AAPG Search and Discovery Article #90007©2002 AAPG Annual Meeting, Houston, Texas, March 1-13, 2002

AAPG Annual Meeting
March 10-13, 2002
Houston, Texas

The Palynological Response to Sea Level Change

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Palynomorphs are present in virtually all marine sediments, from the tropics to the poles and from estuarine to abyssal environments. Their complex organic composition makes them highly resistant as a group, although there are large variations in preservation potential between taxa. Because of their specific gravity, they are transported and deposited together with silt-sized mineral sediment- from land, in the case of pollen and embryophyte spores, or from the sea surface, in the case of planktonic microscopic algal cysts (e.g. dinocysts).

In addition to producing large-scale environmental changes, glacioeustatic sea level variations (particularly those sufficient to produce sequence-bounding unconformities) greatly affect both the transport and preservation of these organic particles. We have taken two approaches to studying the palynological response to sea level: (1) the modern analog approach (i.e. comparing downcore variations with the modern distribution of pollen and dinocysts across the New Jersey margin), and (2) experimental approach (i.e. conducting laboratory experiments to quantify the impact of increasing taphonomic skewing on palynological assemblages)

Figure 1 shows an interpreted seismic reflection profile between ODP Sites 1072 on the outer New Jersey shelf and 1073 on the upper slope (Ewing 9009 MCS Profile 1002, Shipboard Scientific Party, 1998). Six units (labelled A-F), bounded by strong reflectors, contain distinct palynological assemblages which are best understood by considering the palynomorphs as organic sedimentary particles. For instance, the high palynomorph concentrations in Unit A are thought to reflect low rates of siliciclastic flux to the shelfbreak during the early Pleistocene. Low terrigenous flux, and thus little dilution of the palynomorphs, is also recorded by the low ratios of pollen:dinocysts (P:D) in Unit A. The high ratio of autrotophic gonyaulacoid dinocysts vs. heterotrophic protoperidinioid dinocysts (G:P) in these sediments supports the interpretation of low sedimentation rates which would allow oxidation to selectively destroy susceptible protoperidinioid cysts, especially *Brigantedinium* spp. (Hopkins and McCarthy, 2000; Zonneveld et al., 1997).

The results of laboratory experiments performing controlled oxidation on 8 subsamples from each of 2 stratigraphic horizons in ODP Hole 1072A are shown in Figure 2 (Hopkins, in prep.). There is a direct relationship between G:P and the length of time the sediments were exposed to hydrogen peroxide prior to palynological processing and analysis. P:D also increases with exposure time, recording the relatively low susceptibility to oxidation of most pollen taxa that make it to the outer New Jersey shelf. The palynological assemblage in the control subsamples from each horizon clearly records the different taphonomic conditions associated with a sea level highstand (4RCC series within Unit E) and a sea level lowstand (9RCC series at sequence boundary pp3(s)). In the 1072A-4RCC series, the initial dinocyst assemblage is rich in *Brigantedinium* spp., *Spiniferites* spp., and *Operculodinium centrocarpum.* Total palynomorph concentrations decrease sharply after the first half hour of oxidation, as G:P values rise from 1.29 to 10, and P:D values rise from ~5 to ~8. No protoperidinioid dinocysts are found in any of the 1072A-4RCC subsamples exposed for 2 hours or more, at which point *Spiniferites* spp. dominate the assemblage, together with *Operculodinium centrocarpum* and *Bitectatodinium tepikiense* (the latter being a taxon which comprised only ~1% of the control sample, suggesting that it is highly resistant to oxidation). The 1072A-9RCC series, in contrast, was initially dominated by *Bitectatodinium tepikiense*, and had G:P value of 2.7 and P:D value close to 10. This would suggest that these sediments were substantially oxidized *in situ*, an interpretation which supports the generation of sequence boundary pp3(s) during a sea level lowstand. The first half hour of laboratory oxidation destroyed all protoperidinoid taxa, including all *Brigantedinium* spp., and *Bitectatodinium tepikiense* comprised >85% of the assemblage.

