AASP- THE PALYNOLOGICAL SOCIETY

Jen O'Keefe walking across "Sky Bridge" in the Red River Gorge National Geological Area during the pre-meeting field trip.
by Cortland Eble

NEWSLETTER

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Lexington 2012:

A Joint Meeting of the 45th Annual Meeting of AASP - The Palynological Society and Meeting of the CIMP - Commission Internationale de la Microflore du Paléozoïque Subcommissions

21-25 July 2012

Program and Abstracts

Taylor & Francis
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UNIVERSITY OF KENTUCKY
Kentucky Geological Survey

DEPARTMENT OF EARTH & SPACE SCIENCE

45th Annual Meeting of AASP - The Palynological Society and Meeting of the CIMP - Commission Internationale de la Microflore du Paléozoïque Subcommissions

At the
William T. Young Library and Kentucky Geological Survey
University of Kentucky
Lexington, KY
USA

Organizing Committee:
Cortland Eble
Jen O'Keefe

CIMP Symposium Coordinators:
Zélia Pereira
Reed Wicander

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4:00 pm – 5:00 pm	Registration, Kentucky Geological Survey.

Sunday, July 22 –

9:30 am – 6:00 pm	Registration, Kentucky Geological Survey
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10:00 am – 4:00 pm	AASP Outgoing Board Meeting, Kentucky Geological Survey Conference Room
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9:30 am – 9:45 am	Pollen evidence for vegetation response to the Younger Dryas event in the Atlantic Coastal Plain, United States. *Debra A. Willard, Christopher E. Bernhardt*
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2:00 pm – 2:15 pm	Combining standard palynology techniques with δ13C analysis of palynomorphs to understand shifts in relative humidity in the Late Eocene, Antarctica. *K.W. Griener, D.M. Nelson, S. Warny*
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9:30 am – 9:45 am	Stable isotope analysis (δ15N and δ13C) of Tasmanites and Protosalvinia extracted from Late Devonian- Early Carboniferous shales in east Kentucky. *Abigail Rooney, Robbie Goodhue and Geoff Clayton*
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2:15 pm – 2:30 pm	Palynologic Characteristics of Coal Beds in Northeastern Kentucky. *C. Eble*
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3:00 pm – 3:15 pm	Coffee/Tea Break and Posters
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4:15 pm – 5:00 pm	Discussion of Zonations and Datapacks for TS Creator, Kentucky Geological Survey Seminar Room
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Wednesday, July 25 –

7:00 am – 7:45 am	Field Trip check-in, Kentucky Geological Survey
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2 Provenance of the reworked Ordovician Palynomorphs in SDJ1 Borehole - Santa Susana Basin, Ossa Morena Zone, Portugal. *G. Lopes, Z. Pereira, P. Fernandes, J. Matos, D.Rosa, J.T. Oliveira*

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4 Palynology of the Devonian-Mississippian transition in western Montana: Three Forks, Sappington and Bakken formations. *M.M. di Pasquo, G.W. Grader, and P.E. Isaacson*

5 Palynological record of Devonian and Pennsylvanian units in the Espejos Range, western Santa Cruz de la Sierra, central Bolivia. *Mercedes di Pasquo and Heidi Anderson*

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8 'Palynomorph Darkness Index' – a new method for determining thermal maturity. *Robbie Goodhue, Geoff Clayton, and Abigail Rooney*

9 Palynofacies analysis of the Triassic -Jurassic boundary strata in the GSSP Kuhjoch Section, Northern Calcareous Alps, Austria. *A. Ivanovski, H. Jäger, and S. Götz*

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11 Palynofacies of the Sanganeh Formation (lower Cretaceous) in the East of Kopet-Dagh basin, NE Iran. *N. Shokri and A. Heidari*

12 Palynological reconstruction of last glacial cycle palaeo-environments of the Gulf of Papua: research proposal. *M.L. Thomas, S. Warny, S.J. Bentley, and A.W. Droxler*

13 Using palynological signatures to attribute rates of carbon storage to paleo-wetlands. *G.L. Chmura and I.F. Pendea*

Abstracts

Intrabasinal palynostratigraphic correlation of Campanian to Paleogene strata in the Bonnet Plume Basin, Yukon Territory

Kimberley M. Ball[1] and Arthur R. Sweet[2]

[1]Department of Geoscience, University of Calgary, Calgary, Alberta, Canada; [2]Geological Survey of Canada, Calgary, Alberta, Canada

Numerous sedimentary basins in Yukon Territory, including the Bonnet Plume Basin, contain significant coal reserves. These reserves represent some of the thickest and most extensive coal seams known in Yukon. Although these resources are known to occur, the correlations essential for resource evaluation require further corroboration. Coals up to 9 m thick exist in Cretaceous strata in the southern extent of the basin, which has a previously developed biostratigraphic framework. Paleocene coals in the northern part of the basin reach up to 17 m in thickness; correlations in this area have not yet been fully established. The intervening center part of the basin is covered by Quaternary gravels. Determining whether Paleocene and/or Cretaceous coals extend underneath this central vicinity will affect the resource potential of this basin.

Rouse and Srivastava (1972) described the upper Bonnet Plume Formation as Albian, Maastrichtian and Paleocene based on spore and pollen content. We build upon this work by describing three palynoassemblages of late Campanian, Maastrichtian, and Paleocene to possibly early Eocene age from examination of 78 outcrop samples from measured sections of the upper Bonnet Plume Formation. Samples of Albian age were not investigated in this study. Taxa representative of the late Campanian assemblage include *Aquilapollenites reticulatus* (Mchedlishvili) Tschudy & Leopold, *Aquilapollenites senonicus* (Mchedlishvili) Tschudy & Leopold, *Callistopollenites radiatostriatus* (Mchedlishvili) Srivastava, *Porosipollis* sp. cf. *P. porosus* (Mchedlishvili) Krutzsch*, Pulcheripollenites* sp. (new), *Singularia aculeata* Samoilovich and *Triprojectus magnus* (Mchedlishvili) Stanley. This assemblage is comparable to assemblage zone 8 of Nichols and Sweet (1993). Taxa representative of the Maastrichtian assemblage include *Aquilapollenites augustus* Srivastava and *Triprojectus unicus* (Chlonova) Mchedlishvili and the lowest occurrence of *Wodehouseia octaspina* Wiggins and *Wodehouseia spinata* Stanley. This assemblage is comparable to assemblage zone 9 of Nichols and Sweet (1993). The third assemblage is characterized by high abundances of *Alnipollenites* sp., *Caryapollenites* sp., betuloid pollen, *Paraalnipollenites alterniporus* (Simpson) Srivastava, and the presence of *Pistillipollenites mcgregorii* Rouse. This assemblage is Paleocene to possibly early Eocene in age. The palynological assemblages from these outcrop samples were compared to those previously determined from cores in the southern part of the basin (Ball, 2010).

We present a palynostratigraphic relationship between outcrop sections and an intrabasinal correlation between the northern outcrop sections and cores from the southern part of the basin. This framework improves the resolution of Late Cretaceous stratigraphic relationships in the Bonnet Plume Basin and may allow for future interbasinal correlation with other northern basins, such as the Eagle Plain Basin.

References:

Ball, K.M. 2010. Palynostratigraphy of Campanian Strata, Bonnet Plume Basin, Yukon Territory [BSc Honours Thesis]. [Calgary (Canada)]: University of Calgary.

Nichols, D. J. and Sweet, A. R. 1993. Biostratigraphy of upper Cretaceous non-marine palynofloras in a north-south transect of the Western Interior Basin. In Evolution of the Western Interior Basin, Edited by: Caldwell, W.G.E. and Kauffman, E.G. Geological Association of Canada, Special Paper 39, 539-584.

Rouse, G.E. and Srivastava, S.K. 1972. Palynological zonation of Cretaceous and Early Tertiary rocks of the Bonnet Plume Formation, northeastern Yukon, Canada. Canadian Journal of Earth Sciences, v. 9, p. 1163-1179.

Keywords: Bonnet Plume; coal; Cretaceous; Paleogene; palynostratigraphy; correlation

Devonian stratigraphy, correlation and depositional setting based on palynology in Saudi Arabia and Libya, northern Gondwana: comparison and application to oil exploration

P. Breuer, K. Ertug and M. Vecoli

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In the Paleozoic intracratonic basins of the North African Platform and the Arabian Plate ("northern Gondwana"), palynology provides reliable biostratigraphic dating and correlation together with abundant information on depositional settings, source rock distribution, and maturity of organic matter. A comparison of palynostratigraphic zonation of the Devonian successions of Libya, North Africa (Ghadames Basin) and Saudi Arabia is presented.

The Devonian strata in Saudi Arabia represent a relatively conformable succession and are subdivided, in ascending order, into the Tawil, Jauf and Jubah formations. They are clearly separated from the Silurian succession by the regional Late Silurian pre-Tawil unconformity that represents mostly continental to near-shore shallow marine paleoenvironments. Although there are no primary source rocks in the Devonian of the Arabian Plate, thermal maturity is lower in northwest Saudi Arabia compared to eastern Saudi Arabia (Ghawar region). Six palynological zones and nine palynological subzones are established in the Devonian succession of Saudi Arabia, based mostly on spore assemblages. Marine assemblages are only present in the Lower and, locally, the uppermost Devonian. The six palynozones are, in ascending order: the Lochkovian-Pragian D4 Zone (Tawil and lower Jauf formations), the early-middle Emsian D3/D4 Zone (middle Jauf Formation), the late Emsian-early Eifelian D3 Zone (upper Jauf and lower Jubah formations), the late Eifelian-early Frasnian D2 Zone, the Frasnian D1 Zone, and the Famennian D0 Zone (Jubah Formation).

In the Ghadames Basin of northwestern Libya, the Early Devonian, post-Caledonian unconformity succession consists mostly of near-shore, fluvial-dominated progradational delta systems, spanning the Lochkovian-middle Givetian (Tadrart, Ouan Kasa, Emgayet formations, and Member B of the Aouinet Ouenine Formation). This is followed by a widespread marine transgression during late Givetian-early Frasnian time, represented by the Cues Member of the Aouinet Ouenine Formation. The Cues Member, which is rich in strongly fluorescent marine amorphous organic matter (oil prone Type-1 and 2 kerogen), is the most important source rock facies in the Devonian strata of the Ghadames Basin, and is mature enough to produce hydrocarbons in the peak-oil generation and condensate windows. Its

maturity increases from east to west in the basin. Near-shore, fluvial-dominated progradational delta systems of late Frasnian-Famennian age (Member C of the Aouinet Ouenine Formation and the Tahara Formation) complete the uppermost part of the Devonian succession.

The Devonian zonation of the Ghadames Basin consists of seven palynozones based on both spores and acritarchs. They are, in ascending order: the Lochkovian-Pragian D1 Zone (Tadrart Formation), the Emsian D2 Zone (Ouan Kasa Formation), the late Emsian-Eifelian D3 Zone (Emgayet Formation), the Givetian D4 Zone (Member B of the Aouinet Ouenine Formation), the late Givetian-early Frasnian D5 Zone (Cues Member of the Aouinet Ouenine Formation), the Frasnian D6 Zone (Member C of the Aouinet Ouenine Formation) and the Famennian D7 Zone (Tahara Formation).

Most of the spore zonal index-taxa used in the Devonian biozonations of Libya and Saudi Arabia are in common, thus allowing direct correlation between both areas. This in turn, enables a direct comparison of sedimentary facies and paleoenvironmental development during the Devonian in North Africa and Saudi Arabia.

Keywords: Devonian; spores; acritarchs; stratigraphy; North Africa; Saudi Arabia; petroleum systems.

Palynological record of Late Devonian – Early Carboniferous in the Los Llanos Basin, Colombia

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The Llanos Orientales Basin is a large structural depression located in the eastern edge of Colombia. Paleozoic sedimentary sequences yielded palynological assemblages which ranges in age from Ediacaran to Early Carboniferous. These shaly sequences that could reach more than 20.000 feet of thickness in the depocenters, is being analyzed as Gas/Shale reservoirs.

The SM-4 wildcat located in the south western part of the Basin, drilled between 2000ft to 2350ft Early Carboniferous (Tournasian) marginal marine sediments. The palynological assemblages from this interval provided the first evidence for Early Carboniferous strata in the Colombian Llanos Orientales Basin (Dueñas and Césari, 2002) and constituted a new record for northern South America where the only well-known palynofloras of this age come from Brazil and Peru. The dominant spore species consist of morphologically simple, smooth (*Retusotriletes* spp.) or apiculate (*Apiculiretusispora*) retusoids as well as forms showing and representatives of the densospore group (*Densosporites, Indotriradites, Vallatisporites*). The assemblages also contain a number of stratigraphically significant species, including those with an Euramerican affinity and those with Gondwanan previous records. Among the northern species, *Colatisporites decorus* appears in the late Middle/early Late Tournaisian but is often found in Viséan strata of some Gondwanan regions. *Anapiculatisporites concinnus, Spelaeotriletes pretiosus, Apiculiretusispora multiseta and Prolycospora rugulosa*, have been also recorded, these taxa characterize the Viséan in the northern hemisphere. The gondwanic species *Indotriradites daemonii* and *I. dolianitii* have been also recorded. These species are usually present in Viséan strata of northern Brazilian basins.

Thirteen cuttings samples were also studied from the interval 2360-2950ft of the borehole SM4. The preservation is variable within the samples, but frequently is poor to moderate, and the palynomorphs are thermally mature and are dark brown to black. Taken together, the acritarch-spore evidence suggests a probable late Frasnian-Strunian age for the analyzed interval. The following diagnostic spores were recognized: *Ancyrospora ancyrea* (Eisenack) Richardson, *Ancyrospora langii* (Taugourdeau-Lantz) Allen, *Auroraspora solisorta* Hoffmeister, Staplin and Malloy, *Baculatisporites fusticulus* Sullivan, *Grandispora echinata* Hacquebard emend. Utting, *Grandispora spiculifera* Playford, *Hystricosporites multifurcatus* (Winslow) Mortimer and Chaloner, *Hystricosporites spp.*, *Retispora lepidophyta* (Kedo) Playford, *Samarisporites triangulatus* Allen, *Spelaeotriletes* cf. *resolutus* Higgs, *Teichertospora torquata* (Higgs) Mc Gregor and Playford and *Verrucosisporites bulliferus* Richardson and McGregor.

Acritarchs are represented by *Ammonidium* sp., *Daillyidium pentaster* (Staplin) emend. Playford in Playford and Dring, *Duvernaysphera radiata* Brito, *Exochoderma irregulare* Wicander, *Evittia sommeri* Brito, *Gorgonisphaeridium furcillatum* Wicander and Playford, *Gorgonisphaeridium* sp. A González et al., *Hapsidopalla exornata* Playford, *Maranhites britoii* Stockmans and Willière, *Micrhystridium* sp. B Playford and Mc Gregor, *Multiplicisphaeridium ramispinosum* Staplin, *Stellinium micropolygonale* (Stockmans and Willière) Playford, *Umbellasphaeridium saharicum* Jardine et al., *Umbellasphaeridium* sp. A Wood, *Veliferites tenuimarginatus* Brito, *Verhyachium centrigerum* Deunff, *Verhyachium lairdii* Deflandre, *Verhyachium trispinosum* (Eisenack) Stockman and Willière and *Verhyachium* sp. A Playford and Dring.

The distinctive acritarch *Umbellasphaeridium* is present in the interval 2700-2550 ft. Wood (1984) and Vavrdová and Isaacson (1999) recognized a high-latitude microplankton community in Frasnian and Famennian time characterized by recurrent species association of *Umbellasphaeridium saharicum*, *U. deflandrei*, *Stellinium octoaster*, *Navifusa bacillum* and *Maranhites brasiliensis* complex with stratigraphically important fossil miospore species *Retispora lepidophyta* (Kedo) Playford (1976). According with those authors the *Umbellasphaeridium saharicum* bioprovince is represented in South American in Brazil, Bolivia, Peru. This new record enlarges the distribution of the species. In addition, *Daillydium pentaster* and *Maranhites* spp. are also present and are recognized index species for the Late Devonian.

