of the Zlambach section near Bad Goisern (Salzkammergut, Austria). We focus on the lower part of the section which consists of the top of the Hallstaetter limestone and the lower part Zlambach marls. On the basis of ammonoid and conodonts this interval can be regarded to represent the Sevatian Substage of the Norian.

Throughout the section the pollen and spore assemblages are dominated by *Granuloperculatipollis rudis*, *Corollina meyeriana*, *C. torosus*, and *Ovalipollis pseudoalatus*. Accompanying elements are *Rhaetipollis germanicus*, *Ricciisporites tuberculatus*, and *Tsugaepollenites pseudomassuleae*. In the lower part of the Zlambach marls a number of Carnian elements, such as *Enzonalasporites vigens*, *Vallasporites ignacii*, *Patinasporites Ellipsovelatisporites rugosus*, *Partitisporites maljawkinae*, *P. tenebrosus*, *Triadispora spp.* do occur.

Marine palynomorphs such as dinflagellate cysts and acritarchs are abundant. Dinoflagellate cysts (e.g. *Rhaetogonyaulax rhaetica*, *Suessia swabiana*, *Dapcodinium priscum*) are abundant in the higher part of the studied section. Intriguingly, *Rhaetogonyaulax wiggins*, *R. arctica*, *Hebecysta brevicornuta*, *Noricysta* sp. and *Sverdrupiella* sp. occur in the lowermost part of the section which would confirm a Late Norian (s) age for the top of the Hallstaetter limestone and the lowermost part of the Zlambach marls.

The co-occurrence of these "Carnian" sporomorph elements and Norian dinoflagellate cysts has not been reported in earlier studies on the Alpine Late Triassic. This may due to the fact that in the classic Rhaetian sections, the Koessen beds and particularly, the transition to the underlying Plattenkalk, did not yield palynomorph assemblages.

The Sevatian Substage of the Alpine realm may be palynological characterized by the co-occurrence of "Carnian" and Rhaetian pollen and spores in combination with a number of characteristic dinoflagellate cysts.

In contrast to earlier concepts of Visscher and Brugman (1981) the present data indicate that *Rhaetipollis germanicus* occurs already in ammonoid controlled Sevatian deposits. However, the Norian – Rhaetian transition may be characterized by the last occurrences of a number of distinctive gymnosperm pollen types.

Rhaetian palynomorph assemblages without these elements occur in the younger part of the section and are similar to those described from the Koessen beds in Kendelbach and Weissloferbach sections (Morbey, 1975, Mostler et al., 1978).

MORBEY, S. J. 1975. The palynostratigraphy of the Rhaetian Stage, Upper Triassic in the Kendelbachgraben, Austria. **Palaeontographica**, B: 1-75.

MOSTLER, H. SCHEURING, B., URLICHS, M. 1978. Zur Mega-, Mikrofauna und Mikroflora der Koessener Schichten (alpine Obertrias) vom Weissloferbach in Tirol unter besonderer Berücksichtigung der in der *suessi*- und *marshi* - Zone auftretenden Conodonten. **Erdwissen. Komm. (Oesterr. Akad. Wiss.).** 4: 141-174.

VISSCHER, H., BRUGMAN, W.A., 1981. Ranges of selected palynomorphs in the Alpine Triassic of Europe. **Rev. Palaeob. Palynol.** 34: 115-128.

The Palynostratigraphy of redbed and salt units of Mexican petroleum sub-basins of the Gulf of Mexico

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Mexican Mesozoic redbed and salt sequences have recently been dated using the palynostratigraphical method developed by the author at the Mexican Petroleum Institute since 1975. Some of them are the economic basement of the Gulf of Mexico petroleum sub-basins in Mexico, and they represent the beginning of the Mesozoic marine transgression which formed the petroleum systems.

The palynostratigraphical method is based on macro- and microscopic analysis of the organic and inorganic components in palynological residues, and of the glycerinated alcohol in which they are preserved. This analysis allows one to obtain litho-, bio-, and chronostratigraphical data related to tectono-sedimentary and diagenetical processes.

Cahuasas Formation (1969, in the Tampico-Misantla Sub-basin), Rosario Formation (1975, in the Tampico-Misantla Sub-basin), Todos Santos Formation (1982, in the Southeastern Sub-basins and 1987 in the western Veracruz Sub-basin) and La Boca Alloformation (1989, in the Huayacocotla-El Alamar Basin) and some salt units (1970-1993, in the Southeastern Sub-basins) have been dated in the Mexican Petroleum Institute. These obtained data and also that obtained in 1971 by Kirkland and Gerhard, from the caprock of the Challenger Knoll drilled in the center of the Gulf of Mexico, have been useful for understanding sedimentary and tectonic evolutions related to the origin of the Gulf of Mexico.

After these data it is clear that it exists a very important unconformity between the basement and the redbeds from the Middle Jurassic rocks (La Joya, and Todos Santos formations) in the Sabinas and Southeastern sub-basins of the Gulf of Mexico. This unconformity is also found between the Liassic rocks (La Boca Alloformation, and Huayacocotla Formation) from the Middle Jurassic redbeds (La Joya, and Cahuasas formations) in the Huayacocotla-El Alamar Basin, which was probably related to the southeastern Tlaxiaco and Huamuxtitlán basins, as suggested by Salvador (1987). On the other hand, in the Tlaxiaco Basin and in the northern part of the Tampico-Misantla Basin, in some localities the Liassic Rosario Formation redbeds gradually change to the Cualac and Cahuasas formations, which are the base of the transgressive marine Upper Jurassic-Middle Cretaceous sequence. Over this unconformity, the redbeds are of Middle Jurassic age and are slightly older than the evaporitic rocks deposited over the Gulf of Mexico marginal sub-basins (Sabinas, Tampico-Misantla and Southeastern sub-basins). Therefore, the age of these sub-basins is slightly younger than that of the Gulf of Mexico.

Palynostratigraphy of the Mesozoic of southcentral Scania, Sweden

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The Mesozoic sedimentary deposition in Scania, southernmost Sweden, was strongly affected by tectonic movements along the Sorgenfrei-Tornquist Zone (STZ) (Erlström et al. 1997). New subsurface palynostratigraphic data coupled with reflection seismic surveys have provided additional information about the structure and development of the Vomb Trough, a graben situated within the STZ in southcentral Scania. The sedimentary strata of the Vomb Trough were deposited along the eastern margin of the Danish Basin.

A poorly preserved typical Rhaetian microflora containing e.g. *Baculatisporites oppressus*, *Cingulizonates rhaeticus*, *Corollina torosa*, *Limbosporites lundbladiae*, *Lunatisporites rhaeticus*, *Porcellispora longdonensis* and *Ricciisporites tuberculatus* is, if *In situ*, the oldest palynoflora identified in the Vomb Trough. Well preserved, diverse, non-marine assemblages assigned to the Hettangian *Pinuspollenites-Trachysporites* and Sinemurian *Cerebropollenites macroverrucosus* Zones are otherwise regarded as representing the oldest strata in the graben. Late Early to Middle Jurassic strata have not been identified within the Vomb Trough, possibly an effect of volcanic doming that affected central Scania during the Middle Jurassic.

The strata straddling the Jurassic-Cretaceous boundary were deposited in a dynamic coastal environment, shifting between terrestrial, near-marine and fully marine conditions. Well-preserved dinoassemblages representing the late Volgian *Gochteodinia villosa* to early Valanginian *Pseudoceratium pelliferum* Zones have been identified.

The palynological data reveals that significant redeposition of sediments occurred in the area during the Cretaceous. Large amounts of reworked palynomorphs are consistently present in the Early Cretaceous sedimentary sequence, complicating the age assignments. The reworked material represents a whole suite of different ages. A typical Early Cretaceous assemblage contains not only its contemporary taxa, but also minor amounts of Carboniferous spores mixed with more abundant typical Rhaetian-Hettangian taxa and late Early-Middle Jurassic *Nannoceratopsis*.

Dinocyst assemblages of Late Albian-Cenomanian age, containing *Litosphaeridium siphonophorum* and *Epelidosphaeridia spinosa* have also been identified in the Vomb Trough. They are followed by diverse and well preserved dinoassemblages ranging in age from Coniacian to Campanian. The Late Cretaceous assemblages often contain reworked Early Cretaceous material, in addition to the previously mentioned reworked palynomorphs.

The present investigation aims to clarify the complex geology of the STZ in southcentral Scania. It also helps to quantify to what extent the Alpine foreland compression movements affected the structural evolution of the eastern margin of the Danish Basin.

ERLSTRÖM, M., THOMAS, S.A., DEEKS, N. & SIVHED, U., 1997, Structure and tectonic evolution of the Tornquist Zone and adjacent sedimentary basins in Scania and the southern Baltic Sea area. **Tectonophysics** 271: 191-215.