The extremely high G:P and P:D values and the very low total palynomorph concentrations associated with sequence boundary pp4(s) at Site 1072 (Figure 1) record more highly oxidizing conditions than those associated with the generation of surface pp3(s). This is consistent with the much longer hiatus associated with sequence boundary pp4(s), where Upper Miocene sediments are overlain by sediments deposited between ~1.7 and 1.4 Ma (McCarthy and Gostlin, 2000). It is not possible to identify sequence boundary pp4(s) at Site 1073 from the palynological record, probably because this site was too far from the shelfbreak during the early Pleistocene. By the mid Pleistocene, however, progradation (Unit C) had brought the shelfbreak close to its present location. The high-frequency fluctuations over several tens of meters below surface pp3(s) in Hole 1073A (spanning several tens of thousands of years), between sediments with very high G:P and high P:D and sediments with palynological assemblages resembling those in the rest of Unit C, record a protracted interval of periodic spillover of oxidized sediments onto the slope prior to the generation of sequence boundary pp3(s).

The generation of sequence boundary pp3(s) ~400 ka resulted in a dramatic change in sedimentation at Site 1073- the relatively rapid accumulation of pollen-rich/dinocyst-poor muddy sediments was succeeded by alternations of these muddy sediments with sandier sediments. These sandier sediments contain very high palynomorph concentrations and are rich in gonyaulacoid dinocysts and pollen, recording much slower accumulation than in the muds. These alternating sediment facies in Units D-F are also associated with very different ichnofacies which support the deposition of the muddy sediments in Unit C and part of Units D-F during sea level fall and lowstand phases, and the deposition of the sandier sediments by shelf spillover with periodic winnowing and erosion during transgressive/highstand phases (Savrda et al., 2001).

The change in sedimentation on the upper New Jersey slope over the last ~400 ka resulted from the accommodation created on the shelf by sequence boundary pp3(s). Sediments were then able to accumulate on the shelf, starving the slope of sediments during highstands. The aggradation appears to have been complete after over roughly one and a half glacioeustatic cycles (McCarthy et al., in press), consistent with the absence of the nannofossil *Emiliania huxleyi* (FAD 250 ka) at Site 1072 (Shipboard Scientific Party, 1998). The accumulation of Unit F only on the outermost shelf and slope, and the lower amplitude of the palynomorph concentration peak associated with highstands in this unit, suggest that the accommodation generated by sequence boundary pp1(s) is much less than that associated with pp3(s).

We used the same taphonomic approach to reconstruct sea levels in Miocene sequences on the New Jersey margin, and although our sample resolution is much lower, and we have done much less experimental work to assess the relative preservation and transport of Miocene taxa, we were able to identify similar palynological trends. Reconstructions of Miocene to Recent sea level on the New Jersey margin agree well with data from other available proxies, e.g. foraminifera, stable isotopes, and ichnofacies. The palynological record supports the role of eustasy as an important factor in shaping the New Jersey margin.

