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DINOFLAGELLATES AND POLLEN IN MARINE LAMINATED SEDIMENTS FROM LA PAZ BASIN, BAJA CALIFORNIA SUR—A PRELIMINARY STUDY

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Marine laminated sediments contain detailed information on the physicochemical and biological conditions in the basin where they were deposited. The palynomorphs preserved within the biogenic content of these sediments help us estimate some paleoceanographic parameters. Studies of marine sediments from the Gulf of California have been based mostly on the analyses of foraminifera, diatoms and some descriptions of dinoflagellates. So far, no integrated paleoclimatological studies have used the distribution of dinoflagellates and pollen in this region.

The 62 samples analyzed are part of a 50 cm core, taken at a depth of 745 m in the La Paz Basin, Baja California Sur, Mexico (24 23.56 N; 110 04.16 W). Radiocarbon dates indicate that the core encompasses approximately 1000 years (from 928 to 1982 AD). The samples were treated with the conventional palynological technique, and *Lycopodium* tablets were used to estimate the number of specimens in the sediments.

We found about 21 marine palynomorph taxa, including dinoflagellates, acritarchs, microforaminiferal linings test, scolecodonts and copepod eggs. Of these, there are 14 species of dinoflagellates, 12 from the order Gonyalaucales, and 2 of the Peridiniales. The most abundant taxon was *Spiniferites*, with the species *Spiniferites ramosus* appearing in almost all samples. Most of the dinoflagellate species are inner-outer neritic, with some from oceanic environments.

Also 22 pollen taxa were found. The most abundant were the grasses and the pines. Other common taxa, like *Agave*, *Atriplex* and *Aster* probably originated from nearby areas, since they are distributed in the coasts of Baja California Sur and Sonora. Pollen taxa like *Pinus* and *Abies*, were probably transported southward by air, from Sierra San Pedro Martir.

Two palynomorph intervals can be distinguished. The first one, dominated by the dinoflagellate *Spiniferites ramosus* spanned the period from 973 to 1303 AD; the second, marked by an increase in Gramineae, spans the period from 1370 to 1976 AD, and is approximately synchronous with the little ice age (ca. 1300–1850 AD). The abundance of dinoflagellates in the lower interval indicates a lower influx of terrigenous material into the basin. The increase in Gramineae in the upper interval results from more frequent and/or intense rainfall.

A JURASSIC OCCURRENCE OF THE ALGAL COENOBIUM *SCENEDESMUS*

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Scenedesmus Meyen 1829 is an extant fresh-water representative of the Chlorophyta (Order Chlorococcales, Family Hydrodictyaceae) with an oldest reported occurrence in Early Cretaceous (Barremian). This alga is characterized by a linear arrangement or chain of slightly arcuate elongated cells that have may have varying ornamentation at the extremities of the cells. Fossil and present day occurrences of *Scenedesmus* indicate fairly wide paleogeographic and geographic distribution.

Several specimens clearly attributable to *Scenedesmus* were encountered in the Late Jurassic section from a well in Rains Co., Texas, USA. Although isolated from ditch cuttings the specimens are considered to be in place based on their visual maturation index and their absence in overlying sediments.

Scenedesmus was present in a mixed assemblage of pollen, spores, and a few dinoflagellate cysts. This mixed assemblage indicates a marginal marine environment, with some fresh-water input, as suggested by the presence of the colonial alga.

ARE POLLEN COEFFICIENT VALUES IN MELISSOPALYNOLOGY VALID?

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One of the goals of melissopalynology is to determine the floral resources utilized by honeybees in the production of honey. Because some types of commercial honey are preferred over others, those premium types are in high demand and can be sold for higher prices. Verification of these preferred (premium) types of honey is often difficult because many of them come from nectar sources in plants that are either weak pollen producers or have pollen that is traditionally under-represented in honey. In an effort to identify and verify these premium types of honey, researchers developed various methods for "correcting" the relative pollen data. These methods produce what is known as pollen coefficient (PC) values.

Pollen coefficient values are currently being used throughout the honey industry to verify honey types produced from premium types of honey. We have examined the historical development of PC values, the reliability of using PC data, the flaws inherent in the development of various types of PC data, and the steps we believe must be taken to formulate new sets of PC values that will be reliable and will be universally accepted for the verification of honey types.

BALSAS GROUP PALYNOSTRATIGRAPHY: PALAEO-ENVIRONMENTAL AND CHRONOSTRATIGRAPHIC IMPLICATIONS, ZACAPALA AND COATZINGO MUNICIPALITIES, PUEBLA STATE, MEXICO

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In this survey, two sections were analyzed in Zacapala (18°27' N, 97°16' W) and Coatzingo (18°31' N, 98°08' W) municipalities, Puebla state, Mexico. The sections studied belong to the Tepexi-Coatzingo basin formed by lacustrine silts and volcaniclastic rocks whose geologic age has been debated.

The palynological assemblages, represents several types of communities, such as forest of *Picea*, forest of *Pinus-Quercus*, cloud forest represented by Juglandaceae, and a deciduous forest with Asteraceae and Poaceae. They indicate the existence of cold temperate to tropical climates, distributed in an altitudinal gradient.

Both the Zacapala and Puente Atoyac sections, highlight the presence and diversity of the Asteraceae as well as the abundance of Poaceae. Additionally, in Puente Atoyac are present two species of *Aglaoreidia*; index taxa for the Eocene-Oligocene boundary of England.

Palaeoenvironmentally, both localities represent an ancient lake where abundant sapropel with fragments of fresh water algae were deposited. These facies can be correlated with other units previously studied in the Coatzingo-Tepexi basin. These findings confirm the existence of a large palaeolake (Coatzingo-Tepexi) located near sea level, and associated with the movement of the Chortis block.

Based on the age ranges of certain taxa these sediments can be tentatively dated at around the Eocene-Oligocene boundary. It's important to clarify that this age assignment is based not only on *Aglaoreidia* but also other chronostratigraphically important taxa like *Engelhardtia* (*Momipites* spp.) and *Eucommiidites*. The chronostratigraphic results allow the assignment of these units to part of the Balsas group.

With additional studies of the palynomorph assemblages it should be possible to develop an understanding of Tertiary flora of Mexico. This will help to test hypotheses related to the exchange of plants between Laurasia and Gondwana and to unravel the historical geology at southern Mexico.

AN EARLY CRETACEOUS LINEAGE OF COMPLEX CHORATE DINOFLAGELLATES FROM MADAGASCAR

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An Early Cretaceous phylogenetic lineage of complex chorate dinoflagellates that contains many undescribed forms is observed from a well drilled in the northern part of Morondava basin in western Madagascar. Eight distinct species plus many interspecific variants/hybrids of *Amphorula* represented by over 250 well-preserved specimens are recognized. The entire lineage is recorded from a section that is interpreted as Valanginian to Berriasian age based on the dinocyst assemblage associated with the lineage. A similar assemblage was previously reported from the same age interval from Australia. Six zones are differentiated based on the rapid evolution of this morphological group.

One of the species in this group, *Amphorula palmula* Davey, was previously reported elsewhere and assigned to the genus *Systematophora*. A detailed morphological study reveals, however, that the lineage, including the species, should be more appropriately assigned to *Amphorula*, based on the semi-circular process expression, which is a characteristic not possessed by *Systematophora* but unique only to *Amphorula*. Seven new species are proposed.

PALYNOLOGY: SOME HISTORICAL THREADS IN COAL/ OIL EXPLORATION

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Spores/pollen of plants were first illustrated from coal by Witham, 1833. Ehrenberg, 1836, discovered that some rocks, like flint, are constituted of microfossils. Mantell, 1845, demonstrated that dinoflagellates in chalk are organic. He published pictorial atlases of xanthidia, 1850,1854. Ehrenberg's monumental tome "Mikrogeologie" appeared in 1854. During the next 50 years, Schulze and Reinsch described maceration techniques to free spores from coal and other rock, which opened new avenues of research. Dawson published "spore cases" from Nova Scotia coals and Bennie and Kidston's treatise on megaspores was published in Scotland. Other palynomorphs were identified during late 19th century: "acritarchs" by M.C.White in New York; Hind described polychaete jaws from Paleozoic of North America, 1879-1886; and Reinsch identified cysts of Xanthidia as dinoflagellates, 1905.

Thiessen, 1913-1937 analyzed spores *in situ* from many coal seams and correlated some seams. von Post, 1916, and Erdtman showed that analytical diagrams of pollen in peat are useful for identifying environments and climate. "Pollen Analysis" spread

rapidly in America by Cain, Sears, Auer, Wilson, Antevs, Potzger, Buell, and others, 1937-1954. The "Pollen Analysis Circular", 1940-1954, a newsletter, brought together more than 200 palynologists from 22 countries. Several pollen analysts (Schopf, Wilson, Kosanke, Cross, Spackman) switched to coal studies in ensuing years. In the late 1920s and early 1930s, Potonié and Thomson studied European "brown coals." Pioneer studies of chitinozoa (Eisenack) and "hystrichospheres" (Wetzel) were published. Russian palynology exploded in the 1930s with Lyuber, Valtz, and many others with numerous Atlases and palynofloras.

Sanders' 1937 paper was the first on palynomorphs in crude oil (Romania and Mexico). Dutch geologists introduced palynology to Shell exploration with consultants (e.g., Potonié) and with new staff from 1946 to 1956. Labs were established worldwide, 1956-1966. Hoffmeister and Wilson, 1946, correlated two Texas wells by palynology. Tschudy (Venezuela) and Durham (Columbia) applied palynology to correlation in the late 1940s.

REVISION AND CALIBRATION OF THE POLLEN AND SPORE ZONES OF THE PALEOGENE OF VENEZUELA AND THEIR APPLICATION TO CORRELATION IN THE WESTERN MARACAIBO BASIN

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The northern South America pollen and spore zones proposed by Jan Muller and his colleagues in 1985 and 1987 are revised. The practice of defining zonal boundaries with more than one datum has led to overlaps in the zones. These intervals of overlap are assigned to new subzones or redefined with a single datum.

The following subzones are proposed: Subzone 15A (*G. gemmatus* Subzone), the interval between the basal occurrence of *Gemmastephanocolpites gemmatus* and the top occurrence of *Spinizonocolpites baculatus*. Subzone 15B (*Bombacacidites annae* Subzone), the interval between the top occurrence of *S. baculatus* and the top occurrence of *G. gemmatus*.

Other problematic zonal boundaries exist between Zones 15 and 16, Zones 17 and 18, Zones 20 and 21, and Zones 23 and 24. These are simplified by defining them with a single datum. We present a new correlation of the pollen and spore zones to the marine time scale. This is the result of integrated studies of pollen and spores with nannofossils, foraminifera, and some magnetostratigraphy. This correlation demonstrates that a regional stratigraphic break exists between the Paleocene Zone 16 and the early Eocene Zone 17, with much of the Late Paleocene absent over most of western Venezuela.

The revised zonal scheme is applied to the correlation of a transect of well and outcrop sections between the Perijá Mountains and the western shore of Lake Maracaibo. This crosses the Totumo/El Palmar High, which was uplifted in the early Middle Eocene limiting sedimentation to the northern parts of the Lake Maracaibo Basin. Renewed tectonic activity and associated transgression allowed sedimentation to the south of the high in the late Middle Eocene. In the latest Middle Eocene, a plate collision to the south caused a re-configuration of the basin with a new depocenter forming to the south in Colombia.

TECTONICS AND CLIMATE AS CONTROLLING FACTORS ON DEPOSITION OF SALINE LACUSTRINE SEDIMENTS IN THE EOCENE GREEN RIVER FORMATION OF FOSSIL BASIN, WYOMING

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Fossil Basin was a tectonically active, intermontane basin formed near the eastern edge of the Idaho-Wyoming thrust belt during the Laramide orogeny. The upper unit of the Fossil Butte Member of the Eocene Green River Formation was formed during the late stages of lacustrine sedimentation in Fossil Basin. The upper unit grades from massive and bioturbated calcimicrite at the base into kerogen-rich, massive dolomicrite and kerogen-rich, laminated dolomicrite (i.e., oil shale) in the middle part, and then into mudstone and kerogen-poor dolomicrite toward the top. The two primary oil shales in the middle of the upper unit represent major transgressions of the lake. Calcite pseudomorphs after saline minerals (i.e., trona) occur in the oil shales and some of the dolomicrite units. The overall sedimentology of the upper unit suggests deposition in a saline-alkaline lacustrine environment. The saline geochemistry of this unit suggests deposition in an evaporitic environment with a fairly dry climate.

Palynological analysis of oil shales in the upper unit provides additional insight into climatic conditions during deposition of the upper unit. The overall palynoflora of the upper unit suggests a slightly drier climate than earlier in the lake history. Vegetation from the surrounding uplands becomes predominant, while the lake margin vegetation is poorly represented. However, the occurrence of *Platycarya* in the oil shales suggests a climate of high humidity and abundant summer rainfall during the transgressive facies of the upper unit in contrast to the evaporitic environment suggested by the sedimentology and geochemistry.

This apparent contradiction of sedimentological and palynological evidence was resolved by a closer examination of the geological context for the late stages of lacustrine deposition in this basin. The upper unit fits into the underfilled lake basin category in the three end-member classification system of lake basins (i.e., overfilled, balanced-fill, and underfilled). High-frequency wet-dry cycles with minimal fluvial input characterize underfilled basins. In this context, the palynological data corroborate the sedimentological evidence for wet cycles during deposition of the upper unit and its classification as an underfilled basin.

OLIGOCENE–PLIOCENE DINOFLAGELLATES AND SEQUENCE STRATIGRAPHY OF THE SONDA DE CAMPECHE, MEXICO

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Palynologic analyses of 121 cutting samples of the Chac Mool-1 well has allowed us to assign ages and interpret the environments of deposition of a section in the Sonda de Campeche. Fifty-one marine and 26 continental palynomorphs suggest environments of deposition ranging from inner to outer neritic. An analysis of the gamma ray shows regressive and transgressive events.