Palynofloras and plant megafossils of the Hojedk Formation, Kerman, Iran

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Reasonably well-preserved and moderately diverse palynofloras, together with some plant megafossils, occur sporadically in the mainly continental, coal-bearing sediments of the Hojedk Formation, Kerman, southeastern Iran. The palynomorphs are entirely of terrestrial origin and consist exclusively of spores and pollen. The miospores are radiosymmetrical and trilete, whereas the pollen are represented by monosulcate and non-striate bisaccate taxa.

Some distinctive spore species of the palynofloras, viz., *Dictyophyllidites harrisii, Dictyophyllidites mortonii, Klukisporites variegatus, Concavissimisporites verrucosus, Osmundacidites senectus,* and *Converrucosisporites pricei*, collectively suggest a Middle Jurassic age for the Hojedk Formation in the study area. Among the somewhat meager plant megafossils, such species as *Nilssonia feriziensis, Nilssonia obtusa, Klukia exilis*, and *Ferizianopteris undulata* corroborate this dating which, moreover, accords with the stratigraphic position of the Hojedk Formation.

The Hojedk palynofloral and megafloral assemblages exhibit a relatively consistent taxonomic composition through the formation, indicating fairly uniform and probably taxonomically restricted terrestrial vegetation during the Middle Jurassic. Some spore species, notably *Klukisporites variegatus, Dictyophyllidites mortonii, Cycadopites follicularis*, and *Cyathidites australis*, are important quantitatively. Inferred natural relationships of the dispersed spores and pollen imply derivation from a diverse parental flora (e.g., Pterophyta, Coniferophyta, Pteridospermophyta, Ginkgophyta, and Cycadophyta), which is also largely reflected by the identified plant megafossils.

The occurrence of plant megafossils in conjunction with the significant coal content of the Hojedk Formation implies sedimentation in a paludal environment during the Middle Jurassic. Furthermore, the presence of abundant marine invertebrate fossils at some horizons in the formation, testifies to intermittent marine incursions.

Correlation of the Bajocian-Tithonian deposists (Chaman-Bid Formation) in NE of Iran with their equall deposits in the Tethyan realm based on dinoflagellate cysts

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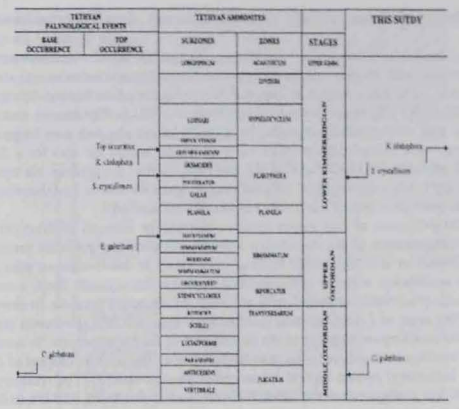
A thick sequence of Mesozoic and Terciary rocks are deposited in Kopet-Dagh basin. The basin covers an area of 55000 km2 in northeast of Iran, southern Turkmanestan and north of Afghanestan. The Chaman-Bid Formation (Late Bajocian - Tithonian) is about 1722 m thick at the type localitiy and decreases toward south and east of the basin. The thickness of this formation in the studied section (Kuhe Sandugh-Shakan) is measured 421 m. The lithology of the formation at the studied section is mainly of shale and marly limestone. In order to correlate these deposits with those of the Tethyan realm, 45 samples were collected and processed palynologicaly. The studied slides led to identification of 78 species of dinoflagellate cysts belonging to 33 genera.

The studied deposits are correlatable to deposits of the same age in the Tethyan realeam, based on the recorded dinoflagellate cyst assemblages. Two dinoflagellate cyst events were identified as follows:



- *Cribroperidinium globatum* event

  Age: Mid Oxfordian to early Kimmeridgian, *Plicatilis* to *Platynota* Ammonite Zones.

  Definition: The interval between the First occurrence of *Cribroperidinium globatum* and the first occurrence of *Scriniodinium crystallinum*.

This event encompasses a thickness of 210 m of the lower part of the section. The co-ocurrence dinoflagellate cysts are: *Acanthaulax downie, A. venusta, Aptea notialis, Canningia rotundata, Chytroeisphaeridia variabilis, Endoscrinium ciclum, Kalyptea stegasta, Pareodinia psiloperforata, Prolixosphaeridium granulata, Rhynchodiniopsis cladophora, Sentusidinium villersense, Tubotuberrella apatela, Wallodinium krutzchii*.

This event is correlatable with the one with the same name in the Tethyan realeam that is reported by Jan du Chêne et al (1999).

- *Scriniodinium crystallinum* event

  Age: Early Kimmeridgian, Platynota Ammonite Zone.

  Definition: The interval between the First occurrence of Scriniodinium crystallinum and the last occurrence of Rhynchodiniopsis cladophora. This event encompasses about 43 m of the strata of the middle part of the section.

The co-ocuurance dinoflagellate are: *Aldorfia aldofensis, Amphorella expirata, Aptea grande, Apteodinium nuciforme, Cribroperidinium sarjeantii, C. hansenii, Dingodinium cerviculum, Endoscrinium*

eisenackii, Escharisphaeridia pocockii, Gonyaulacysta dualis, G. eisenackii, G. jurassica, Lithodinia planoseptata, Leptodinium ambigua, Sentusidinium rioultii.

This event is correlatable with the one with the same name in the Tethyan releam erected by Jan du Chêne et al (1999).

Based on the recorded assemblages an age of Middle Oxfordian - Early Kimmeridgian is quoted to the lower and middle part of the section studied.

JAN DU CHENE, R., ATROPS, F., EMMANUEL, L., RAFELIS, M. DE & RENARD, M. (1999). Palynology, ammonites and sequence stratigraphy from Tethyan Middle Oxfordian to Lower Kimmeridgian, S-E France. Comparison with the Boreal realm. Bull. Centre Rech. Elf Explor. Prod. 22.2, 273-321.

Algal bloom and ocean eutrophication caused by the Mjølnir meteorite impact (Volgian-Ryazanian boundary, Barents Sea)

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During the Late Jurassic and earliest Cretaceous the Barents Shelf was dominated by fine-grained clay, organic-rich sedimentation, with mostly anoxic to hypoxic depositional conditions. At the time of the Volgian-Ryazanian boundary (142 ±2.6 Ma) a 1.6 km in diameter bolide hit the paleo-Barents Sea and created the 40 km in diameter Mjølnir Crater (DYPVIK et al. 1996, SMELROR et al. 2001a). The impact and crater formation led to significant disturbance and environmental changes, both at the crater site and over large distances of the paleo-Barents Shelf. Tsunamis were formed and travelled back and forth across the seas for a day or two after impact. Continuing collapse of unstable, unconsolidated highs and rims, formed avalanches, slumps and slides developing into gravity flows into the crater surroundings. Simulations of ejecta formation and distribution show major ejecta transportation along the path-direction of the bolide i.e. toward the northeast.

There are no evidences of any major biotic extinction or changes in diversity related to the impact event, but the overall compositions of the microfossil assemblages show a significant turnover within the impact-influenced strata (BREMER et al. 2003, SMELROR et al. 2001b). In the lowermost post-impact deposits in the Mjølnir Crater, and in association with the ejecta-bearing strata on the adjacent shelf, a conspicuous acme of the marine prasinophyte *Leiosphaeridia* combined with an influx of abundant juvenile freshwater algae of the genus *Botryococcus* occur. This acme of *Leiosphaeridia* reaches more than 503 000 specimens per gram sediment (post-compacted) in the oldest post-impact deposits in the central part of the impact crater. In contrast, the dinoflagellate cysts do not show any increase in numbers in the post-impact strata. The prolific blooms of *Leiosphaeridia* suggest that these algae had a behavioral pattern typical for so-called disaster species. The recovery of the algal bloom in deposits off Troms, 500 km to the south of the Mjølnir Crater, and on Svalbard, 450 km to the north, suggest that a regional eutrophication event were induced in the impact-ocean.

BREMER, G.M.A., SMELROR, M., NAGY, J. & VIGRAN, J.O. 2003. Biotic Responses to the Mjølnir Meteorite Impact, Barents Sea: Evidence from a Core Drilled within the Crater. In: H. DYPVIK, M. BURCHELL & P. CALYES (eds.) **Cratering in Marine Environments and on Ice.** Impact Studies, pp. 21-38. Springer Verlag, Heidelberg.

