(SS26) Advancing High-Resolution, High-Throughput Research in Paleoecology

Date: August 28
Place: Room 5235 (oral), Room 6310 (poster)
Organizers: Surangi W. Punyasena & Feng Sheng Hu
Contact email address: punyasena@life.illinois.edu
Purpose: This session brings together researchers in palynology and paleobotany that are developing novel methods that seek to fundamentally transform the nature of paleoecological research. We focus on approaches designed to provide high-resolution, quantitative analyses of paleoecological, paleoclimatic, and biostratigraphic data using new computational techniques, microscopic methods, genetic analysis, and biogeochemical advances. These methods aim to expand the hypotheses that can be addressed in palynology and paleoecology by increasing the taxonomic, temporal and spatial resolution of paleoecological data across both Quaternary and pre-Quaternary timescales.

Oral Presentation

Aug. 28 [AM1] Room: 5235

Chair: Feng Sheng Hu

9:00-9:20 **Paleoecology and the era of "big data"** SS26-O01 (419)

Surangi W. Punyasena

9:20-10:00 **[Keynote] Records and high-resolution records of environmental and climatic change: makes the difference sense?** SS26-O02 (194)

H. Hooghiemstra, R.G. Bogotá-A, M. Groot, L. Lourens, D. Rincon, J.C. Berrio, Z. González-Carranza, E. de Boer

10:00-10:20 **Seeing the trees for the forest: Improving the taxonomic resolution of pollen and spore records of ancient vegetation** SS26-O03 (305)

Luke Mander, Surangi W. Punyasena

Aug. 28 [AM2] Room: 5235

Chair: Surangi W. Punyasena

10:50-11:10 **Biostratigraphic dating using maximum likelihood** SS26-O04 (212)

Carlos Jaramillo, Surangi Punyasena, Yuelin Du, Felipe de la Parra, John Ortiz, Carlos Moreno

11:10-11:30 **The value of quantitative palynology in enhancing regional stratigraphic standards; an example from the Late Jurassic of The Netherlands** SS26-O05 (357)

Dirk Munsterman, Roel Verreussel, Susan Kerstholt-Boegehold, Oscar Abbink, Timme Donders

11:30-11:50 **Assessment of the carbon stable isotope composition of pollen as an ecophysiological indicator in the paleorecord** SS26-O06 (367)

David Nelson

11:50-12:10 **The Permo-Triassic transition in western Pangea - A first sign of plant life** SS26-O07 (297)

Cindy V. Looy, Renske P.J. Kirchholtes, Greg H. Mack, Tom B. van Hoof, Neil J. Tabor

Aug. 28 [PM2] Room: 5235

Chair: Surangi W. Punyasena

14:30-15:10 **[Keynote] Generalized dissimilarity modeling (GDM) of late-Quaternary variations in palynological compositional dissimilarity** SS26-O08 (571)

John W. Williams, Jessica Blois, Simon Ferrier, Glenn Manion, Matt Fitzpatrick, Sam Veloz, Zhengyu Liu, Bette Otto-Bliesner, Feng He

15:10-15:30 **Putting pollen on the map: new techniques in spatial analysis** SS26-O09 (90)

Basil A.S. Davis

15:30-15:50 **An early Permian vegetational Pompeii: Forest reconstruction, paleoecology, and paleobiogeography** SS26-O10 (555)

Jun Wang, H.W. Pfefferkorn, Yi Zhang, Zhuo Feng

Poster Presentation

Aug. 28 [PM1] Room: 6310

13:30-14:30 **First high resolution marinopalynological stratigraphy of Late Quaternary sediments from the Black Sea** SS26-P01 (126)

Mariana Filipova-Marinova, Danail Pavlov, Marco Coolen, Liviu Giosan

Biofacies characterization: the first step towards property prediction in shale gas exploration. An example from the Posidonia Shale in The Netherlands SS26-P02 (547)

R.M.C.H. Verreussel, F. Van Bergen, M. Horikx, D.K. Munsterman, S. Nelskamp, M.H.A.A. Zijp

SS26-O01 (419)

Paleoecology and the era of "big data"

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This session (Session SS26, Advancing High-Resolution, High-Throughput Research in Paleoecology) provides an overview of research in palynology and paleobotany that breaks through the current temporal, spatial, and taxonomic limitations of paleoecological research. Through advances in geochemistry, informatics, image analysis, and quantitative biostratigraphy, paleoecological research is finding new mechanisms for testing long-standing hypotheses in plant ecology and evolution using increasingly large and increasingly more complex datasets. This introductory talk will provide an overview of the common themes that will be addressed by this session's speakers. I will also provide an example of how automated, high-throughput methods in palynology can be used to develop large modern pollen rain datasets that can be used to understand pollen production and its sensitivity to short-term climatic variation in modern tropical forests.