Palynological assemblages near the Devonian-Carboniferous boundary have been reported from the North Africa, Iran, China, Turkey, Australia, Bolivia and Brazil. Palynofloras from the SM-4 well increases the knowledge on the geographic distribution of these palynofloras.

Keywords: Paleozoic, Late Devonian, Llanos Orientales Basin, Colombia.

Using palynological signatures to attribute rates of carbon storage to paleo-wetlands

Gail L. Chmura[1] and I. Florin Pendea[2]

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Differentiation of wetlands in the paleo record is valuable for understanding coal deposition and past landscapes, but also climate dynamics, isostacy and sea level change. Historically, palynological research has focussed on interpretation of the record of terrestrial landscape change with considerably

less attention paid to wetland records. To help remedy that we are developing a database of modern wetland pollen analogs to better enable reconstruction of wetland dynamics and identify key indicators of distinct wetland types. Here we present palynomorph signatures for boreal wetlands of the Hudson Bay lowlands, based upon an initial data set from the coastal region of eastern James Bay, Quebec which is undergoing isostatic rebound. A discriminant analysis model shows that a small subset of palynomorph taxa can effectively classify four types of boreal wetlands: low and high elevation tidal marshes, fens, and bogs. The use of palynomorph assemblages to discriminate among wetland types was not dependent solely upon a local plant source, as taphonomic processes also help to distinguish palynological assemblages. For instance, dinoflagellate cysts and bladders of conifer pollen, both carried in tidal water, are clear indicators of tidal influence in marshes. Pollen from local vegetation, Cyperaceae, Poaceae, and *Potamogeton-Triglochin*- type are important to the classification of high marshes. Bryidae spores (derived from brown mosses) and pollen of *Myrica gale*, Cyperaceae, and Poaceae are indicative of fen. As expected, moss spores alone, primarily from *Sphagnum*, but also Bryidae type were indicators of bog.

We applied the palynological signatures to a young wetland deposit, dated at a decadal resolution using ^{137}Cs and ^{210}Pb profiles, to determine rates of carbon storage in various stages of wetland development that occur during isostatic rebound. The palynological record reveals transformation of tidal marsh to first stages of a freshwater fen within the last 70 yr. Using bulk density and carbon analyses we then calculated carbon accumulation rates of 87 and 182 g C m^{-2} yr^{-1} for the tidal marsh and fen, respectively - rates six times higher than the global long term (millennial) average for northern peatlands (a term that embraces fens and bogs). These results suggest an alternative explanation for the decrease in atmospheric CO_2 that occurred between 12 and 8 ka presently attributed to high summer insolation and increasing temperatures driving peat accumulation. We suggest that, during this same period, initiation of peat-accumulating wetlands on rebounded marine surfaces could explain decreased concentrations of atmospheric CO_2. By comparing the area of land submerged by ancient seas in northern North America during the early Holocene and the current wetland area we calculate that peatland development on rebounding marine surfaces could have occurred over ~330,000 km^2, representing ~27% of the total Canadian peatland area, alone. Further development of our modern analogues and additional paleo-reconstructions in northern wetlands will help us to constrain the rates of wetland transition during rebound, and feedbacks to past and future climate.

Keywords: Holocene, peatlands, tidal marsh, isostatic rebound, dinoflagellate cysts, Bryidae spores

Palynostratigraphy and palynofacies of Upper Devonian rocks in the Appalachian Basin, U.S.A.

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The uppermost part of the Cleveland Member of the Ohio Shale Formation in the Appalachian Basin near Morehead, Kentucky, includes a large granite dropstone. Well-preserved miospore assemblages from this section indicate a position within the LN Miospore Biozone of latest Famennian age. Further east in the Appalachian Basin, sections at Sideling Hill, Maryland and Crystal Spring, Pennsylvania, include diamictites of definite glaciogenic origin. Carbonized miospore assemblages from these sections are assigned to the late Famennian LE and LN biozones, enabling correlation with the Morehead section.

The Three Lick Bed is an important marker within the Ohio Shale, with its top defining the base of the Cleveland Member. The Three Lick Bed consists of three thin gray shales with intercalated thin black shales. Miospore assemblages have been obtained from this unit at its type section, approximately seven miles west of Morehead. The assemblages lack *Retispora lepidophyta*, but contain numerous specimens of *Vallatisporites hystricosus* and are therefore tentatively assigned to the Famennian VH Miospore Biozone. However, specimens assigned to *Knoxisporites* cf. *K. literatus* and *Verrucosisporites* cf. *V. nitidus* have also been recorded. If present, *K. literatus* and *V. nitidus* would indicate a position within the younger LL or LN biozones.

Organic residues from the black shales are dominated by amorphous organic matter (AOM); the most abundant palynomorphs are *Tasmanites* spp. and *Leiosphaeridia* spp. Organic residues from the pale gray shales contain many more phytoclasts and less AOM. Miospores are the most abundant palynomorphs, with significant numbers of typical Late Devonian acritarchs and prasinophytes, such as *Gorgonisphaeridium absitum* and *G. ohioense*, also present. Palynofacies analysis utilizing the generalized Tyson classification suggests a distal suboxic–anoxic basin depositional environment for the black shales, and an oxic shelf environment for the pale gray shales. The latter interpretation differs from the dysaerobic depositional environment indicated by faunal evidence.

Miospore assemblages from the pale gray shales differ markedly from those from the black shales. The former are diverse in terms of morphology whereas the latter are dominated by small, smooth, simple spores. Changes in salinity could have produced the different levels of organic productivity/preservation and the different relative proportions of acritarchs and prasinophytes observed in the two lithologies, but not the difference in dominant miospore type.

The palynofacies results are consistent with a regressive origin for the pale gray shales that would have resulted in a more proximal setting for the site of deposition, with less transport and sorting of the terrestrial organic matter. Downslope mass transport of fine-grained sediment that had accumulated on the shelf may have resulted in subsequent re-deposition of the organic matter in a dysaerobic basinal environment.

Keywords: Famennian; palynostratigraphy; palynofacies, Three Lick Bed; Appalachian Basin; glaciogenic.

Latest Ordovician-earliest Silurian chitinozoans from northwestern Argentina, Western Gondwana

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The Ordovician-Silurian boundary remains undetermined in northwestern Argentina, at the southern end of the Central Andean Basin on the western Gondwana margin. The Zapla Range exposes Ordovician and Silurian deposits in the eastern part of this basin. Glacial deposits of the Zapla Formation are traditionally assigned to the Hirnantian, and postglacial deposits of the Lipeón Formation are assigned to the early Silurian. Previous palynological studies by the authors in the area constrain the lower part of the Lipeón Formation to the Aeronian-Telychian. A detailed study of chitinozoan assemblages is being carried out in additional outcrops of the uppermost Zapla Formation and lowermost Lipeón Formation in order to constrain the ages of these units, and to contribute to the knowledge of the glacial and post-glacial depositional events.

Massive and stratified matrix-rich diamictites within the Zapla "glacial horizon" have a maximum thickness of 58 m along the type area. Because of the pervasive synsedimentary flow features and ductile deformation it is interpreted as redeposited till, probably along a proglacial slope in subaqueous environments with no indication of wave or storm action. The unit truncates the underlying stratigraphy at different levels across sharp boundaries, implying deep erosion within the substrate. No striated pavements have been observed. Hence, erosion may be related to a major sea-level drop coeval with the waxing stage of the Hirnantian glaciations, whereas most of the unit records the glacial retreat. The flooding surface in the base of the Lipeón Formation initiates the deposition of several basin-wide oolitic ironstones that record high-frequency sea-level fluctuations. These economic deposits are interpreted as related to repeated transgressive-ravinement surfaces that truncate Fe^{+2}-saturated estuaries after the glacial waning stage and glacioisostatic rebound.

Palynological samples, taken from the Zapla Formation outcropping in the Capillas River, come from a thin interval of dark green to black shales (15.3 m below the contact of Zapla-Lipeón formations) present between graded sandy beds above the massive glacially derived diamictite, and also from a highly organic-rich black shale at the very top of the unit. The chitinozoan assemblages mainly contain *Desmochitina minor*, *Spinachitina* cf. *S. oulebsiri*, *Hercochitina* spp, and *Belonechitina* spp. The Lipeón Formation begins with a 1 m thick transgressive conglomerate, which truncates the underlying unit. In this area, 0.3-0.5 m of greenish silty-shales gradationally overlie the basal conglomerate of the Lipeón Formation, containing *Spinachitina fragilis*, *Cyathochitina caputoi*, *Ancyrochitina* cf. *A. nodifera*, and *Belonechitina* cf. *B. postrobusta*. This succession continues with regionally and laterally continuous oolitic ironstone beds (~2.2 m, 1.2 m and 0.3 m) overlain by greenish to yellowish silty-sandy pervasively bioturbated shales. Thin finer- grained partitions between the major two lower beds (2.7 m above the contact) contain *Cy. caputoi*, *Spinachitina maennili*, *Pogonochitina djalmai*, *Ancyrochitina udayanensis*, and *Sphaerochitina silurica*. Silty sandy beds above the ironstone horizons contain *Cy. caputoi*, *P. djalmai* and *A. udayanensis* (5 m above the contact). The rest of the pervasively bioturbated silty-sandy shales (~340 m thick), exposed above and along the Los Matos Creek, contain Telychian-Sheinwoodian chitinozoan assemblages.

These preliminary results from the studied chitinozoan assemblages corroborate a Hirnantian age for the complete Zapla Formation up to its very top, including an interval immediately above the glacially derived diamictites. The chitinozoan assemblages constrain an earliest Silurian age for the base of the Lipeón Formation, hence the unconformity below the ravinement conglomerate may be under chitinozoan biostratigraphic resolution. A Rhuddanian age is interpreted for the shale atop the conglomerate, representing a condensed interval coeval with the flooding surface that occurred after the Hirnantian glacial waning stage. The shale intervals within and immediately above the major ironstone beds are interpreted to be an Aeronian age, though for the rest of the Lipeón Formation

cropping in this region a Telychian-Sheinwoodian age is suggested. This biostratigraphic constrain indicates that the ironstones are also quite condensed, along with the peculiar oolite-rich ironstones that need an extremely low sedimentation rate, which is compatible with maximum flooding surfaces. The age for the Lipeón Formation largely agrees with the acuminatus and atavus Zones recorded from this unit in the region (Rickards et al., 2002), however the detailed sampling herein allows constraining gaps and condensed intervals as represented by postglacial omission, flooding and maximum flooding surfaces.

Integration of high resolution palynological and sedimentary studies contributes to the unraveling of key surface hierarchy and intervening hiatuses in stratigraphy. In peri-Gondwanan regions, ironstones and hot shales characterize the postglacial stratigraphy and overlie Hirnantian glacial intervals. Age constrains within these postglacial intervals allow for enhancing correlations of such important global events and their better understanding.

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Keywords: Chitinozoans; latest Ordovician-earliest Silurian; northwestern Argentina; Western Gondwana.

Palynological record of Devonian and Pennsylvanian units in the Espejos Range, western Santa Cruz de la Sierra, central Bolivia

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As part of a major Carboniferous-Permian project in Bolivia between 2007 and 2009 (undertaken by geologists from different countries and funded by Spain), palynological investigations were carried out to test the Pennsylvanian biostratigraphic scheme (KA, RS, BC, MR and TB zones) in the central portion of the Tarija-Chaco Basin and its aid in stratigraphic discrimination. This contribution presents the palynological results of several sections located in the Espejos range along the La Angostura-Bermejo-Samaipata-Mairana highway, west of Santa Cruz de la Sierra.

The geology of the Espejos range is tectonically complex consisting of faulted anticlines and synclines of Devonian to Permian and Mesozoic and Cenozoic strata. Cenozoic and Mesozoic strata crop out on the east side of the range, whereas the Paleozoic succession appears after La Angostura. Different Devonian, Carboniferous and less frequently Permian rocks (at La Angostura) crop out to the west up to Mairana. The stratigraphic units are generally in faulted contact and structural repetition of units is quite common.

Pennsylvanian units are represented by the Macharetí (McG) and Mandiyutí (MdG) groups which consist of interbedded sandstone and diamictite units with minor shale and mudstone beds. Each

group has traditionally been divided into formations based on the first occurrence of sandstone within mudstone- or diamictite-dominated units. The McG is divided into five formations in Bolivia (oldest to youngest): Tupambí, Itacuamí, Chorro, Tarija and Taiguati. The MdG consists of the Escarpment and San Telmo formations. This lithostratigraphic scheme is well applied in southern Tarija-Chaco Basin where contacts between sandstone-dominated (Tupambi, Chorro) and mudstone-diamictite-dominated (Itacuamí, Tarija/Tupambi) units is clear. However, to the north unit contacts are difficult to establish due to increased interbedding of sandstone and diamictite units, reinforced by tectonic effects. This study focuses largely on the McG because the MdG in this area, mainly exposed in the upper part of the mountains, is dominantly red in color (four samples were barren).

Twenty six samples were taken from the McG at five different locations between Mairana and Bermejo. From west to east, near Mairana one productive sample was taken from a grey muddy diamictite whilst other seven from reddish and greenish grey muddy diamictites were barren. Two productive samples were taken from grey diamictites 24 km from Samaipata toward Bermejo (Point 1). Fourteen kilometers ahead (Point 3), one barren sample taken from light grey very fine-grained sandstone over Devonian rocks (faulted contact) and up-section, two productive samples were collected from grey diamictites. Thirteen kilometers ahead, a thick McG section (Ginger's Paradise, ca. 500 m) was sampled. From this area, eleven grey and greenish-grey mudstone and diamictites were productive whilst two reddish brown mudstones were barren.

The palynoassemblages recovered from McG are composed of biostratigraphically important indigenous species such as *Cristatisporites chacoparanensis*, *Cristatisporites* spp., *Dictyotriletes bireticulatus*, *Granulatisporites varigranifer*, *Verrucosisporites morulatus, V. patelliformis, V. quassigobbettii, Endosporites rhytidosaccus*, *Vallatisporites arcuatus*, *Costatacyclus crenatus*, *Potonieisporites magnus*. Abundant reworked palynomorphs from Devonian (e.g., *Umbellasphaeridium saharicum*, *Maranhites* spp., *Retispora lepidophyta*, *Grandispora pseudoreticulatus*) and Mississippian (e.g., *Pustulatisporites gibberosus*, *Cristatisporites peruvianus*, *Cordylosporites magnidictyus*) rocks are present, as well as from the underlying Bashkirian KA-RS zones in agreement with previous works (e.g., *Schopfipollenites ellipsoides*). The stratigraphic distribution of the indigenous species supports the correlation of all assemblages to the Bashkirian-Moscovian *D. bireticulatus–C. chacoparanensis* (BC) Zone, reinforced by the presence of exclusive forms such as *C. chacoparanensis*, *D. bireticulatus*, *E. rhytidosaccus*, and *V. morulatus*. It corresponds to the Tarija Formation and the base of the Escarpment Formation in northern Argentina and southern Bolivia (Tarija-Chaco Basin). The diamictitic units bearing the BC Zone in the studied area are similar lithologically to the Tarija Formation in southern part of the basin, thus confirming their stratigraphic attribution.

Three productive samples were collected from Los Monos/Iquirí mudstones (Givetian-Frasnian) under a faulted contact with the Carboniferous (Point 2, ten km from previous Point 1), which yielded abundant and diverse well preserved palynomorphs (spores, acritarchs, prasinophytes and chitinozoans). Species such as *Lunulidia micropunctata, Maranhites* spp., *Samarisporites triangulatus*, *Angochitina mourai*, *Lagenochitina avelinoi*, and *Fungochitina pilosa* allowed the attribution of these assemblages to the late Givetian - late Frasnian.