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Lower Cretaceous palynostratigraphy of northern regions of Western and Middle Siberia

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The detailed palynological analysis of the sections from the wells and outcrops of northern Siberian regions has allowed the comprehensive investigations of Lower Cretaceous microphytoplankton (dinoflagellate cysts (dinocysts), acritarchs and green algae) as well as spores and pollen of terrestrial plants. It provides the basis for the development of the stratigraphic scheme based on palynological data for northern regions of Western and Middle Siberia. The taxonomical composition of palynological assemblages as well as stratigraphical range of characteristic taxa and their groups have been appreciated using original materials and published data. Dinocyst and spore-pollen zones and subzones have been established taking into consideration first and last appearance of characteristic taxa, its abundance and diversity as well as frequency and abundance fluctuations of dominant, common and accessory taxa. The stratigraphical position of palynological zones is controlled by published macrofauna data (Fig. 1).

Although dinocysts have been traditionally used for biostratigraphic, paleoenviromental and paleoclimatic investigations in many regions of Europe, Australia, America and European part of Russia, little dinoflagellate research has been carried out in Western and northern Siberia, and published data are very rare. The Berriasian – Barremian succession of dinocyst zone has been proposed for the first time. Microphytoplankton assemblages include a wide number of dinocyst taxa, which are characteristic for Arctic and Boreal regions of Siberia, Europe and Canada providing long distance correlation. The investigations have been carried out with the financial support of Russian Fund of Fundamental Researches N 03-05-64391.

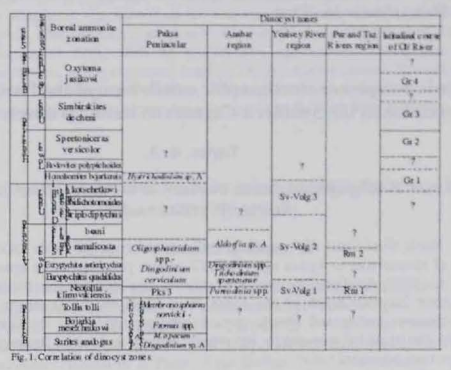

Fig. 1. Correlation of dinocyst zones

Subdivision and correlation of the Aptian *Diconodinium davidii* Zone in Australia

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The *Diconodinium davidii* Zone of Helby et al. (1987) is essentially based on subzone c of the *Odontochitina operculata* Zone and subzone a of the *Pseudoceratium turneri* Zone of Morgan (1980), zones

established in the Oodnadatta well in the Eromanga Basin of eastern Australia. On the North West Shelf of Australia, the *D. davidii* Zone is encountered in many exploration wells within the Windalia Radiolarite, and above the Muderong Shale. The zone has been investigated, on a stable platform area in the Southern Carnarvon Basin of Western Australia. It is fully cored in two holes, where it is 45m and 24m thick, and partially cored in one hole with a thickness 11m. Another (air-core) hole, further to the north, has an intersection of 84m. Closely spaced samples from these holes allow high-resolution biostratigraphy and subdivision of the *D. davidii* Zone, and detailed study of palynological changes at the base and top of the zone. A series of distinct biostratigraphic intervals are evident through the zone. At the base is a thin interval without *Ovoidinium striatum*, then an interval with common-abundant *Ovoidinium striatum*, followed by an interval with common *D. davidii* and near the top an interval with less common *D. davidii*. The highest samples contain relatively common *Chlamydophorella nyei*. *Endoceratium turneri* and *Cribroperidinium edwardsii* appear at the base of the *D. davidii* Zone, with the lowest occurrence of *D. davidii* and *Muderongia tetracantha* (in the sense of Morgan, 1980) at, or just above, this level. The top of the zone is defined as the highest occurrence of *D. davidii*, but because this species is rare at the top of its range alternative markers have been established. The age of the *D. davidii* Zone is constrained at the top by the lowest occurrence of *Litosphaeridium arundum* just above the highest occurrence of *D. davidii*, which marks the top of the zone. In Europe the lowest occurrence of *L. arundum* is near the base of the Albian, therefore the age of the top of the *D. davidii* Zone is at, or just below, the top of the Aptian.

Planktonic foraminiferal data support a Late Aptian age for the *D. davidii* Zone by comparison with the European succession, and indicate a maximum marine flooding interval that approximately corresponds to the *O. striatum* Acme in the lower part of the *D. davidii* Zone. The benthonic foraminifera in the *D. davidii* Zone correspond to the upper depositional sequence in the type Doncaster Member of the Wallumbilla Formation in the Eromanga Basin succession.

HELBY, R., MORGAN, R. and PARTRIDGE, A.D., 1987, A palynological zonation of the Australian Mesozoic. AAP Mem. 4, 1-94.

MORGAN, R., 1980, Palynostratigraphy of the Australian Early and middle Cretaceous. Geological Survey of New South Wales, Memoir 18, 153pp.

Towards a sequence stratigraphic subdivision of the Early Cretaceous succession in the Southern Carnarvon basin (Western Australia)

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On the North West Shelf of Australia, petroleum reservoirs in fields such as Barrow Island, Chervil, Spar and Stag are of Hauterivian to Aptian age (135-112 million years ago). The ages have been derived from the standard Helby *et al.* (1987) dinoflagellate cyst zonal scheme; however, a higher biostratigraphic resolution is still required for this time interval. South of the North West Shelf on the Southern Carnarvon Basin (SCB) a programme of continuous coring and closely spaced sampling funded by the Geological Survey of Western Australia and UWA has provided material for the present project, and initial findings from a dinoflagellate cysts stratigraphic analysis are presented.

Based on five sections on the in the basin, seven key sequence surfaces/events have been identified using lowest and highest appearances of key dinoflagellate cyst taxa, dinoflagellate to spore-pollen ratios, sedimentary descriptions and known benthic foraminiferal associations. These are:

(1) A late Hauterivian to early Barremian unconformity signifying the initial flooding of the platform;
(2) A major marine transgression during the Barremian, marked by a surface and a changeover from terrestrial- to marine-dominated microfossil assemblage with consistent *Muderongia australis*;
(3) Ovoidinium cinctum acme occurring together with *Muderongia* sp. aff. *testudinaria* and *Scrinodinium attadalense* prior to maximum marine flooding;
(4) A maximum flooding surface/interval within the Barremian, expressed by a high dinoflagellate to spore-pollen (marine/terrestrial) ratio together with a maximum diversity of microplankton and benthic foraminiferal taxa;

(5) A sequence break during the late Barremian-early Aptian highlighted by the last occurrence of the dinoflagellate cysts *Muderongia mcwhae* and *Batioladinium longicornutum*, and the first occurrence of Muderongia crucis associated with consistent *Odontochitina operculata*;
(6) A depositional hiatus of early Aptian age evident by a low dinoflagellate to spore & pollen (marine/terrestrial) ratio, and the last occurrence of four dinoflagellate cyst taxa; and
(7) The first appearance of the dinoflagellate cysts *Cribroperidinium edwardsii*, *Endoceratium turneri* and *Diconodinium davidii*, are taken to mark the base of the Late Aptian.

HELBY R., MORGAN R. & PARTRIDGE A. D. 1987. A palynological zonation of the Australian Mesozoic. In: Jell, P. A. (ed). Studies in Australian Mesozoic Palynology, Memoir 4, 1-94. Association of Australasian Palaeontologists, Sydney.

Dinoflagellate cysts as proxies for recognizing the Albian-Cenomanian boundary in the U.S. Western Interior

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The position of the Albian-Cenomanian boundary in the U.S. Western Interior has been the subject of debate for a very long time. Various researchers have traditionally used ammonites and sporomorphs to locate this boundary in outcrop sections in the region and have not agreed on its exact position. In this study, more than 200 samples from 26 outcrops sections in Montana, Wyoming, Colorado, Oklahoma and New Mexico have been analyzed for palynomorphs. Emphasis was placed on the recovery and preservation of the dinoflagellate cysts, which varied from poor to good. There was also variation in diversity. The assemblages were dominated by typical late Albian to early Cenomanian taxa, such as *Ovoidinium verrucosum*, *Ovoidinium scabrosum*, and *Palaeohystrichophora infusorioides*, which suggested brackish to very shallow marine depositional environments. In some sections in Montana, Wyoming, and northern Colorado, however, a few diagnostic taxa have been identified and used to locate the Albian-Cenomanian boundary close to the Clay Spur Bentonite horizon.

Palynological study of the dinosaurs-bearing wealden facies sediments of Bernissart (Belgium)

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The natural pit of Bernissart (Belgium) is well-known by paleontologists because of its exceptional dinosaurs content (at least twenty-eight specimens of *Iguanodon bernissartensis*, one specimen of *Iguanodon atherfieldensis*), numerous fishes, turtles, crocodiles, amphibians, insects and fragments of plants extracted between 1878 and 1881 from a coal mine at 322 and 356 meters deep. The "Iguanodons of Bernissart" are the first complete skeletons of dinosaurs historically found. However their geological age remains poorly known, ranging from Late Jurassic to Early Cretaceous.