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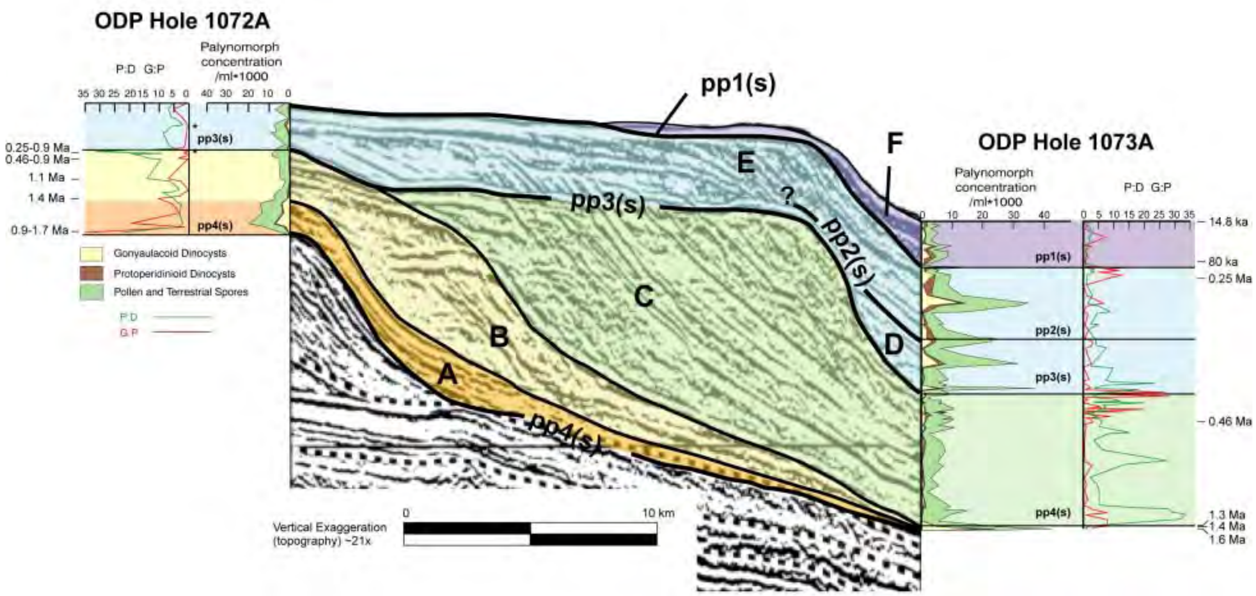
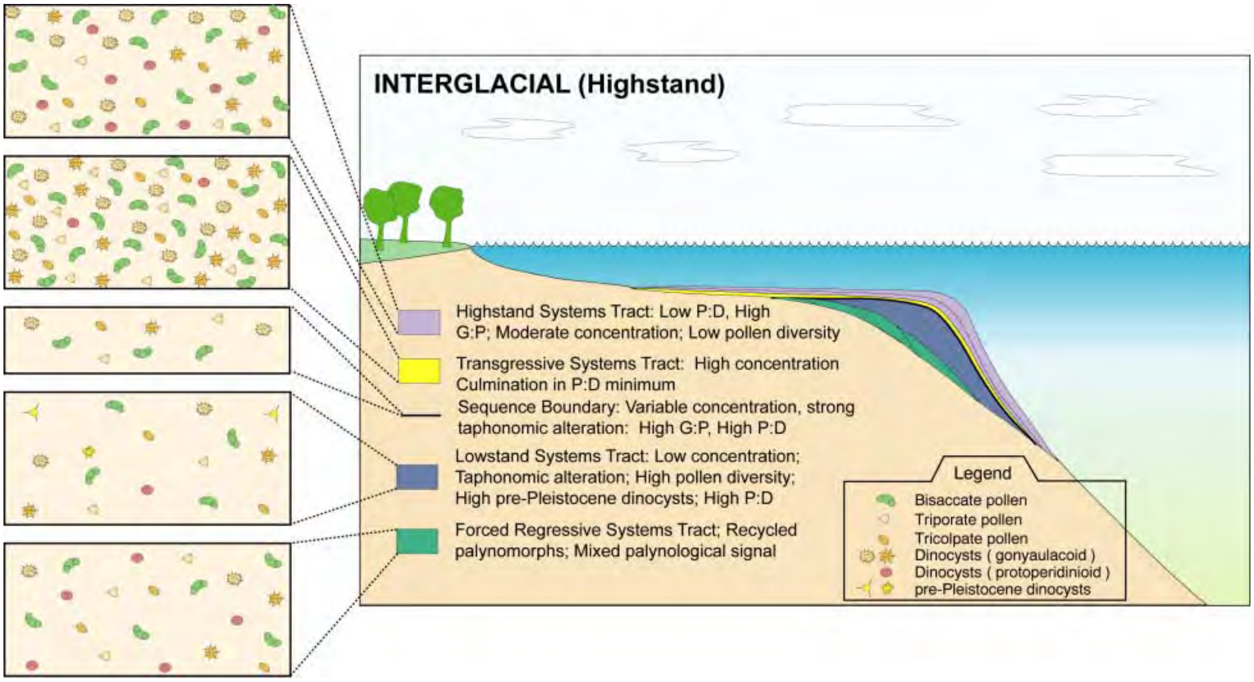
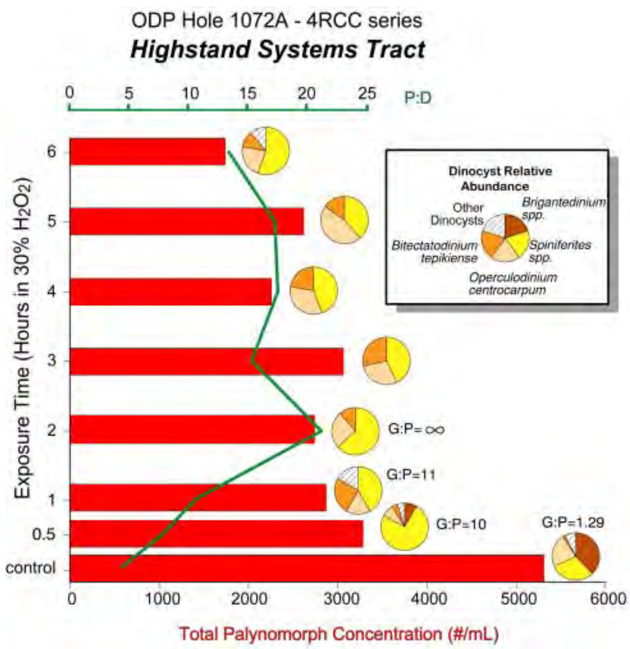
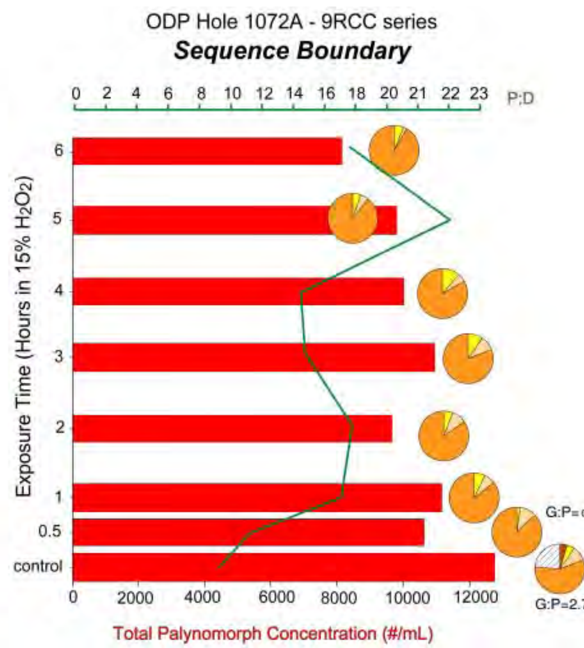