Identification of palynomorphs of the BC Zone in diamictites below the Escarpment Formation in the central Tarija-Chaco Basin supports the previous biostratigraphic scheme for the Macharetí Group developed from deposits in northern Argentina and southern Bolivia. Even though tectonic complexity disrupts the succession, this work demonstrates that the biostratigraphic zones follow lithostratigraphic boundaries across the basin and that the lithologic changes from south to north in the Tarija-Chaco Basin are related to major shifts in paleoclimate during the Pennsylvanian.

Keywords: Palynostratigraphy, Macharetí and Mandiyutí Groups, Pennsylvanian, Tarija-Chaco Basin, central Bolivia.

Palynology of the Devonian-Mississippian transition in western Montana: Three Forks, Sappington and Bakken formations

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Late Devonian-Early Mississippian strata east of the Antler continental borderlands in the incipient Central Montana Trough (CMT) are coeval with the Exshaw of Alberta and Bakken formations of the Williston intracratonic basin. Carbonates and siliciclastics of the Middle Famennian Three Forks Formation and latest Famennian-Tournaisian Sappington Formation are characterized by a facies change and pinch-out associated with high-amplitude eustatic base-level changes and widespread marine disconformities (i.e. 3rd-order sequences or 2nd-order icehouse episodicity occurring over several Ma). Like the Bakken, Sappington facies represent distally-thinning and -fining shoreface though offshore clastic-dominated ramp facies (black shale, burrowed siltstone and sandstone). Whereas South American and eastern North American palynology from the middle Famennian Tournaisian interval (~6 Ma) has been well studied, spore and pollen assemblages from Montana are not known. Black and dark green shales from CMT outcrops show promising initial results and work has been extended to well cores in NW Montana.

Two palynologically productive samples from the Trident Member at Milligan Canyon on the Lombard Thrust and six from Logan Gulch on the Horseshoe Hills in Montana yielded low diverse palynoassemblages, with different preservations (e.g., orange well-preserved, dark brown and black poorly preserved palynomorphs). The Milligan assemblages (MEAs) and the older three samples from Logan (LAs1) are mostly composed of cosmopolitan, long ranging phytoplankton species that are recorded from the Frasnian to the Strunian (e.g., *Cymatiosphaera perimembrana* Staplin*, Elektoriskos dolos* Wicander and Loeblich, *Gorgonisphaeridium ohioense* (Winslow) Wicander, *Gorgonisphaeridium absitum* Wicander, *Gorgonisphaeridium plerispinosum* Wicander, *Maranhites britoi* Stockmans and Willière, *Michrystridium adductum* Wicander, *Solisphaeridium astrum* Wicander, *Stellinium comptum* Wicander and Loeblich, *Unellium piriforme* Rauscher, *Unellium lunatum* (Stockmans and Willière) Eisenack et al.). Some species have a more restricted stratigraphic range (*Ammonidium garrasinoi* Ottone from Givetian to late Frasnian, *Gorgonisphaeridium evexispinosum* Wicander from the Famennian, *Unellium elongatum* Wicander and *Pterospermella latibalteus* Wicander from mid-late Famennian, *Exilisphaeridium simplex* Wicander from ?Strunian, and *Leiotriletes struniensis* Moreau-Benoit from Strunian palynofloras). Hence, these marine assemblages (MEAs and LAs1) are likely pre-Strunian Famennian in age.

Four samples processed from very carbonaceous lower Sappington black shales at Milligan East were barren and one from the very thin, basal brown shale at Logan (LAs2) yielded only leiosphaerids with an internal folding named here “monosacoid” due to its similarity with the *Plicatipollenites* and *Potonieisporites* monosaccate pollen grains.

Two samples processed from USGS Bakken cores from NW Montana (Big Sky 1, lower Bakken at 9926 and 9920 ft), yielded two different assemblages. The older one is composed of a fairly well preserved assemblage with the same species recorded in MEAs and LAs1. Hence, a correlation between

them is here proposed. The other assemblage yielded less diverse acritarchs (*Gorgonisphaeridium ohioense, G. absitum, Hemiruptia legaultii* Ottone) and abundant leiosphaerids of different sizes (ca. 50 up to 400 µm) and morphologies (i.e., without folding, with random folding, with monosacoid folding). Although this assemblage has no biostratigraphical useful species, its stratigraphic position and the presence of leiosphaeirids with monosacoid folding suggest correlation to the LAs2, in a lagoonal depocentre.

From the basal part of the Lodgepole depositional system (upper Sappington shale) at Logan, dark brown shales yielded badly preserved, dark brown to black trilete spores with quite abundant *Botryococcus braunii* Kützing. A Tournaisian age is given to the upper Sappington (LAs3) based on few biostratigraphically useful species such as *Waltzispora polita* (Hoffmeister et al.) Smith and Butterworth, *Leiotriletes sphaerotriangulus* (Loose) Potonié and Kremp, ?*Grandispora echinata* Hacquebard, and *Punctatisporites glaber* (Naumova) Playford.

The ages observed in this study agree with previous conodont work for the Three Forks Formation (Trident Member - middle Famennian *marginifera*/*trachytera* Zones), lower Sappington (*expansa* Zone), and for the upper Sappington black shale (Tournaisian *duplicata*/*sandbergi* Zones). The Strunian *praesulcata* Zone was previously defined in shales of the Unit 4 interbedded within the middle Sappington (reservoir) in the Bridger Range in Montana. A *Retispora lepidophyta* assemblage was found in the same unit. The latter was not observed here, but more detailed studies will be developed.

Evaporitic, shallow through deep marine rocks of the Three Forks and Sappington formations in western Montana represent local intrashelf troughs inboard of active Devonian-Mississippian arches along the Montana-Idaho border. Few of these units nor easily recognizable Sappington facies occur on these uplifted and down-dropped paleohighs that were rapidly buried by active Antler sedimentation. On the other hand, remarkably similar and widespread latest Famennian stacking patterns across the "more stable" part of the Montana craton (and other parts of the world) suggest primary global controls during abrupt late Famennian change in climate/eustasy, arborescence, and transition to a Carboniferous icehouse.

Keywords: Palynology; depositional setting; Bakken Three Forks and Sappington formations; Late Devonian; Early Mississippian; Montana, U.S.A.

Palynology and paleoenvironment of the Cisuralian Vitiacua Formation in southern Bolivia

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The Vitiacua Formation was previously described comprising of three transgressive restricted marine cycles ranging from lower to upper Permain and Triassic age. Similar units were correlated into Peru and associated with widespread volcanism and extension. This study presents new stratigraphic and palynologic data of the Vitiacua Formation from three locations in southern Bolivia: the La Yesera area

(West and Centre) and at Canaletas near Tarija. These outcrops overlie massive sandstones beds of the eolian to estuarine Cangapi Formation and are composed of thin grey and green silty micritic limestone beds that are interbedded with faintly laminated fissile shale with some silt and chert lenses.Overall thicknesses of the three sections are ca. 300 m.

Eight productive samples (of 14 samples processed) yielded 62 species of terrestrial palynomorphs of which 17 are spores (11 trilete and 6 monolete), 42 are pollen grains (11 monosaccate and bisaccate non-striate, and 31 striate and costate), and 3 species of algae. The well preserved Yesera Centre assemblage (YCA, one sample) is defined by the presence of several species of *Vittatina*, *Lunatisporites*, *Pakhapites* and *Lueckisporites virkkiae* (Potonié and Klaus) Klaus together with other species of *Hamiapollenites*, *Mabuitasaccites*, *Striomonosaccites*, *Striatoabieites*, *Striatopodocarpites*, *Weylandites*, and *Botryococcus brauni* Kützing. The well preserved Yesera West assemblage (YWA, three samples) is characterized by abundant to frequent monolete (e.g., *Polypodiisporites mutabilis* Balme, *Reticuloidosporites warchianus* Balme, *Thymospora rugulosa* Mautino et al.) and trilete spores (*Lundbladispora braziliensis* (Pant and Srivastava) Marques Toigo and Pons emend. Marques Toigo and Picarelli*, Convolutispora uruguaiensis* Mautino et al.) with subordinate algae and pollen grains (e.g., *Pteruchipollenites*, *Vitreisporites*). The Canaletas assemblage (CA, four samples) was poorly preserved but contained scarce pollen grains including *Lueckisporites virkkiae*, *Striatoabieites multistriatus* (Balme and Hennelly) Hart, *Pteruchipollenites indarraensis* (Segroves) Foster, and *Botryococcus brauni*. The YCA and CA are correlated to the Lower Member Assemblage (mid Asselian to early Sakmarian) of the Copacabana Formation at Apillapampa in central Bolivia. However, the samples collected at Yesera West are similar to the overlying Copacabana Coal Member (early Sakmarian- Artinskian?).

Diverse pollen grains (striate and non striate) of gymnospermous affinities are dominant in the YCA and CA, whereas notable pteridophytes, sphenophylls and lycopods are dominant in the YWA. These groups of plants characterized the terrestrial landscape of forests under a temperate climate belonging to the *Glossopteris* Flora during the Cisuralian in southern Bolivia. Algae such as *Botryococcus* indicate the development or input from fresh water environments (lakes and rivers). Calcareous muddy rocks, stromatolites, pyritization of palynomorphs in sample CICYTTP-Pl 333 (VI3) at Canaletas and abundant fish teeth suggest shelf marine conditions, although not clear is the extent of hyposaline conditions. Some stratigraphic interpretations suggest extensive deepwater marine environments. However a paucity of marine macrofauna, significant volcaniclastics, rare paleosols and terrestrial palynoassemblages suggest cyclic, restricted mud-prone sedimentation in a back arc or rift setting.

These new stratigraphic data and palynology results from the lower Vitiacua Formation support correlative relationships and facies changes with respect to the upper Coal Member of the Copacabana Formation, in southern and central Bolivia. Radiometric data from interbedded tuffs in both places (Yesera and Canaletas) are under preparation.

Keywords: Palynology; sedimentology; paleoenvironment; Vitiacua Formation; Cisuralian; southern Bolivia.

Palynologic Characteristics of Coal Beds in Northeastern Kentucky

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In the Central Appalachian Basin, Pennsylvanian stratigraphy is largely based on marine zones. Although these marine zone marker beds are widespread, they often are difficult to identify in areas along the basin margins where the section is compressed, and marine zones are difficult to identify. This paper describes the palynology of Pennsylvanian coal beds in northeastern Kentucky, a compressed section area, with emphasis on forms that assist age assignment and correlation.

The stratigraphically oldest coals in northeastern Kentucky include some unnamed beds, the Beattyville, Gray Hawk and Zachariah coal. Most are dominated by *Lycospora* and contain *Laevigatosporites, Schulzospora*, *Endosporites*, *Densosporites irregularis* and *Radiizonates striatus*. Collectively, the assemblages are indicative of a late Early Pennsylvanian (late Langsettian, late Morrowan) age. In stratigraphic sequence, the next younger coals include the Bruin, Little Caney, and Cannel City. These coals are dominated by *Lycospora*, but differ from coals below the Betsie Shale in that they contain higher percentages of tree fern affiliated spores (*Punctatisporites minutus*, *Punctatosporites minutus* and *Apiculatisporites saetiger*) and lack *Schulzospora, Densosporites irregularis* and *Radiizonates striatus*. Palynologically, this interval is early Middle Pennsylvanian (early Duckmantian, early Atokan) in age. The next younger coals include the Whitesburg and Fire Clay, with the Fire Clay marking the introduction of *Triquitrites sculptilis* and *Microreticulatisporites sulcatus*. Palynologically, these coals are mid Middle Pennsylvanian (late Duckmantian, middle Atokan) in age.

The next stratigraphically-younger coals include the Princess No. 3 and 4 coals. These coals contain diverse palynofloras that typically show an abundance, and diversity, of, tree fern taxa. Of note are the first occurrences of *Laevigatosporites globosus*, *Torispora securis*, and *Radiizonates difformis,* and *R. rotatus.* Palynologically, this interval is late Middle Pennsylvanian (early to mid Bolsovian, late Atokan) in age.

The Princess No.5 to 9 coals are the stratigraphically-youngest coals of Middle Pennsylvanian age in northeastern Kentucky, and include the origins of *Murospora kosankei, Triquitrites minutus, Cadiospora magna*, *Mooreisporites inusitatus* and *Schopfites dimorphus*. Forms that terminate this interval include *Radiizonates difformis*, *Densosporites* spp.*, Dictyotriletes bireticulatus, Vestispora magna* and *Savitrisporites nux, Lycospora*, *Granasporites medius, Triquitrites sculptilis Cirratriradites, Vestispora, Thymospora* and *Torispora securis.* Palynologically, this interval is late Middle Pennsylvanian (late Bolsovian to Asturian, late Atokan to Desmoinesian) in age.

The Brush Creek coal marks the beginning of Late Pennsylvanian (Stephanian, Missourian) age palynofloras, which are conspicuously devoid of *Lycospora*. Coals between the Brush Creek coal and the Ames Limestone are all tree fern spore dominant (principally *Punctatisporites minutus*), with subdominant *Laevigatosporites* (larger species that are calamite-affiliated). The Ames Limestone is the stratigraphically youngest marine zone that can be identified in NE Kentucky, and approximately coincides with the Stephanian A/B (Missourian-Virgilian) boundary. Coal beds above the Ames are marked by the introduction of *Thymospora thiessenii*, which becomes very abundant at the Pittsburgh coal horizon.

Miocene dinocysts from the Florida panhandle and ties to standard foraminiferal zones and timescales

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Miocene and Pliocene dinoflagellate cyst assemblages from 40 core samples from the Florida panhandle are paired with planktonic foraminiferal assemblages from the same stratigraphic intervals. The dinocyst samples include material from the Chattahoochee, Chipola, Bruce Creek, Oak Grove, Shoal River, Choctawhatchee, and Intracoastal Formations, and an unnamed Pliocene formation. Recent compilations of foraminiferal zonations and numerical ages allow detailed correlations (Wade et al., 2011; Iaccarino et al., 2012). Miocene dinocyst Zones DN 1-10 were first used in the mid-Atlantic Coastal Plain (de Verteuil and Norris, 1996) and then extended by Köthe (2003) into Germany. Most of these can now be recognized in Florida. Comparisons of occurrences in coastal Georgia (Weems and Edwards, 2001) and the North Sea (Munstermann and Brinkhuis, 2004 and Dybkjær and Piasecki, 2010) reveal geographic similarities and differences.

Two samples from near the Oligocene-Miocene boundary illustrate the difficulties of correlation in Florida and Georgia. The highest occurrences of *Chiropteridinium* spp. and of abundant *Homotryblium* spp. are offset stratigraphically. In North Sea basin sections, the interval between the two highest occurrences has been termed the *Homotryblium* spp. Zone and calibrated to 23.36-?21.6 Ma (Dybkjær and Piasecki, 2010). Although this zone can be recognized in Florida and Georgia, further work is needed to determine whether dinocysts, foraminiferal, and numerical ages are latitudinally consistent.

The precise location of the lower-middle Miocene (Burdigalian-Langhian) boundary has not yet been established by international agreement. In the Florida material, dinocyst assemblages bearing *Labyrithodinium truncatum modicum* alone are succeeded by assemblages with *Labyrinthodinium truncatum modicum* and transitional forms, which are succeeded by assemblages with *Labyrithodinium truncatum modicum* and *Labyrinthodinium truncatum* sensu stricto together. The foraminifera in the same stratigraphic interval show the successive lowest occurrences of *Globigerinoides sicanus*, *Praeorbulina glomerosa*, *Orbulina suturalis*, and *Fohsella peripheroacuta*. Within the upper middle and upper Miocene of western Florida, successions of the highest occurrences of *Cleistosphaeridium placacanthum*, *Sumatradinium soucouyantiae*, *Hystrichosphaeropsis obscura,* and *Erymnodinium delectabile* conform to the succession of these occurrences in the mid-Atlantic Coastal Plain.