We did make palynological preparations on silts and clays collected in the same level than the dinosaurs. The palynomorphs are very well preserved and have a continental origin only. Some of them have been previously described by the palynological pioneering work of Delcourt & Sprumont (1955). We mainly recognised macrospores (*Dijkstrasporites helios*, *Minerisporites marginatus* & *Membranisporites trifoliaceus*), ferns spores

(*Trilobosporites, Gleicheniidites, Pilosisporites, Cicatricosisporites & Concavissimisporites*) and pollen of gymnospermian affinity (*Eucommiidites, Applanopsis & Vitreisporites*), associated with a freshwater algal flora (*Botryococcus, Schizosporis, Ovoidites & Tetraporina*). This association confirms a sedimentation in the neighbouring of lakes and marshes. We also recognised a small amount of pollen attributed to the biorecords SUPERRET-*croton* and HAUTERIVIAN-*cactisulc, sensu* the nomenclature of Hughes (1994), respectively of angiospermous and probably gymnospermous affinity. In comparison with the well dated and *stratotype* successions of the Weald and Wessex Sub-basins, this assemblage suggests a Middle Barremian to Earliest Aptian age for the sediments of Bernissart and for the dinosaurs trapped within these sediments. This work highlights again the potential relevance of the pollen of angiospermian affinity for dating the continental sediments and their macrofossil contents during the Mesozoic era.

DELCOURT A. & SPRUMONT G. 1955. Les spores et grains de pollen du Wealdien du Hainaut, Mémoire de la Société Belge de Géologie, Paléontologie et Hydrologie, 5, 1-73.

HUGHES N.F. 1994. *The enigma of angiosperm origins*. Cambridge University Press, 303 p.

Cretaceous Palynology of the Interior Sudan Basins: An extensive database of pollen and spores from the Central African Rift System

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Extensive hydrocarbon exploration activities are currently being undertaken in the interior basins of the Sudan mainly in Muglad and Melut Basins. These two basins are part of the Central African Rift System, which started to evolve during Early Cretaceous period. Except for a paper published by KASKA (1989), palynological data from these basins are largely publicly unknown in spite of nearly thirty years of petroleum exploration activities in this region. Because of the economic importance of these basins, it was necessary to establish detailed chronostratigraphic scheme in these basins to have better understanding of the spatial and temporal distribution of the petroleum geological elements and processes which include timing of trap formation, timing of hydrocarbon generation and lateral facies distribution.

The present study was established to achieve the following goals; i) conduct taxonomic analysis of the Cretaceous pollen and spores, ii) analyze the stratigraphic and geographic records of the identified species; iii) establish a database with taxonomic description, stratigraphic ranges and geographic records of selected key species; iv) develop a software system for pollen and spore identification and biostratigraphic interpretation.

Seventy key pollen and spore species were selected to develop a biostratigraphic framework for the Cretaceous period using graphic correlation. Almost all the Cretaceous key species have previous records throughout the same period in West and Central Africa as well as in northern South America.

KASKA, H. V. 1989. A spore and pollen zonation of Early Cretaceous to Tertiary nonmarine sediments of the central Sudan. Palynology. 13; 79-90

A continuous and well-dated early angiosperm pollen record from mid-Cretaceous coastal deposits (Lusitanian and Algarve Basins, Portugal): Implications for the timing of angiosperm radiation

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The accurate timing of the major radiation of angiosperms during the Early Cretaceous is still a matter of debate. This is due to the lack of adequate continuous records as well as to uncertainties in dating of most fossil

plant-bearing strata. Considering both diversity and preservation, angiosperm mesofossil floras from the northern part of the Lusitanian Basin play a key role in the discussion of the early radiation of flowering plants (FRIIS et al., 1999, 2001). However, the stratigraphy of the fossiliferous horizons is poorly constrained and a Barremian or possibly Aptian age has been proposed.

Here, we present detailed and continuous palynological records from two extended successions in the Portuguese Algarve and Lusitanian Basins, which document the diversification of early angiosperm pollen during the Barremian to Albian time interval. Based on bio- and chemostratigraphy (dinoflagellate cysts and stable carbon-isotopes), an accurate stratigraphic framework has been established for the studied near-shore deposits (HEIMHOFER et al., 2003). The qualitative and quantitative analysis of the palynofloras of the two sections revealed a total of 62 different types of angiosperm pollen. Most of them (53 taxa) are monoaperturate grains of magnoliid or monocot affinity. In both records eudicotyledons, represented by various tricolpate taxa (9 taxa), are restricted to the post-Aptian part of the sections. Angiosperm pollen display a distinct increase in both, diversity (up to 19 taxa per sample) and relative abundance (up to 12%) between the Late Barremian and the Middle Albian. Detailed comparison with published studies (e.g. DOYLE & ROBBINS, 1977, HOCHULI & KELTS, 1980) show strong similarities with regard to floral composition and the timing of first appearance of particular angiosperm pollen forms.

Our results shed new light on the age interpretation of the Portuguese angiosperm mesofossil floras from the Lusitanian Basin. Several lines of evidence, including sequence- and biostratigraphy as well as palynology, indicate a post-Aptian age for these assemblages (incl. the Famalicão, Buarcos and Vale de Agua mesofloras), hence demonstrating a major radiation phase during the Albian.

FRIIS, E. M., PEDERSEN, K. R. & CRANE, P. R. (1999): Early angiosperm diversification: The diversity of pollen associated with angiosperm reproductive structures in Early Cretaceous floras from Portugal. Ann. Missouri Bot. Gard., 86, 259-296.

FRIIS, E. M., PEDERSEN, K. R. & CRANE, P. R. (2001): Fossil evidence of water lilies (Nymphaeales) in the Early Cretaceous. Nature, 410, 357-360.

HEIMHOFER, U., HOCHULI, P. A., BURLA, S., ANDERSEN, N. & WEISSERT, H. (2003): Terrestrial carbon-isotope records from coastal deposits (Algarve, Portugal): a tool for chemostratigraphic correlation on an intrabasinal and global scale. **Terra Nova,** 15 (1), 8-13.

DOYLE, J. A. & ROBBINS, A. I. (1977): Angiosperm pollen zonation of the continental Cretaceous of the Atlantic coastal plain and its application to deep wells in the Salisbury Embayment. Palynology, 1, 43-78.

HOCHULI, P. A. & KELTS, K. (1980): Palynology of Middle Cretaceous black clay facies from Deep Sea Drilling Project sites 417 and 418 of the western North Atlantic. Initial reports of the Deep Sea Drilling Projects, 51-53, 897-935.

Early Cretaceous mesofossils with tricolpate pollen *in situ*: evidence for early radiation of eudicot angiosperms

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The earliest fossils that can with certainty be assigned to the eudicot angiosperms are tricolpate pollen grains found in dispersed palynofloras from the Early Cretaceous (Barremian-Aptian) of England, Egypt, Israel, western Africa, and North America. A number of mesofossils (flowers and dispersed stamens) with tricolpate pollen in situ have now also been discovered from Early Cretaceous floras and have provided some insight into the systematic diversity and reproductive biology of the early eudicots. The oldest mesofossil assemblages with eudicot angiosperms are from the Barremian or Aptian of Portugal. Slightly younger (Aptian and Albian) mesofossil floras are reported from eastern North America. The earliest tricolpate pollen grains are all small with simple, elongate apertures. In the dispersed palynofloras from the Barremian and Aptian tricolpate pollen are rare, but very early they show a considerable diversity in pollen wall structure and ornamentation, indicating that a diversity of eudicot lineages was established early in the evolution of angiosperms. This is supported by the study of the Early Cretaceous mesofossil floras. About 13 different kinds of tricolpate pollen have been observed in the

Portuguese floras. This accounts for about 15 per cent of all angiosperm pollen types reported from these floras. All the in situ pollen grains are small, ranging from about 10 to 25 µm in length and have simple colpi. One flower type includes striate pollen and has features indicating relationship with modern Buxaceae, a basal eudicot family. Pollen grains observed in the other mesofossils are reticulate or foveolate. They are also thought to be related to basal eudicots, but features critical for a more precise systematic assessment are lacking. The plants producing the early tricolpate pollen were most likely insect pollinated. Anther dehiscence was typically valvate, connective tissue often extensive and with a prominent apical extension, and pollen sacs were small. Such features are in extant angiosperms linked to insect pollination. Low pollen production in the tricolpate producing plants is indicated by the small size of the pollen sacs and indirectly by the lack of tricolpate pollen in the dispersed palynofloras associated with mesofossil floras. The rare occurrence of tricolpate pollen in the Early Cretaceous palynofloras might also indicate that although the eudicot plants were diverse early in angiosperm history they were not a prominent component of the Early Cretaceous vegetation.