Keywords: paleoecology, paleobotany, palynology, automation, informatics.

SS26-O02 (194)

Records and high-resolution records of environmental and climatic change: makes the difference sense?

H. Hooghiemstra[1], R.G. Bogotá-A[1,2], M. Groot[1], L. Lourens[3], D. Rincon[4], J.C. Berrio[5], Z. González-Carranza[1], E. de Boer[1]

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Increasing evidence shows tropical biomes are highly responsive to climate change and are understudied compared to temperate- and cold-climate systems. One of the reasons is that during the last decades large international research projects focused attention on the oceans (IODP), tropical glaciers, and high latitude ice sheets while terrestrial systems were almost neglected. Well organised international consortia of research institutes successfully generated added value of multidisciplinary analysis and are able to address more adequately complex sets of cutting-edge research questions. Fast procedures for sample treatment and analysis are needed to reach high-resolution records, and only well calibrated proxies allow quantitative reconstructions and paleodata-model comparisons. Compared to such adequate research settings terrestrial paleo-ecology in general needs a booster, and tropical paleo-ecology in particular needs better calibration. The latter relates to more complex and diverse ecosystems, and dominant precipitation-driven change in the tropics, a climatic variable more difficult to reconstruct than temperature. New high-resolution records of three terrestrial sites from Mauritius and Colombia are presented and compared with marine and ice-core records. Current limitations to generate suites (i.e. multiproxy) of datasets consisting of thousands of sample points are discussed. Downcore variations in pollen, sediment fractions, and geochemistry are used to infer relationships between the biotic and abiotic environments. However, bottle necks are various and include the absence of robust overlap in expertise of the researchers involved. The potential high sensitivity of tropical mountains to present and past climate change is discussed. However, past distributions patterns of biota are responsable for large changes in past connectivity and insensitiveness to site-specific climate change. The reconstruction in tropical mountain ecosystems of biome-specific ecological change is more difficult as the observational system should migrate in concert with the migrating biome. However, such understanding is necessary to better anticipate effects on biota related to current and future Global Change. We show that 'locked' biomes are not necessarily stable of taxonomic composition and may pass internal tipping points. Resolution of past environmental and climatic change at decadal time scales is needed to address current future effects of Global Change which also operates at decadal time scales.

Keywords: high-resolution analysis, biotic-abiotic relationships, sensitivity, locked biomes, tipping point.

SS26-O03 (305)

Seeing the trees for the forest: Improving the taxonomic resolution of pollen and spore records of ancient vegetation

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Pollen and spores (sporomorphs) are a valuable record of plant life, and have provided information on subjects ranging from the nature and timing of evolutionary events to the relationship between vegetation and climate. However, sporomorphs can be morphologically similar at the species, genus, or the family level. Studies of extinct plant groups in pre-Quaternary time often include dispersed sporomorph taxa whose parent plant is known only to the class level. Consequently, sporomorph records of vegetation suffer from limited taxonomic resolution and typically record information about plant life at a supra-specific level. Here we review a range of studies where the limited taxonomic resolution of sporomorph records has hampered the study of vegetation change, and aim to highlight ways in which greater taxonomic precision may be attained. Cases where the parent plant of a dispersed sporomorph is unknown, or is only known at a high taxonomic level such as class, are typically addressed by detailed studies of the morphology of the sporomorph in question. This typically involves a combination of scanning and transmission electron microscopy, which can reveal taxonomically significant ultrastructural details that are not visible using optical microscopy. Once the systematic position of a problematic sporomorph has been clarified, the composition of the source vegetation is known in greater detail. In certain situations, such as the quantification of plant diversity or the mapping of spatial patterns of plant life, only the total number of sporomorph morphotypes in a sample (rather than their systematic position) is of interest. Such studies may also fall prey to the low taxonomic resolution of sporomorph records because trends in sporomorph diversity, either through time or in space, may document patterns at the generic or familial level. This reduces the applicability of fossil data to contemporary ecological problems such as plant extinction. In many classic cases such as the evolution and diversification of grasses, the low taxonomic resolution of sporomorph records has been partially overcome by appealing to other fossil groups such as macrofossils and phytoliths. Finally, we present data to argue that maximizing the amount of morphological information recovered from sporomorphs using advances in imaging technology, and the analysis of such information using tools from fields such as pattern analysis, represents a critical step in the evolution of palynology. This step has the potential to significantly improve the taxonomic resolution of sporomorph records, and hence improve understanding of the nature and timing of plant evolution.