Ten sedimentary cycles are defined. The LAD of *Homotryblium tenuispinosum*, *H. abbreviatum* and Glaphyrocysta *exuberans* indicate the Oligocene-Miocene boundary, and those of *Selenopemphix nephroides* and *Sumatradinium* sp. indicate the Miocene-Pliocene boundary. The Early-Late Pliocene boundary is indicated by the LAD of *Hystrichosphaeropsis obscurum.*

Comparison between the Chac Mool-1 well stratigraphic column with the eustatic sea level chart enables us to construct a chronostratigraphic framework for the Late Oligocene to Late Pliocene interval in the Sonda de Campeche. It includes 21 chronostratigraphic datums.

PALEOZOIC PALYNOLOGICAL ASSEMBLAGES FROM THE COLOMBIAN LLANOS BASIN

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The Colombian Llanos Basin is a structural depression located in the eastern edge of Colombia. The sedimentary sequence of this depression is clearly divisible on a regional scale into three Units, palynologically dated as Paleozoic, Cretaceous and Tertiary. The Paleozoic Unit presents three depocenters filled with more than 15,000 ft of sediment.

The thick Paleozoic sedimentary sequence yielded palynological assemblages of Pre-Cambrian (Vendian), Middle to Early Cambrian, Late Cambrian, Early Ordovician, Middle to Late Devonian and Early Carboniferous ages. Silurian sediments have not been reported in the Basin, but they outcrop in the Eastern Cordillera and could be present in the foothill areas, although they have not been penetrated in the wells drilled to date.

Paleozoic sediments have received little attention up to date, probably because they have been erroneously considered as metamorphic strata and therefore the economic basement of the Basin. Palynological data clearly shows that the Paleozoic is made up of unmetamorphosed sediments and there may be some hydrocarbon potential in this thick sequence contrary to present opinion.

BIOSTRATIGRAPHY AND PALAEOCEANOGRAPHY OF EOCENE–OLIGOCENE DINOFLAGELLATE CYSTS FROM THE NORWEGIAN–GREENLAND SEA

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The Eocene–Oligocene interval is a critical period in earth's history, marking a major climatic transition from greenhouse conditions in the Cretaceous to icehouse conditions in the Cenozoic. To understand the nature and timing of Eocene to Oligocene climatic and environmental change in the Norwegian-Greenland Sea previously cored sections need to be studied at a greater resolution with enhanced techniques; these can provide better magnetobiostratigraphic control with abundant age-diagnostic assemblages.

In contrast to previous dinoflagellate cyst biostratigraphic studies from the Norwegian-Greenland Sea, the high-resolution study employed for this project has resulted in a dinoflagellate cyst assemblage that shows affinities with those from the North Sea and European reference sections. This has enabled an indirect correlation with the global standard nannoplankton (NP) zonal scheme. In particular, sediments from Site 913B and 338 contain several dinocyst species have not been previously recorded outside the North Sea. These species include: *Cerebrocysta magna*, *Phthanoperidinium regalis, Phthanoperidinium distinctum* and *Areosphaeridium michoudii*. The presence of abundant age-diagnostic species has enabled the development of a new high-resolution biostratigraphy for the Norwegian-Greenland Sea against which the climatic perturbations can be set. This is particularly important, as the calcareous microfossil groups that are usually used for biostratigraphy are generally absent in these high latitude Eocene-Oligocene sediments due to dissolution. In addition, the development of a new magnetic reversal stratigraphy for Site 913B, will hopefully determine the placement of the Eocene-Oligocene boundary in this core and firmly tie the biostratigraphy into the global timescale for this period.

Results from palynofacies and dinocyst analyses show the Early Eocene Norwegian-Greenland Sea being fully marine, with surface water exchange between the North Atlantic and adjacent seas. Several basin-wide episodes of increased palaeoproductivity have been recorded during the mid to later Eocene as indicated by abundance peaks in *Phthanoperidinium* spp., and will be the focus of future research.

ORDOVICIAN SCOLECODONTS (ANNELIDA; POLYCHAETA) OF NORTH AMERICA; PAST, PRESENT, AND FUTURE RESEARCH

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Scolecodonts, jaws of polychaete annelid worms, are abundant microfossils in sedimentary rocks from the Ordovician onwards. Although their research history extends back to the middle of the 19th century, scolecodonts are not particularly well known compared to many other fossil groups. Much of the pioneering work on Ordovician scolecodonts in North America was carried out on specimens recovered from strata exposed in northeastern U.S.A. and southeastern Canada. Being the isolated parts of multi-element polychaete jaw apparatuses, which rarely are preserved as articulated clusters, the historical scolecodont taxonomy was, with very few exceptions, single element-based. Hence, differently shaped jaws belonging to one and the same species were described and named independently of each other. This is by no means unique, and closely resembles the research history of other fossil groups, particularly those of multi-sclerite bearing animals. In the middle of the 20th century an apparatus-based taxonomy arose independently of the single element-based one, and, thus, two classification systems were simultaneously in use. Merging of these classification systems is crucial for our understanding of the evolution of the Polychaeta and is also required to meet the rules of the ICZN. Estimates of temporal and spatial distributions as well as taxonomic diversity are impossible to make if based on the plethora of described single element "species". Not until the faunas are described, applying a natural multi-element taxonomy, can any reasonably safe conclusions be drawn. Otherwise there is an overwhelming risk that the number of taxa occurring in a particular area and stratigraphic interval is highly exaggerated.

An extensive collection of Cincinnatian (Upper Ordovician) scolecodonts from the type Cincinnatian region of Indiana, Ohio, and Kentucky is currently under study. Some 40 to 50 multi-element polychaete species belonging to a dozen families can be identified. *Oenonites* Hinde, *Kettnerites* Zebera, *Ramphoprion* Kielan-Jaworowska, *Protarabellites* Stauffer, "*Arabellites*" Hinde, *Kalloprion* Kielan-Jaworowska, *Leptoprion* Kielan-Jaworowska, and *Hadoprion* Eriksson and Bergman comprise the most common and/or characteristic genera. This collection serves as a good basis for not only a revision of single element taxa described in previous papers, but it also helps elucidate on the intercontinental distribution of Ordovician polychaete taxa. Although nearly all families and genera encountered occur also in coeval strata of Baltica, there are some notable differences in overall taxonomic composition. For example, placognath and ctenognath types, as well as members of the Polychaeturidae, are considerably less common in Laurentia whereas hadoprionids have not been identified in Ordovician deposits in Baltica. Distinct faunal associations and some rapidly evolving taxa, particularly *Oenonites* species, suggest biostratigraphic utility. Ultimately, a scolecodont biozonation for the Upper Ordovician of North America seems attainable.

A MIO-PLIOCENE PALYNOFLORA FROM THE EASTERN CORDILLERA, BOLIVIA: IMPLICATIONS FOR THE UPLIFT OF THE CENTRAL ANDES

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An assemblage of 33 fossil pollen and spores was recovered from the 3600 m high Pislepampa locality, Eastern Cordillera, Bolivian Andes. The plant microfossils include *Isoetes*, *Lycopodium* (3 types), *Cnemidaria*, *Cyathea* (3 types), *Grammitis*, *Hymenophyllum*, *Pteris*, trilete fern spores (2 types), *Danaea*, monolete fern spores (4 types), *Podocarpus*, Gramineae, Palmae, *Ilex*, cf. *Oreopanax*, *Cavanillesia*, cf. *Pereskia*, Compositae (3 types), Ericaceae, *Tetrorchidium*, and unknowns (3 types). The diversity of Compositae suggests a maximum age around the Miocene-Pliocene boundary, that is, 6–7 Ma. All members presently grow in the cloud forest that occurs between MATs of 10-20°C. The Pislepampa flora probably represents the lower limits of this forest because Palmae and Bombacaceae ranging up from the lowlands are present as a minor component, and the leaves all have entire margins. Presently the lower limits of the cloud forest has MATs of ~ 20°C, MAP of 1000–1500 mm, and that part containing most of the identified genera of fossil pollen is found at elevations of 1200–1400 m. When various factors are taken into account (climate, isostatic rebound), the paleoelevation estimate suggests that from 1/3 to 1/2 of the uplift of the Eastern Cordillera had occurred by the beginning of the Pliocene. This estimate is consistent with other paleoelevation estimates from the Central Andes.

SALINITY, DINOFLAGELLATE CYST GROWTH AND CELL BIOCHEMISTRY

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Dinoflagellates are an extremely diverse group; however, L*ingulodinium polyedrum* (Stein) Dodge may be regarded as a model dinoflagellate. It is single celled, photoautotrophic, marine, planktonic, exhibits circadian rhythmic cellular functions of swimming behaviour, cell division, photosynthetic activity and bioluminescence. The hypnozygote or cyst wall is composed of dinosporin, enabling preservation in the fossil record. Numerous studies from artificial laboratory and natural environmental conditions have associated reduced process length of this and other dinoflagellate cysts whose walls are also composed of dinosporin. Unfortunately, although such observations have been common and recent work has linked salinity to process length, the rationale has been less forthcoming.

A possible explanation for this phenomenon is salinity affects the dynamics of the encystment mechanism causing premature

rupture of the outer membrane that encompasses the cell during cyst growth. In laboratory experiments, *Lingulodinium polyedrum* cells encysting in salinities of 20 and 35 were observed and process growth and membrane expansion rates were calculated. The resulting morphometric data implied membrane and process length growth rate was independent of salinity. Further laboratory experimentation found evidence that intracellular concentrations of dinosporin precursor material or 'building blocks' are likely to be intrinsically linked to the volume of dinosporin manufactured by each cell. One such precursor is believed to be tocopherol; commonly known as vitamin E. Motile cells cultured in salinities of 15 generally had a lower concentration of tocopherol than motile cells cultured in a salinity of 32. The evidence suggests the existence of a relationship between motile cell biochemistry, hypnozygote process length, dinosporin production, and salinity.

NEOGENE DINOFLAGELLATE ASSEMBLAGES IN THE SOUTHERN GULF OF MEXICO

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In the southern part of the Gulf of Mexico, approximately 3000 m of mostly marine sediments have been deposited since the Late Oligocene. Age assignments of these sedimentary sequence are based on marine and terrestrial palynomorphs, and calibrated with results from other microfossil groups. Analyses of the environmental signature of the dinoflagellates recovered indicates four distinct assemblages in the sequence, these are:

- *Homotryblium* assemblage, found in upper Oligocene strata, represents shoreline to inner neritic environments. This assemblage also contains *in situ* and reworked specimens of *Cordosphaeridium* and *Glaphyrocysta*.
- *Selenopemphix* assemblage, found mostly in lower Miocene strata, represents inner to middle neritic environments. This assemblage is usually sparse and also contains *Polysphaeridium*, *Lejeunecysta* and *Operculodinium*.
- *Impagidinium* assemblage, found in middle to upper Miocene strata, represents middle to outer neritic environments. This assemblage is normally sparse, and also contains *Nematosphaeropsis* and sparse *Operculodinium*.
- *Polysphaeridium* assemblage, found in upper Miocene to Pleistocene sediments, represents inner to middle neritic environments. This assemblage is usually abundant, and also contains common *Lingulodinium* and several species of *Spiniferites*.

MIDDLE EOCENE DINOFLAGELLATES AND PALINOSTRATIGRAPHY FROM WESTERN VENEZUELA AND ITS RELATION WITH REGIONAL TECTONICS

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In western Venezuela, south of the Andes, lower Tertiary marine strata locally overlie a Cretaceous sedimentary sequence. This unconformity is related to the emplacement of the Lara Nappes and the eastward movement of the Caribbean Plate along the northwestern border of South America. Near the El Baul arch, the underlying Cretaceous Burguita sandstones are probably late Maastrichtian in age and correspond to Third Order Cycle UZA-4.5 (71–68 Ma).

Core samples from the overlying Gobernador and Paguey Tertiary strata contain a diverse and abundant microflora including dinoflagellates, pollen, and calcareous nannofossils. The palynomorph taxa observed include the dinoflagellates *Batiacasphaera compta*, *Cordosphaeridium exilimurum*, *Cribroperidinium tenuitabulatum*, *Diphyes colligerum*, *Homotryblium plectilum*, *Lejeunecysta fallax*; the acritarch *Cyclopsiella elliptica*, and the pollen species *Retitricolporites guianensis* and *Bombacacidites soleaformis*. The fossil assemblages also include the nannofossils *Reticulofenestra reticulata* (NP16-19) and *Chiasmolithus solitus* (NP12-16) assigning the samples to Zone NP16 (late Middle Eocene). This assemblage indicates a late Middle Eocene age, which corresponds to Third Order Cycle TA-3.5 (42.5–40.5 Ma).

The unconformity between the Cretaceous and Tertiary strata encompasses approximately 25.5 Ma (ca. 68–42.5 Ma) and is recognized regionally. This hiatus is related to a compressive regime in the area, originated by the emplacement of the Lara Nappes in northern Venezuela during Early to Middle Eocene times. These Nappes were forced upon the northern edge of South America by the eastward moving Caribbean plate. At approximately 42.5 Ma, compressive deformation moved to the northeast of the area, causing rapid subsidence and deposition of the Gobernador and Paguey formations.

OXIDATION AND THE PALYNOLOGICAL RECORD

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The ubiquitous occurrence of palynomorphs in marine sediments allows for their use as stratigraphic markers and paleoenvironmental proxies. Their common occurrence can be attributed to their inert chemical composition consisting of a resistant organic compound known as sporopollenin. Despite the resilience of sporopollenin, various palynomorph taxa have been shown to be sensitive to postdepositional oxidation. Previous studies observ-

ing the preservation potential of pollen and dinoflagellate cysts in natural environments have illustrated that some taxa are more vulnerable to degradation by oxygen than others. Our study involves a closer examination of the differential resistance of pollen and dinocysts to oxidation employing a laboratory approach. We have treated marine sediments with an oxidizing agent (H2O2) in a controlled laboratory setting. By varying the exposure time and concentration of oxygen we have obtained a more detailed and quantitative picture of the effects of postdepositional oxidation on pollen and dinocyst assemblages.