Paleoecogeographic and pollination implications of early angiosperm pollen from the mid-Cretaceous Dakota Formation of Courtland Clay pit, Minnesota

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Mid-Cretaceous is a crucial time for angiosperm evolution and dispersal. Understanding the pollination of early angiosperms is important for understanding how angiosperms became the earth's dominant vegetation. The sediments in the Courtland Clay Pit, Minnesota were deposited during the mid-Cretaceous time as the Western Interior Sea was in a transgressive phase.

Samples were collected from the flanks of an ancient meandering stream channel which may be subject to tidal influence (30% dinoflagellate cysts present). The palynomorph record supports the interpretation of sedimentary environments. The angiosperm pollen recovered from the sediments of meandering channel swale are dominated by animal-pollinated (entomophilous) pollen types (93%). However angiosperm pollen is dominated by wind-pollinated (anemophilous) forms (83%) in the oxbow lake sediments. These data indicate that the animal-pollinated early angiosperms probably lived in wet, disturbed environments and the wind-pollinated early angiosperms probably lived in higher levee environments where the wind is appropriate for pollination. In the swale environment most animal-pollinated pollen grains (diameter less than 20 µ) usually stick together in clumps of more than five grains. Also animal-pollinated pollen *Tricolporoidites* sp.1 and *T.* sp.2 each account for 40% respectively (80% in total). So the low wet swale areas were favorable environments for the early animal-pollinated angiosperms. In the oxbow environment, high percentage (83%) of *Foveotricolpites* sp. and low diversity with only one species that is wind-pollinated, indicate that early wind-pollinated angiosperms probably lived together in densely spaced monospecific stands of vegetation. Thus single species stands of wind-pollinated angiosperms may be traced back to mid-Cretaceous. The animal-pollinated angiosperms probably were pioneering plants of disturbed habitats such as those of newly forming meander channels. Animal-pollinated angiosperms probably occupied these areas first and later were succeeded by wind-pollinated angiosperm species in the more stable levee environments.

Dinocysts and Cenomanian–Turonian Anoxic Events, Western Australia

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The middle Cretaceous was a time of geographically widespread, short-lived episodes of increased organic carbon burial. Of these Oceanic Anoxic Events, the Bonarelli Event in the latest Cenomanian – Early

Turonian is the most pronounced and can be considered the type example. Although extensively studied in recent years, most research has necessarily concentrated on the proto-North- and South-Atlantic and their margins.

In two recently drilled cores from onshore Western Australia, the latest Cenomanian to Middle Turonian is characterised by thin (cm to decimetre thick) organic-rich intervals (ORI's) superimposed on a progressively less organic-rich background. This feature, which is invisible in weathered outcrops, allows a detailed biofacies analysis.

Dinocyst diversities before the Bonarelli Event are high and appear to reflect relatively normal marine conditions. In contrast, the onset of the Bonarelli Event is marked by a dominance of low diversity leiosphaerid algal cysts with rare, small generalist dinocysts (eg. *Spiniferites* and *Microdinium*). Assuming relatively constant input of terrestrial spores/pollen, this impoverished dinocyst assemblage appears real rather than an artifact of an algal acme.

ORI's broadly decrease in organic richness up-section, from 27% to 11% organic carbon. Richer ORI's are characterised by leiosphaerid assemblages but, with decreasing organic richness, they grade into peridinioid dinocyst dominated assemblages (eg. *Isalbelidinium* or *Ascodinium*). In conjunction with foraminiferal biofcies and biomarker geochemistry, this is taken as an indication that the ORI's are linked to increased surface productivity.

Background (or inter-ORI) assemblages above the start of the Bonarelli Event grade progressively from a low diversity *Microdinium-Spiniferites* assemblage; through higher diversity *Palaeohystrichophora infusorioides* or *Circulodinium distinctum* dominated assemblages; to a pre-Bonarelli Event like assemblage in the Late Turonian. These assemblage changes correlate well with changes in percent organic carbon in the sediment. There is little indication of high surface productivity within these intervals.

Palynology and diamonds: an unlikely couplet

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Abundant fossil spores, pollen and dinoflagellates have been recovered from shale xenoliths, clastic fragments, and post-eruptive crater-fill deposits, in the Lac de Gras region, Slave Craton, Northwest Territories, Canada (65° N). The study was to determine depositional environments and ages, and to place constraints on the thicknesses of the now eroded cratonic sedimentary cover, whose only preserved record is the chaotic mix of clastic xenoliths and finely dispersed clastic material mixed in with the kimberlite. The character of the pre-eruptive sedimentary cover is considered to have affected the style of the eruptive process and the maximum age of the eruptions to provide a prediction of the abundance of diamonds.

Assemblages interpreted as Middle to Late Albian, (~100-105 Ma), mid Cenomanian? to Turonian (~90-95 Ma), Late but not latest Campanian (~73-80 Ma), and Late Maastrichtian to Early Paleocene? (61 to 69 Ma) were recovered. Recognition of these ages allows the correlation of inferred sequences in the Lac de Gras region with other similarly aged stratigraphies in western Canada, including those along the Manitoba Escarpment (49.5° N), which provide a valuable analog as they are located along depositional strike. The maximum thickness of the Albian through Paleocene Manitoba Escarpment section is 1000 m, setting a likely maximum thickness for the sedimentary cover over the Slave Craton. Plant microfossils characteristic of latest Turonian through Early Campanian, latest Campanian through Early Maastrichtian, and Late Paleocene ages have not been recognized in the Lac de Gras xenoliths suggesting hiatuses of these ages occurred within the now eroded sedimentary cover (SWEET ET AL. 2003). During these hiatuses, erosion may have removed strata leaving behind only enhanced thermal maturity profiles (STASIUK ET AL. 2003) as evidence for their former presence.

Near shore conditions during the Albian are indicated by mixed miospore and dinoflagellate assemblages. The presence of diverse and abundant dinoflagellates in Cenomanian to Turonian and, Late but not latest Campanian samples provides evidence for the mid-continental seaway extending across the craton in the early Late Cretaceous and again, at least partially, in the Late Campanian. Late Campanian samples also contain *Expressipollis* spp., *Fibulapollis* and *Loranthacidites pilatus* indicating an Arctic source area to the north northeast. During this time the Late Campanian interior seaway probably provided a barrier to the west and southwest.

The exclusive presence of spores and pollen in Late Maastrichtian and Early Paleocene assemblages implies the establishment of a terrestrial landscape. This is consistent with the latest Cretaceous withdrawal of the interior seaway. Late Maastrichtian assemblages include *Aquilapollenites conatus, A. reductus, Mancicorpus notabile, Myrtipites scabratus, Porosipollis porosus, Wodehouseia octospina,* and *W. spinata* indicating a shift to a west southwest source. These youngest assemblages from the kimberlites provide a maximum Early Paleocene age for many of the diatremes.

The kimberlite in the Giraffe diatreme has been dated at 47.4 Ma (LOCKHART ET AL.) providing a maximum middle Eocene age for the associated crater-fill sediments, establishing their correlation with the fossil forests of Axel Heiberg Island. Such crater-fill sediments contain pristinely preserved miospore assemblages, with those from Giraffe including a diverse angiosperm pollen flora dominated by oak (HAMBLIN ET AL. 2003). There is synchroneity between the emplacement of the Greenland mantle plume and the Paleogene Lac de Gras kimberlites.

HAMBLIN, A.P., STASIUK, L.D., SWEET, A.R., LOCKHART, G.D., DYCK, D.R., JAGGER, K. & SNOWDON, L.R. 2003. Post-kimberlite Eocene strata within a crater basin, Lac de Gras, Northwest Territories, Canada. 8th International Kimberlite Conference, Victoria B.C., June 22-27, Long Abstract, (published in CD format).

LOCKHART, G., GRUTTER, H. & CARLSON, J. 2003. Temporal and geomagnetic relationship of Ekati economic kimberlites. As above.

STASIUK, L.D., SWEET, A.R., ISSLER, D.R., KIVI, K., LOCKHART, G.D. & DYCK, D. 2003. Pre- and post-kimmberlite emplacement thermal history of Cretaceous and Tertiary sediments, Lac de Gras, Northwest Territories. Canada. As above.

SWEET, A.R., STASIUK, L.D., NASSICHUK, W.W., CATUNEANU, O. & MCINTYRE, D.J. 2003. Paleontology and diamonds: geological environments associated with kimberlite emplacement, Lac de Gras, Northwest Territories, Canada. As above.