Keywords: palynology, palaeoecology, plant extinction, plant evolution.

SS26-O04 (212)
Biostratigraphic dating using maximum likelihood

Carlos Jaramillo[1], Surangi Punyasena[2], Yuelin Du[2], Felipe de la Parra[3], John Ortiz[1], Carlos Moreno[1]

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Relative abundance is an important element of the microfossil record**,** but one that is rarely used for dating stratigraphic sequences. Here, we present a maximum likelihood biostratigraphic method that uses abundance to date isolated or groups of samples. Our method, in contrast with many other biostratigraphic alternatives, has a probabilistic approach provided by the likelihood analysis that results in not only providing ages but also giving confidence intervals to those ages. That is a unique

characteristic of our method that we think could be very useful to improve the reliability. We performed a field test of the method, from data collected from an oil well from the Catatumbo Basin, Colombia, illustrating the use of our approach in a real-world case study and highlighting how our method could be generalized to a wide range of stratigraphic problems. We also developed a free, multiplatform software, to be able to carry out a maximum likelihood analysis.

Keywords: palynology, biostratigraphy, abundance, correlation, dating.

SS26-O05 (357)

The value of quantitative palynology in enhancing regional stratigraphic standards; an example from the Late Jurassic of The Netherlands

Dirk Munsterman, Roel Verreussel, Susan Kerstholt-Boegehold, Oscar Abbink, Timme Donders

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Exploration in a mature basin requires a detailed classification and standardization of rock stratigraphy to adequately comprehend the depositional history and prospect architecture. The pre-Quaternary Stratigraphic Nomenclature of the Netherlands compiled by Van Adrichem Boogaert & Kouwe in 1993 provided a consistent framework for use by the Dutch geological community. The combination of non-marine to shallow marine lateral facies changes, repetitive log and facies characteristics in time, sea-level and climate change, salt tectonics and structural compartmentalisation hamper straightforward seismic interpretation and log correlation. Over the past twenty years, new biostratigraphic techniques and continued exploration in the Netherlands have provided additional stratigraphic information. Applying e.g. the Sporomorph Eco Group (SEG) technique enables the user to recognize sea-level changes and furthermore to separate sea-level and climate signals for independent interpretation and correlation. The basic principle, on which this technique is founded (Abbink, 1998), is the existence of a relationship between a pollen or spore taxon, its botanical affinity, and, with that, its inferred habitat and ecological preference. With the SEG technique, botanical affinities are established (or have been established in the past) by extracting pollen and spores from reproductive organs of plant fossils. Because these fossils are derived from outcrops, the depositional environment and paleolatitudinal setting is usually known. In the ideal case, all occurring pollen and spores can be classified in groups, the so-called Sporomorph Ecogroups, such as River, Lowland, Coastal, Upland etc. In a non-marine setting close to the sea, the aerial extent of particular the Lowland and Coastal groups will shrink or expand when sea level rises and falls. Likewise, the changes in the composition of the climate dependent types reflect changes in climate changes. The sea-level and climate signal can be separated and interpreted independently, when the warm-cool curves are based on a single group only. Recognition of three genetic sequences by Abbink et al., 2006 enabled an improved reconstruction of the geological history. The sequences can be correlated with major changes in sea-level and climate, and are bounded by well defined dis- and unconformities driven by regional tectonics. The improved stratigraphic detail and reliability, new facies and age information of the successions, and insights on the tectonostratigraphic development of the northern Dutch offshore area form the basis of the present revision and update of the Stratigraphic Nomenclature (Munsterman et al., in press).