Results of our oxidation analysis indicate that overall palynomorph concentration decreases by approximately 50% within the initial 0.5-hour exposure period. Protoperidinioid dinocyst taxa, such as *Brigantedinium* spp. and *Selenopemphix* spp. are most susceptible to decay, disappearing from our assemblages at minimal exposure times and concentrations. On the other hand, several autotrophic (gonyaulacoid) taxa such as *Bitectatodinium tepikiense*, *Spiniferites* spp., and *Lingulodinium machaerophorum* can withstand prolonged oxidation, remaining well preserved in the assemblages until maximum exposure times. Pollen taxa generally exhibit a greater degree of resiliency within marine sediments, with bisaccate pollen being the most resistant, although some become disarticulated after maximum exposure.

Accurate interpretations of the palynological record require not only a qualitative appreciation of the impact of taphonomy on assemblages, but a quantitative way to measure and adjust for this skewing. The more accurate the attempted paleoenvironmental interpretation is (e.g. quantitative reconstructions using transfer functions), the more important it is to determine the relative importance of environmental parameters and taphonomic factors on the palynological assemblage being studied. Especially in continental margin settings, where sea level fluctuations can result in very different preservational potentials and sediment transport over relatively short timespans, erroneous interpretations can result if the role of taphonomy is not considered.

THE EARLY EOCENE FLORAS OF EQUATORIAL LATITUDES: FIRST RECORD OF A TROPICAL RAINFOREST IN GEOLOGIC HISTORY

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There is a long period of global warming across the Paleocene-Eocene transition. Was tropical vegetation affected by this global warming? The diversity, composition, and structure of pollen and spore floras across the Paleocene-Eocene transition of several sections in southern Nigeria and central Colombia were analyzed. A number of techniques were used to analyze the pollen/spore record such as the range-through method, rarefaction, bootstrap, diversity and similarity indexes, and detrended correspondence analysis.

The palynofloral record indicates that the lower to middle Eocene strata contain a significantly higher diversity than upper Paleocene strata. This pattern is maintained after collection biases are accounted for. Early Eocene palynofloras have higher alpha and beta diversities, and a higher equitability than Paleocene palynofloras. During the Early to Middle Eocene, increases in diversity and spore abundance suggest that equatorial climate became wetter. This study documents the first record of tropical floras that are similar in diversity and structure to those of modern lowland tropical rainforests.

MIGRATION AND FORAGING RESOURCES OF *PLUTELLA XYLOSTELLA,* DIAMONDBACK MOTH

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The diamondback moth (DBM) (*Plutella xylostella* Linnaeus) is the most important insect pest of cabbage in Brazil. The larvae feed on the leaves of the cabbage heads leaving holes in them. Because of this damage, consumers reject the cabbage. Cost to control DBM is $120-340 per hectare of cabbage per growing cycle because the cabbage is sprayed every 3-7 days. Some fields even were sprayed when DBM was not present or was in low numbers. Because of the number of insecticide applications, DBM have developed resistance to many insecticides. During DBM research, it was observed that large numbers of DBM adults would sudden appear in fields that were previously free of DBM. Pollen analyses are being used to help determine local and/or long distance migration of DBM and to determine if DBM forage on the flowers of native vegetation. Both scanning electron and light microscopy were used to examine the pollen found on these insect pests. In preliminary results, over five pollen and three spore types have been found in the samples. None of the pollen is from crops grown in the area indicating that DBM adults are moving into cabbage fields from native habitats. The spread of the genes for insecticide resistance is greatly increased when insects migrate from one location to another. Therefore, knowledge of DBM migration, source zones, and foraging patterns is important to help prevent insect resistance and help in control methods.

POLLEN ANALYSES OF THE PARASITIC WASPS *AGATHIRSIA* (HYMENOPTERA: BRACONIDAE)

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The genus *Agathirsia* is a member of a cosmopolitan subfamily of insects that parasitizes larval Lepidoptera (moths and butterflies). The 30 species of *Agathirsia* are found in arid regions of Mexico

and the southwestern United States. These wasps are relatively small, about 6 to 12 mm long. The tongue length of the species of *Agathirsia* ranges from around 0.25 to 5.5 mm. Some species of the family Braconidae, in which the *Agathirsia* belong, have a proboscis and "feed readily" on flowers of the Asteraceae. When fed a carbohydrate food source such as honey or sugar, there is an increase in survival and fecundity of some parasitic wasps. Parasitoid wasps are commonly found feeding on flowers but too few have been observed or collected enough to ascertain a reliable trend in host plant range. We examined 127 specimens of *Agathirsia*: 66 females, 57 males, and 4, sex unknown. Both scanning electron and light microscopy was used for the analyses. Of the 116 pollen types found, 52 were Asteraceae and 7 were Fabaceae. Over 650 pollen grains were counted in the light microscopy samples. Females contained a greater diversity of pollen taxa and more pollen grains; however, there was no significant difference between the sexes. With increased understanding of the needs of these parasitic wasps, it may be possible to utilize them in biocontrol efforts against crop pests such as corn earworm, *Helicoverpa zea*.

PALYNOSTRATIGRAPHY OF EARLY PLIOCENE PETROLEUM RESERVOIRS IN THE SOUTH CASPIAN BASIN—EXAMPLES FROM THE ACG (AZERI–CHIRAG–GUNASHLI) FIELD, OFFSHORE AZERBAIJAN

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High-resolution palynological studies increasingly play an important role in the geological description and modelling of petroleum reservoirs. This is particularly true in the Early Pliocene, Lower Productive Series (Pereriv and Balakhany X reservoirs) of the South Caspian Basin, where the abundance and high diversity of palynomorph assemblages enables particularly detailed stratigraphic subdivision, intra-reservoir correlation and facies description. The results and interpretations of fully quantitative palynological analyses of cored Pereriv and Balakhany X reservoirs in the ACG field, offshore Azerbaijan are presented. A palynofacies model is outlined which enables the recognition of palynomorph and sediment provenance, environments of deposition and climatic fluctuations. This model indicates that the primary reservoirs were deposited in an extensive lacustrine delta system, analogous to the modern Volga delta, whilst interbedded mudstones are predominantly characterised by relatively arid palynofloras deposited in lake settings starved of coarse clastic input. Climatic fluctuations are recognised palynologically at a range of frequencies and are believed to have exerted a major influence on the nature and volume of sediment supply as well as changes in relative lake levels.

The reservoir description of the ACG field has also been significantly enhanced by the palynological characterisation of individual intra-reservoir mudstone units. Hence the specific, distinctive and sometimes-unique palynological assemblage characteristics of a particular mudstone, enable us to differentiate between mudstones of limited local extent from those of field-wide lateral extent (important factors for modelling the barriers and baffles to hydrocarbon flow).

This work on the ACG field is ongoing and is part of a multidisciplinary effort using seismic character, sedimentological core description and petrophysical data to provide realistic parameters for dynamic simulation in sector and full field models. Having established a robust intra-reservoir biozonation the next phase will involve its application in "real time" to assist wellsite operational decision-making.

PALYNOLOGICAL ZONATION, PALEOENVIRONMENTAL AND PALEOCLIMATIC TRENDS FOR THE MIDDLE JURASSIC (LAJAS FORMATION) OF THE NEUQUÉN BASIN, ARGENTINA

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The Neuquén Basin is a back-arc basin, located in the western central part of Argentina. It originated during latest Triassic times and was an important region of sedimentation during the Jurassic and Early Cretaceous. The Cuyo Group (Lower-Middle Jurassic) represents the first major marine depositional episode after the formation of the basin. The study area is located in the southern part of the Neuquén Basin close to Zapala city (38° 48'–39° 16' S and 70° 03'–70° 06' W) and comprises four sections (Lohan Mahuida, Puente Picún Leufú, Puesto Bascuñán and Portada Covunco). In the Cuyo Group, the Lajas Formation consists of sand-rich shallow marine deposits (late Aalenian – early Callovian). From the sequence stratigraphic and biostratigraphic studies (mainly ammonites) three third-order depositional sequences (JC4, JC5 and JC6) and five 4th order sequences (JC4.1 to JC4.5) has been recognized in this formation. The objective of the present study is to analyze the palynological organic matter (palynomorphs, phytoclasts and amorphous organic matter) of 37 outcrop samples belonging to the Lajas Formation.

Taking into account the first appearance datum (FADs) and taxon ranges of characteristic species, a palynological zonation is proposed. Two zones and eight subzones based on sporomorphs and associated microplankton are defined.

The *Callialasporites* "complex" Zone (Late Aalenian–Middle Early Bajocian) is characterized by the presence of *Callialasporites dampieri*, *C. microvelatus*, *C. segmentatus*, *C. turbatus* and *C. trilobatus* up to FAD of trisaccate forms (genus *Microcachryidites*). It comprises five subzones: *(1) Callialasporites trilobatus* Subzone (presence of *C. trilobatus* up to FAD of *Antulsporites saevus*); (2) *Antulsporites saevus* Subzone (FAD of *A. saevus*, *Callialasporites dampieri*, *C. microvelatus* and *C. segmentatus* to

FAD of spores belonging to the genera Ischyosporites and *Klukisporites* genus, such as *Klukisporites labiatus*); (3) *Klukisporites labiatus* Subzone (FAD of foveolate spores assigned to the genera *Ischyosporites* and *Klukisporites*, such as *K. labiatus* to FAD of *Interulobites variabilis*); (4) *Interulobites variabilis* Subzone (FAD of *I. variabilis* to FAD of *Uvaesporites minimus*); and (5) *Uvaesporites minimus* Subzone (FAD of *U. minimus* to FAD of *Neoraistrickia truncata* and/or trisaccate pollen of the genus *Microcachryidites*).

The *Microcachryidites* Zone (Middle Early Bajocian – Early Callovian), beginning with the FAD of trisaccate forms of *Microcachryidites*. This zone is characterized by the gradual replacement of monosaccate pollen (*Callialasporites* "complex") by trisaccate pollen. It comprises three subzones: (1) *Neoraistrickia truncata* Subzone comprising the total range of spores of the genus *Neoraistrickia*; the FAD of trisaccate grains of the genus *Microcachryidites* indicate the base of this subzone; (2) *Microcachryidites castellanosii* Subzone (FAD of *M. castellanosii* to FAD of *Taurocusporites quattrocchiensis* and *Interulobites lajensis*); and (3) *Taurocusporites quattrocchiensis* Subzone (total range of *T. quattrocchiensis* and *I. lajensis*).

Based on the relative frequency fluctuations of plant families the existence of a warm and humid climate with a relative deterioration to temperate and sub-humic conditions are inferred. These latter pulses correspond to the Early Bajocian (JC4.2-TST until JC4.4-TST, with a maximum deterioration in JC4.3-TST) and in the Bathonian – Callovian limit (JC5-TST). Palynofacies analyses suggest a nearshore, well-oxygenated high-energy environment (with tide and wave action) proximal to the continental sediment supply.

EARLY ANGIOSPERMS POLLEN FROM THE CRETACEOUS OF MEXICO (MERIDIONAL LAURASIA): PALEOGEOGRAPHIC AND CHRONOSTRATIGRAPHIC SIGNIFICANCE

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A palynologic survey of early angiosperms in Mexican territory has been initiated in order to assign ages to certain lithostratigraphic units.

The genus *Afropollis* sp. has been recovered from the Tepalcatepec Formation in Colima and Michoacán states. Previously *Afropollis* species have been reported from the Oaxaca state. These findings suggest the influence of the northern Gondwana flora (ASA) in southern Mexico.

In the Tlayúa Formation (Puebla state), there is a distinct horizon that yields a rich assemblage of *Retimonocolpites* sp., *Asteropollis* sp. and *Lethosamites* sp. These taxa, together with the presence of the Normapolles group, help to constrain the age of the Tlayúa Formation to the lowermost Cenomanian.

At Durango state, in northern Mexico, a package of black slates and limestone, known as the Gran Tesoro Formation, contains abundant cheirolepidaceous pollen, and scarce *Tricolpites* and *Jugella* species supporting an Early Cretaceous age (Albian) for this unit.

In general, the Early Cretaceous palynoflora of Mexico have a distinctive Laurasian affinity with an admixture of Gondwana taxa in the south.

LATE-PLEISTOCENE OUTBURST FLOODING RECORDED BY REWORKED TERTIARY POLLEN IN SOUTHWESTERN BRITISH COLUMBIA, CANADA

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Saanich Inlet on southern Vancouver Island is a deep near-shore marine basin with anoxic bottom waters and sediments that preserve a detailed record of postglacial marine and terrestrial environments. Cores collected by ODP Leg 169S reveal a massive, silty clay unit 40–50 cm thick, radiocarbon dated between 10,100–10,500 years old. This deposit is marked by a very sharp lower contact with laminated sediments, and an abundance of reworked Tertiary palynomorphs. Deposition of this unit has been interpreted as resulting from massive floodwater discharges caused by the collapse of glacial dams in the Fraser River drainage of mainland British Columbia. A mainland source of sediment is postulated by clay mineralogy, and the Fraser River source is defined by palynology, which matches the Tertiary pollen in the clay layer to sedimentary rocks of the Fraser Lowland near Vancouver. The upper Paleocene to lower Oligocene Huntingdon Formation (including former Kitsilano and Burrard Formations) is the most likely source for most of the microfossils, which include *Carya, Pterocarya, Juglans, Ulmus, Fagus, Tilia, Intratriporopollenites, Osmunda,* and other pollen and spores. Some contributions from the Miocene Boundary Bay Formation are also likely, based mainly on abundant *Cedrus*-type pollen.

The erosion of Fraser Lowland bedrock by massive floodwaters of glacial origin, followed by transport across southern Georgia Strait in a sediment plume, is the best explanation for the "flood clay deposit" and its enclosed Tertiary palynomorphs in Saanich Inlet.