A new palynostratigraphical correlation of the Cretaceous successions of West Greenland and Labrador Shelf

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The Cretaceous dinoflagellate cyst biostratigraphy described from onshore wells and outcrop sections from Svartenhuk Halvø and Nuussuaq, West Greenland (NØHR-HANSEN, 1996), has recently been revised and used for correlation with the two offshore West Greenland wells (Qulleq-1, Ikermiut-1) and two selected Canadian Labrador Shelf wells (Ogmund E-72, Skolp E-07).

Twenty new palynological intervals have been proposed for the Cretaceous. The stratigraphy is preliminary, as several intervals occur only in one well, and because nonmarine to brackish-water intervals need further correlation to fully marine sections.

The oldest recognised strata are thick Aptian to Albian nonmarine to brackish-water successions, which are represented onshore Nuussuaq and in the Ogmund E-72 well. The flora is characterised by the presence of the genera *Nyktericysta, Vesperopsis* and *Quantouendinium*. Nonmarine Cenomanian deposits with common *Rugubivesiculites* pollen overlie the Albian deposits in the two Labrador Shelf wells, where the Turonian–Santonian succession is represented by a hiatus.

Marine sediments of Turonian to Santonian age have been recorded from a section onshore Svartenhuk Halvø. The flora is characterised by the presence of the species *Heterosphaeridium difficile, Arvalidinium scheii, Chatangiella* cf. *madura* and *Trithyrodinium* spp. The Santonian is the youngest recorded Cretaceous stage on Svartenhuk Halvø. Offshore, Santonian palynomorphs have been recorded from the lower, sandy part of the Qulleq-1well.

A thick Lower Campanian marine succession dominates the Cretaceous deposits in the offshore West Greenland wells Ikermiut-1 and Qulleq-1 and is also known from the Skolp E-07 well on the Labrador Shelf. The succession is characterised by the presence of Dinoflagellate type E Ioannides 1986.

A remarkable Late Campanian to Early Paleocene hiatus is present in the two offshore West Greenland wells Ikermiut-1 and Qulleq-1. The hiatus is probably related to uplift during latest Maastrichtian or earliest

Paleocene time. This event has been recorded in large parts of the areas offshore West Greenland but is only recorded as a minor hiatus in the two studied Labrador Shelf wells. The K/T boundary has been studied in detail in a Cretaceous–Palaeocene succession onshore northern Nuussuaq (NØHR-HANSEN & DAM 1997).

A thick, Upper Campanian to Upper Maastrichtian marine succession dominates the Cretaceous sequence in Skolp E-07 and onshore Nuussuaq, whereas the Upper Campanian to Upper Maastrichtian marine succession is thin in Ogmund E-72. The Maastrichtian is characterised by the presence of the genera *Palynodinium grallator, Chatangiella biapertura, Isabelidinium cooksoniae* and *Alterbidinium acutulum*. The Upper Campanian is characterised by the presence of the genera *Odontochitina operculata, Callaiosphaeridium asymmetricum* and *Fromea nicosia*.

NØHR-HANSEN, H. 1996: Upper Cretaceous dinoflagellate cyst stratigraphy, onshore West Greenland. Bulletin Grønlands geologiske Undersøgelse 170, 104 pp.

NØHR-HANSEN, H.& DAM, G. 1997: Palynology and sedimentology across a new marine Cretaceous/Tertiary boundary section on Nuussuaq, West Greenland. Geology. 25: 9. 851-854.

Palynofacies and sea-level changes in the Middle Coniacian–Late Campanian (Late Cretaceous) of the East Coast Basin, New Zealand

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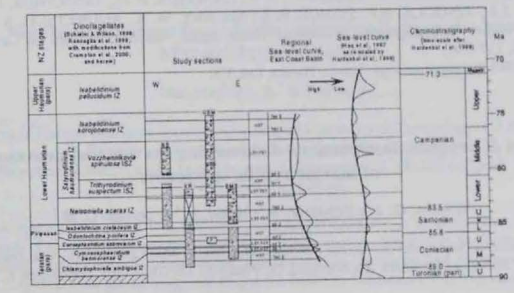
A palynofacies analysis of four sections through the Paton and Herring Formations of the East Coast Basin in southern Marlborough shows that the two formations were deposited in a marine environment with conspicuous input of plant material from adjacent land area. The Paton Formation was deposited on the inner to mid-shelf under oxic conditions and in proximity to a river delta. The deposition of the Herring Formation took place farther offshore, on the mid-shelf, in a mud-dominated environment under poorly oxygenated conditions at the sediment/water interface, following a landward shift of shoreline. A stratigraphic analysis of changes in palynofacies and lithology through the four sections allows a breakdown of the succession into seven depositional sequences, separated by unconformities or their correlative conformities. A regional sea-level curve for the Middle Coniacian–Upper Campanian in the East Coast Basin is proposed on the basis of the inferred sequences and chronostratigraphic control from dinoflagellate biostratigraphy. The sea-level cycles thus inferred for the East Coast Basin show a poor correlation with the re-scaled Haq cycle chart, suggesting that regional tectonics rather than eustasi controlled the East Coast Basin sequences.



Inferred regional sea-level curve for the East Coast Basin. Section abbreviations are: BMS=Ben More Stream tributary; KR= Kekerengu River, headwaters; NS=Nidd Stream; UBM=Ben More Stream, upper reaches. H=Herring Formation, P=Paton Formation, HST=highstand systems tract, LST= lowstand systems tract, TST=transgressive systems tract, mf=maximum flooding, sb=sequence boundary.

Morphology and taxonomy of fungal palynomorphs from the Tar Heel Formation (Campanian) of Atlantic Coastal Plain of United States

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Fungi are saprophytes or parasites and many are known to have angiosperms as hosts. Fungal palynomorphs including spores, hyphae and fruiting bodies were recovered from 103 samples collected from six different Campanian (Tar Heel Formation) localities (Elizabethtown, Goldsboro, Ivanhoe, Lock, Tar River, and Willis Creek) of the Atlantic Coastal Plain of southeastern United States. The modified maceration technique developed in the Palynological Laboratory at North Carolina State University was employed to recover good quality and abundant palynomorphs from samples of Tar Heel Formation. Although the conventional technique of maceration yielded identifiable palynomorphs, the number of grains obtained was always lower than obtained with the modified technique. The cost and time effective modified technique is a valuable tool for processing clastic sediments.

The morphological types exhibited variations in their cell number, size and arrangement of septa. The diversity is shown by the presence of monocellate (*Inaperturopollenites*), dicellate (*Dicellites*, *Didymosporiporonites*), tetracellate (*Tetracellites*) and multicellate (*Fractisporonites*, *Multicellaesporites* and *Scolecosporites*) forms. Fruiting bodies of *Phragmothyrites* and hyphae of form-genus *Palaencistrus* sp. were also found.

The form-genus *Multicellaesporites* shows a general trend of increased abundance from stratigraphically older to younger strata at Ivanhoe and Willis Creek localities. Changes in diversity and relative abundance of fungal palynomorphs could reflect changes of paleoclimate (Elsik, 1993). Studies by Jansonius (1976) and Staplin et al. (1976) showed increase in abundance and diversity of Neogene fungal palynomorphs in sediments of the cyclic warm periods. It could also be speculated that changes in relative abundance could possibly reflect the changes in relation to parasitism and saprophytism (Traverse, 1988). Fungal spores of *Multicellaesporites* were previously unknown from Campanian sediments as these are reported from Late Paleocene to Recent sediments.

ELSIK, W.C. 1993. The morphology, taxonomy, classification and geologic occurrence of **fungal palynomorphs.** The American Association of Stratigraphic Palynologists, Inc. A shortcourse. **2nd edition. 236 pgs.**

JANSONIUS, J. 1976. Paleogene fungal spores and fruiting bodies, Canadian Arctic. Geoscience and Man. 15, 12-132.

STAPLIN, F.L. (ed)., FOURIER, G. R., LEBLANC, A. E., LANGHUS, B. G., JANSONIUS, J., POCOCK, S.A. J., SULEK, J.A., ZINGULA, R.P., PIERCE, R. L., MICKEY, M. B., AUDRETSCH, A. P. and LESKIW, K. 1976. Tertiary biostratigraphy, Mackenzie Delta region, Canada. Bulletin of Canadian Petroleum Geology. 24, 117-136.

TRAVERSE, A. 1988. Paleopalynology. Unwin Hyman Ltd, UK

Dinos & dragons down under– determining the age and provenance of marine reptile specimens

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The development in recent years of a refined biostratigraphy for the New Zealand Upper Cretaceous, based on dinoflagellate cysts, has provided the opportunity to assign more accurate dates to many marine reptile fossils. It has also permitted the localisation of specimens whose provenance was previously in doubt. In this paper we outline the results obtained for South Island and Chatham Island specimens.