Reworked specimens, although rare in these samples, provide important information that may help unravel details related to uplift, subsidence, sediment sources, and paleocurrents. Neither Cretaceous nor Paleogene specimens were observed in the oldest material studied. Eocene reworking was noted in the middle Miocene (middle Shoal River; foraminiferal zone ~M9a). Slightly higher in the section, both Cretaceous and Paleogene material are locally present (upper Shoal River, M10, to the top of the studied section).

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Keywords: Dinoflagellates; foraminifera; Miocene; Pliocene; Florida

The efficiency and nature of organic carbon burial in slope apron turbidite systems

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Burial of organic carbon (OC) in marine sediments is the second largest sink of atmospheric CO_2. However, characterising the efficiency of OC burial in deep water turbidite systems, an important sedimentary system to OC burial, remains incomplete. It was originally thought that much of the organic matter was oxidised on the shelf, but more recent work on the Bengal Fan concluded that burial in deeper water turbidite sequences was very efficient. The Moroccan Turbidite System (MTS), situated offshore Morocco, is a modern deep water slope apron turbidite system that is characterised by complex seafloor topography. The sedimentation of the MTS is characterised by an interfingering between several large volume 'megaturbidites', sourced from either the Moroccan Shelf (organic-rich), Canary Islands, or surrounding seamounts, and thin hemipelagites characteristic of deep water basins. It has been shown that a single turbidity current may deposit up to 200 km^3 of sediment through the 1500 km run-out of the MTS. However, volumetric constraints on the amount of organic carbon (OC) buried or oxidised (to produce CO_2) have yet to be calculated.

Here, the burial efficiency of a single organic-rich 'megaturbidite' is calculated for the Agadir Basin, an intraslope basin in the MTS. The burial efficiency is calculated based on basin-wide deposit isopachs, generated from core-photographs and core logs, and Total Organic Carbon (TOC) analyses at two central core sites. Furthermore, palynological analyses have been utilised in order to constrain the composition of particulate OC transported and buried by the turbidity current. These analyses provide an insight into vertical and likely downstream fractionation in types of OC in a turbidite, and the consequences for labile OC exposed to diffusive contact with bottom waters. Burial efficiency is subsequently estimated at 0.76 (where 0 equates to complete oxidation of OC and 1 equates to complete preservation and sequestration of OC). Three primary controls on burial efficiency are identified; the composition of OC that enters the slope apron system, basin morphology, and the

recurrence interval for turbidites. Oxidative loss of ~24% OC to produce 0.18 Pg CO_2 indicates that slope apron systems are surprisingly inefficient mechanisms for organic carbon burial, in contrast to presumed much more efficient submarine fan systems. Such contrast between deep water turbidite depositional systems may have implications for major burial terms in carbon cycle modelling.

Keywords: carbon burial, turbidites, palynofacies, Holocene/Recent, Moroccan Turbidite System

Palynology of the Kingscourt Outlier (Ireland)

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The Kingscourt Outlier occupies a roughly triangular area on the southern part of the Lower Palaeozoic Longford–Down Massif in eastern Ireland. It comprises a condensed succession of sedimentary rocks that record the onset of fluvio-deltaic sedimentation across eastern Ireland during Late Viséan to Late Bashkirian (Jackson, 1955, 1965). The outlier forms a syncline structure with an axis orientated approximately north-south and parallel with the normal Kingscourt Fault that downthrows beds of Carboniferous and Permo-Triassic age against the Lower Palaeozoic rocks. Variscan deformation and subsequent erosion affected the area, since the base of the oldest Permian rocks rest unconformably on various Carboniferous units. Post-Variscan subaerial exposure was responsible by partial oxidation and reddening to various depths of the upper Bashkirian beds.

Four outcrops of the Kingscourt Carboniferous succession were studied for biostratigraphical palynology. The first outcrop is located along the Ardagh Glen and exposes the Ardagh Shale. From the samples studied only one, Ard 8, located in the middle part of the approximately 70 m thick succession, yielded miospores. The occurrence of the key species *Verrucosisporites morulatus* is indicative of the upper part of the NC biozone (Owens *et al.* 2004) and assigns the Ardagh Shale to the late Pendleian, which is consistent with the age of the goniatite *E. pseudobilingue* recorded by Jackson (1955, 1965).

The second outcrop corresponds to the Carrickleck Shale and was investigated in the disused Carrickleck Quarry. The samples studied were located in the basal part of the Carrickleck Shale; CQ 1 immediately above the sandstones, and CQ 5 about 1.3 m above the sandstones. The samples yielded a relatively abundant miospore assemblage dominated numerically by the genera *Densosporites* and *Lycospora*. Only five different species where found occurring in both samples studied. The miospore taxa recorded from the Carrickleck Quarry indicate a possible transitional age between the TK and SO biozones. The occurrence of the species *Kraeuselisporites ornatus* is indicative of the SO biozone as appears at its base (Owens *et al.,* 1977). The miospores *Knoxisporites dissidius* and *Ibrahimispores brevispinosus* also suggest a SO biozone age. However, *Tripartites vetustus*, disappears at the top of the TK biozone (Owens *et al.,* 1977). The miospore can be interpreted either as suggesting a position for the samples at the TK/SO boundary, or, that the specimens of *T. vetustus* are reworked. The age for the basal part of the Carrickleck Shales as suggested by miospore taxa is younger than the age assigned to Jackson (1955, 1965) based on goniatites. Jackson (1955, 1965) recorded *E. bisulcatum* (E2a) and *C. nitidus* (E2b) indicating a lower to middle Arnsbergian age, respectively. Whereas the miospore taxa suggest an age of late Arnsbergian to early Chokierian.

Seven samples from the Clontrain section were studied. The samples yielded a diverse miospore assemblage with 48 different species recorded. Although diverse, this assemblage is dominated by a restricted number of miospore genera; *Densosporites*, *Lycospora* and *Crassispora kosankei*. Samples Clt. 4 and Clt. 6 are from the *Reticuloceras reticulatum* (R1c) Marine Band (Jackson, 1955, 1965). Perhaps the most reliable indication of the age of the Clontrain section is the great number of *Crassispora kosankei*, which was recorded from all the samples from this section. This miospore species occurs from the biozone NC onwards but in low numbers until the base of the KV biozone. Other species that strongly suggests the KV biozone is the presence of *Kraeuselisporites echinatus.* The appearance of the species *Cristatisporites indignabundus* indicates the lowermost part of the FR biozone (Owens *et al*., 1977) suggesting that the age of Clontrain section lies at the KV/FR boundary. The occurrence of *Tripartites vetustus* and *Tripartites trilinguis* can be interpreted as recycled species since both species are thought to disappear at the top of the TK biozone. The age of the Clontrain section given by the miospore assemblage is consistent with to the upper Kinderscoutian age based on the goniatite faunas (Jackson, 1955, 1965) but could indicate a slightly younger (Marsdenian) age.
A single sample studied from the Kilmainham Wood section yielded a miospore assemblage similar to the Clontrain section, although the number of taxa recorded was lower. The Kilmainham Wood section can be therefore assigned to the KV biozone which corresponds to the Kinderscoutian to upper Marsdenian. However, since *Reticuloceras reticulatum* (R1c) was previously recorded from shales in this locality (Jackson, 1955, 1965), an upper Kinderscoutian age is the most likely.

Keywords: Namurian, Palynology, Kingscourt Outlier, Ireland

Provenance of the reworked Ordovician Palynomorphs in SDJ1 Borehole - Santa Susana Basin, Ossa Morena Zone, Portugal

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The detail palynological study of the exploration borehole SDJ1 located in the Santa Susana / Moinho da Ordem disused coal mine area (1927-1944), western border of the Ossa Morena Zone (OMZ) in Portugal, is presented here.

The borehole intersects lithologies of the Toca da Moura Complex (TMC) and the Santa Susana Formation (SSF), dated as mid late Viséan and Moscovian (Carboniferous), respectively, based on palynomorphs (Cunha in Andrade et al., 1991; Pereira et al., 2006; Machado, 2010; Pereira et al., 2011) and macroflora (Wagner & Sousa, 1983).

Together with the miospore associations recovered, assemblages of exceptional well- preserved Lower Palaeozoic acritarchs, cryptospores and spores were identified, which are interpreted as

reworked. From these, the major percentage is Ordovician acritarchs. The ages of the reworked palynomorphs suggest that considerable erosion of exposed

Lower Palaeozoic OMZ basement occurred during early Carboniferous times. The exposure of these rocks may have occurred by the first phases of the Variscan Orogeny in the OMZ.

In this work the acritarch assemblages recovered from the SDJ1 borehole are compared with the acritarch assemblage identified from the *Phyllodocites Shales* Formation (Cunha & Vanguestaine, 1988; Pereira et al, 2011) in Barrancos region. Due to the resemblance in the acritarchs assemblages of both places we suggest that the Early Ordovician *Phyllodocites Shales* and correlatives were one of the main sources of the reworked acritarchs (Piçarra et al., 2011).

Keywords: Ordovician; palynomorphs; Santa Susana Basin; Portugal.

'Palynomorph Darkness Index' – a new method for determining thermal maturity

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Palynomorph Darkness Index (PDI) is a new thermal maturity indicator. It is calculated from measurement of the red, green and blue (RGB) intensities of light transmitted through palynomorphs, using standard palynological microscopes and digital cameras. Laboratory heated Tasmanites show a progressive increase in PDI with increasing temperature suggesting that the technique is applicable through a broad temperature range, encompassing the whole of the oil window and at least part of the zone of dry gas generation. Potential applications of this inexpensive method include the estimation of thermal maturity of sections deficient in vitrinite, such as pre-Devonian strata and many marine black shales. PDIs determined by different microscope and camera combinations show excellent correlation, suggesting that the method is largely platform-independent. Calibration is achieved using photographic filters as standards.

Keywords: Palynomorph Darkness Index; maturity; Tasmanites; transmitted light; RGB.

PDI of Mississippian palynomorphs heated by an igneous intrusive

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The range of palynomorph colours within a sample is dependent on the diversity of taxa in terms of their wall thickness, ornamentation, and folding and, most significantly, the degree of thermal maturation they have experienced. The Palynomorph Darkness Index (PDI) method has been developed to allow accurate, rapid and low-cost quantification of this maturation-related colour change.

Observing a range of thermally induced changes in palynomorph colour from a single thin siltstone bed is possible where it has been heated by an igneous intrusion. The North Star Dyke, Ballycastle, Co. Antrim is a composite 4 m thick olivine dolerite intrusion of Tertiary age (c. 61 Ma). It intruded shallow marine / fluviodeltaic strata which can be confidently assigned to the *Bellispores nitidus – Reticulatisporites carnosus* (NC) Miospore Biozone that spans the boundary between the Brigantian and Pendleian Western European regional stages within the late Mississippian.

The siltstones within the c. 2 m wide aureole were rapidly heated during intrusion, producing a range of kerogen colours from yellow to black with decreasing distance to the dyke. PDI determinations from 11 samples for two common taxa, *Lycospora pusilla* and *Densosporites intermedius* show excellent correlation with vitrinite reflectance measurements from the same samples. PDI profiles are presented based on different parts of these miospore taxa (body, zona, cingulum).

Keywords: PDI, thermal maturation, colour change, igneous intrusion.

Combining standard palynology techniques with δ13C analysis of palynomorphs to understand shifts in relative humidity in the Late Eocene, Antarctica

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Antarctica was mostly ice-free with vegetation and mean temperatures above freezing prior to the Eocene-Oligocene (E-O) Boundary, ~34 Mya (Barrett, 1996). Previously published palynological research implies a significant changes in vegetation and climate at the E-O Boundary (e.g. Anderson et al., 2011). These investigations of Antarctic SHALDRIL Core 3C indicate that decreases in palynomorph abundance and diversity occurred at this boundary, with dinoflagellate assemblage showing colder sea surface temperatures compared to other Eocene Antarctic assemblages (Warny and Askin, 2011).

The driving mechanism behind these changes in Antarctica's climate at the E-O Boundary is a highly contested topic, with much debate centered on rising CO2 levels (e.g. DeConto and Pollard, 2003) versus Antarctica's tectonic isolation and the development of the Antarctic Circumpolar Current (e.g. Kennett, 1977), and still further dispute over the timing of the opening of Antarctica's gateways. Determining the ultimate cause of Antarctica's shift from greenhouse to icehouse has become one of the great enigmas of climate research. Better apprehension of this conundrum involves fully understanding changes in climate such as precipitation. Previous studies in have used plant leaf margins (e.g. Francis et al., 2008) or ratios of smectite to illite or kaolinite to illite concentrations respectively (e.g. Christian and Kennett, 1997) to gauge changes in Antarctic precipitation. However, these analyses are limited due to difficulty in obtaining fossil leaves and reworking of minerals.

It therefore becomes a necessity to develop new methods and proxies for Antarctic climate research. We use a new technique, which employs a moving-wire device interfaced with an isotope-ratio mass spectrometer (e.g. Sessions et al., 2005; Nelson et al., 2008) to analyze stable carbon isotopes (δ13C) of small amounts of palynomorphs known to be present in Antarctic Eocene SHALDRIL cores (e.g. Anderson et al., 2011). We extract individual grains of Nothofagus palynomorphs from SHALDRIL residue and analyze small amounts (50-70 grains at a time) for their δ13C values. Plant δ13C values are

indicative of a plant's water-use efficiency, which is related to the amount of water available in an environment (e.g. Read and Farquhar, 1989).

Our pollen Δ13C values exhibit an overall decreasing trend upcore in the SHALDRIL 3C Eocene cores, indicating that relative humidity was declining during this interval that spans a short period of time around ~35.9 Mya (Bohaty et al., 2011). Comparison with palynology published on the same core (Warny and Anderson, 2011) shows close correlation between Nothofagus palynomorph abundance and Δ13C values through the first half of the core, indicating that changes in abundance are likely due to a decrease in precipitation. We consider explanations behind changes in relative humidity and the effects of hydrology changes on vegetation.

Keywords: Nothofagus, Antarctica, Eocene, relative humidity, precipitation, δ13C values

When Palynology Does Not Benefit from Radiocarbon Dating: Evidences from south-central Missouri and Western Australia

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Carbon-14 (^{14}C) dating should ideally provide results with a high precision and accuracy, allowing reliable dates from recent times to ~50,000 years BP. This works best when dating only biological fragments, such as twigs, leaves, and shells. In the absence of plant and animal remains, bulk sediments can be dated for their ^{14}C content. However, several factors can result in anomalous radiocarbon dates whereby the dates obtained for shallower sediments are older than those of deeper units. Reworked material can be tens to thousands of years older than the organic matter that originates in a horizon. In addition, aquatic organisms originating in regions with carbonate bedrock can be affected by the old carbon effect that results in diluted carbon ratios. The effects of reworking and old carbon effect have been detected in drill cores from man-made freshwater lakes in south-central Missouri and ephemeral hypersaline lakes in Western Australia. Radiocarbon dates obtained in the Missouri drill cores indicate older ages for some horizons close to the top and younger ages at the bottom. Since historical records about the actual age of lake construction are known, these radiocarbon dates are thousands of years older than the lakes. In Western Australia a similar anomaly is also observed for some radiocarbon dates, and palynological data strongly suggests that reworking has played a large role in the sedimentation history of the lakes.