PALYNOLOGICAL INSIGHTS INTO ANOMALOUS $CaCO_3$ PRESERVATION IN THE ABYSSAL NORTH PACIFIC

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ODP Site 1179 is at 5586.5 m water depth in the mid-latitude western North Pacific Ocean. The site is > 1 km below the CCD, so the mean $CaCO_3$ concentration is < 1%. Total palynomorph concentrations in Late Miocene to Recent sediments are very low,

as is typical of the Pacific Ocean, averaging < 400 palynomorphs per milliliter. The most common dinocysts are *Impagidinium aculeatum* and *Operculodinium centrocarpum*, each found in nearly 2/3 of the samples analyzed. *Pinus* pollen was found in most of the samples, and is especially common in Pleistocene sediments.

Two short intervals contained relatively abundant, quite well preserved calcareous planktonic microfossils, so that $CaCO_3$ comprised up to 7.7 and 6.9 % of the sediments. Biostratigraphic and paleomagnetic data provide ages of ~ 2.5 Ma and ~ 900 ka for these intervals, respectively. Both protoperidinioid dinocysts and pollen grains are relatively abundant in these planktonic foram-rich sediments, resulting in total concentrations nearly an order of magnitude greater than the mean value for the Late Miocene to Recent. Most of the cysts (up to 91%) in these samples are the smooth round brown cysts produced by the dinoflagellate genus *Protoperidinium*, which are highly susceptible to oxidation. This suggests that a combination of increased sea surface productivity and rapid burial allowed calcareous microfossils to be preserved. Protoperidinioid cysts are rare to absent in non-calcareous sediments, although some of these samples contain relatively high pollen concentrations.

Two other intervals, dated ~ 3.4 and 1.64 Ma, are associated with even higher $CaCO_3$ concentrations—17.7 and 20.7%, respectively. In these sediments, the $CaCO_3$ is present as calcite crystals. Total palynomorph concentrations are also high in these samples, more than double the mean value for the Late Miocene to Recent, but the bulk of this is comprised of gonyaulacoid dinocysts. In fact, a single species, *Operculodinium centrocarpum*, makes up ~ 76% of the total palynological assemblage and 86% of the dinocyst assemblage in the middle Pliocene sample, suggesting a bloom of the dinoflagellate *Protoceratium reticulatum*. The presence of $CaCO_3$ thus appears to have resulted from high productivity at the sea surface, but low rates of sediment accumulation resulted in oxidation of the palynological assemblage and dissolution of the calcareous microfossils, allowing the $CaCO_3$ to recrystallize as calcite crystals.

The significant global cooling and expansion of Northern Hemisphere ice recorded for the times represented by $CaCO_3$ peaks suggests a link with the global climate system. Enhanced productivity in the Pacific Ocean may have driven late Cenozoic global cooling by sequestering high concentrations of CO_2 in the equatorial to mid latitude Pacific basin.

APPLICATION OF PALYNOMORPH BIOSTRATIGRAPHY TO CORRELATION OF AQUIFER UNITS IN NON-MARINE FACIES OF THE CRETACEOUS POTOMAC FORMATION, DELAWARE COASTAL PLAIN

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Non-marine sands of the Potomac Formation (Barremian-Aptian to Cenomanian) are major sources of groundwater in northern Delaware. New palynological findings support a revised stratigraphic framework for the Potomac Formation in New Castle County, Delaware that provides an improved understanding for the correlation of aquifer units. The basis for this framework is the recognition of a geophysical well-log correlation datum within the Potomac Formation that approximates the boundary of Potomac spore-pollen Zones II and III.

In the study area, the Potomac Formation is composed of fluvial and overbank sands, interfluvial silts and clays with scattered lignites, and paleosol units of red and light gray clay. The base of the formation onlaps a south-dipping basement unconformity. In the southern part of the study area, the top of the formation is a major Cretaceous erosional unconformity that truncates successively older Potomac strata updip and has more than 10 m of relief. Santonian marginal-marine strata overlie it. Along its extreme northern limit, the Potomac Formation is truncated and overlain by Quaternary deposits. The new log correlation datum is recognized within the formation at the sharp basal contact of a 20-30-m-thick sand over a prominent silt-clay interval and probably represents a major shift in depositional systems.

Spores and pollen are common in many of the finer-grained beds, with charcoal commonly abundant in both the sands and silt/clay beds. Angiosperm pollen provide the primary basis for biostratigraphic control, with the rapid evolution of early angiosperms yielding a number of stratigraphically useful pollen types previously defined by Doyle and Robbins (1977). The angiosperm pollen constrain log correlations across a distance of 11 km from two recent coreholes near New Castle examined for this study to two wells near Delaware City previously studied by Doyle and Robbins. The zones identified suggest that the log correlation datum approximates the Albian-Cenomanian boundary. Taxa in samples above this log marker contain tricolporate taxa with thickened colpus margins including *Tricolporopollenites* sp. B and *Tricolporopollenites* aff. *T*. sp. A of Doyle and Robbins as well as *Tricolpites nemejci*. These forms are considered to have their first appearance in Zone III, which is likely Cenomanian. Below the marker is an assemblage that appears to represent Zone IIC and is generally considered Albian. Taxa present include *Tricolporoidites subtilis* and *Tricolporoidites* aff. *T*. sp. A.

DO-IT-YOURSELF SEARCHABLE PHOTOGRAPHIC PALYNOLOGY DATABASES—A QUICK AND EASY APPROACH USING MICROSOFT ACCESS

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A number of database software packages have added tools in recent years to easily embed photographs and other graphics objects in data tables. In the past, the development of photographic taxonomic databases has generally required significant programming ability in addition to palynologic expertise. However, newer database software puts the capability for construction of such databases in the hands of a broader range of users.

In the last two years, we have begun to build photographic reference databases at the Delaware Geological Survey to docu-

ment palynological identifications in an easily searchable format. We use a widely available database software (Microsoft Access) that allows relatively rapid construction of searchable photographic databases with a small amount of macro programming effort. This approach was utilized to construct a searchable photographic version of our modern pollen reference collection. The main component of this database is a data table that contains detailed information on each species in the collection: family, genus, species, and common names; morphologic type; shape; sculpture; size; collection and repository information; and photographs of the species. A user can browse the database using a standard, single-page viewing form that displays these data in an easily readable fashion. Alternatively, one may use the species query form to extract a subset of the primary data table meeting a specific set of criteria. For example, a user could specify morphologic criteria for a difficult-to-identify specimen under the microscope and generate a subset of species descriptions and photographs on the computer screen for comparison.

Our modern pollen slide collection and database currently includes 149 species. Pollen preparations were made from plant voucher specimens provided by the U.S. Geological Survey and from plants collected in parks and gardens in or near Delaware, predominantly from labeled specimens. Representative pollen grains for each species were photographed using a Polaroid camera and the photographs converted to digital images using a scanner. We are using this same format to build several other databases. One database under construction will serve as a photographic catalog of the results of an investigation of fossil palynomorphs from the Upper Cretaceous to Miocene section in a well in central Delaware. We are also building several other databases that capture and organize descriptions and photographs from the literature in an easily searchable format.

NEW INSIGHT INTO THE PALYNOSTRATIGRAPHY (DINOFLAGELLATE CYSTS) OF THE CENOZOIC OF THE AQUITAINE BASIN (SOUTHWESTERN FRANCE)

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Cenozoic dinocyst assemblages from southwestern France are known so far through a small number of studies, limited in space and confined to a narrow time interval. During the course of a field trip in August 2000, samples were collected over a wider area from well-calibrated sections, ranging in age from Thanetian to Miocene (Langhian, NN5).
The most salient features of these assemblages are presented, and compared to their counterparts in coeval sediments of other northwest Europe basins.

MODERN POLLEN TRANSPORT AND DEPOSITION IN THE HUMID TROPICS OF NORTH EASTERN AUSTRALIA

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Mechanisms of pollen transport and deposition in fluvial and marine systems of northeastern Australia were investigated to aid in the interpretation of the ODP 820A marine pollen record. Pollen assemblages are compared for sediments from three different depositional settings across the study region:

1. Modern (surface) sediments from the present day estuaries of the Russell/Mulgrave and Barron Rivers;
2. Holocene core sediments from fossil shorelines on the continental shelf (cores KG 951 VC1 and VC2);
3. Holocene core sediments from the continental slope (ODP 820A marine core).

The combined results contribute to our understanding of pollen transport and deposition in the humid tropics of northeastern Australia. Distinctive pollen assemblages are recorded for the estuaries climatically contrasting river catchments, and there is no evidence for the fluvial sorting of pollen types into sand-sized and silt-sized components as reported elsewhere. A clearer picture of the regional biases in production and dispersal of pollen types provides a stronger basis for the interpretation of marine cores from beyond the continental shelf.

PALYNOLOGICAL INVESTIGATIONS IN THE LOWER CRETACEOUS OF EASTERN ASIA: PALEOENVIRONMENT AND AGE OF STRATA IN THE CHOYR BASIN, MONGOLIA

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The Choyr Basin, located in the eastern part of the Gobi Desert, Mongolia, contains nonmarine sedimentary rocks consisting of conglomerate, sandstone, mudstone, claystone, and coal. In earlier work these strata were assigned to the Sharilin, Tsagaantsav, and Shinekhudag Formations. Our recent fieldwork indicates that this classification of the deposits is incorrect and that the formation names have been misapplied. The new interpretation is that the differing lithologies are facies of a single basin-fill unit composed of alluvial fan, fluvial, and lacustrine deposits. The entire interval may be referred to the Shinekhudag Formation, but a new stratigraphic name might be more appropriate to avoid

unintended implications of correlation and geologic age. These rocks contain a varied fauna including invertebrates (ostracodes, mollusks) and vertebrates (fishes, reptiles, dinosaurs), and a more limited flora represented by megafossils and palynomorphs. Although the Choyr Basin deposits are generally considered to be Early Cretaceous in age, more precise age determinations are disputed. Estimates range from Valanginian to Albian.

Samples of mudstone and claystone from several outcrop sections near the locality Khuren Dukh on the western side of the basin yielded palynomorph assemblages dominated by pteridophyte spores and gymnosperm pollen. Cysts of aquatic chlorophyte algae verify a lacustrine depositional environment for the sampled interval; dinoflagellate cysts of presumed freshwater origin are present, as well. The spores and gymnosperm pollen are consistent with Early Cretaceous age but are not definitive. The biostratigraphically most significant palynomorphs are pollen of the primitive angiosperm genus *Asteropollis* in association with rare specimens of tricolpate angiosperm pollen. These taxa in a region that was at mid-latitude in Cretaceous time are indicative of middle to late Albian age. This determination is supported by comparison with similar assemblages in well-dated middle to late Albian strata in North America.

PALYNOFACIES MODEL OF MARINE TRANSGRESSIONS: MID-CRETACEOUS FLOODING, WESTERN INTERIOR SEAWAY

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Upper Albian to Lower Cenomanian siliciclastic rocks in the U.S. Western Interior record several transgressive-regressive cycles, which briefly connected Tethyan (Gulf) and Boreal (Arctic) Seas. The ephemeral seaways likely provided opportunities for south to north biotic exchange. A multidisciplinary approach using sedimentology, micropaleontology, palynology, and chemostratigraphy is employed to analyze four stratigraphic sections in New Mexico, Colorado, and Wyoming, with a view to interpret the interrelationship between sequence stratigraphy and high-frequency sea level fluctuations.

Statistical analysis of dispersed organic matter in samples from the Muddy/South Platte, Mowry, Belle Fourche and Graneros formations define four palynofacies associations that indicate progressive loss up dip of marine influence. Marine shoreface and shelf deposits are dominated by marine palynofacies and a diverse *Skolithos* ichnofacies. Marine influence progressively diminishes up dip until only brackish-tolerant ichnofauna and few marine palynomorphs remain. Amorphous organic matter, wood, and to a lesser degree, black debris are the most significant of the organic matter components that define the palynofacies associations. This study also shows how the concept of palynofacies can be used as a tool to recognize sequence boundaries in these rocks that extend laterally for a distance of about 200 kilometers. It tests the hypothesis that during the Muddy depositional cycle the Boreal and Tethyan Seas were briefly connected and selective biota exchanged.

MAASTRICHTIAN DINOFLAGELLATES FROM THE JAGUEL FORMATION, NEUQUÉN PROVINCE, ARGENTINA

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A Maastrichtian interval of the Jaguel Formation is exposed in the Lomas Coloradas section, Neuquén Province. This section consists of 90 m of mudstones and claystones, in part calcareous, with occasional interbeds of sandstone. The interval immediately below the Jaguel Formation consists of gypsiferous evaporites representing presumably a sabkha facies, occurring within the uppermost part of the underlying Allen Formation. The Los Loros Formation unconformably overlies the outcropping interval of the Jaguel Formation.

This study interprets the origin and age of the sediments in the section based on the dinoflagellate associations and species richness. Within the basal 10 m, organic-walled microplankton are abundant, but with low diversity, consisting of a highly variable population of ?*Vozzhenikovia* sp., along with *Glaphyrocysta* sp. cf. *G. ordinata*, few specimens of *Palaeocystodinium golzowense* and *Pterospermella australienis*. This association of species and its low diversity is interpreted to represent the transition to an inner to outer neritic facies that developed on a transgressive surface above the sabkha.

The interval above presents clear evidence of relative sea level rise with increasing species diversity. *Areoligera senonensis*, *Trithyrodinium* sp., Kleithriasphaeridium sp., *Dinogymnium westralium*, Coronifera *oceanica*, Turbiosphaera *filosa* and *Cordosphaeridium* spp. were registered. The first occurrence of Deflandrea *galeata*, *Pierceites pentagonus* and *Alisocysta circumtabulata* among others was documented above the basal 30 m, clearly indicating a Late Maastrichtian age for the upper part of the section.

Variations within these assemblages suggest episodes of sea level fluctuations. This interpretation is supported by the changes of species diversity and abundance of specimens and by the ratio of *Glaphyrocysta /Areoligera/Cyclonephelium* complex to the *Spiniferites/ Achomosphaera* complex. A similar relationship has been observed in the Cretaceous of the Western Interior Seaway of the United States and for the Maastrichtian in other Northern Hemisphere locations.