Dinoflagellate analyses of marine reptile sites in southeastern Marlborough, North Canterbury, North Otago and on Chatham Island, indicate that the localities range from Lower to uppermost Haumurian (Middle Campanian to Upper Maastrichtian) in age, spanning a period of about 15 million years. Sites in the Waipara River area are principally Upper Haumurian and range from the *Alterbidinium acutulum* Dinoflagellate Zone to the *Manumiella* druggii Zone. Sites in the Haumuri Bluff-Ngaroma Station-Cheviot/Jed River area are Lower Haumurian to lower Upper Haumurian and range from the *Satyrodinium haumuriense* Zone to the *Isabelidinium pellucidum* Zone. The Shag Point locality is Upper Haumurian (*Alterbidinium acutulum* Zone) indicating a general correlation with the Waipara localities. The Chatham Island locality is Lower Haumurian (*S. haumuriense* Zone) indicating a similar age to the oldest Haumuri Bluff sites. Material from two unknown sites appears to be from the Waipara River area, based on the associated dinoflagellate assemblages. The results of this study have permitted us to consider whether more than one reptile fauna is represented in the New Zealand Upper Cretaceous.

A view of the Conway Formation exposed in the cliffs overlooking the Waipara River, North Canterbury. A number of marine reptile specimens have come from this section.

New heterosporous fern (*Azolla*) microfossils from the latest Maastrichtian of Bolivia.

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A new species of aquatic fern affiliated with *Azolla* Lamarck is reported from latest Maastrichtian terrestrial sediments of the Eslabón Formation, Bolivia. The new species, ascribed to *Azolla boliviensis* sp. nov., is based on associated megasporocarps, megaspores, microsporangia, massulae and microspores recovered from outcrop samples collected from the northwestern end of the Bolivian Subandean belt, 315 km NNW of La Paz.

Azolla boliviensis is characterized by ellipsoid-ovoid megasporocarps with a spongy, 54 µm thick, wall that tightly encloses the single functional megaspore. The ovoid megaspore apparatus averages 384 µm long and incorporates a roughly spherical spore body surmounted by a dome-shaped supraspore bearing up to 30 floats in three tiers or spirals. The megaspore wall is two-layered: the more prominent external perine layer formed of fused-columellate elements forms a reticulum with 1-2.5 µm wide muri enclosing 1-2 µm diameter areolae. The perine bears loose, 0.5 µm diameter, simple, twisted hairs. Microsporocarps are not preserved but microsporangia are spherical-ovoid, 150-210 µm in maximum dimension, thin-walled, and enclose four or more massulae. The alveolate massulae average around 105 µm in diameter and bear scattered, anchor-shaped, aseptate glochidia. The number of microspores within the massulae is uncertain but dispersed microspores are circular, averaging 35 µm diameter, with a thin laevigate-scabrate exine. The new fossils have been illustrated by light micrography and scanning electron micrography.

Azolla is first recorded in the fossil record around Early to mid-Cretaceous times but the genus apparently underwent dramatic radiation during the Santonian-Maastrichtian. Most Cretaceous records are from Laurasia but a few examples are known from India and Argentina. The presence of abundant *Azolla* microfossils in Bolivia adds to this portrait of rapid geographic dispersal and diversification near the close of the Cretaceous.

Abundant *Botryococcus* preserved with *Azolla* suggests that the sampled sediments accumulated in freshwater lacustrine environments. Several pollen types in the studied assemblages have affinities to palms and gnetaleans. Together with *Azolla*, these groups are traditionally considered to favour relatively warm climates and this accords with the low palaeolatitudinal setting (c. 10°-20° S) interpreted for Bolivia in the latest Cretaceous.

At least ten *Azolla* species previously described from Maastrichtian sediments persist into the Paleocene suggesting that the Cretaceous-Tertiary mass extinction, which generally had a large impact on Southern Hemisphere vegetation (VAJDA *et al.* 2001), caused few extinctions among *Azolla* species. Impact-winter conditions have been invoked following the Chixculub bolide impact, with altered environmental conditions including decreased average temperatures at the Cretaceous-Tertiary boundary. Extant *Azolla* species favour the relatively equable conditions of tropical to warm-temperate lacustrine settings. However, they have notable potential to survive periodic frost damage, salinity change, and drought. The preference of *Azolla* species for equable lacustrine settings and their potential for rapid vegetative regeneration and dispersal may have facilitated their rapid recovery in the wake of the end-Cretaceous event compared to other, less-mobile and less stress-tolerant, vascular plants dependent on sexual propagation.

To some extent, modern *Azolla* are also buffered from changes in available lake nutrients owing to their symbiotic relationship with the nitrogen-fixing cyanobacterium *Anabaena azollae*. Although this symbiosis has not been demonstrated in Cretaceous fossils, such a relationship may have provided *Azolla* with additional benefits to buffer nutrient fluctuations during the dramatic environmental changes following the Cretaceous-Tertiary boundary event.

VAJDA, V., RAINE, J.I. & HOLLIS, C. 2001. Indication of Global deforestation at the Cretaceous-Tertiary boundary by New Zealand fern spike. **Science** 294: 1700-1702.

Terrestrial palynology of New Zealand Cretaceous-Paleocene sediments

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There is now overwhelming evidence for global disruption of vegetation at the Cretaceous-Tertiary boundary (KTB). However, there are important regional differences in the signature of vegetation turnover. The data suggest both massive devastation and mass extinction of plants at many KTB sections in North America (NICHOLS & JOHNSON 2002) but mainly mass-kill of vegetation at Southern Hemisphere high latitudes resulting in dramatic but short-term changes in the relative abundance of plant groups (VAJDA et al. 2001, VAJDA & RAINE 2003). New Zealand, located in the Southern Hemisphere at the time of impact and far from the Chixculub crater site, provides an invaluable opportunity to test the global effects of the bolide impact on ecosystem biodiversity. Recent palynological data comes from five New Zealand KTB sections: two drillcore sections from Greymouth Coalfield, two outcrop sections from the same coalfield, and one outcrop section from the marine units of mid-Waipara. The boundary has been pinpointed by palynology in all five sections and is characterized by massive vegetation disruption.

Biostratigraphically significant events identified at the KTB, include the last appearances of the Cretaceous key taxa *Tricolpites lilliei*, *Nothofagidites kaitangata*, *Proteacidites palisadus*, *Quadraplanus brossus*, and *Grapnelispora evansii* and the incoming of *Nothofagus waipawaensis* and *Tricolporities phillipsii* in the Paleocene, agreeing well with the miospore zone boundary PM2/PM3 of RAINE (1984).

The palynological signal through the New Zealand KT sections is nearly identical to those of the southern and central United States. The turnover in the flora is very sudden in the New Zealand sequences where disruption of the vegetation at the KTB is recorded by a 4mm layer of fungal spores coincident with an iridium anomaly of 4ppb. The pioneer recovery vegetation, following the end-Cretaceous catastrophe consists of *Laevigatosporites ovatus*, related to modern *Blechnum*, succeeded by *Gleicheniidites*, both representatives of ground ferns. Younger assemblages are dominated by spores of tree ferns eg. *Cyathidites* and *Cibotiidites*. Following an interval of fern dominance, gymnosperms and later angiosperms return to the palynological record. Fungal dominance is estimated to have lasted only a few years at the most, as the recovery of ferns initiates before iridium has returned to background levels, suggesting rapid re-establishment of ferns in the aftermath of the Chicxulub impact event.

The total absence of vascular plant spores and pollen and the abundance of fungal spores is evidence of wholesale dieback of photosynthetic vegetation at the KTB at least in this region. The fungal abundance possibly reflects a dramatic increase in the available dead organic matter serving as food source for saprophytic organisms following vegetation dieback. Post-impact conditions of high humidity and low insolation due to increased atmospheric sulfur aerosols and dust would have favoured saprophyte activity over photosynthetic organisms.

NICHOLS, D.J. & JOHNSON, K.R. 2003. Palynology and microstratigraphy of Cretaceous-Tertiary boundary sections in southwestern North Dakota. In: J.H. Hartman, K.R. Johnson, D.J. Nichols (eds). **Geol. Soc. Am. Spec. Paper 361**: 95-144.

RAINE, J.I. 1984. Outline of a palynological zonation of the Cretaceous to Paleogene terrestrial sediments in West Coast Region, South Island, New Zealand. *Report*, ***NZ Geol. Surv.*** *109: 82 p*

VAJDA, V., RAINE J.I. & HOLLIS C.J. 2001. Indication of global deforestation at the Cretaceous-Tertiary boundary by New Zealand fern spike. **Science** 294: 1700-1702.