Keywords: reworking, palynology, radiocarbon, Western Australia, south-central Missouri

Palynology of some Late Givetian and Frasnian shale sequences in the Appalachian Basin of western New York State, USA

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Palynological assemblages are described from the latest Givetian and Frasnian of the north Appalachian Basin of western New York State. The succession studied comprises the Genesee, Sonyea and West Fall Groups. Each group is composed of thick sequence of marine mudrocks that typically have a black shale unit at the base that represents a major deepening event in the basin. Five outcrop sections have been studied and these provide an almost complete composite stratigraphic section through the latest Givetian and Frasnian interval. The mudrock samples investigated are rich in particulate organic matter, however the palynomorphs are only poorly to moderately preserved. The palynological assemblages recorded throughout the succession are dominated by process-bearing acritarchs and sphaeromorphic acritarchs, with the latter being particularly abundant in the black shale units. Three successive acritarch assemblages are identified, these are *Hapsidopalla chela - Cymatioshaera peiffferi* Assemblage, the *Unellium – Maranhites* Assemblage and the *Evittia geometrica - Veryhachium ceratoides* Assemblage. Miospores are relatively sparse in the palynological assemblages, nevertheless, a surprising number of stratigraphically important Frasnian taxa have been recorded, these include: *Verrucosisporites bulliferus, Hystricosporites multifurcatus, Rugospora bricei, Auroraspora hyalina, Teichertospora torquata,* and *Grandispora gracilis.* The successive appearances of these taxa in the succession allow tentative correlations to be made with the established Euramerican Upper Devonian miospore zonation schemes. In addition, palynological correlations are proposed with the conodont biostratigraphy that has been established for the marine mudrock succession of the study area.

Key words: palynology; acritarchs; miospores; Givetian; Frasnian; Appalachian Basin.

Within-basin variation in modern pollen assemblages in two neotropical lakes

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Within-basin patterns of pollen deposition have been studied in temperate North America, Europe, New Zealand, and tropical Australia, but detailed studies are lacking in the neotropics. A common finding in studies outside of the neotropical region is that pollen percentages do not change dramatically from point to point within a lake, a situation attributed to sediment redistribution. However, selected pollen percentages, or ratios between types, have been found at some sites to change systematically with changes in depth or distance from shore. Here we examine modern pollen assemblages in dredge samples collected along transects across two lakes located 2 km apart on the central Caribbean slope of Costa Rica, to support interpretations of pollen in lake-sediment cores. Laguna Hule, in which we studied pollen along one transect, is a large (55 ha) lake occupying a volcanic explosion crater. Laguna María Aguilar is a small (2.7 ha) lake dammed by lava or lahar flows; in this lake we studied surface pollen along two perpendicular transects. In both lakes, surface pollen concentrations are generally higher at greater water depths, but percentages for the most common pollen types are fairly uniform, with a few exceptions. Laguna María Aguilar showed slightly higher

variability in surface pollen percentages, perhaps due to the much smaller size of the lake and to variation in vegetation within the watershed. However, considerable mixing of pollen also occurs in this lake. Bulk stable carbon isotope signatures in the dredge samples from Laguna María Aguilar support the interpretation that the sediments of the lake are well mixed.

Keywords: modern pollen, lakes, Costa Rica, surface sediments, stable carbon isotopes

Palynology of a middle Eocene Lignite, Tennessee

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The palynology of a low-rank, clay-rich lignite from Weakly Co., TN, is being examined and compared to similar deposits in the region. It is thought that this lignite is part of the Clabornian-stage lignite outcrop belt in the upper Mississippi Embayment. Samples were processed using the O'Keefe technique (O'Keefe and Eble, 2012), which is designed to optimize recovery from clay-rich lignite samples with a minimum of hazardous chemicals. Overall, the deposit is palynologically similar to known Claibornian-stage lignites in the region, although it contains a more restricted flora. Notably, the spectrum recovered is different from assemblages recovered from clay pits in Tennessee. This is likely due to differences in processing and also the more restricted flora present in peat-producing wetlands. Preliminary results indicate that the deposit is dominated by *Cupuliferoidaepollenites* sp. assemblage, with other tree pollen, especially *Carya* sp. and *Quercoiidites* sp. being common. Ferns are also present, as is an assemblage of fungal material, primarily hyphae.

Reference

O'Keefe, J.M.K. and Eble, C.F., 2012. A comparison of HF-based and non-HF-based palynology processing techniques in clay-rich lignites from the Claiborne Group, upper Mississippi Embayment, United States. Palynology 36, 116-130.

Keywords: Claiborne Group; Lignite; Eocene; Cenozoic; Terrestrial

Palynofacies analysis of the Triassic -Jurassic boundary strata in the GSSP Kuhjoch Section, Northern Calcareous Alps, Austria.

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In the Kuhjoch section a major lithological change is observed near the Triassic-Jurassic boundary, from the carbonate shelf succession of the Rhätian to shales and marlstones above continuing into the lower Jurassic. A detailed palynofacies study was carried out from the uppermost Rhätian to the basal Hettangian, covering the section from the uppermost limestones throughout the shale interval into the overlying marlstones. Corresponding to the lithological change from limestones to shales and marlstones palynofacies analysis shows a significant change in the kerogen too. Major differences are observed in total amounts of dinocysts and foram linings, indicators of fully marine conditions, and the amount of phytoclasts, especially strongly degraded phytoclasts. Limestones show maximum numbers of marine palynomorphs and a lack of degraded phytoclasts. In contrast shales and marlstones above show high numbers of phytoclasts, mainly an increase of degraded phytoclasts, and almost no dinocysts and foram linings. Minor changes are observed in the shales and marlstones regarding the amount of AOM, sporomorphs and phytoclasts, again mainly degraded phytoclasts. Based on terrestrial : marine proxies and other transgression - regression indicators a major change from marine to terrestrial dominated conditions is recorded from the top of the limestones into the shale interval. From the upper shale interval to the overlying marlstones kerogen is mainly terrestrial, changing slightly but continuously back to more marine conditions. Palaeoenvironmental analysis shows a trend from distal shelf conditions in the limestones to more proximal shelf conditions in the shale interval and back to more distal shelf conditions in the marlstones. In terms of sequence stratigraphy the limestones represent the highstand system tract and the overlying shale to marlstones the following lowstand system tract. The sequence boundary is placed at the boundary between the limestones and the shales. The Kuhjoch area generally represents a marginal marine basin, changing from a shallow marine shelf system to mainly brackish depositional settings close to a swampy delta plain. Palynofacies analysis of the section indicates humid climatic conditions in a strongly proximal setting, where sea-level variations lead to slightly distal trends in a generally strongly proximal environments.

Keywords: palynofacies analysis, Triassic, Jurassic, sequence stratigraphy, palaeoenvironmental analysis

Black shale deposition on a carbonate platform (Aran Islands, Ireland) - palynology, geochemistry and sequence stratigraphic interpretation

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The Aran islands are made of Lower Carboniferous limestones of typical carbonate platform facies. Several hundred meters of platform limestones represent a very stable palaeoenvironment, covering several million years (Upper Visean). Within this thick limestone succession a thin black shale interval was observed. This gives evidence of a significant palaeoenvironmental change from an oxygenated, highly bioproductiv to an euxinic, low biopdroductive platform environment. The limited thickness (0,2 - 1,6 m) and sharp lithological boundaries of this shale interlayer suggest a short-lived and rapid change of the depositional system on this platform.

Two different lithostratigraphic units can be distinguished within this interval. The black shales in the upper part of this interval are rich in pyrite aggregates, often several cm in size, and rich in C_{org}. It shows a continuous thickness of 0,2 - 0,3m along the whole length of the accessible section. The lower

part of the shale interval consists of medium grey mudstones still rich in pyrite nodules, getting darker in the upper part. Its thickness shows strong lateral variation with >1m in some places and pinching out in other places. These lithological differences suggest a significant change of palaeoenvironmental conditions even within the shale deposition. For a better understanding of the palaeoenvironmental changes and the factors controlling shale deposition on this platform, a detailed palynological and geochemical study was undertaken, including palynofacies analysis, TOC and CNS analysis, clay mineralogy, just as C-isotopes.

Based on miospores in the uppermost part the shale interval is precisely dated for regional just as long distance correlations along the Lower Carboniferous carbonate shelf south of Laurussia. Palynofacies of the shales shows a change from restricted marine conditions almost without any terrestrial input at the bottom to shallow marine conditions with high terrestrial input at the top. The lower part of the shale interval represents deposition within locally restricted deeps (residual water ponds) on the platform, isolated from both terrestrial and normal marine input. Towards the top increasing marginal marine influence is observed. The black shale at the top represents widespread deposition on the platform with substantial terrestrial input. TOC is very low in the lower part of the shales, increasing strongly in the black shales at the top due to the input of terrestrial organic matter on the platform.

Shale deposition and composition is mainly controlled by sea-level. A significant sea-level fall at the base, representing the sequence boundary (SB), led to isolated ponds of sea-water on the platform, cut off from any terrestrial input during the early lowstand system tract (LST). Shale deposition during the LST shows 4 phases, representing the different stages of early sea-level rise and connection to the hinterland. The black shales at the top of the interval are interpreted as transgressive surface (TS), overlain by the thick succession of carbonate platform deposits of the transgressive system tract (TST). Organofacies analysis of the kerogen composition throughout this sequence gives a high-resolution data set on development of hydrocarbon potential within this sequence. This gives a good example for transgressive shale systems on carbonate shelfs, often linked to hydrocarbon systems throughout earth history.

Keywords: black shales, palynology, geochemistry, sequence stratigraphy, hydrocarbon potential

Iroquois & Euro-Canadian impact on Crawford Lake

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Crawford Lake is a unique body of water located near the edge of the Niagara Escarpment in a park run by Conservation Halton that includes an Iroquoian village learning center. The lake occupies a small (2.4 ha, ~250 x 150 m) but deep (z_{max} 22.5 m) dolostone bedrock basin that is thought to have been excavated by hydraulic mining during the last deglaciation. Due to its dimensions, the lake is meromictic (does not fully turnover), resulting in anoxic bottom waters in the deepest part of the basin. This, in turn, allowed undisturbed annual laminae (varves) that have an exceptional fossil record to accumulate over much of the last millennium. Not only are cysts of dinoflagellates abundant in the sediments, but thecae of the freshwater dinoflagellate *Parvodinium inconspicuum* (Lemmerman) Carty were preserved in varved sediments from 67 cm and from 25 through 22 cm - one of a handful of

reports of dinoflagellate thecae in the fossil record. The presence of these thecae allowed the affinity of abundant tiny (~16-20 µm in diameter), smooth, spherical to slightly ovoid cysts with golden-brown plastids in the same palynological preparations to be determined. Cell contents are visible in cysts through most of the core, and cysts remained viable for over a century (~A.D. 1845-1860). Spongy-walled hypnozygotes of *P. inconspicuum* were observed undergoing meiosis, and their similarity to the tiny resting cysts found in the sediments reaffirms the inferred theca-cyst affinity. Larger (~38-45 µm by ~42-50 µm) cavate and proximate cysts lacking ornamentation or shoulders were also observed encysting when samples were inadvertently cultured in test tubes while processing. Resulting empty thecae resemble *Peridinium willei* Huitfeld-Kaas, but they are smaller than thecae of *P. willei* previously documented in lakes in this region, are ovoid and slightly dorso-ventrally flattened, and have a considerably smaller 5-sided 1'-plate, allowing us to identify them as *Peridinium volzii* Lemmerman. Their cysts are impossible to distinguish from cysts of *P. willei* whose affinities were previously established based on culturing and DNA studies, except by size (~48 - 58 µm by ~49 – 52 µm) and slightly invaginated in the sulcal area forming two distinct shoulders. Cysts assigned to *Peridinium wisconsinense* Eddy were also found in low abundances, particularly in the lower portion of the 72 cm frigid fingernail core.

Abundant cysts and thecae are exceptionally preserved in varves containing abundant non-arboreal (herb) pollen recording human activity (land clearing and agriculture) in the Crawford Lake catchment. Both Iroquois farming (~A.D. 1286-1486) and Euro-Canadian forestry and agriculture (since ~A.D. 1841) introduced large amounts of nutrients into the lake, increasing primary productivity and further depleting the bottom waters of oxygen. As suggested by the diatom and rotifer records, Crawford Lake did not return to its pre-disturbance status following Iroquois farming. Surprisingly, the peak dinoflagellate cyst abundance is in sediments deposited from 64 cm to 59 cm (~A.D. 1290-1330), so more intense eutrophication appears to have been associated with Iroquois farming than with Euro-Canadian disturbance over the last 150 years.

Keywords: Crawford Lake, dinocyst, dinoflagellate, *Parvodinium inconspicuum*, *Peridinium volzii, Peridinium willei, Peridinium wisconsinense*

Paleoclimate and Paleoecology in the southern Appalachians during the late Neogene

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A recently discovered Neogene site from Gray of northeast Tennessee (aka Gray Fossil Site [GFS], 36.5^{o}N, 82.5^{o}W) has yielded rarely preserved floral and vertebrate remains, demonstrating a unique combination of North American and Eurasian biota in a forest-woodland refugium. The site is biostratigrahically dated between 7 and 4.5 Ma, i.e. the Hemphillian Land Mammal Age (the latest Miocene to earliest Pliocene), based on the presence of the rhino *Teleoceras* and short faced bear *Plionarctos.* This is the only fossil site of this age in the southern Appalachians and also represents a rare Neogene site in the eastern half of North America. It has yielded a diverse array of fossils, which can provide an unusual window to get an insight into the conditions of paleoclimate and paleoecology in

southeast United States during the late Neogene, a critical transition period of dramatic climate and vegetation changes.

The GFS deposit extends laterally approximate 2.6 ha and consists of about 40 m of dark colored sediment of lacustrine origin. The 4 m-thick fossiliferous laminated facies preserves excellent record of plant fossils, represented by wood, seeds, leaves, and pollen grains. Forty-eight palynological samples from seven different test-pits were analyzed. All pits exhibit a low pollen yield, a result of basic pH levels, drought, and fire events that occurred during the deposition. The palynofloral assemblage has a low to moderate diversity and is largely dominated by a *Quercus–Carya–Pinus* assemblage (~ 90% of the palynoflora). In addition, about 19 morpho-species of freshwater organic-walled algal micro-remains were also identified. The diverse assemblage of fossil algae provides insights into the paleoenvironment condition of the paleosinkholes at the GFS. Most identified algae prefer meso- to eutrophic conditions, and are characteristic of stagnant or slowly flowing shallow fresh water; and therefore the lacustrine fossiliferous sediments at the GFS represent pond deposits, consistent with the presence of aquatic vertebrate fossils.

Floristically, we have recognized at least 40 genera, representing more than 25 families of seed plants. Based on the nearest living counterpart comparisons, these fossils can be identified with certainty to a specific modern genus. Therefore, the Coexistence Approach, a well-established quantitative paleoclimate reconstruction method, was used to reconstruct the paleoclimate condition. Seven climatic parameters are calculated as follows:

	Temperature (^{o}C)			Precipitation (mm)			
Comparison	Mean annual	Cold Month	Warm Month	Mean annual	Wettest Month	Driest Month	Warmest Month
Paleoclimate at Gray	14-16	3-7	24-27	979-1520	148-225	9-24	120-149
Current climate at Gray	13.1	-4.1-1.1	23.6	1033.8	109.2	81.3	109.2

The comparison clearly indicates that the Gray region in the southern Appalachians was under a climate quite different from the modern; especially its winter in the late Neogene was much warmer (above freezing), which could explain the occurrence of alligators and beaded lizards in the fossil record. Furthermore, the much drier month at Gray in the past might trigger intensive forest fires, which contribute the common occurrence of charcoals all over the fossiliferous layers. In general, the paleoclimate at Gray appears less seasonal in the late Neogene.

Keywords: Paleoenviornment, paleoclimate, Paleoecology, pollen, Neogene, Tennessee, North America

Dinoflagellate cysts from the latest Miocene–Early Pleistocene of the Caribbean Sea, ODP Site 1000: paleoceanography, climate, and shoaling of the Central American Seaway: preliminary results

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The gradual shoaling and closure of the Central American Seaway during the latest Miocene through Early Pleistocene has been linked to dramatic changes in North Atlantic paleoceanography and Northern Hemisphere climate change, and has left a profound signature at Ocean Drilling Program Site 1000, Caribbean Sea. This site was drilled in 916 m of water in the Pedro Channel, 265 km southwest of Jamaica, and comprises periplatform sediments and sedimentary rocks, interbedded with volcanic ash layers. There are also intervals of redeposited periplatform/pelagic and neritic carbonate sediments from the slopes and tops of adjacent shallow carbonate banks. It has a detailed marine isotope stratigraphy from the Upper Miocene through Upper Pliocene. Palynological analyses based on an initial set of samples have revealed an abundant, well-preserved, and moderately diverse record of dinoflagellate cysts and other palynomorphs, and show strong promise for paleoenvironmental reconstructions as well as the development of an astronomically-calibrated low-latitude dinoflagellate cyst biostratigraphy for the upper Cenozoic.