Keywords: sporomorphs, dinoflagellate cysts, nomenclature, North Sea.

SS26-O06 (367)

Assessment of the carbon stable isotope composition of pollen as an ecophysiological indicator in the paleorecord

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Pollen-inferred variation in the composition of plant communities in the paleorecord is often explicitly or implicitly hypothesized to result from the influence of shifting environmental conditions on plant ecophysiology. However, testing such hypotheses remains difficult, as there exist few independent indicators of changes in paleophysiology. One promising approach for addressing this issue is $\delta^{13}C$ analysis of sporopollenin. Recent innovations that greatly increase sample throughput and the feasibility of this approach include (1) isolation of pollen from sediments using micromanipulation and (2) $\delta^{13}C$ analysis of sub-nmol quantities of carbon. This presentation uses published and unpublished results to highlight two areas in which sporopollenin $\delta^{13}C$ provides quantitative ecophysiological information relevant to interpreting records of grassland responses to environmental change. First, recent studies using herbarium specimens and surface sediments show that individual grains of pollen from the grass (Poaceae) family, which are typically morphologically indistinct beyond the family level, have distinct $\delta^{13}C$ values thus enabling determination of the relative abundance of C_3 and C_4 grasses on the landscape. C_3 and C_4 grasses differ greatly in their physiological processes and the increased taxonomic and physiological information provided by $\delta^{13}C$ of grass pollen provides opportunities to address new paleoecological questions. Second, $\delta^{13}C$ of sporopollenin may enable assessment of variation in the gas exchange physiology of C_3 plants since carbon isotopic discrimination (Δ) during photosynthesis in C_3 plants is influenced by the ratio of intercellular to atmospheric CO_2 concentrations (C_i/C_a), which reflects the proportion of net photosynthetic assimilation and stomatal conductance. To address this idea I measured $\delta^{13}C$ of small quantities (~25 grains/sample) of sporopollenin obtained from herbarium specimens of five species of *Ambrosia* and *Artemisia*, C_3 plants whose pollen types are common in sediment records from grass-dominated ecosystems. Estimates of Δ were compared with measures of plant water availability, including monthly precipitation, vapor pressure deficit, and the Palmer Drought Severity Index. The results indicate significant relationships between sporopollenin Δ and one or more climate parameters for each species, which provides confidence for using Δ as an indicator of community-level moisture-stress. Such an approach could be used to assess enigmas about the Holocene vegetation history of the northern Great Plains of North America, as well as questions about how C_i and C_i/C_a, and therefore gas exchange physiology, vary through time.

Keywords: C_3 photosynthesis, C_4 photosynthesis, micromanipulation, spooling wire microcombustion.

SS26-O07 (297)

The Permo-Triassic transition in western Pangea - A first sign of plant life

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Virtually nothing is known about the paleoenvironmental changes during the Permo-Triassic transition (PTB) in the western and central part of tropical Pangea, as we lack good macro- or microfloral fossil records. Sedimentary strata from the Panthalassan continental margin of tropical Pangea outcrop in Caprock Canyons State Park in northern Texas. Fluvial sandstones and overbank mudstones of the Quartermaster formation likely preserve the PTB, as determined by U-Pb dating of single crystal zircon analyses and Ar-dating of biotite in volcanic ashes. In addition, minute quantities of enclosed organic matter preserve chemostratigraphic d13C trends expected close to the PTB. Caprock Canyons' sedimentary rocks, which are typical redbed formations deposited under oxidizing conditions, have yet to yield fossil pollen and are considered to be barren with respect to plant fossils. Yet, when the same samples were processed according to standard phytolith extraction techniques, numerous fossil vascular plant forms were discovered. In addition, we have recovered the first plant macrofossils from the Quartermaster fm in the form of wood petrifications. Preliminary analysis of the samples revealed that almost all samples contain phytoliths. Twenty-three morphotypes were recognized, most notably those with imprints of circular boarded pits that are characteristic features of coniferous wood macrofossil petrifactions found in the same section, suggesting that conifer-containing vegetation was present along the coastal Panthalassa margin of Pangea during the Early Triassic, post-Permian mass extinction. These finds, both phytoliths and wood, are the first evidence for plant life in this region. If the Quartermaster fm would prove to be stratigraphically conformable, then these results imply that, contrary to what has been generally suggested, the Panthalassa margin of Pangea was not barren, but preserved woodland ecological elements throughout the time period crossing the PTB. For our future work we will focus on establishing the botanical affinity of the encountered phytolith morphotypes, increasing our sample set, and exploring the phytolith data set as a biostratigraphic tool.

