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Abstracts

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Notions of Stinking Oceans? Models for Organic Carbon Burial During Cretaceous "Anoxic Events"

In modern marine environments, preservation of organic carbon in sediments is influenced by several variables: (1) primary production; (2) water depth and bottom-water oxygen content; and (3) bulk sedimentation rate—higher sedimentation rates enhance organic carbon accumulation rates. High organic carbon values and accumulation rates are found today under highly productive upwelling zones where intense oxygen-minimum zones ($O_2 < 0.5$ mL/L) impinge on upper continental slopes or outer shelves. However, high organic carbon concentrations are also found in the abyssal sediments of the anoxic Black Sea, where surface productivity is relatively low. Therefore, when examining occurrences of ancient marine "black shales," we must be able to distinguish the relative effects of the variables discussed above. The globally widespread "black shales" of some periods in the geologic past cannot be simply explained by patterns of upwelling alone; other, perhaps unusual, conditions must have contributed to their origin.

The Cretaceous is one period during which, at times, marine "black shales" were much more globally widespread than today. These intervals of time have perhaps unfortunately been termed "oceanic anoxic events," but the basic concept of an "anoxic event" involves a time envelope on the order of 10^6 years, during which organic carbon burial appears to have been more widespread in a variety of marine environments than at other times. However, regional or interbasinal differences in the timing, amounts, and types of organic carbon preserved are apparent during a single "anoxic event," and "anoxic events" of different ages differ in overall character. Therefore, no single model can explain the origin of these widespread episodes of organic carbon deposition. There are common associations between "anoxic events"; they tend to occur during global marine transgressions, and they are marked by warmer, more equable global climates.

Three main "anoxic events" occurred during the Cretaceous. These were of late Barremian-mid-Albian age (peak at Aptian-Albian boundary), mid-Cenomanian-early Turonian age (peak at Cenomanian-Turonian boundary), and late Coniacian-early Campanian age. During portions of the first two "anoxic events," organic carbon burial in pelagic and hemipelagic environments may have exceeded 10 times that of today, as indicated by calculations of accumulation rates and model calculations from secular $\delta^{13}C$ curves. The amount and types of organic carbon preserved in strata of different basins suggest that expansion and intensification of deep-water oxygen deficits were responsible for organic carbon preservation in many settings. This may have been partly due to the decreased solubility of oxygen in warm, saline deep-water masses. The feedback between sea level and development of surface and deep-water masses was an important factor. During the Aptian-Albian episode, overall surface-water productivity appears to have been low, and burial of terrestrial organic carbon in marine environments was significant. Enhanced marine surface productivity may only have been important during the relatively brief Cenomanian-Turonian episode.

It is important that we understand the nature of these "anoxic events" so that predictive models of organic contents and types can be constructed and utilized in frontier areas of hydrocarbon exploration, among other reasons.

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Cretaceous Wave-Dominated Delta, Barrier Island, and Submarine Fan Depositional Systems of the Rocky Mountains: Clastic Models for Hydrocarbon Exploration

The distinctive characteristics of the three sand-dominated depositional systems are described with emphasis upon criteria useful in recognizing the systems in outcrop and subsurface settings. Interrelationships between the systems are examined with the aid of a complete sediment dispersal network extending from fluvial coastal plain through wave-dominated delta, strand plain, and barrier island systems to basin floor submarine fans. This network was deposited along the western margin of the Cretaceous interior seaway and was subsequently exposed in the Book Cliffs of Utah and Colorado.

Wave-dominated deltas are commonly cuspate to arcuate in plan, and sheet-like in cross section. Apparent widths range up to 40 mi (64 km). Typical delta front facies tracts consist of laterally extensive shoreface-foreshore sequences locally replaced by distributary mouth-bar deposits. The bar deposits reflect density flow processes and hyperpycnal inflow at the shoreline. Extensive coals and thin transgressive units cap the delta front sequences. The deltas occur in both vertically stacked and imbricate patterns.

The barrier island system is characterized by a sheet sand-body geometry, and by a dip-oriented facies tract consisting of a shoreface-foreshore barrier sequence replaced in a landward direction by tidal inlet and flood tidal delta deposits. Brackish-water lagoonal sediments overlie the entire tract. Characteristics of the system indicate deposition in a microtidal setting.

Submarine fans occur in distal settings beneath the prograding delta and barrier-island systems. Fan deposits are lenticular in cross section and isolated in basinal shale. The deposits range from thickening-upward sandstone-shale sequences reflecting deposition in outer fan environments to thick, sand-dominated, channelized sequences reflecting deposition in more proximal fan environments.

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Mode of Extension of Continental Crust

Cordilleran continental crust, from central British Columbia through Sonora, has been doubled in width by middle Eocene through Quaternary extension. Extensional structures seen at comparable levels of erosion are similar throughout the Cordillera and elsewhere in the world, so a model of general application can be deduced. "Core complexes" form beneath normal-fault blocks of basin-range type.

The lower third of the crust (seen in the Cordillera primarily by seismic reflection profiling; typically granulite-facies rocks where exposed elsewhere) is extended by laminar ductile flow. Preexisting rock masses are transposed into subhorizontal sheets.

The middle crust (seen in Cordilleran outcrop in Eocene through Pliocene "core complexes," as well as by reflection profiling) is extended by discontinuous ductile flow. Rocks are transposed, and recrystallized commonly in greenschist facies, in anastomosing ductile shear zones along which lenses of all sizes up to tens of kilometers long slide apart.