INTERGLACIAL (Highstand)
Highstand Systems Tract: Low P:D, High G:P; Moderate concentration; Low pollen diversity
Transgressive Systems Tract: High concentration Culmination in P:D minimum
Sequence Boundary: Variable concentration, strong taphonomic alteration: High G:P, High P:D
Lowstand Systems Tract: Low concentration; Taphonomic alteration; High pollen diversity; High pre-Pleistocene dinocysts; High P:D
Forced Regressive Systems Tract; Recycled palynomorphs; Mixed palynological signal
Legend
Bisaccate pollen
Triporate pollen
Tricolpate pollen
Dinocysts (gonyaulacoid)
Dinocysts (protoperidinioid)
pre-Pleistocene dinocysts


ODP Hole 1072A - 4RCC series
Highstand Systems Tract
P:D
Exposure Time (Hours in 30% H2O2)
Dinocyst Relative Abundance
Other Dinocysts
Brigantedinium spp.
Bitectatodinium tepikiense
Spiniferites spp.
Operculodinium centrocarpum
G:P=∞
G:P=11
G:P=10
G:P=1.29
Total Palynomorph Concentration (#/mL)


ODP Hole 1072A - 9RCC series
Sequence Boundary
P:D
Exposure Time (Hours in 15% H2O2)
G:P=∞
G:P=2.7
Total Palynomorph Concentration (#/mL)