The Cretaceous-Paleogene boundary was not identified in this section, although it has been recognized in the Jaguel Formation in outcrop located 12 km to the south.

BIOSTRATIGRAPHIC UTILITY OF TRIPROJECTATE POLLEN SPECIES FROM THE LATE PALEOCENE TO OLIGOCENE OF THE BEAUFORT SEA–MACKENZIE DELTA REGION

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Typical triprojectate species encountered in Paleogene deltaic sediments from the Mackenzie Delta and Beaufort Sea include *Aquilapollenites tumanganicus* Bolotnikova 1973, *Novemprojectus traversii* Choi 1984 and *Parviprojectus* sp. A of Rouse. They have long been considered true Paleogene time markers and have been used to constrain the age of outcrop and subsurface strata. Other triprojectate-like forms with reticulate or striato-reticulate sculpture, tricolpate equatorial evaginations and polar domes, assigned to *Pseudolaesopollis* or *Accuratipollis,* are also Paleogene species, but their stratigraphic range in the Beaufort-Mackenzie area remains to be refined. We believe that a third group of small striato-reticulate grains, assigned by various authors to *Aquilapollenites*, *Integricorpus* or *Parviprojectus*, are of Eocene to possibly Oligocene age, but as yet the possibility cannot be discounted that they are reworked from older strata.

This third group, pollen showing varying degrees of striae development, has been consistently reported from Eocene subsurface strata in the Beaufort-Mackenzie region and is known to occur in outcrop in the Caribou Hills, near Inuvik. The fine to coarse reticulate pattern of some of these grains closely resembles that of specimens of the Late Cretaceous–Early Paleogene species *Integricorpus reticulatus* (Mtchedlishvili 1961) Stanley 1970, while forms with more prominent striate elements are similar to the species *Parviprojectus* sp. A of Rouse which has been reported from late Eocene/Oligocene strata in south-central British Columbia and the Yukon, and from middle Eocene-Oligocene, and possibly older strata, in the Beaufort-Mackenzie region. The similarity between Rouse's species and some of the striato-reticulate forms has lead in some cases to the two groups being treated as synonymous. *Parviprojectus* sp. A as originally described, and as reported from younger strata, appears to have less pronounced equatorial projections than the reticulate specimens. The reticulate forms may be distinct from *Parviprojectus* sp. A.

DINOFLAGELLATE CYSTS AND RED TIDES IN TODOS SANTOS BAY—1999–2000.

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Cysts of eighteen dinoflagellate species were identified from sediment samples collected in the Todos Santos Bay from fall 1999 to spring 2000. The forms recovered are characteristic of temperate to cool-temperate regions and belong mainly to the Gonyaulacaceae, and Congruentidiaceae families. *Lingulodinium polyedrum* Stein (Dodge) has been reported as one of the most abundant species during the recurrent spring and summer red tides in this area, and was the dominant species, both in the sediments studied and in the water column.

We observed two kinds of cysts of *L. polyedrum*: temporary cysts with cellulosic wall, and resistant ones with dinosporin wall. The dinosporin cysts are concentrated in discrete areas at depths of less than 25 m, associated with fine-grained sediments, and appear in colder, nutrient poor conditions. The cellulosic ones are found suspended in the water column, and are produced in warmer, nutrient rich conditions.

During the spring of 2000, two blooms occurred. A weaker one from April 4 to 12 (172×10^3 to 2200×10^3 cells $\cdot$ l^{-1}), and a stronger bloom from May 5 to June 22 (377×10^3 to 11880×10^3 cells $\cdot$ l^{-1}). These events seem to be controlled by the level of nutrients within a thermal window. During these events, the abundance of planktonic cells is inversely proportional to the concentration of resistant cysts of the same species in the sediments. During the interval in between blooms, resistant cysts appeared in the sediments, suggesting that it takes less than one month for this species to produce the dinosporin cyst wall and then excyst.

MORPHOLOGY OF SELECTED DINOFLAGELLATE CYSTS FROM THE OLIGOCENE-PLIOCENE OF THE ANGOLA BASIN

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Dinoflagellate cyst assemblages were recovered from Pliocene to Oligocene sediments of the Angola Basin, off West Africa. These are shales and fine-grained siliciclastics deposited into neritic to bathyal environments. Dinocyst diversity is often high and a large number of species were observed. Species of the following genera: *Spiniferites*, *Batiacasphaera*, *Impagidinium*, along with the Peridiniaceae (*Protoperidinium*, *Selenopemphyx*, *Ttrinovantedinium*) are particularly abundant and diversified.

It is not always possible to refer them to published literature. This poster illustrates some of these morphotypes, and discusses their morphology.

MODERN DINOFLAGELLATE CYSTS IN ESTUARINE SYSTEMS OF NEW ENGLAND (U.S.A.)

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Dinoflagellate cysts are one of the most interesting objects in palynology. Studies of dinoflagellate cysts in marine and oceanic surface sediments demonstrate that cysts serve as an indicator of environmental conditions such as temperature, salinity, ice-cover and offshore/inshore distance. Dinoflagellate cysts from estuarine systems are by far less studied, especially in North America. In estuarine sediments, however, cysts are useful for reconstruction of environmental conditions. Our research aims at the study of diversity, spatial distribution, and applicability of dinoflagellate cysts to reconstruct past and present environmental conditions in estuarine systems.

We have examined dinoflagellate cyst assemblages from surface sediments of back-barrier lagoons of Rhode Island and small side embayments of Buzzards Bay, Massachusetts. The samples were taken from different locations characterized by varying levels of pollution, nutrient concentrations, and a salinity range (15–32 psu). More than 45 taxa of dinoflagellate cysts were observed, including some unknown cyst morphotypes. Cyst species diversity and abundance is highly variable between the estuaries and even within a single system. Our observation of significant heterogeneity, seen in these enclosed coastal waters, is contrary to that reported in studies of more open estuarine systems. However, the dinoflagellate cyst distribution at our sites probably reflects the distributional pattern of estuarine phytoplankton.

Assemblages dominated by *Spiniferites* spp. with short processes or with well-developed membranes were found in low salinity environments. In this temperate setting we see a significant presence of the species *Islandinium minutum*, *I.*? *cezare* and *Pentapharsodinium dale*, which are considered to be the indicators of cold environments. At the same time warm-water species, *Operculodinium israelianum* and *Lingulodinium machaerophorum*, are found in noticeable proportion in assemblages from neighboring sites. Comparison of dinoflagellate cyst assemblages and environmental parameters indicates that cyst assemblages reflect environmental conditions such as levels of pollution, nutrients and salinity in estuarine systems, and thus can be sensitive indicators of those conditions.

PRELIMINARY PALYNOLOGIC REPORT ON THE CUAYUCA FORMATION: A TERTIARY LACUSTRINE ENVIRONMENT IN MEXICO

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The Cuayuca Formation is characterised by lacustrine sequences and had previously been considered to be of Miocene age. Although the Cuayuca Formation does not contain macrofossils, the presence of palynomorphs in shale layers allows us to reconstruct the ancient vegetation, the environment of deposition, and to establish an Oligocene for the sediments.

Outcrops of the Cuayuca Formation are located in Puebla and Morelos states but the stratotype section is near Cuayuca City (18°31' N and 98°34' W at-1000–1300 m asl). In the present study we have examined samples from four sections: the principal Cuayuca section (25 m thick), Lagunilla (14 m), Tzumpaguacan (14 m), and the Amatitlán 8 m, section. Lithologies consisted largely of gypsum with some shale layers. A total of 31 samples were collected and ten contained palynomorphs.

The principal Cuayuca section had high pollen diversity with more than 50 taxa present. The dominant plants were *Pinus*, *Picea*, *Momipites coryloides*, *M. microcoriphaeus*, Asteraceae, and *Ephedra*. In the Lagunilla section, 20 plant groups were registered, although only Asteraceae were important. The Tzumpaguacan section samples had the lowest diversity but with *Momipites coryloides*, Liliacidites, and *Stereisporites* present. Finally the Amatitlan section contained about 20 taxa with *Stereisporites* dominant, but including *Cicatricosisporites* cf. *paradorogensis*, *Verrucingulatisporites,* and *Echinatisporis*.

The general assemblages suggest different types of vegetation probably distributed through an altitudinal gradient. The presence of abundant phycomes and freshwater algae suggest a lacustrine to brackish water environment.

An Oligocene age for the Cuayuca Formation is suggested by the presence of the *Momipites* group and *Cicatricosisporites* cf. *Paradorogensis*. These taxa seem to be of stratigraphic importance, although it is important to mention that they have previously been reported from the Eocene-Oligocene interval in the de Balsas Group at the Tepexi de Rodríguez sections.

MIOSPORE BIOSTRATIGRAPHY AND ALLOSTRATIGRAPHIC RELATIONS OF THE BORDEN DELTA COMPLEX (LOWER CARBONIFEROUS; TOURNAISIAN–VISEAN) IN KENTUCKY AND INDIANA

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The Borden Formation (Lower Carboniferous) in Kentucky and Indiana represents a prograding wedge of deltaic facies with their origins in the Acadian Highlands in the east. Outcrops of these

rocks in Kentucky and Indiana represent the bottomset beds containing prodeltaic muds and siliciclastic-rich fan deposits, foreset beds of the delta slope, and the topset beds of the shallow marine platform.

Regional lithostratigraphic relations are not well known due to the time transgressive nature of the boundaries resulting from the progradation. The Borden Formation is subdivided into different members in different areas, and no reliable correlations exist for these units.

The study area is subdivided into four Primary Depositional Centers (PDC-I through PDC-IV), which were sampled for miospores. In PDC-I (northeastern KY), the miospore assemblage is representative of the PC Biozone (Tn3a). The PC Biozone is defined by the first appearance of *Spelaeotriletes pretiosus*. In PDC-II (Tn3b; south-central KY), the miospores represent the upper part of the PC Biozone. In the westernmost localities in the study area, PDC-IV (Tn3c), the miospores are representative of the CM and Pu Biozones. In south-central Indiana, most of the sections are representative of the CM Biozone, which is defined by the first appearance of *Schopfites claviger*. In the upper part of the sections within PDC-IV, *Lycospora pusilla* makes its first appearance. The first appearance of *L. pusilla* marks the base of the Pu Biozone and also marks the base of the Visean (Vn1).

Although the Primary Depositional Centers are part of the same sequence, they are represented by different progradational phases. Sequence stratigraphic concepts are applied to all the PDC's and combined with the miospore biostratigraphic data to gain a better understanding of the spatial relationships of the time transgressive boundaries of the Borden Delta.

A SELECTIVE REAPPRAISAL OF THE DINOFLAGELLATE CYST GENUS *WANAEA* COOKSON AND EISENACK 1958

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Selected species of the dinoflagellate cyst genus *Wanaea* from Australasia and Europe have been restudied. The new species *Wanaea lacuna* from the late Bathonian of Australia demonstrates that the genus may be extensively cavate and the generic diagnosis has been emended. Other new species from the Bathonian and earliest Callovian of Australia include *Wanaea enoda* and *W. verrucosa*. *Wanaea enoda*, *W. lacuna* and *W. verrucosa* is all 'energlynioid' forms that lack a prominent posterior paracingular flange. The European and sub-Mediterranean energlynioid species *Wanaea acollaris* Dodekova 1975 and *W. zoharensis* Conway 1978 have been redescribed and emended. *Wanaea zoharensis* may have a solid extension to the antapical horn or protuberance and the term antapicular structure is proposed for this feature.

In Australia, the form originally described as *Epicephalopyxis spectabilis* Deflandre and Cookson 1955 has been subsequently misidentified. The species has a complex paracingular flange comprising three distinct zones; it is also stratigraphically important, being confined to the mid Oxfordian. It was transferred to *Wanaea* in 1958, however the figured specimen accompanying this transfer is not conspecific with the type. This specimen has a narrower flange comprising short, regular processes, which are connected distally by a trabeculum. Subsequent identifications of *Wanaea spectabilis* have followed the latter specimen. The new species *Wanaea talea* is erected to accommodate these latter forms.

The more flamboyant species of this genus with lace-like paracingular flanges are consistently younger than the 'energlynioid' species. 'Energlynioid' species are largely confined to the Mid Jurassic (late Bajocian-Callovian) worldwide, and are most prominent in the Bathonian. However the, presumably more evolved, flanged forms are confined to the mid Callovian to early Oxfordian in Europe and the mid Callovian to earliest Kimmeridgian in Australasia. Most species of *Wanaea* exhibit marked North-South provincialism and are currently known only from Europe and surrounding areas or the Indo-Pacific region. The exception to this is *Wanaea indotata,* which is cosmopolitan and may be an intermediate between the energlynioid and flanged species.

PRELIMINARY RESULTS OF A COMPARISON BETWEEN THE JURASSIC DINOFLAGELLATE CYST RECORD IN THE NORTHERN HEMISPHERE AND AUSTRALASIA

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The Jurassic dinoflagellate cyst record in the Northern Hemisphere (largely based on European studies) and Australasia appears to exhibit marked incoherence. The ranges of selected cosmopolitan species are apparently markedly different. For example, the range tops of *Nannoceratopsis pellucida* and *Rigaudella aemula* are significantly younger than in Europe. Reworking may not explain any of these disparate ranges. It is possible that palaeogeographical and/or palaeolatitudinal factors may explain some of the incoherence.

The principal areas of similarity and disparity are analyzed in this preliminary assessment of existing literature. Macrofaunal correlations are significantly more problematic than palynological ones as molluscs exhibit more endemism than palynomorphs. Approaches other than standard species range analysis may prove useful to long distance palynological correlation. These include generic ranges and statistical methods of assemblage characterisation.