Abundant *Polysphaeridium zoharyi* indicates a restricted marine environment, and its association with pollen of mangrove communities (e.g. *Avicennia* spp. and *Pandanus* spp.) reflects proximity to shorelines. Gonyaulacacean dinoflagellate cysts include *Amiculosphaera umbraculum*, *Batiacasphaera* cf. *hirsuta*, *Dapsilidinium pseudocolligerum*, *Edwardsiella sexispinosa*, *Hystrichokolpoma rigaudiae*, *Impagidinium aculeatum*, *I. paradoxum, I. plicatum, I. strialatum, Lingulodinium machaerophorum*, *Nematosphaeropsis labyrinthus*, *Nematosphaeropsis rigida*, *Operculodinium bahamense*, *O. centrocarpum/israelianum*, *O. janduchenei*, *O. longispinigerum*, *Spiniferites* spp. including *S. bentorii*, *S. mirabilis, S. ramosus*, and *S. rhizophorus,* and *Tuberculodinium vancampoae*; and reflect the fluctuating interplay between oceanic and neritic influences at this site. Protoperidiniaceans include *Brigantidinium* spp., *Lejeunecysta* spp., *Selenopemphix quanta*, and *S. nephroides*, and were found with variable preservation attributed to taphonomic factors including bottom current activities. The acritarchs *Cyclopsiella elliptica/ granosa*, *Nannobarbophora walldalei*, and *Paralecaniella indentata* were also reported along with terrestrial palynomorphs, represented primarily by angiosperm pollen and bryophyte spores. Foraminiferal Mg/Ca paleotemperatures already available from the same sample intervals as used in this study are being used with palynomorph assemblage compositions to reconstruct the paleoceanographic evolution of this site.

Key words: dinoflagellate cysts; paleoceanography; Miocene–Pliocene; Caribbean Sea.

Palynological insights into continental margin architecture

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Because the age, provenance and depositional history of acid-resistant organic sedimentary particles can be much more comprehensively determined than that of the siliciclastic particles with

which they are deposited, palynology have proven useful in sequence stratigraphic studies.The palynological signature of sediments is the product of the initial environmental conditions at the depositional setting, together with taphonomic skewing of that record due to differential transport and preservation, all of which can be related to sea level change along a continental margin. The New Jersey margin is ideally suited to study the response of continental margin architecture to Cenozoic sea level fluctuations and IODP EXP 313 filled the critical gap in the NJ/MAT between the New Jersey coastal plain (ODP Legs 150X and 174AX) and the continental slope (Ocean Drilling Program [ODP] Legs 150 and 174A). Excellent recovery of seven lithological units and fourteen unconformity-bounded fossiliferous sequences of Miocene age allowed us to refine the ages of seismic reflectors, improving the accuracy of comparisons with eustasy inferred from the global ^{18}O record.

The dinocyst zonation of de Verteuil and Norris (1996) was used together with more recent zonations developed in the North Sea (particularly Dybkjaer and Piasecki, 2010) to correlate unconformity-bounded sequences between IODP EXP 313 Holes M0029A and M0027A on the New Jersey shallow shelf and with sequences outcropping on the Atlantic Coastal Plain in New Jersey. The unconformities themselves have a distinct palynological character, with relatively sparse samples dominated by non-saccate pollen and phytoclasts (high T:M), and winnowing and low sedimentation rates are evident in the dominance of degradation-resistant gonyaulacoid cysts (high G:P). High terrigenous flux records rapid progradation of the shelf during the Miocene, particularly from the late Burdigalian through Serravallian, and strong peaks in terrestrial vs. marine palynomorphs in phytoclast-dominated samples in sequences m7 (DN1), m5.45 (DN3), m4.5 (lower DN5, to HO of *Apteodinium tectatum*) and m4.1 (DN6) correlate with isotopic events Mi1a, Mi1b, Mi3a and Mi4. Low T:M and a dominance of AOM in onlapping sequences 5.3 through 5 (DN4 through lower DN5, ~16 - 14 Ma) in contrast, reflect low terrigenous flux to these sites resulting from accommodation generated during the preceding lowstand (Mi1b event) as well as the eustatic rise and high sea surface productivity associated with the Mid Miocene Climate Optimum and the Monterey carbon isotope excursion.

Palynological analysis thus suggests that eustasy strongly controls the architecture of the New Jersey margin, confirming one of the long-held assumptions of sequence stratigraphy.

Keywords: New Jersey shelf, Miocene, dinocyst stratigraphy, palynofacies, sequence stratigraphy, eustasy

Application of Palynofacies Analysis to Miocene Marine and Holocene Freshwater Samples

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Palynofacies analysis has long been used in marine sediments to record sea level change. Palynofacies analysis of samples from IODP EXP 313 Holes 27A and 29A, for instance, record sea level change through the lower to middle Miocene on the New Jersey shelf. The ratio of terrigenous phytoclasts vs. marine amorphous (“fluffy”) organic matter varies from 87:1 (301.61 mbsf) to 0.22:1 (314.91mbsf) in Hole 27A and from 71:1 (339.99 mbsf) to 8:1 (324.3 mbsf) in Hole 29A. Palynofacies analysis and T:M ratios generally depict more neritic conditions in the upper Miocene compared to the lower Miocene, reflecting aggradation and progradation of the margin. Samples from Unit II Hole 27A

depict an increase in phytoclasts from the early Serravallian, ~15 mya. Samples from Holes 27A and 29A Unit III (late Burdigalian to Langhian, ~16.2 mya) T:M ratios indicate a high terrigenous flux. Palynofacies of Hole 27A Unit III supports the T:M data, indicating samples containing 87% terrigenous phytoclasts. Erosional surfaces present in the upper Miocene of Hole 27A due to near shore environments decrease the amount of terrigenous phytoclasts present in the palynofacies, and increase the amount of phytoclasts in Hole 29A of the upper Miocene. The process of analyzing palynofacies was modified for freshwater samples. Surface samples from 8 freshwater lakes in eastern North America, and 2 marginal marine samples from the Bay of Fundy were analyzed. The initial purpose of palynofacies analysis differed minutely between the freshwater and marine samples. The two samples from the Bay of Fundy contained both marine dinoflagellate cysts and animal zooplakton (rotifer loricas and arthropod remains). Samples from freshwater lakes contained a greater diversity of acid-resistant materials (compared to marine samples) derived from plants (ex: pollen), animals (ex: rotifer loricas and various arthropod remains), protozoans (ex: thecamoebians and ciliates) and algae (ex: dinoflagellate cysts and desmids). This diversity in acid-resistant organic matter provided insights into the conditions of the drainage basin and limnological conditions such as productivity and dissolved oxygen. In the freshwater study, palynofacies from oligotrophic and eutrophic lakes concluded that eutrophic lakes contain more biodiversity and more AOM.

Keywords: marine; freshwater; palynofacies.

Re-illustration of the type material of Raynaud 1978

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In 1978 Jean-François Raynaud published a number of Early Cretaceous and Late Jurassic dinocyst taxa. Some of them are classic markers in the North Sea area. The size of the illustrations (14x20 cm plates), imposed by the small format of the publication does not do justice to the quality of the material.

6 of the species described in 1973 are here re-illustrated:

Athygmatocysta granulata
Hystrichosphaeridum (now *Systematophora*) *scoriacea*
Gonyaulacysta (now *Cribroperidinium*) *gigas*
Scriniodinium (now *Endoscrinium*) *anceps*
Phoberocysta tabulata
?Senoniasphaera frisia

Reference:

Raynaud J.F. 1978. Principaux dinoflagellés caractéristiques du Jurassique supérieur de Mer du Nord. Palynologia, Numero extraordinario 1.

Keywords: Jurassic; Marine; dinoflagellates

Miospore zonation of the Mississippian in the Eastern and Midwest U.S.A.

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No miospore zonal scheme exists in the U.S.A. comparable to that in Western Europe, though parts of the European scheme have been successfully applied in several instances. Most of the successions discussed are located in the Eastern Interior Basin (EIB) and the Appalachian Basin (AB). The ages of miospore occurrences from the former basin, especially those from the Mississippi Valley, are generally well-constrained by independent faunal and microfaunal evidence but the miospore succession is fragmented by numerous barren intervals in this carbonate-dominated sequence. The miospore succession from the AB is represented by well-preserved assemblages from extensive clastic intervals but independent evidence of age is typically scarce.

Kinderhookian, Osagean and Meramecian assemblages from the AB (Kentucky, West Virginia, Pennsylvania and Ohio) closely resemble assemblages of similar age from Western Europe, and the European zonation can be applied with some modification. However, assemblages of this age from the Mississippi Valley (Missouri, Illinois, Indiana and Iowa) differ considerably in composition, with many key taxa absent, or appearing later than in regions to the east. For example, the first appearance of *Lycospora pusilla* in the Mississippi Valley is in the Chesterian (Late Visean) compared with the base of the Visean in Europe.

A provisional, composite miospore zonation is presented for the Mississippian of the EIB and AB though this includes significant gaps. Where applicable, Western European zones are used, but often with redefined basal definitions. Where assemblages differ substantially in composition from Western European assemblages, new zones are tentatively proposed.

Keywords: Mississippian, miospores, zonation, Appalachian Basin, Eastern Interior Basin, U.S.A.

Palynostratigraphic importance of the Strunian in the Iberian Pyrite Belt

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The Iberian Pyrite Belt (IPB) is an important VMS base metals province, with giant massive sulphide deposits such as Neves Corvo Aljustrel (Portugal), Rio Tinto and Tharsis (Spain).

Stratigraphically is composed of two major units, the Phyllite Quartzite Group (PQG) and the Volcanic-Sedimentary Complex (VSC). The PQG is dated as lower Givetian-Strunian by ammonoids and palynomorphs and forms the detrital basement. The PQG consists of phyllites, quartzites, quartzwackes

and shales with intercalations of limestone lenses and nodules at the upper part of the unit which were laid down in a marine siliciclastic platform. The thickness is in excess of 200 m. The VSC is dated as Late Devonian to late Viséan mainly based on palynomorphs. The VSC incorporates several episodes of bimodal volcanism, with dominant rhyolites and dacites, with minor basalts and acessory andesites, and intercalations of black shales, siltstones, minor quartzwackes, siliceous shales, jaspers and cherts and a purple shale formation at the upper part. The thickness is variable (few tens of meters to more than 1000 m). The VSC was laid down in a submarine environment. Overlaying the VSC are the late Visean-Moscovian turbidites of the Baixo Alentejo Flysch Group.

Palynostratigraphic research programs, some developed in collaboration with the mining and exploration companies operating at the IPB, allowed the dating of the sediments of the VSC, that host the massive sulphide deposits and related stockwork structures. Research is based on detailed palynomorph study and characterization of the miospore biozones. The key horizons are dark grey and black shale units that host stockwork and massive sulphide ores in several deposits, e.g., Neves Corvo, Lousal, Caveira and Montinho in Portugal. In Spain similar data was obtained at Alznalcollar and Tharsis deposits.

At the Lousal old mine, recent investigation of two exploration boreholes (LS0801 and LS0802), allowed the identification of the LN Miospore Biozone of Strunian age, in the dark shales with disseminated pyrite, interbedded in the massive sulphides and in the intense stockwork veins. Available palynological research of the black shales intercalated in the massive sulphides of the Caveira old mine presented similar miospore associations of the LN Biozone. Recent U-Pb geochronology data in zircons recovered from felsic volcanics ca. 300m SSE of the Caveira mine Luisa Shaft indicates an age of 361±4Ma.

At the Montinho old mine, one borehole (M1) was investigated for palynostratigraphy. Dark grey shales hosting the massive sulphides mineralisation yielded a poorly preserved assemblage assigned to LN Miospore assemblage aged late Strunian.

In the Neves Corvo mine, the massive sulphide orebodies always occur intercalated with the black shales of the Neves Formation. Detailed palynostratigraphic research in the Neves Formation, complemented with the study of samples from the black shales hosting the massive sulphide lenses (Graça, Corvo, Lombador and Semblana) including small thinly bedded (milimetric scale) black shales intercalated within the massive sulphide ore bodies allowed the determination of rich and relatively well preserved miospore assemblages assigned to the LN Biozone of late Strunian age. All the studied VMS deposits referred are intercalated in dark grey and black shales, dated late Strunian age. Considering this data and the dimension of some giant deposits (e.g. Neves Corvo and Tharsis) a significant IPB mineralization episode occurred during the time interval of the LN Biozone, and its age should be placed somewhere between 360,7 ± 0,7 Ma and 362.0 Ma (late Strunian). More research is being done, using complementary geocronological methods, in order to calibrate this interval, using the Re-Os black shale geochronometers.

The detail palynostratigraphic studies proved to be very useful to constrain the geological models and to define the more accurate exploration VMS favorable settings. Late Strunian age therefore becomes an important key stratigraphic horizon and an exploration guide in IPB, showing a favorable geological time period of ~2 Ma were the paleogeographic conditions were extremely favorable to hydrothermal fluid circulation and VMS deposits formation. These exceptional conditions were also favorable for the development of specific environmental conditions favorable to the increase of acritarchs and prasinophytes populations and to the palynomorph preservations in general. Detailed studies will be dedicated to know the paleogeographic settings of the Strunian deposition environments.

Keywords: Strunian, Palynology, Iberian Pyrite Belt, massive sulphides

Palynological Studies in the Devonian and Carboniferous of the Samara Oblast, Volga-Urals Region, Russia

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The Upper Devonian (Frasnian-Fammenian) and Carboniferous (Visean-Bashkirian) rocks of the Volga-Urals region of Russia represent some of the most prolific petroleum reservoir rocks in the world. A broad, well used lithostratigraphic framework has been developed over the last several decades and forms the basis for regional and local correlation. Some age data has been published, but appears to be little used by oil companies exploring in the region; in all likelihood, the lithostratigraphic units vary in age and facies. To this end, we have undertaken a preliminary study to investigate if palynology can be used to resolve the chronostratigraphy and provide additional information to refine paleoenvironmental interpretations.

Our investigations have focused on the palynological analyses of 13 core samples from wells that penetrated the Upper Devonian Domanik Formation, the regional source rock, and the Carboniferous B2 and A3 reservoir units. In general, palynomorph recovery and preservation has been good to excellent. Despite looking at only 13 samples, we think the palynological assemblages show promise in helping to resolve the age relationships of the units. Planned future studies of foraminifera will help refine age and paleoenvironments.

The Domanik Formation is dated as Frasnian based on the presence of *Verrucosisporites confertus, Archaeoperisaccus* spp., possibly *Raistrickia aratra*, and the acritarch *Unellium piriforme.* The B2 reservoir is dated as Visean (Mississippian) based on the abundance of *Murospora* spp. and *Tripartites* spp. together with representatives of *Lycospora pusilla* and *Diatomozonotriletes hughesii.* The A3 samples contain numerous examples of monosaccate pollen accompanied by *Endosporites globiformis* and *Raistrickia saetosa* indicating a possible Moscovian (Pennsylvanian) age. Calibrating published western European zonal schemes with Russian schemes is challenging especially when limited to core samples only.

Keywords: Volga Urals; Samara; Devonian; Carboniferous; palynology

Possible organic-walled microfossils from the Middle Run Formartion (Neoproterozoic?) of Ohio, U.S.A.