VAJDA, V. & RAINE J.I. 2003. Terrestrial palynology of the Cretaceous/Tertiary boundary at mid-Waipara River, North Canterbury, New Zealand. **NZJGG** 46: 255-273.

Palynoflora from the Deccan Intertrappeans of Nawargaon, India and its implication on Palaeoecology and Palaeobiogeography

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The Deccan Intertrappean flora has evoked considerable interest in recent years because of its link with the Cretaceous-Tertiary (K/T) boundary and the associated major episode of basaltic volcanism in the Indian subcontinent. Due to lack of onshore exposure of carbonaceous sediments in the intertrappean horizons and their poor preservation and recovery, palynofossils seldom documented from the trap associated sediments. The palynoflora reported here belongs to an Intertrappean bed exposed in Palkundha nala near Nawargaon, Wardha District, Maharashtra, India.

A fairly rich palynoflora, typical of *Aquilapollenites* related assemblage has been recorded from the brownish coal samples. The assemblage is dominated by *Aquilapollenites bengalensis* followed by fairly large number of palm pollens (*Palmaepollenites* sp., *Longapertites* sp., *Mauritiidites crassinexus*) and pteridophytic spores (*Acrostichumosporites* sp., *Ariadnaesporites* sp., *Azolla cretacea*, *Cicatrisporites* sp., *Gabonisporites vigourixii*, *Lycopodiumsporites* sp., *Todisporites* sp., *Triporoletes reticulatus*). Besides the terrestrial palynotaxa, dinoflagellates (*Cleistosphaeridium* sp., *Deflandrea* sp., *Gonyaulax* sp., *Thalassiphora* sp.) and other planktons (acritarchs) showing marginal marine and brackish water affinities have also been recorded.

The palynoflora of Nawargaon intertrappean beds is essentially an *Aquilapollenites bengalensis* associated one that was reported earlier from Mohgaonkalan. Presence of *Ariadnaesporites* sp., *Azolla cretacea*, *Aquilapollenites bengalensis*, *Gabonisporites vigouroxii* and *Triporoletes reticulatus*, confirms Late Maastrichtian age for the Nawargaon intertrappeans, since most of these forms are documented from well dated strata having good palynological, stratigraphical and geophysical controls. Although the Nawargaon palynoflora is comparable

with most of the assemblages described from other onshore intertrappean beds, the best correlation can be made with the subsurface sediments of Krishna-Godavari Basin, as both of them have marine phytoplanktons in association with *A. bengalensis* related palynoflora. Accordingly, the general palynological preparations examined and the almost constant presence of phytoplanktons provides additional evidence for a marginal marine affinity to the deposition of the late Maastrichtian Nawargaon intertrappean sediments. Coastal depositional setting as evidenced by palms (*Nypa, Hyphaene*), intertidal forms (*Sonneratia, Acrostichum*) and dinocysts is thus inferred for the Nawargaon intertrappeans. Considering this environment, it is suggested that the northwestern shore of the Deccan was linked to the equatorial ocean (south western Tethys sea) probably through the Narmada valley during the Late Cretaceous period.

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TERTIARY PALYNOLOGY

Palynology of the lower Tertiary Kelalan formation, Bario, Sarawak, Malaysia

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Twenty-six outcrop samples were obtained, mostly from riverbank exposures, in the interior of northwest Sarawak, near the village Bario, approximately 3 km to the border with Kalimantan, Indonesia. These rocks were previously mapped as an equivalent of the predominantly marine, Neogene Kelabit Formation.

Thirteen suitable samples were run for palynology, foraminifera and nannofossil analysis. Only seven proved to be fossiliferous. The diversity and abundance of palynomorph and foraminifera are both moderate to good. The palynomorph and arenaceous deepwater benthic foraminifera are very well preserved. However, the calcareous planktonic foraminifera are not only rare, but also poorly preserved and have developed crystalline tests. This indicates reworking of shelf sediment prior to deposition in a deep marine environment.

The palynomorph assemblage indicates that the age of the outcrops are Early Tertiary, younging slightly towards the south becoming Late Eocene. The depositional environment indicates a deepwater deposition, (outer neritic to outer bathyal) in the north, and shallowing to more proximal deposition in the south (shallow marine and brackish water-influenced, lower coastal plain). Based on this evidence, the outcrops are thought to be equivalent to the upper part of Kelalan Formation, and may represent its southern extension.

Some of the key palynomorph assemblages recorded at this locality are comparable with the stratigraphically equivalent Kayan Formation in west Sarawak (Muller, 1968), although their diversity and abundance are less. The occurrence of pollen, resembling *Florschuetzia trilobata* tp. in Bario outcrops, together with *Psilatricolpites kayaensis* and *Spinizonocolpites baculatus,* may imply an Early Eocene to Paleocene age. These taxa have not been recorded from the Kayan Formation. If the Bario outcrops proves to be correctly dated, then this study will have recorded the oldest occurrence of *Florschuetzia trilobata* tp., predating the occurrence in the Middle Eocene of Nanggulan Formation in Java and Late Eocene Mangkalihat coal in Kalimantan, Indonesia (Morley, 1998, 2000). This may also imply that the precursor of the *Florschuetzia trilobata* tp. may have become adapted to brackish water environment as early as Early Eocene and Paleocene.

Pantropical palynomorphs in the Eocene of the Malaguides (Betic Cordillera, southern Spain)

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A quite diverse palynologinal pantropical assemblage was found in Lower-Middle Eocene sediments of the Malaguide Complex, near Malaga. This is the highest tectonic (nappe) complex of the essentially metamorphic Internal Zones of the Betic Cordilllera. In spite of the strongly tectonized, partially chaotic character and structural disorganization of the Malaguide Meso-Cenozoic outcrops around Malaga, four productive samples were collected from a quarry carved near the Harania cement factory. A relatively organized Paleogene succession several tens of meters thick was recognised there. The succession is composed by: 1) continental to very shallow marine *Microcodium*-rich calcarenites, conglomerates and marls attributed to the Paleocene; 2) very shallow marine *Alveolina*-rich limestones (sometimes bearing also red algae and small *Nummulites*) of Cuisian-lowermost Lutetian that lie unconformably and transgressively upon previous deposits; 3) the stratigraphically highest beds of Alveolina limestones are interlayered with greenish-grey and white marls intervals with intercalated gastropod-bearing limestones deposited in coastal marshy freshwater to moderately saline environments. This marshy facies, that become predominant upwards in the succession, also contain lateraly discontinous thin beds of lignite and black clays from which four palynologically productive samples were obtained.

The assemblage is characterized by the abundance of Angiospermae, especially the form-genus *Proxapertites* (up to 54 % ot the total association) and *Diporoconia* (17 %), together with a small proportion of other taxa, mainly of Restionaceae, Icacinaceae, Bombacaceae, Sapotaceae, *Cissus, Ilex*, Juglandaceae and Myricaceae. *Proxapertites* is known since the Upper Cretaceous of tropical-subtropical in Africa, Asia and America. Recently it was recorded from Austria and Spain. In the Malaga outcrop *Proxapertites* is represented mostly by *P. operculatus* Van der Hammen, minor proportion of *P. psilatus* Sarmiento (only recorded in Colombia, and western Venezuela up to now) and *P.* sp., possibly a new form. In the countries surrounding the Mediterranean sea *Proxapertites* has been only cited in Egypt (Upper Cretaceous) and Spain (Eocene). Some ferns are also present, such as Schizaeaceae, the type *Lygodium* being present in particular in a high amount, and a smaller proportion of Pteridaceae type *Acrostichum*, as well as the form-genus *Polypodiaceoisporites*, Gleichenaceae and Osmundaceae. One sample has also provided one speciment cyst of *Operculodinium*, that points out to brackish water conditions, together with several specimens of fresh-water green algae *Botryococcus*. This former palynofacies bears evidence of limited taphonomic effects/perturbance: abundance of large plant tissue with cuticles, brown wood remains, palynomorphs being all well preserved, and no separation into halves of most specimens of *Proxapertites*. The lithological and palynological features confirm deposition under warm and wet tropical climate in a coastal freshwater pond within a marshy environment, that was temporarily connected with normal marine environments, as indicated by facies analysis.

Quantitative biostratigraphy for the Tertiary of the Llanos Foothills, Colombia: Improving palynological resolution for oil exploration

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Oil exploration in Colombia has traditionally taken place in areas with relatively few structural complexities. However, in the last decade, exploration has moved to regions characterized by complex structural deformation, poor seismic resolution, and many stratigraphic problems, such as in the Llanos Foothills. In this region, the major reservoirs occur in mostly continental Paleogene sequences, where palynomorphs are usually the