THE PALYNOSTRATIGRAPHY OF THE CAMELS BUTTE MEMBER OF THE GOLDEN VALLEY FORMATION AT CAMELS BUTTE, DUNN COUNTY, NORTH DAKOTA

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This presentation is an initial report on the findings of the 2000 and 2001 fieldwork seasons in western North Dakota. The objective

of the fieldwork was to relocate and resample localities originally sampled in 1973 and add to them additional sections from the United States Museum Megafossil Localities, which formed the original framework for the Golden Valley Formation established by Hickey in 1977. The 2000 field season resampled the type section of the Camels Butte Member of the Golden Valley Formation. It is located in the SE _ section 27, T. 141 N., R. 96 W. .GPS N. 46° 59.966' W. 102° 49.485', Dunn County, North Dakota. Shales were sampled above and below the Alamo Bluff Lignite, the bottom of which marks the Paleocene-Eocene Boundary in the Williston Basin. Additional 1973 sections included in the study span the contact between the lower and upper members of the Formation.

At and above the Alamo Bluff Lignite, the palynological record shows distinctive changes interpreted to represent the first of the Eocene. The palynoflora is within the Eocene *Tiliaepollenites* Zone. It is named for *Tiliaepollenites vescipites*. Species restricted to the zone, not found in the underlying palynozone, include *Azolla cretacea, Aquilapollenites spinulosus, Tiliaepollenites vescipites,* and *Quadrapollenites vagus*. Species found in the *Tiliaepollenites* and the preceding *Maceopolipollenites* zones include *Platycaryapollenites swaskoides, Ulmoideipollenites krempii, Tricolpites parvus, Caryapollenites simplex, Triporopollenites maximus, Tricolpopollenites angululuminosus, Pistillipollenites mcgregorii,* and *Maceopolipollenites triorbicularis.* Species decreasing in relative abundance within the zone include *Tricolpites parvus, Caryapollenites simplex, Triporopollenites maximus, Cyathidites minor, Momipites tenuipolus, Laevigatosporiies albertensis,* and *Maceopolipollenites triorbicularis.* There is a distinctive increase in the number of representatives of Junglandaceae, Ulmaceae, and the Betulaceae. The sediments immediately above the Alamo Bluff Lignite include floods of *Pediastrum*. This suggests the existence of extensive-fresh water swamps at the beginning of the Eocene.

The lowermost two color zones of the Bear Den Member of the Golden Valley Formation have a palynoflora in common with the upper Sentinel Butte Formation both qualitatively and quantitatively. The latest Paleocene palynozone in western North Dakota is the *Maceopolipollenites* Zone, named for *Maceopolipollenites triorbicularis*, which occurs consistently for the first time at the base of this zone. Species characteristic of the zone are *Maceopolipollenites triorbicularis*, *Alnipollenites verus*, *A. trina*, *Triporopollenites maximus, T. subtriangularis, Ulmoideipites krempii, Pandaniidites texus,* and *Momipites coryloides.* Future work on the palynological transition to the Eocene were collected in the summer of 2001 and will be tied to the completed study of the Eocene of coastal Georgia and South Carolina.

PALYNOLOGY OF THE AQUICLUDES WITHIN THE HAGERMAN FOSSIL BEDS NATIONAL MONUMENT, HAGERMAN, IDAHO

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This presentation presents the initial results of an evaluation of the pollen and spore microflora entrapped within the shales of the aquicludes associated with the famous Fossil Gulch at the Hagerman Fossil Beds National Monument, Hagerman, Idaho. Fossil Gulch is best known for the Hagerman Horse, *Equus simplicidens*, a late Pliocene (3.5 million years before present) zebra-like species, extensively quarried from the locality since the 1930s. The shales of the aquicludes are within the late Pliocene (early Blancan) Glenns Ferry Formation and appear to represent a locally unique sedimentary environment. The sediments of the Glenns Ferry Formation sampled are exposed on the west bank of the Snake River (GPS N 42° 49.527', W 114° 56.238').

Five samples were taken from shales of the aquicludes (elevation 3100') located approximately 200 feet below the Horse Quarry (elevation 3300'). The pollen and spore content of the sediments is interesting in that it sheds some light on the character of the local flora at the time contemporary with the Hagerman Horse (*Equus simplicidens*). The sediments of the aquicludes are not the sediments within which the vertebrates were entombed. The data were compiled for each of the five samples collected in the preliminary investigation. The analysis looked at the composite flora as if it was one sample. The presence of the various diatoms and *Pediastrum* and other algal forms, added to the recovery of water lily pollen, tells us the sediments were from clear, cool, oligotrophic ponds. The ponds were surrounded by high grass prairie or meadow. Surprisingly, only a few grains of sage (*Artemesia*) and ragweed (*Ambrosia*) were recovered. Some of the expected riparian river corridor hardwood species were found including oaks (*Quercoidites*), holly (*Ilexpollenites*), willow (*Salixipollenites*), poplar (*Inaperturopollenites*), and hemlock (*Tsugaepollenites*). The recovery of fir (*Abietineaepollenites*), pine (*Pinuspollenites*), and spruce (*Piceapollenites*) indicate airborne and water borne input from the surrounding coniferous forest.

The overall impression is that the primary community associated with the formation of the aquicludes was an upland wet meadow surrounding biogenically (beaver) or geologically (lava flow) created oligotrophic ponds.

EARLY CRETACEOUS DINOFLAGELLATES FROM THE SOUTHERN BORDER OF THE NEUQUEN BASIN, ESTANCIA SANTA ELENA LOCALITY, ARGENTINA

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An assemblage of dinoflagellates is reported from the lower part of the Agrio Formation (Late Valanginian-Hauterivian) of the southern Neuquén Basin, Argentina. Twenty-nine species or morphotypes are recognized. The diagnosis of the genus *Odontochitina* is emended, the new genus *Neuquenia* is proposed and the genus *Heliodinium* Alberti retained. Two new species are described: *Oligosphaeridium quattrocchioae* and *Neuquenia crassicornuta*, while the new combinations *Heliodinium ramoides* (Alberti), *Neuquenia rhakodes* (Bint) and *Xenascus spinosus* (Wilson) are proposed. The stratigraphic significance of the assemblage is discussed, in comparison with other assemblages from the Early Cretaceous of the Southern Hemisphere.

DEVELOPING A MICROFOSSIL-BASED RECALIBRATED TIME SCALE FOR THE MIDDLE AND LATE CRETACEOUS (APTIAN THROUGH MAASTRICHTIAN)

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The need for a recalibrated Cretaceous time scale is acute for micropaleontologists in both industry and academia. The most recent time scales and sequence chronostratigraphic charts are macrofossil-based with very little Cretaceous microfossil data directly calibrated to sequences or absolute time. The microfossil events listed essentially represent a relative biostratigraphic zonation. Furthermore, the individual listed microfossil zonations were developed separately from each other with no integration between groups. Therefore, development of a new Cretaceous time scale based on integrated microfossil data will greatly improve upon the existing time scale. It will be much more useful to industry and academia than a macrofossil-based scale (i.e., with greater geographic scope and range of useful geologic sections because of the much greater recovery of microfossils and the greater ease of their use in core and ditch-cuttings samples).

Furthermore, microfossil biostratigraphy is an ideal unifying tool to integrate other time scale parameters. In contrast to the Cretaceous, such a microfossil-based integration served as the primary tool in the construction of the recent Cenozoic time scale. This approach involves integration of magnetostratigraphy, radiometric dates, cyclostratigraphy and macrofossil zonations via microfossil biostratigraphy. Also, it is the authors' contention that an integrated microfossil zonation can be constructed that will match or exceed the age resolution of the established macrofossil biozonations and, in addition, have the broader applicability provided by microfossils.

An example of the methodology used for time-scale construction is provided from an ongoing re-calibration study of the Coniacian and Santonian stages utilizing Niobrara Chalk outcrops in western Kansas. The Niobrara section presents what may be the best Coniacian-Santonian time scale "laboratory" in terms of section completeness, microfossil preservation, cyclostratigraphy, magnetostratigraphy, and the potential for radiometric dating. By combining this study with detailed analyses of the proposed boundary stratotypes for the Coniacian and Santonian, a total recalibration of the stages will be complete by early 2002. The recalibrated Coniacian and Santonian will then serve as the foundation for the construction of a new time scale for the entire middle and Upper Cretaceous.

CHANGING OCEAN CHEMISTRY AND CO_2 AS CONTROLS ON PHYTOPLANKTON DIVERSITY

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The pattern of genus-level taxon diversity in the phytoplankton follows closely that of ocean water chemistry that alternates between "aragonite" and "calcite" seas. During "calcite" seas (Cambrian–Devonian; mid Triassic–Paleogene), phytoplankton diversity was high, and during "aragonite" seas (latest Vendian–Lower Cambrian; Carboniferous–Early Triassic; Neogene–Recent), diversity was lower. Changes in ocean chemistry are thought to be due to varying refluxing of hydrothermal brines at mid-ocean ridges that affect the concentrations of Mg^{2+}, Ca^{2+}, and HCO_3^-. The phytoplankton composition of the two Phanerozoic "calcite" seas is quite different however; the earlier one being composed of acritarchs and the later a mix of coccolithophorids, diatoms and dinoflagellates. This difference is puzzling given a growing body of molecular and biochemical evidence suggesting that both diatoms and dinoflagellates are quite ancient groups.

During the time of first "calcite" ocean, atmospheric pCO_2 was up to 16 times the present-day concentration. Since the upper oceans are in dynamic equilibrium with atmospheric pCO_2, dissolved CO_2 was relatively more available to the phytoplankton, obviating the selective pressure for the development of carbon concentration mechanisms (CCMs) and efficient Rubisco in the lineages that produced the acritarchs (algal cysts). The re-radiation of the phytoplankton beginning in the mid-Triassic occurred under conditions of lesser CO_2 availability necessitating the use of CCMs and more efficient Rubisco in the coccolithophorids and the diatoms. Thus, even though CO_2 is never considered to be a limiting nutrient in the modern oceans, it is possible that phytoplankton diversity in evolutionary time was controlled more by CO_2 and Ca^{2+} availability than by fluctuations in P and N that tend to vary more widely in ecological time.

PALYNOLOGY, PALYNOFACIES, AND SEQUENCE STRATIGRAPHY OF THE CRETACEOUS NAPO GROUP IN THE ORIENTE BASIN, ECUADOR

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The Napo Group of the Oriente Basin in eastern Ecuador represents a sedimentary sequence, consisting of organic rich shales, limestones and sandstones. It was deposited in a shallow marginal marine basin, which was bordered by the Guyana Shield in the east and an incipient Andean uplift to the west. Ranging in age from the Late Albian to the Campanian it also contains oil-bearing sandstones and organic rich shales of source rock quality. Similar contemporary successions in Colombia and in Venezuela show a connection of the basin to the early Atlantic Ocean.

The study of spore-pollen, dinoflagellate cysts and calcareous nannoplankton in core samples from a shallow well from the western part of the Oriente Basin leads to a new biostratigraphic breakdown, which reveals the existence of several hiatuses (time breaks) in this area. The palynological and palynofacies data are used together with other fossils and lithological evidence to define a sequence stratigraphic framework. The distribution of palynomorphs and palynofacies indicates a strong terrestrial input for the lower part of the Napo Group (Napo Basal and Lower Napo Formation). In the upper part (Middle and Upper Napo Formation) this input is reduced. A restricted marine environment with several disoxic to anoxic intervals can be inferred from the palynofacies. The reduced diversity of most dinoflagellate assemblages restricts both the precision of biostratigraphic dating and correlation with neighboring basins.

The spore-pollen assemblages of Albian to Cenomanian age are comparable to those described from West Africa and Brazil corresponding to the "Northern Gondwana province". The Late Cretaceous pollen assemblages from the Oriente Basin are strongly dominated by syncolporate pollen, thus they differ considerably from the assemblages assigned to the African "Palmae province".

The hydrocarbons present in the studied well are traditionally regarded as locally sourced. However, several lines of evidence (TAI, Tmax, VR) prove the immature stage of the source rock in this borehole as well as in a larger area. Thus, the origin of the hydrocarbons remains to be explained.

NEOGENE DINOFLAGELLATE CYSTS FROM A DEEP WATER WELL, OFFSHORE SABAH, NORTHERN BORNEO

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The palynological analysis of a one well pilot study are presented; the first part of a research project with the objective to establish a dinoflagellate cyst biozonation for deep-water wells drilled offshore Sabah and Brunei in Northern Borneo. These wells penetrate sediments deposited in prodeltaic deep-water (bathyal) environment. The dinoflagellate cyst biozonation is envisaged to complement the biozonations based on nannoplankton, foraminifera, and pollen.

Ditch cutting samples have been analyzed for dinoflagellate cysts only. Their presence is restricted to the upper part of the investigated interval from 2610' to 6495'. A set of slides prepared from the oxidized fraction of the samples has been fully analyzed, resulting in real counts of dinoflagellate cysts, complemented with a screening of the unoxidized fraction for thin walled Protoperidiniacean dinoflagellates; *Selenopemhix spp, Brigantedinium spp.* and *Lejeunecysta spp*, the bulk of which has been removed by oxidation. The palynological assemblages are overwhelmingly dominated by land plant material; pollen, spores, fungi and macerals. Marine elements (dinoflagellate cysts, acritarchs and algae) contribute 2–5% of the microflora in the interval from 2610' to 6495'. The low percentage of dinoflagellate cysts vis-à-vis land plant material and the low species diversity of dinoflagellate cysts is explained by the heavy influx of freshwater in the prodeltaic bathyal environment, expelling the dinoflagellate cysts, which prefer to live in pure salt water, leaving the fresh water resistant forms behind. In the lower part of the investigated interval from 6705' to 7905' the ditch cutting samples are virtually barren of marine palynomorphs. They still contain some (caved?) pollen and spores, but are dominated by dark brown debris. This interval represents the turbidite reservoir section of the well, the sands being devoid of palynomorphs.

The interval from 2610' to 4140' is of Late Pliocene age, 4290' to 5430' is Early Pliocene, and 5640' to 6495' is Late Miocene, based on the distribution of nannoplankton, foraminifera, and pollen. A suite of FDO's of dinoflagellate cysts in descending order is presented over the full interval. The correlation potential of the FDO's reported for this well has to be confirmed in additional wells.