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The Middle Run Formation was discovered and described in the early 1990's by the Ohio Department of Natural Resources, Division of the Geologic Survey, while drilling a deep-core in Warren County, southwestern Ohio (DGS 2627). The unit is composed of roughly 1800m of arkosic sandstone with some siltstone intervals and containing cross-bedding and some small-scale ripple marks throughout. Stratigraphically, the unit is located below the Cambrian-aged Mt. Simon Sandstone and above the Precambrian basement. Relative and absolute dating by several authors have suggested an age of Neoproterozoic. Sedimentologically, the unit is believed to have been deposited as rift-fill which may be associated with the break-up of Rodinia, with some possible fluvial overprints.

Seven samples were taken as a strictly exploratory project from some of the finer lithologic intervals in the middle part of the cored unit. The samples yielded a low-diversity, moderately abundant assemblage of probable organic-walled microfossils. The specimens show a variety of vesicle shapes ranging from round to ovate to sub-triangular. Some of the specimens show slight equatorial thickening, while others exhibit a completely smooth vesicle. A number of the specimens have evidence of some ornamentation, containing short, rounded processes. The occurrence of these probable organic-walled microfossils raises questions about the depositional environment of this unit and the location of this part of North America with respect to the paleo-coastline. At this point, the occurrence of these specimens is not completely understood and more work and additional sampling will need to be done to gain a complete understanding of the occurrence of this assemblage, the depositional environment of the Middle Run Formation, and any biostratigraphic implications that may arise.

Keywords: Neoproterozoic, Ohio, organic-walled microfossils, Middle Run Formation

Stable isotope analysis ($\delta^{15}N$ and $\delta^{13}C$) of *Tasmanites* and *Protosalvinia* extracted from Late Devonian- Early Carboniferous shales in east Kentucky

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Organic matter in Late Devonian and earliest Carboniferous rocks of Eastern Kentucky preserve chemical information that may reflect glaciation/deglaciation events known to have occurred at this time. Results from experimental work to verify the fidelity of stable nitrogen isotopes ($\delta^{15}N$) suggest that neither thermal maturation nor chemical treatments used to extract the organic residues affects the values to a significant extent.

A preliminary composite $\delta^{15}N$ chemostratigraphic profile from four sections sampled in Eastern Kentucky shows significant differences in values between bulk organic material (BOM) and a single component, the widely occurring and stratigraphically long-ranging (Proterozoic – Recent) prasinophyte, *Tasmanites*. The analysis of single organic components should yield a more reliable $\delta^{15}N$ profile, which reflects changes in ocean chemistry, than a $\delta^{15}N$ curve of BOM which is highly susceptible to changes in the relative proportions of components.

Preliminary $\delta^{15}N_{Tasmanites}$ and $\delta^{15}N_{BOM}$ chemostratigraphic profiles are presented and compared with published sedimentological and paleoenvironmental interpretations. Tentative correlation of the profiles with known glaciation/deglaciation events is discussed.

Results of stable isotope analyses of the enigmatic alga, *Protosalvinia* are also presented from several sections, demonstrating the scale of variation in ocean chemistry between North American basins in the late Devonian.

Keywords: *Tasmanites*; *Protosalvinia*; carbon isotopes; nitrogen isotopes; Late Devonian

Palynofacies of the Sanganeh Formation (lower Cretaceous) in the East of Kopet-Dagh basin, NE Iran

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Kopet-Dagh basin with 55000 square kilometers area has been formed in northeast of Iran, a large part of south Turkmenistan and northwestern Afghanistan. A large thickness of sediments has deposited during Mesozoic and Tertiary in this basin. Sanganeh Formation is one of the Lower Cretaceous Formations (Aptian – Albian in age) of this basin. It conformably overlies Sarcheshmeh Formation and is overlaid by Aitamir Formation. This Formation is known as a source rock in Kopet-Dagh basin, which has produced some natural gas reservoir. The thickness of this Formation is 320m in Karizak section which is located in the most eastern part of Kopet-Dagh basin. It consists of dark gray shale, some interbeds of siltstone with Ammonite and nodules in some layers. A total of 75 samples has prepared for palynological studies. This section has relatively poor marine palynomorphs (< 2%). In most samples, phytoclast group is characterized by a high abundance of black particles. Based on amount of phytoclasts, marine palynomorphs, and amorph organic matter (AOM) with Tyson (1995), three palynofacies have been recognized for studied section. These palynofacies show that Sanganeh Formation has been deposited in highly proximal to proximal shelf and oxic to suboxic condition. Present of relatively high oxygen has caused high abundant phytoclast and low marine palynomophs in most of studied samples. Total organic carbon (TOC) analyses of this section show low values (< 0.6) that means it was a poor source for hydrocarbon content in study area.

Keywords: palynofacies, Lower Cretaceous, Sanganeh Formation, Iran

Probable Paleoproterozoic prokaryotic palynomorphs

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In this report I describe a newly discovered assemblage of carbonized microfossils extracted by acid maceration (palynomorphs) from 2 billion-year-old shales from the Nastapoka Group, Canada. Microfossils consist of degraded filaments embedded in organic (carbonized) groundmass and organic

spheroids that display cohesive, granular structure but lack discrete cell walls. The microfossils differ from younger acritarchs in significant ways and add to a growing body of evidence indicating that Precambrian organisms at a prokaryotic cellular level can survive extraction via acid maceration. I suggest these palynomorphs be referred to as granular organic microfossils, GOMs, in order to distinguish them from acritarchs and other organic-walled microfossils (OWMs), which, as their name implies, possess discrete walls. A comparison of GOMs from the Nastapoka with similar forms preserved in thin section from the 2 Ga Belcher Group, and with both younger and older palynomorph assemblages, helps provide an expanded record of prokaryotic life in Archean and Paleoproterozoic sediments. The absence of eukaryotes in 2 billion-year-old fossiliferous sediments suggests that the eukaryotic cell probably originated between 2.0 and 1.8 Ga.

Keywords: Paleoproterozoic life, Precambrian palynology, goms, Nastapoka Group

Middle Jurassic vegetation dynamics from allochthonous palynological assemblages: an example from a marginal marine setting; Lajas Formation, Neuquén Basin.

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Palaeoenvironmental reconstructions using palynology are often based upon transported pollen and spores but rarely take into account how the transportation and deposition processes of the material alter the assemblages, leading to misinterpretations. To resolve this, a statistical methodology has been used in a case study that aims to eliminate the bias of the sedimentation process and gives a new interpretation on palaeoenvironmental analysis and floral dynamics.

Middle Jurassic marginal marine sediments from four successions within the Lajas Formation, Neuquén Basin, Argentina, were analysed to establish their palynofloral composition. The palynofloras, mostly of terrestrial origin, are characterised by a dominance of *Classopollis* spp. and common *Pityosporites* spp; *Deltoidospora* spp; Araucariaceae pollen and inaperturate pollen.

Statistical analyses performed on the palynomorph assemblage data identified ecological groupings characteristic of a number of palaeoenvironments including coastal/deltaic, river margins and floodplains, and higher altitude arid forests. The ecological groupings differ between the four studied successions through the Lajas Formation indicating a dynamic ecosystem. The delta top settings have ecological groupings characteristic of mid-late seral communities, whereas pro-delta and bayfill settings have ecological groupings displaying early-mid seral successions. This indicates a possibility that the depositional environment has a taphonomic effect on the palynofloral assemblage.

The relationships between the ecological groupings, determined using statistical analyses, provide evidence for the first order drivers of vegetation dynamics. It is proposed that water availability and environmental stress (substrate disturbance) are the most important drivers of palaeo-floral succession during the Jurassic of the Neuquén Basin.

Keywords: Jurassic; taphonomy; palaeoecology; multivariate statistics; vegetation dynamics

Changes in Early Cretaceous Angiosperm Average Pollen Size: Implications for Angiosperm Diversification and Evolution

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Understanding of the structure of early flowers and pollination biology had been indirect because a 10 my gap between the earliest accepted angiosperm pollen and flowers. Ecological studies suggest pollen size is associated with reproductive characters including pollinator type, and style length/stigma depth. The fossil pollen flora provides size data that can statistically test hypotheses of Early Cretaceous flowering plants evolution. The average largest pollen dimension increased 56% from the Valanginian-Hauterivian to the Aptian with significant stepwise increases between ages. In addition, the size distributions changes with the size range 20-24 µm having the highest percentage during the Valanginian, the less than 20 µm size range the highest during the Hauterivian and Barremian, and 25 to 40 µm highest during the Aptian. Average pollen diameter of living plants varies with eudicot (tricolpate) pollen significantly smaller than monocot (monosulcate) pollen. The average pollen diameter of the basal ANITA grade is significantly larger than the fossils until the Aptian suggesting a major pre-Cretaceous diversification of living angiosperms is unlikely. These data support the hypothesis that early angiosperm had initially insect and ambophilous pollinated flowers, and that length of the pollen tubes were short indicating of short styles and apocarpy. The driving forces for changes in angiosperm pollen size appear to be due to increases in advanced pollination include nectar feeders and wind, and the evolution of longer styles and syncarpy. Placement of the earliest reported grains suggest Cretaceous angiosperms diversified in the central Tethys seaway islands and with movement later into in tropical areas of Africa and South America, and temperate regions.

Keywords: Angiosperms, Cretaceous, Evolution, Mesozoic, Pollen

Palynological reconstruction of last glacial cycle palaeo-environments of the Gulf of Papua: research proposal

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Palynological analysis of sedimentary sections obtained from the 2004 PANASH and 2005 PECTEN cruises in the Gulf of Papua, Papua New Guinea, is being conducted to assess diversity and distribution of palynomorphs. Phase I of the project examines the modern distribution of species to determine spatial changes in environments using dinoflagellate cysts as a proxy for current oceanographic conditions (salinity, temperature, and nutrient concentration), while dispersal of pollen and spores will be evaluated in relationship to vegetation distribution on land. Phase II will build on Phase I palynological results to reconstruct palaeoenvironmental conditions and understand temporal change in the Gulf of Papua over Marine Isotope Stages 5 to 1. Using results obtained from Phase I, dinoflagellate cyst assemblages will serve as a proxy to examine changes in oceanographic conditions through time and estimate past variations in salinity, temperature, and nutrient content. Vegetation information obtained from pollen and spores will aid in constraining the intensity of glacial and interglacial cycles and transitions from drier to more humid precipitation regimes. Sediment samples obtained from the PANASH and PECTEN cruises have been palynologically processed, and analyses are being conducted at the Louisiana State University Center for Excellence in Palynology (CENEX) laboratory. Preliminary results from Phase I material show different species assemblages and variations in diversity depending on location in the gulf. Relative abundance of dinoflagellate cysts and transfer functions will be applied to define dinocyst assemblages in correlation with oceanographic conditions. Further constraining our understanding of modern oceanographic conditions using species ecology will allow for better reconstruction of tropical palaeo- environments especially when combined with other proxy records, such as known $\delta^{18}O$ values for sea level change.

Keywords: marine; terrestrial; Holocene/Recent

The John Williams' Index of Palaeopalynology

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The John Williams Index of Palaeopalynology (JWIP) is a card catalogue stored at the Natural History Museum, London, and is based around a central index of over 23,350 references (as of February 2012). The card catalogue began in 1971 by John Williams who has been the sole contributor to this unique resource since its creation. The references included within the catalogue are a thorough collection of palaeopalynological journal articles, textbooks, selected conference abstract volumes, and MSc and PhD theses etc. available online, that have been reviewed by the author since creation of the catalogue some 40 years ago. The catalogue evolves around a central card index (labelled 'JWIP References'), from which each reference is then cross-referenced into separate card catalogues categorised by palynomorph group (spores/pollen, dinoflagellate cysts and acritarchs, chitonozoans and miscellaneous), taxa (spores/pollen, dinoflagellate cysts, acritarchs and chitonozoans), geological period (26 divisions) and geographical region (17 regions).

Due to this unique format, the card index enables a user to undertake a search based on the specific needs of their research, whether it is the investigation of individual taxa in a taxonomic study, or an evaluation of assemblage data in a specific time or region, for example, allowing the user to find all the relevant references. The number of references obtained during each card index search surpasses generic web searches and/or academic search engines in terms of accuracy and detail. In addition, whilst the entire card index has been compiled by John Williams, each publication is also assiduously checked by John prior to being inputted into the card index. This results in the reliability and consistency encountered in the card index surpassing that of Palynodata, the only known comparable compilation of palynological data.

The card index is still growing, with John Williams adding information to the index of some 1000 additional references each year. The NHM are in the process of evaluating potential avenues to convert this into a digital resource. This presentation will review the resource, its structure and provide examples of its application to existing and potential palynological research.

Keywords: card index; database; marine; terrestrial; Cenozoic; Mesozoic; Palaeozoic.

A less-toxic method to concentrate pollen from Quaternary peat

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The analysis of pollen preserved in sediments remains a key source of information for reconstructing Quaternary paleoenvironments. The pioneers of palynology took on the challenge of extracting pollen from various types of sediment to unlock the history recorded in bogs, lakes, and other depositional environments. Their efforts developed "standard methods" for concentrating pollen preserved in these sediments for identification by light microscopy. Standard methods in practice are best described as a modular toolkit to chemically or mechanically remove non-pollen constituents of the sediment matrix to concentrate palynomorphs. However, standard methods of sediment processing to concentrate pollen employ extremely hazardous chemicals and fail to yield pollen slides of sufficient purity for efficient manual counting in some sediments, especially those rich in lignin. Recent efforts to develop non-toxic or less-toxic sediment processing techniques are providing new tools to extract pollen from Quaternary sediments.

Here I present results of trials of less-toxic methods to concentrate pollen from lignin-rich peat, for which standard methods failed to produce concentrated pollen residues. The aim of these trials was to develop a protocol that was: 1) less-toxic; 2) more effective at removing lignin; and 3) allows quantitative analysis of pollen assemblages preserved in peat. Best results were achieved with a protocol that includes carbonate dissolution with 10% hydrochloric acid, sediment deflocculation and humic acid extraction with hot 10% potassium hydroxide, coarse particle removal by mechanical screening, plant and algal polysaccharide degradation by enzymatic hydrolysis, lignin oxidation with 3% alkaline sodium hypochlorite, silicate mineral reduction by density separation with lithium polytungstate, pollen staining with safranin, dehydration of pollen residue with ethanol and *tert*-butanol, and infiltration of pollen residue with silicone oil. None of the chemical treatments presented here are in themselves novel. I found that less-toxic techniques developed for other palynological applications can be combined to effectively concentrate pollen from peat.

Keywords: Pollen processing, peat, sediment, Quaternary, paleoecology, paleoenvironmental change, non-toxic, biogeography.

Anthropogenic impact inferred from non-pollen palynomorphs at Lake Simcoe, Ontario, Canada

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Lake Simcoe, the largest lake within Southern Ontario, is situated 40 km southeast of Georgian Bay and 70 km north of the Lake Ontario. It extends 45 km both south to north and west to east and has two bays (Kempenfelt Bay and Cook's Bay); mean and maximum water depths within the lake are 5-9 m and 30 m, respectively. Lying within the West St. Lawrence Lowland the lake is surrounded by clay plain and sand plain of glacial Lake Algonquin.

Since shortly after deglaciation Lake Simcoe region has been impacted by humans initially by Native inhabitants and then by European settlers. As a result, water quality in Lake Simcoe has been declining for many years due to the increase in nutrient inputs accompanying agriculture, urbanization and industrialization. The distribution of non-pollen palynomorphs (NPP) in two cores (from Cook's Bay and main basin) shows a response to these anthropogenic changes. Moreover, in contrast to simple measuring the concentration of major nutrients and the products of photosynthesis and biomass in water, analysis of NPP not only presents a brief snapshot at any particular time, but also reflects long-term human impact on the whole freshwater system.