Keywords: end-Permian crisis, paleobotany, phytoliths, fossil wood, Texas.

SS26-O08 (571)

Generalized dissimilarity modeling (GDM) of late-Quaternary variations in palynological compositional dissimilarity

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In paleoecology and paleoclimatology, compositionally dissimilar fossil assemblages usually indicate dissimilar environments; this relationship underpins assemblage-level techniques for paleoenvironmental reconstruction such as mutual climatic ranges or the modern analog technique. However, there has been relatively little investigation into the form of the relationship between compositional dissimilarity and climatic dissimilarity. Here we apply generalized dissimilarity modeling (GDM; Ferrier et al. 2007) as a tool for modeling the expected non-linear relationships between compositional and climatic dissimilarity. We use the CCSM3.0 transient paleoclimatic simulations from the SynTrace working group (Liu et al. 2009) and a new generation of fossil pollen maps from eastern North America (Blois et al. 2011) to 1) assess the spatial relationships between

compositional dissimilarity and climatic dissimilarity and 2) whether these spatial relationships change over time. We used a taxonomic list of 106 genus-level pollen types, six climatic variables (winter precipitation and mean temperature, summer precipitation and temperature, seasonality of precipitation, and seasonality of temperature) that were chosen to minimize collinearity, and a cross-referenced pollen and climate dataset mapped for time slices spaced 1000 years apart. When GDM was trained for one time slice, the correlation between predicted and observed spatial patterns of community dissimilarity for other times ranged between 0.3 and 0.73. The selection of climatic predictor variables changed over time, as did the form of the relationship between compositional turnover and climatic predictors. Summer temperature was the only variable selected for all time periods. These results thus suggest that the relationship between compositional dissimilarity in pollen assemblages (and, by implication, beta diversity in plant communities) and climatic dissimilarity can change over time, for reasons to be further studied.

Keywords: Beta diversity, Generalized Dissimilarity Modeling, Holocene, North America, late Quaternary.

SS26-O09 (90)
Putting pollen on the map: new techniques in spatial analysis

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The increasing development of public databases of fossil pollen data has made available a new resource for palynological research based on multi-site analysis that allows us to view the palaeoecological record in an increasingly integrated manner through both time and space. This new perspective presents new opportunities to understand past changes in climate, vegetation and land use, through improved spatial and temporal resolution, but also better integration with models of the same earth system processes. A series of examples from Europe and the Northern Hemisphere during the Late Quaternary are used to illustrate the past, present and future of this expanding research area.

Keywords: databases, mapping, late Quaternary, earth system modeling.

SS26-O10 (555)
An early Permian vegetational Pompeii: Forest reconstruction, paleoecology, and paleobiogeography

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Due to preservational biases most reconstructions of past vegetation are largely conceptional (rather than actual) in nature. Only catastrophically preserved forests from the deep past offer a rather

unbiased window into the composition and ecology of ancient vegetations. Our finding of a peat-forming forest preserved in an early Permian volcanic air-fall tuff from Inner Mongolia allows a quantitative spatial reconstruction of actual sites in three plots of together over 1000 m^2. The flora was dominated by Marattialean tree ferns, tree lycopsids, and Noeggerathiales, a generally rare group of extinct spore-bearing plants of uncertain systematic position. This vegetational Pompeii is unique in offering a confirmation of Permian coal swampy community, showing the floral ecology, for instance forest heterogeneity including the first site ever recorded that was dominated by Noeggerathiales, and ecological gradients, mostly notably the separation of the canopy plants *Sigillaria* and *Cordaites*. The composition is both similar and distinctly different from that recognized in floras of the same time interval in Europe or North America. This swamp forest reveals clearly the complexity of Late Paleozoic vegetation and contributes significantly to a more complete understanding of paleoecology and paleophytogeography of tropical vegetation of the early Permian.