Overall, the dinoflagellate cyst assemblage is rather similar to the open oceanic assemblages of Neogene age from the Eastern Indian Ocean and Northeastern Australian Margin. The only difference is the rare presence of open oceanic genera like *Impagidinium* spp. and *Nematosphaeropsis* spp. The dinoflagellate cyst assemblage is dominated by *Brigantedinium* spp., *Spiniferites* spp. and *Operculodinium* spp. Large size varieties of *Operculodinium israelianum* and *Operculodinium walli* are commonly present, similar to those described in the Bahamas in Neogene sediments deposited in a tropical environment. *Selenopemphix nephroides, Tuberculodinium vancampoae, Lingulodinium machaerophorum* and *Polyshaeridium zoharyi* are consistently present over the full interval.

The FDO's of *Hystrichokolpoma rigaudiae* and *Hystrichokolpoma okinawainum* at 3150' could be of stratigraphic value within the Upper Pliocene section. However, highest occurrences have been reported within the Pleistocene in the Western and Northern Pacific and Gulf of Mexico. The informal species *Operculodinium* sp. A (covered with very distinctive fibrous processes) could be of considerable stratigraphic importance with a consistent range underneath a FDO at 3840'. Also *Dapsilidinium pastielsii* with a FDO at 4140' is considered to be of stratigraphic

value within the Upper Pliocene section. Its highest occurrence has been reported in the Late Pliocene in Eastern Indian Ocean and Northeastern Australian Margin.

The FDO of *Lingulodinium pycnospinosum* at 4950' is considered to be of stratigraphic value within the Lower Pliocene section. A questionable highest occurrence has been reported in the Late Oligocene in Germany. Several rare occurrences have been detected in this interval which could have stratigraphic potential; *Homotryblium tenuispinosum* with FDO at 4290' (possibly reworked), *Lejeunecysta* cf. sp. *2* (Biffi and Grignani, 1983) at 4950' (also possibly reworked), *Spiniferites* sp. A (Duffield and Stein, 1986) with FDO at 5115', *Trinovantidinium ferugnomatum* at 5115' and *Selenopemphix dionaeacysta* at 5640'.

Analysis of ditch cutting samples invalidates the use of LDO's. However, it should be noted that the presence (in ditch cutting samples) of *Barssidinium* cf. *graminosum, Barssidinium evangelineae* and *Achomosphaera granulata* is restricted to the Pliocene interval.

A Late Miocene age assignment from 5640' to 6495' is supported by the FDO at 5760' of *Selenopemphix brevispinosa* subsp. *brevispinosa* with a reported highest occurrence in the Latest Miocene in the eastern United States. Further support could be the top of the consistent occurrence of the informal species *Achomosphaera* sp. B at 5760'. Of stratigraphic importance is also the presence of *Systematophora placacantha* at 6495'. Its highest occurrence has been reported in the Late Miocene in Italy. The presence of *Edwardsiella sexispinosum* at 5995' and *Lejeunecysta fallax* at 6435' could also be of significance. However, the highest occurrence of *E. sexispinosum* has been reported in the Late Pliocene in Italy. The highest occurrence of *Lejeunecysta fallax* has been reported in the Middle Miocene in the Pacific. The analyzed specimen could be reworked.

PALYNOLOGY AND PALEOENVIRONMENT OF THE LACUSTRINE CAÑADÓN ASFALTO FORMATION, JURASSIC OF CENTRAL PATAGONIA, ARGENTINA

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During the Jurassic extension of southwestern Gondwana, the Cañadón Asfalto Formation, of late Middle Jurassic to Early Cretaceous age, filled a hemigraben located in the central area of Chubut province. It outcrops mainly in the middle Chubut river valley, consisting of alternating volcanites, biochemical, pyroclastic and epiclastic deposits. The palynological and especially the palynofacial study of dark grey pelites of the "Lower Section" of the Cañadón Asfalto Formation at Cañadón Lahuincó locality, allows a more complete paleoenvironmental characterization of this central part of the Cañadón Asfalto Basin.

The abundance of amorphous organic matter (80–90%) in all the palynological samples studied is characteristic of stagnant bottom conditions. It consists of finely dispersed and, in minor proportions, granular to membranaceous amorphous material. Fluorescence is weak; colors are brown and, in some cases, grey to yellow. The material corresponds mostly to destroyed palynomorphs, including plankton and *Botryococcus*. The scarce opaque phytoclasts consist of black, equidimensional, structureless material. The presence of *Botryococcus* indicates falling lake levels and probably more saline conditions. Diagenetic processes such as degradation, corrosion and the absence of pyrite in all the samples indicate that aerobic bottom conditions alternated with dysaerobic conditions. The Cheirolepidiaceae dominated the spectrum (up to 80% of *Classopollis* spp.), associated with the Araucariaceae (up to 20%). The climatic conditions may have been warm and relatively humid, as indicated by high percentages of the thermophilic Cheirolepidiaceae in association with the Araucariaceae, which need relatively humid conditions. The presence of Bryophyta (*Nevesisporites* cf. *radiatus*) and pteridosperms (*Alisporites similis*) are suggesting probable local humid conditions for the lower part of the "Lower Section" of the Formation.

Sedimentologial analysis of the Cañadón Asfalto Formation at Cañadón Lahuincó shows a volcano-sedimentary sequence with basalts and green tuffs at the base, overlain by a lacustrine siliciclastic sequence. Sediments represent short cycles related with periods of contraction and expansion of the level of water in the paleolake. During expansion the lake flooded litoral areas, producing black pelites and limestones of palustrine type. In contrast, during extremely dry intervals the body of water contracted, with precipitation of gypsum and formation of desiccation breccia, characteristic of a sabkha environment. These conditions are prevailing in the higher levels of the "Lower Section" of the formation, where sedimentation changes from carbonatic into a silicoclastic one, with levels indicating deltaic environments and hyperconcentrated deposits characteristic of the "Upper Section" of Cañadón Asfalto Formation.

ACRITARCH RESEARCH IN THE 21ST CENTURY: SOMETHING OLD, SOMETHING NEW, SOMETHING BORROWED, BUT DEFINITELY NOT BLUE

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The group Acritarcha was originally proposed by Evitt in 1963 for small organic-walled microfossils that had previously been assigned to the hystrichospheres, but could not be attributed to the dinoflagellates on the basis of definitive morphological criteria. Evitt clearly considered acritarchs to be a polyphyletic assemblage of "widespread, often abundant, and morphologically varied microfossils," and he intended that the group be considered an

informal and utilitarian category treated under the Botanical Code of Nomenclature. Evitt further stated that whenever the biological affinities of individual acritarch genera are determined, those genera are then transferred out of the acritarchs and assigned to their proper biological category. Interestingly, in spite of Evitt's clear intentions, the use and meaning of the term acritarch has undergone its own evolution during the past 38 years. As a new century begins, it is important to review the history of acritarch research and look ahead to what the study of these enigmatic organic-walled microfossils may hold.

Although the term acritarch was not proposed until 1963, serious study of these fascinating microfossils began in the 1930s when Alfred Eisenack described in detail numerous species of spiny cyst-like organic-walled microfossils from Paleozoic glacial erratics of the southern Baltic region. With the recognition that acritarchs were an important fossil group, particularly in biostratigraphy, acritarch research entered its second phase during the 1960s and 1970s. During this time, careful detailed descriptions, enhanced by scanning electron microscopy of well preserved specimens from various localities in which there was good stratigraphic control, enabled researchers to better utilize the potential of acritarchs in a variety of studies. Following this second phase, during which there was a tremendous increase in the naming and description of taxa, the emphasis in acritarch research was primarily on refining their biostratigraphy, taxonomy, nomenclature, and classification. Research also expanded into other fields such as paleoecology and paleobiogeography, as well as the role played by acritarchs in the evolution of the Proterozoic and Paleozoic marine ecosystem.

As acritarch research moves into the 21st century, what lies ahead? As the title indicates, there is still much to be done (something old) in terms of basic taxonomic, systematic, and biostratigraphic research. Within the past few years there have been exciting advances in acritarch research (something new) in the fields of biochemistry and the biological affinities of acritarchs, statistical studies relating to taxonomy, biodiversity studies, taphonomy, and functional morphology, to name just a few. Multidisciplinary studies are also increasing (something borrowed) and there is no need to be blue about the future of acritarch research as new techniques and insights are applied to the already solid foundation of acritarch knowledge.

PALYNOLOGY OF THE SCENIC MEMBER, BRULE FORMATION, SAGE CREEK WILDERNESS AREA, BADLANDS NATIONAL PARK, INTERIOR, SOUTH DAKOTA

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Palynomorphs were analyzed in support of a sedimentologic and paleontologic taphonomic study conducted by the junior author in the Tyree Basin (1997-99), Badlands National Park, Interior, South Dakota. The Brian Maebius (BM) site lies within the Lower Nodular Zone of the Scenic Member, Brule Formation. These Oligocene deposits are part of the White River Group. Mineralogy indicates a southern Black Hills provenance for the sediments that were deposited in a laterally migrating, anastomosing fluvial system. Thin, lacustrine carbonates and hydric paleosols (identified by soil structures and maturity color index) were deposited during a pluvial period lasting approximately 7000 years.

Gastropods, including *Xerarionta* sp., *Pupoides* sp. and *Gastrocopta* sp., and a diagnostic vertebrate fauna of Orellan North American Land Mammal Age (NALMA) were recovered. Vertebrate and invertebrate ranges compare favorably with those reported from the Douglas, Wyoming [Orellan NALMA, magnetostratigraphic level of Chron 13N(N3), and tephrostratigraphic level 6d]. A parautochthonous biocoenose proximal to a carnivore's den was identified in the middle units of the section. The presence of numerous bones displaying tooth impacts and the lack of evidence of transport indicates that the bones are *in situ*. Carnivoran coprolites were collected from many of the bone horizons. Macrofloral remains include *Celtis hatcheri, C. willistoni, C. reticulata*, and the first in situ tree stump reported from the Badlands National Park. The stump also is of Orellan age.

Ephemeral lacustrine limestone and carnivoran coprolites yielded the first preserved pollen from the Scenic Member in South Dakota. The presence of these palynomorphs is significant in that few others have been reported from much studied deposits of comparable age in the central plains area. Pollen of *Ambrosia* sp., Chenopodiaceae-Amaranthceae, Asteraceae, Gramineae, *Carya* sp., *Eucomia*-type, cf. *Myrica* sp., *Nyssapollenites* sp., *Pinus* sp., *Quercus* sp., *Ulmus/Zelkova* sp., and rare, indeterminate trilete spores were recovered. *Pinus* was relatively abundant and apparently derived, like the sediments themselves, from the Black Hills. Associated pollen of local origin indicates a riparian setting (e.g., levee and back levee swamp) with adjacent open areas supporting xerophytes. The freshwater alga *Botryococcus* sp. and rare fungal spores also were recovered.

PIEL CHARTS: A NEW BIOSTRATIGRAPHIC TOOL

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A new type of range and distribution chart is described. (The senior author refers to these as Piel Charts in recognition of their originator, Dr. Kenneth M. Piel.) Total range, frequency of reported occurrence, and time distribution data for each selected taxon as reported in the PALYNODATA database is plotted against Age. The data used may be worldwide or regional depending on whether the PALYNODATA search is restricted geographically. Data are displayed as butterfly plots and the number of papers reporting a particular taxon is printed on the butterfly plot for each time (Age) interval shown. These charts display the total range and distribution data that exists in the PALYNODATA

database either worldwide or regionally; they do not treat individual sections.

Currently, Piel Chart generation requires considerable hand manipulation of the data. The following steps are followed in generating a Piel Chart:

1) Run a PALYNODATA search for the required data. (For example, extract the range and distribution data for all Cenozoic dinoflagellate cysts.)
2) Refine data file by deleting all records of reworked taxa, caved specimens, informal taxonomy, taxon qualified by "cf.", etc.
3) Verify taxonomic status of each taxon. (For the above example, refer to the latest Williams et al. "Index of Fossil Dinoflagellate Cysts" and literature published after that volume.)
4) From the cleaned data of the PALYNODATA search, tabulate the number of papers that report each taxon for each time interval [e.g., *Evittosphaerula paratabulata*: Messinian (2 reports), Tortonian (2), Serrivallian (3), etc.].
5) Determine number of column widths on the butterfly chart appropriate for the number of papers that report each taxon within each time interval.
6) Plot data verses Age, then sort by tops, bases, or alphabetically.

Piel Charts can provide various information on each taxon displayed. Using the example noted above, they:

1) show the dinoflagellate cysts most, and least, likely to be encountered in samples from a certain time interval.
2) show taxa that will most likely be major and minor components of assemblages.
3) point out potential problems of possible reworking, incorrect taxonomic identification, caved occurrences, etc. that have not been previously recognized. (Numbers 1, 2, and 3 could be called "predictive palynology.")
4) show the part of the section from which each taxon is most commonly reported and its frequency of report in each time interval.
5) show which taxa most and least commonly occur together worldwide, or regionally.

KEY TO ONSITE PALYNOLOGIC ANALYSES IN ANTARCTICA: MICROWAVE DIGESTION IN THE MOST SOUTHERLY PALYNOLOGIC LABORATORY IN THE WORLD

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The Cape Roberts Project needed real time palynostratigraphic support during the coring of sea floor sediments in the Ross Sea, Antarctica. Expeditious sample preparation was required for analyses to keep up with the drilling program. Onsite palynology had not been conducted in Antarctica previously, in part because traditional open beaker acid digestion of samples would liberate unacceptable amounts of toxic acid fumes into the environmentally sensitive Antarctica atmosphere. The use of a microwave digestion (MD) machine with a scrubber unit facilitated onsite palynologic analyses in Antarctica for the first time. During the 1997–1999 CRP drilling seasons, the most southerly palynologic processing laboratory in the world was operated in the Crary Science and Engineering Center (CSEC), McMurdo Station, Ross Island, Antarctic.