Low concentrations of nutrients in samples with little NAP in sediments deposited during pollen zones 1 through 3of McAndrews (1994) record low disturbance prior to early European settlement (late 18th century). These sediments are relatively rich in desmids such as *Cosmarium spp*., *Euastrum spp*., and *Staurastrum spp*., an assemblage indicative of oligotrophic conditions. A decline in desmids together with an increase in dinocysts *(Parvodinium inconspicuum, Peridinium wisconsinensis, P, willei, P. volzii*), thecamoebians (especially *Difflugia spp., Centropyxis spp, Cucurbitella tricuspis*), cyanobacteria (*Microcystis spp.)*, and ciliates (*Codonella cratera,* stalked ciliates) up-core is consistent with increased nutrient concentration. Abundant phytoliths in sediments that are relatively rich in Gramineae and other NAP in the middle parts of the cores record the draining of the Holland Marshes in the 1920's and 1930's. A sharp increase in nutrient levels, together with a transition from high nitrite to high nitrate concentrations, records a sudden increase in BOD leading to depletion of DO associated with the creation of polders at that time. This is also manifested in maximum concentration of dinocysts *(Parvodinium inconspicuum, Peridinium wisconsinensis, P, willei, P. volzii*) and peaked content of cyanobacteria *(Microcystis spp.)*. A second influx of phytoliths up-core immediately followed by the sharp rise in *Ambrosia* corresponds with rapid land-clearing accompanying the five-fold post-war increase of population in the Lake Simcoe watershed. These *Ambrosia*-rich sediments are rich in heavy metals, and have high TP and NO_3, and eutrophication is confirmed by abundant *Pediastrum spp*., *Peridinium spp*., *Microcystis spp., Cucurbitella tricuspis*. The abundance of *Codonella cratera, Cucurbitella tricuspis* and *Centropyxis spp*. from the upper part of the core records low DO associated with continued eutrophication of Cook's Bay. The trend towards resurgence of *Cosmarium spp.* toward the top of the cores, together with a decline in *Codonella cratera, Peridinium spp*., *Microcystis spp.,* and

Centropyxis spp. as well as zinc, lead, and arsenic concentration suggests a slight improvement in ecosystem health in response to recent efforts to reduce TP input.

Keywords: Lake Simcoe; non-pollen palynomorphs; human impact; Holocene

Palynostratigraphy of the Upper Devonian Saverton Shale and Lower Mississippian Hannibal Shale, Illinois, U.S.A.

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Diverse and reasonably well preserved palynofloral assemblages have been recovered from the Upper Devonian Saverton Shale and Lower Mississippian Hannibal Shale exposed along a bluff at Atlas South, Pike County, Illinois, U.S.A. Of the six samples analyzed, three were collected from the 13 m-thick section of the Saverton Shale, and three from the 17 m-thick Hannibal Shale. Both formations were deposited in a normal, offshore, marine environment.

The acritarch assemblage comprises 27 species assigned to 12 genera, and the prasinophytes are represented by 12 species (five genera). The overwhelming majority of the microphytoplankton taxa are from the Saverton Shale, with only a few occurring in the Hannibal Shale. The miospore flora consists of 14 species and 13 genera. Scolecodonts were also noted as a very minor component.

Several of the miospore species, with a near-worldwide distribution in the Upper Devonian–Mississippian interval, are present in both the Saverton Shale and Hannibal Shale. These include *Grandispora cornuta* Higgs, 1975, *Indotriradites explanatus* (Luber *in* Luber & Waltz, 1941) Playford, 1991, *Retusotriletes incohatus* Sullivan, 1964, and *Verrucosisporites nitidus* Playford, 1964. Three species, *Retispora lepidophyta* (Kedo, 1957) Playford, 1976, *Teichertospora torquata* (Higgs, 1975) emend. McGregor & Playford, 1990, and *Vallatisporites hystricosus* (Winslow, 1962) Byvsheva, 1985 are, however, restricted to the Upper Devonian and were encountered only in the Saverton Shale. The presence of *R. lepidophyta* is of particular significance because it restricts the age of the Saverton Shale to the latest Devonian (Famennian Fa2d–Strunian). None of the three aforementioned Late Devonian miospores occurs in the Hannibal Shale, which contains other trilete forms characteristic of the Early Mississippian.

The Saverton Shale's acritarch and prasinophyte assemblage indicates a Late Devonian (Famennian) age, corroborating the miospore age determination. Typical Late Devonian microphytoplankton recovered (but not necessarily restricted to the Famennian) include: *Barathrisphaeridium chagrinense* Wicander, 1974, *Craterisphaeridium sprucegrovense* (Staplin, 1961) Turner, 1986, *Gorgonisphaeridium absitum* Wicander, 1974, *G. elongatum* Wicander, 1974, *G. ohioense* (Winslow, 1962) Wicander, 1974, *G. plerispinosum* Wicander, 1974, *Muraticavea enteichia* Wicander, 1974, *Puteoscortum polyankistrum* Wicander & Loeblich, 1977, and *Unellium elongatum* Wicander, 1974. A marked decrease in microphytoplankton diversity and abundance is evident in the Hannibal Shale when compared to the Saverton Shale, with the former generally yielding only small, morphologically simple acritarchs such as *Micrhystridium* and *Veryhachium*.

The palynofloral data clearly indicate positioning of the Devonian–Mississippian boundary between the Saverton Shale and Hannibal Shale at this location, probably within the intervening Glen Park Limestone (a silty, dolomitic limestone, 1 m thick, of palynologically unsuitable lithology).

The composition of the Saverton Shale microphytoplankton assemblage is very similar to other previously described North American Upper Devonian assemblages from Indiana, Iowa, Ohio, Kentucky, U.S.A., and southern Saskatchewan, Canada. The Saverton additionally contains many, essentially cosmopolitan microphytoplankton taxa with prior reports from Upper Devonian strata of South America, Europe, the Middle East, China, and Australia.

Keywords: Saverton Shale; Hannibal Shale; Upper Devonian; Lower Mississippian; acritarchs; prasinophytes; miospores; palynostratigraphy.

Pollen evidence for vegetation response to the Younger Dryas event in the Atlantic Coastal Plain, United States

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Three well-dated, high-resolution pollen records from Chesapeake Bay and the Florida peninsula show a rapid vegetation response to precipitation and temperature changes associated with the onset and termination of the Younger Dryas (YD) and the transition into the early Holocene.

A 4.5 m section of core MD02-2579, collected in Tampa Bay, Florida spans the interval from ~20 ka – 11.5 ka. Dominance of Amaranthaceae and common occurrence of *Carya* pollen during the full glacial is consistent with cooler and drier than modern conditions. An overall pattern of increased *Pinus* pollen abundance, associated with progressively warmer and wetter climates, characterizes the deglacial interval. Superimposed upon this pattern are several dry intervals, including the YD; these are indicated by sharp increases in abundance of Amaranthaceae pollen.

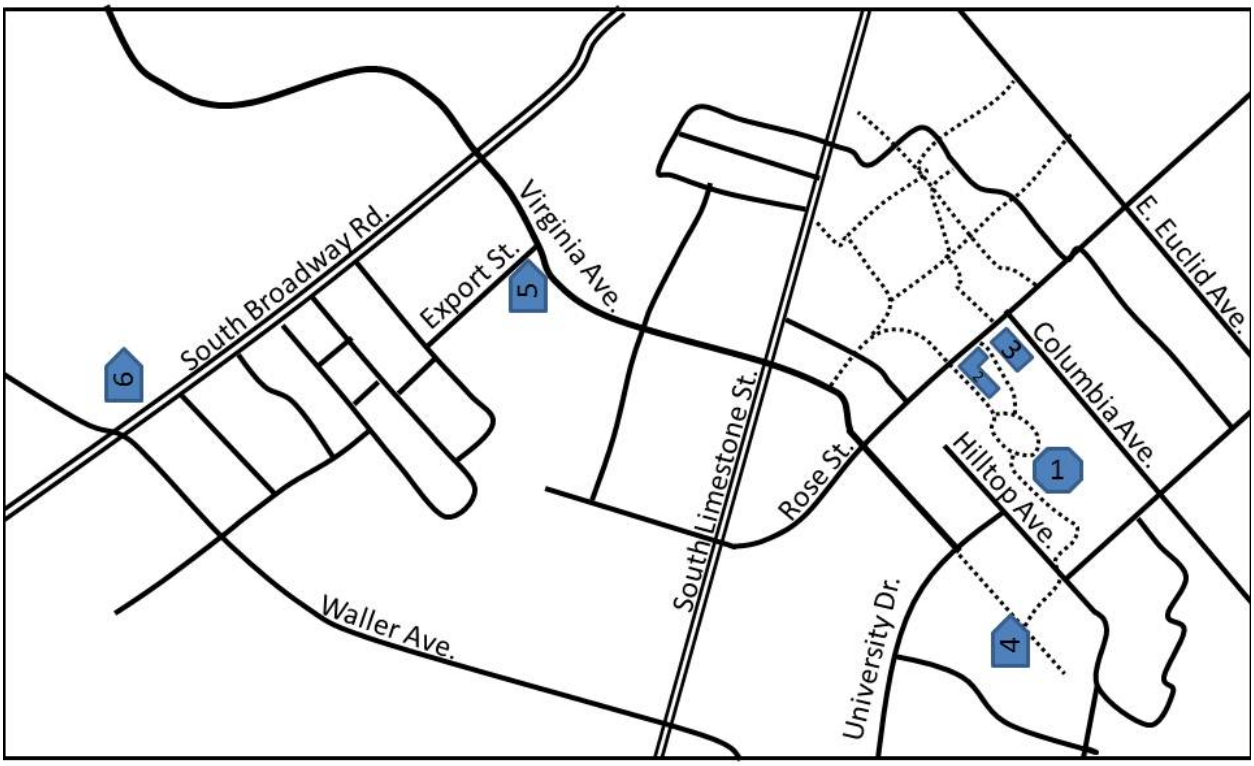
Two cores detail the transition from the YD into the early Holocene: core LSS DC-IV from Little Salt Spring, Florida and core MD03-2663 from Chesapeake Bay. Core LSS DC-IV is 8.2 m long and contains sediments deposited between ~6.5 ka and 13.5 ka. A rapid increase in abundance of *Quercus* and *Carya* pollen at 12.9 ka is suggestive of reversion to cooler, drier conditions, consistence with previous analyses of calcareous microfossils from this site. The late YD is characterized by a gradual increase in *Pinus* abundance and a corresponding decrease in *Carya* abundance. This is punctuated by a rapid increase in *Quercus*, *Ambrosia*, *Carya* and *Opuntia* pollen at 10.5 ka that we interpret as a brief period of cooler, drier climate. This was followed by an abrupt shift to organic sedimentation and bayhead swamp pollen assemblages between ~10.4 and 9 ka, with dominance of *Pinus* pollen and fern spores and introduction of *Ilex* pollen.

Core MD03-2663 is a ~17 m core collected in the Chesapeake Bay, approximately 1600 km north of Little Salt Spring. Over 13 m of sediment spans the interval between ~18 ka and 9 ka. *Pinus banksiana, Picea glauca,* and *Abies* pollen, which are indicative of cool climate conditions, decrease in abundance during warming of the deglacial and abruptly increase during the YD. A sharp increase in *Tsuga* and *Quercus* abundance marks the end of the YD. The overlying 650 cm, deposited during the next 1000-1500 years, provide an annually- to decadally-resolved record of the earliest Holocene. As

seen in the LSS record, *Pinus* pollen dominates the earliest Holocene, followed by *Quercus* dominance during the remainder of the early Holocene.

Collectively, these records indicate a uniformly rapid onset and termination of relatively drier conditions during YD. The earliest centuries of the Holocene were relatively wet, followed by the warm, dry climates of the early Holocene, when *Quercus* pollen dominated most Atlantic Coastal Plain assemblages. These data document the rates of vegetational response to climate changes associated with the deglacial and the periodic climate reversals that characterized that time.

Keywords: pollen, Younger Dryas, Atlantic Coastal Plain, paleoclimate



Major Road

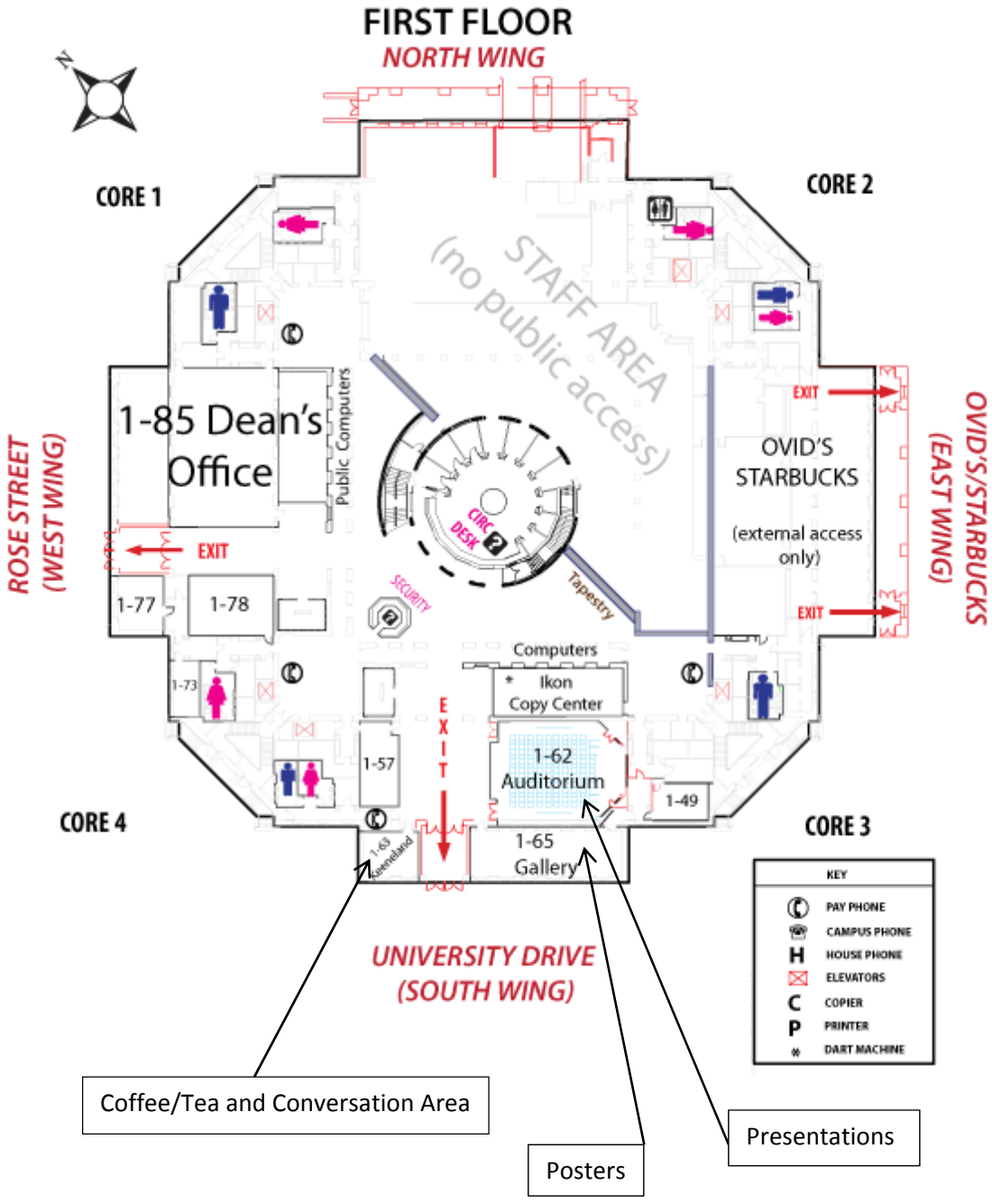
Road

Foot and Bicycle Traffic Only

1 William T. Young Library
2 Kentucky Geological Survey
3 Hillary Boone Center
4 Towers Dormitory Complex
5 Holiday Inn Express
6 Crowne Plaza

A more detailed map can be found at: http://goo.gl/maps/XwFk

William T. Young Library



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