Keywords: coal swampy community, volcanic ash, Permian, Wuda.

SS26-P01 (126)

First high resolution marinopalynological stratigraphy of Late Quaternary sediments from the Black Sea

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Spores, pollen and dinoflagellate cysts of Late Quaternary sediments were analyzed from Giant Gravity Core 18 from the Black Sea continental slope, recovered from a water depth of 971 m. The investigated length of the core is 203.5 cm. It includes 3 lithological units: light grey clay, sapropels and coccolith-bearing ooze. The core was sampled at 5 cm intervals. Sampling from 130.5 to 140.5 cm was carried out at every 1 cm. AMS radiocarbon dating of bulk organic carbon was performed on 18 selected sediment layers. This chronological data gave opportunity for the first high-resolution pollen stratigraphy of Late Quaternary sediments from the western Black Sea area to be presented. The percentage spore-pollen diagram is divided into 6 local pollen assemblage zones. The trends in the vegetation dynamics and climate changes and the early history of migration of the majority of the arboreal taxa that nowadays occur in the Eastern Balkan Range were traced out. The palynological record suggests that open oak forests were spread in the Eastern Balkan Range at the beginning of the Holocene and shows early migration of the major temperate arboreal species such as *Quercus*, *Ulmus*, *Tilia* and *Carpinus betulus*. This vegetation palaeosuccession continues with the spreading of mixed oak forests from 8950 until 2620 cal. yrs BP followed by a destructive changes due to human impact and climate deterioration. A cooling of Holocene climate that is well known as the "8200 yrs cold event" is identified for the first time in marine core records from the Black Sea. The assemblages of dinoflagellate cysts and acritarchs were investigated to provide a reconstruction of surface seawater salinity and surface seawater temperature changes. Two main dinoflagellate cyst assemblages, one dominated by fresh- to brackish water species such as *Spiniferites cruciformis* and *Pyxidinopsis psilata* and a subsequent one, that is characterized by euryhaline marine Mediterranean species such as *Lingulodinium machaerophorum*, *Spiniferites belerius*, *Spiniferites bentorii*, *Operculodinium centrocarpum* and acritarchs *Cymatiosphaera globulosa* testified a change in SSS from low salinity (< 7 ‰) to present day conditions after 7990 cal. yrs BP. Substantial freshening of Black Sea surface waters at 2570 cal. yrs BP is established and connected with the transition from a relatively dry and warm to relatively cold and wet climate. Based on combined lipid biomarkers and fossil DNA analysis of alkenones of *Emiliania huxley* a gradual cooling from 19ºC to 15ºC at the

coccolith-bearing ooze is identified.

Keywords: pollen, dynocysts, 8.2ka cold event, vegetation history, palaeoecology.

SS26-P02 (547)

Biofacies characterization: the first step towards property prediction in shale gas exploration. An example from the Posidonia Shale in The Netherlands

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A key factor in shale gas exploration is being able to predict the reservoir properties. Unfortunately, most organic-rich shales are heterogeneous in a vertical and horizontal sense. The first step towards property prediction is biofacies characterization. A palynological and geochemical study is carried out on three wells on an onshore-offshore transect. Based on the results it is concluded that anoxia lasts 1.5 million years longer in the proximal location. The main driver for stratification of the water column appears to be fresh water influx. The most intense water column stratification, associated with the highest TOC, occurs around the so-called Early Toarcian Carbon Isotope Event. The palynological results indicate a rapid change in climate from warm and arid to humid and a gradual return to arid again. Two types of algae dominate the Posidonia: Tasmanites, with a high Hydrogen Index (HI), and “sphericals” with a low HI. Tasmanites mark the transition from normal marine to stratified marine conditions and are more abundant in the distal setting. The “sphericals” dominate the most intensely stratified marine intervals. The “sphericals” are probably better adapted to prolonged low salinity conditions. The next step is linking biofacies to physical properties and construct a predictive property model.