In general, the benefits of using an MD unit include: 1) faster sample digestion than with traditional techniques, 2) computer control of pumping reagents into the digestion vessel, 3) lower reagent consumption, 4) capturing and cleaning digestion fumes by a scrubbing unit, and, 5) easy computer programming of processing protocols.

Microwaves are electromagnetic energy and are more efficient at heating a sample than is conventional conductive heating. Sample vessel walls are transparent to microwaves, passing most of the energy on into the sample-acid mixture. In contrast, much of the conductive heat energy is expended on heating the walls of the sample vessel before the remaining heat energy establishes convection currents within the sample-acid mixture.

Early MD units were similar to domestic microwave ovens and proved to be impractical for palynologic sample processing. A magnetron sprays microwaves into the heating chamber, where they ricochet inefficiently all around the chamber. These units are time consuming to load, operate at high temperature and pressure, and can be dangerous to use. Improperly sealed digestion vessels can, and do, explode with great force.

Current focused microwave digestion (FMD) units, such as the ProLabo unit used by CRP in Antarctica and those produced by CEM Corporation (Mathews, North Carolina) should not be confused with oven type units. FMD units focus microwaves on the sample-acid mixture in the digestion vessel for maximum heating efficiency. They operate at normal atmospheric pressure, with unsealed digestion vessels, precluding the chance of explosions. Sample through put is relatively slow with the one-sample-at-a-time ProLabo unit. (Digestion takes about 1 hr/sample.) Units produced by CEM process either two or six samples simultaneously, thereby increasing sample output. The use of an environmentally friendly FMD unit by CRP in Antarctica demonstrates the feasibility of conducting safe palynologic processing and analyses on shipboard, on offshore drilling platforms, and at remote, environmentally sensitive locations where immediate palynologic results are needed.

DINOFLAGELLATE CYST RESPONSE TO POST-EOCENE CLIMATIC AND TECTONIC CHANGES IN ANTARCTICA AS DOCUMENTED IN THE CAPE ROBERTS CORES 1, 2/2A, AND 3

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Deposits recording the Late Cretaceous to Oligocene geologic record of East Antarctic are not exposed on land due to extensive ice cover of the continent. East-dipping submarine beds off Cape Roberts, East Antarctica, were interpreted to be composed of sediments covering this critical window of geologic time. Study of these deposits would provide insights into the tectonic, environmental, climatic, and biologic evolution of East Antarctica.

Three conventional cores (CRP 1, 2/2A, and 3) sampled a composite section of more than 1700 m during three years of drilling (1997-1999). Most of the section was early Oligocene to Quaternary in age; but below a major unconformity, more than 100 m of Devonian of the Beacon Supergroup (Arena Sandstone?) were penetrated before coring was stopped.

In situ marine palynomorphs recovered from the core include dinoflagellate cysts (dinocysts), acritarchs, prasinophyte phycoma, and foraminifer linings. The recovery of dinocysts from post-Eocene Antarctic sediments is significant, because they were thought to have gone extinct in Antarctic waters after the Eocene. The distribution of approximately 70 in situ marine palynomorph taxa, most of which occur within the upper 1100 m of the composite section, was tracked. The abundance and species diversity of palynomorphs in any one sample are low compared to contemporaneous lower latitude assemblages, or Eocene assemblages from Seymour Island or the McMurdo erratics.

Paleocene–Eocene Antarctic dinocyst assemblages are less endemic than the CRP dinocyst assemblages, 16 and 35 endemic taxa respectively. Unlike the Eocene Antarctic dinocysts, most of which were produced by photosynthetic dinoflagellates, most new CRP dinocyst species are those of heterotrophic dinoflagellates.

Low diversity Quaternary and Miocene marine palynomorph assemblages are similar in composition (though they differ in species) to those reported from Neogene and Quaternary deposits of the Arctic. Both assemblages are the product of comparable cold polar conditions. The CRP assemblages demonstrate for the first time that bipolarism exists among these protists.

The low species abundance and diversity, the occurrence of numerous undescribed endemic dinocyst species, the change in trophic structure, and evidence of marine palynomorph bipolarism in the post-Eocene dinocyst assemblages, document that a major climatic and environmental change occurred during the latest Eocene or earliest Oligocene. The deterioration of the Antarctic environment after the advent of the Circum-Polar Current is clearly indicated by changes in the marine palynomorph assemblages.

OLIGOCENE TO QUATERNARY MARINE PALYNOLOGY OF THE CAPE ROBERTS DRILLHOLES, VICTORIA LAND BASIN, ANTARCTICA

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The Cape Roberts Project (CRP) was designed to investigate the tectonic and climatic evolution of the East Antarctic during latest Cretaceous-to-Oligocene time. CRP continuously cored more than 1700 m of sediments in three cores (CRP-1, -2/2a, and -3) from the floor of the Ross Sea off Cape Roberts. Most of the section proved to be much younger (Early Oligocene-to-Quaternary) than anticipated. CRP-3, the deepest and oldest core, was terminated below an unexpected major unconformity (early Oligocene overlying Devonian) after recovering more than 100 m of the sub-unconformity Beacon Supergroup.

The dinoflagellate cyst, acritarch, and prasinophycean algae assemblages recovered from the CRP cores are sparse and of low diversity relative to contemporaneous, lower latitude assemblages, or those yielded by Antarctic Paleocene-Eocene deposits (e.g., the Seymour Island sediments). The presence of *in situ*, post-Eocene cysts is of particular interest. Prior to CRP, cyst-producing dinoflagellates were thought to have disappeared from Antarctic seas after Eocene time, because none had been found in younger sediments. The dinoflagellate cysts collected from the CRP cores are the first recovered from well-dated post-Eocene sections in the Antarctic. More significantly, the *in situ* dinoflagellate cyst assemblages consist almost exclusively of undescribed, endemic species in association with new acritarchs and prasinophycean algal taxa. These assemblages permit the establishment of the first post-Eocene Antarctic dinoflagellate cyst zonation. The eight zones are defined primarily on new species of *Lejeunecysta* and *Phelodinium cranwelliae* recovered from CRP-1, -2/2a, and -3.

Most CRP dinoflagellate cysts were produced by protoperidinioids, heterotrophic dinoflagellates, whereas most Eocene Antarctic dinoflagellate cysts derive from autotrophic dinoflagellates and relatively few protoperidinioids are present. This suggests that a major change in the trophic structure of the Antarctic dinoflagellate cyst-producing community occurred during the latest Eocene or earliest Oligocene.

The CRP post-Eocene marine palynomorph assemblages are similar to those reported from Neogene and Quaternary deposits of the Arctic Ocean, though the species are different. The CRP assemblages demonstrate for the first time that bipolarism exists among these protists. These data document that a major climatic and environmental change occurred by early Oligocene time,

probably in response to the advent of the Circum-Polar Current. The development of this major oceanographic barrier is clearly indicated by the evolution of the *in situ* marine palynomorph assemblages recovered from the CRP cores.

AN EARLY OLIGOCENE TO QUATERNARY DINOFLAGELLATE CYST ZONATION FOR ANTARCTICA

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The Cape Roberts Project (CRP) cored a sequence of east dipping, submarine sediments in the Ross Sea, offshore from Cape Roberts East Antarctica. The purpose was to study the tectonic, paleoenvironmental, and paleoclimatic record contained in the sediments. More than 1700 m of sediments were recovered in three conventional cores (CRP-1, 2/2A, and 3) drilled between 1997–1999. These cores form a composite core with about 31 m overlap between CRP-1 and CRP-2/2a, and no overlap between CRP-2/2A and CRP-3. These cores provided a unique opportunity to study a very thick sequence (> 1100 m) of Oligocene deposits.

Initial palynological analyses revealed low diversity, relatively sparse marine palynomorph assemblages consisting of *in situ* early Oligocene-to-Quaternary and reworked dinoflagellate cysts, acritarchs, and prasinophyte phycoma. More than 20 new species of dinoflagellate cysts, mostly species of *Lejeunecysta* and other protoperidinioid cysts, are being described at this time. For the present, informal taxonomy is applied to these new species. The *in situ* cyst assemblages are the first recovered from well-dated, post-Eocene Antarctic sediments. These assemblages permit the establishment of the first post-Eocene marine palynomorph zonation for Antarctica. The zones below 624 m in the composite core are tentative due to the lack of overlap between CRP-2/2A and CRP-3. The scarcity of palynomorphs precludes zoning the lowest part of the composite core. The eight zones recognized in the composite core are, from youngest to oldest:

Zone H (0.00–36.62 m): The base of the zone is marked by the last occurrence of *Brigantedinium pynei, Lejeunecysta cowiei*, and *L. fallax*.

Zone G (36.62-82.18 m): the last occurrence of *B. pynei, L. cowiei*, and *L. fallax* mark the zone top, and the last occurrence of *Phelodinium cranwelliae* marks its base.

Zone F (82.18-157.59 m): The zone top is based on the last occurrence of *P. cranwelliae*. The first appearance of *B. pynei, P. cranwelliae*, and the last occurrence of *L.* sp. 1 mark the base.

Zone E (157.59- 378.32 m): The zone top coincides with the last occurrence of *L* sp. 1, and the first appearance of *B. pynei* and *P. cranwelliae*. The first occurrence of *L.* sp. 1 and the last occurrence of *L.* sp. 5 mark the base of Zone E.

Zone D (378.32-526.76 m): The first occurrence of *L.* sp. 1 and the last occurrence of *L.* sp. 5 mark the top of Zone D. The base of the zone is marked by the last occurrence of *Impagidinium* cf. *elegans*.

Zone C (526.76-723.79 m): The top of the zone is marked by the last occurrence of *I.* cf. *elegans*. The first occurrence of *L.* sp. 7 and last occurrence of *L.* sp. 9 mark the base of Zone C.

Zone B (723.79-897.77 m): The first occurrence of *L.* sp. 7 and the last occurrence of *L.* sp. 9 mark the top of Zone B. The zone base is marked by the first occurrence of *L.* sp. 5.

Zone A (897.77-1039.00 m): The top of the zone is marked by the first occurrence of *L.* sp. 5 and the base by the first occurrence of *Cymatiosphaera invaginata*.

DINOFLAGELLATES FROM THE UPPER CAMPANIAN–MAASTRICHTIAN OF COLOMBIA AND WESTERN VENEZUELA: BIOSTRATIGRAPHIC AND SEQUENCE STRATIGRAPHIC IMPLICATIONS

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Dinoflagellate biostratigraphy of the Upper Campanian–Danian was studied in five surface sections from Colombia and one from western Venezuela (Rio Loro section). The Rio Molino section is in northern Colombia, the Chiguata Creek and Tausa sections are in the central part of the Eastern Cordillera, La Buitrera Creek section is in the western flank of the Eastern Cordillera, and the Aico Creek Section is in the Upper Magdalena Valley. At least twenty-two biostratigraphically significant events where identified in the upper Campanian and Maastrichtian of the studied sections. In the absence of calcareous macro- and microfossils the Campanian/Maastrichtian boundary was identified based on the highest occurrence of *Trichodinium castanea* and near the lowest occurrence of *Phelodinium tricuspe*, *Yolkinigymnium lanceolatum* and *Hafniasphaera fluens*. The K/T boundary is present in the Venezuelan section but coincides with an 11.5 m unexposed interval separating uppermost Maastrichtian dinoflagellate events below from Danian dinoflagellates above.

Several third-order coarsening upward cycles were recognized within the overall shallowing upward pattern displayed in the six sections. Dinoflagellates tend to be more abundant at the base of these cycles and peridinoid cysts dominate the dinoflagellate assemblage in most samples. During the upper Campanian carbonate sediments accumulated in northern Colombia (Socuy Limestones), while high paleo-productivity conditions generated biosiliceous sediments and condensed phosphorites in the Eastern Cordillera and the Upper Magdalena Valley (Plaeners Formation and Lidita Superior). These become younger to the east. Continuous, cyclic progradation from the east and south during the upper Campanian accumulated coarse-grained siliciclastics in proximal settings where sandstones are interbedded with porcelanites and cherts (Chiguata and Tausa sections). In more distal environments, micritic limestones and dark mudstones from the Buscavida Formation represent coeval sediments (La Buitrera Creek and

Aico Creek sections). An expanded section of mudstones and sandstones from Los Pinos and Tierna Formations were recognized in the Chiguata Creek section relative to the Aico, La Buitrera, Rio Molino and Tausa sections.

PALYNOLOGIC AND PALEOENVIRONMENTAL CHARACTERIZATION OF STRATA NEAR THE TRIASSIC–JURASSIC BOUNDARY IN NORTHERN PATAGONIA, ARGENTINA

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The uppermost Triassic and the lowermost Jurassic of northern Patagonia are represented by the Paso Flores Formation ("Rhaetian") and the Nestares Formation (Lias). The microflora of Paso Flores Formation includes form species of a large Mesozoic distribution, others which are limited to the Triassic, like *Craterisporites rotundus, Foveogleicheniidites atavus, Polypodiisporites ipsviciensis, Equisetosporites steevesii, Falcisporites nuthallensis, Chordasporites australiensis, Platysaccus queenslandii* and those characteristic of the Late Triassic and Early Jurassic, like *Alisporites lowoodensis*, *Annulispora microannulata/folliculosa, Polycingulatisporites crenulatus/mooniensis, Retitriletes rosewoodensi, Foveosporites moretonensis, Striatella seebergensis* and *Rogalkaisporites cicatricosus*. The Nestares Formation is characterized by exclusively Liassic species like *Skarbysporites elsendoornii*, *Retitriletes semimuris* and *Cycadopites reticulatus*. There are also forms present with a Late Triassic to Early Jurassic distribution such as *Auritulinasporites scanicus* and *Todisporites cinctus*. The Nestares Formation contains the oldest known Liassic, *Otozamites* and *Cladophlebis* bearing megaflora of Argentina, whereas the *Dicroidium* bearing megaflora of Paso Flores Formation is the youngest Triassic flora of this country.

The paleoenvironmental systems indicated by earlier sedimentological analysis are lacustrine, braided and meandring fluvial for Paso Flores Formation and deltaic (transitional) with scarce paleomicroplankton for the Nestares Formation.