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Eocene-Oligocene: A Time of Transition

The Eocene-Oligocene is a time of transition from a warm early Tertiary world with low vertical and latitudinal thermal gradients to the Neogene world with steep vertical oceanic gradients and high latitudinal gradients between equator and poles. The transition between these two regimes occurred primarily between the middle Eocene and middle Oligocene and can be observed in faunal and floral assemblage changes, associated paleotemperature changes, periodic current intensification as implied by increased carbonate dissolution and hiatuses, eustatic sea level changes, and the curious association of microtektites and iridium anomalies with several of these intervals.

Population studies of planktonic foraminifers in 14 DSDP sites in the Atlantic, Pacific, and Indian Oceans indicate a general cooling trend between the middle Eocene and Oligocene. Major faunal changes indicating cooling episodes occur, however, at discrete intervals: middle Eocene 44 to 43 Ma (P13); middle/late Eocene boundary 41 to 40 Ma (P14/P15); late Eocene 39 to 38 Ma (P15/P16); Eocene/Oligocene boundary 37 to 36 Ma (P18); and late Oligocene 31 to 29 Ma (P20/P21). Each cooling episode resulted in the extinction of warmer water species and evolution and dominance of cooler water species. This trend is associated with the development of a steep vertical thermal gradient and resulting stratification in the upper water masses (0 to 300 m, 1,000 ft) in the latest Eocene. ^{18}O analyses of individual planktonic species indicate that distinct surface, intermediate, and deep dwelling assemblages appear in the latest Eocene (P17), nearly coincident with the development of the psychrosphere. Major deep-sea hiatuses occur coincident with changes in the eustatic sea level at the middle/late Eocene boundary, the late Eocene, and in shallow sections in the Oligocene (30 to 29 Ma). These hiatuses suggest that vigorous bottom water circulation began developing in the middle Eocene, consistent with the faunal cooling trend and well before the development of the psychrosphere.

The presence of microtektites and iridium anomaly in latest Eocene sediments has resulted in the scenario of catastrophic extinctions due to a bolide impact. The present study reveals multiple microtektite occurrences at 43 Ma, 40 Ma, 38 Ma, 34 Ma, and 30 Ma. Moreover, these microtektite occurrences coincide with intervals of increased carbonate dissolution and/or hiatuses. This suggests that microtektites are concentrated as a result of carbonate dissolution and selective winnowing of sediments at these intervals. Consequently, a concentration of microtektites in deep-sea sediments may not always imply a bolide impact, nor is there any evidence of catastrophic extinctions during Eocene-Oligocene time.

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Use of Fission-Track Annealing Systematics in Constraining the Thermal Evolution of Sedimentary Basins

Fission-track annealing systematics in detrital apatite provide a promising means for evaluating the thermal histories of sedimentary basins. Significantly, the temperature range for fission-track annealing, 90° to 135°C (194 to 275°F), is similar to the temperature range for petroleum maturation. Compared to vitrinite reflectance measurements and other techniques currently used to monitor thermal histories of sediments, the fission-track annealing technique is superior, as it is not affected by chemical complexities or fluid composition. In addition, the kinetic laws for track annealing are relatively well characterized.

The usefulness of the technique is demonstrated by examination of natural annealing data from drill holes and by calculation of hypothetical fission-track age versus depth relations for particular thermal histories. These results are used to evaluate currently popular models for the evolution of sedimentary basins. Simple instantaneous stretching models for sedimentary basin evolution do not appear to predict thermal and subsidence histories consistent with fission-track data. Temperatures necessary to account for petroleum maturation and fission-track annealing require stretching rates that, in the published models, lead to subsidence of a factor of 2 to 3 times greater than that observed.

As the temperatures predicted by the simple tectonic stretching models are not consistent with the fission-track data, other factors that affect the temperature distribution in a sedimentary basin must be considered. These include basin hydrodynamics and the time-varying thermal properties of the basin sediments. It is concluded that the thermal history of petroleum source rocks within sedimentary basins is primarily controlled not by the processes and parameters that form the basis of the tectonic stretching models, but rather by processes operating within the basin. The relative thermal effects of these processes within basins can be effectively monitored using fission-track annealing systematics.

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New Cements for Old Radiaxial Fibrous Calcite—A Reassessment

No abstract.

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Unconformity-Associated Replacement Limestones After Anhydrite in Mississippian of Williston Basin

Locally in southeastern Saskatchewan, Mississippian nodular anhydrites (after subaqueous gypsum) beneath an unconformity have been altered to limestone—limestones that are commonly porous and oil-bearing. Such carbonates are commonly intergrown with pyrite and celestite, and thus are difficult to interpret from logs. At localities with calcitized anhydrite, the unconformity is overlain by Jurassic red beds in which pigments have been reduced to green hues. In the region, carbonates beneath the unconformity are normally overlain by red beds and have been completely dolomitized and plugged with anhydrite to form an impermeable caprock. Mississippian anhydrites subcrop at the unconformity surface and reveal little evidence of alteration—even to gypsum.

Textures in replaced anhydrites indicate that calcitization involved both creation of porosity and in-situ (small-scale) replacement leading to retention of anhydrite (and later gypsum) fabrics. Celestite formed as strontium was released from anhydrite during replacement by gypsum and calcite. Sulfur in associated pyrite is isotopically lighter than the anhydrite, suggesting anhydrite-alteration involved the activities of sulfate-reducing bacteria. Evidently, H_2S liberated during the reaction migrated across the unconformity to reduce overlying red beds.

Limestones of this type do not appear to have been reported previously. Stratigraphic and petrographic evidence indicates replacement, although spacially related to the unconformity, was not a weathering phenomenon. It occurred after the unconformity was buried.

Unexpectedly heavy $\delta^{13}C$ and $\delta^{18}O$ values (+1.22 to 1.54, and −1.0 to −3.7) obtained from the replacement limestones seem to preclude the utilization of organic carbon in the reaction. The

source of carbonate and of the energy required for sulfate-reducing bacterial activity is therefore problematic.

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Organic-Matter Preservation in Chattanooga Shale: Revised Late Devonian Correlations, Kentucky and Tennessee

Continued interest in the carbon-rich shale of Devonian and Mississippian age in Kentucky is reflected by intensive leasing and drilling to evaluate the potential reserves of oil shale. Hydrocarbons and heavy metals are associated with layers rich in organic matter (OM). Thicker accumulations of shale suitable for surface extraction lie along the flanks of the Cincinnati arch in both the Illinois and Appalachian basins. Distribution of the OM-rich shale is not uniform, but is controlled by subtly defined lithostratigraphic units. The shale tends to thin across the Cincinnati arch by an order of magnitude (100 versus 10 m, 330 versus 33 ft), and individual units disappear entirely. Key beds have been used with mixed success in tracing these changes.

Recognition of these key beds in cores provided by a recently completed 70-core drilling program in and near the outcrop is the basis for revising earlier suggested correlations. One key bed, marked by the occurrence of the alga? *Foerstia* (*Protosalvinia*), occurs in the lower part of the lower (Huron) member of the Ohio Shale in the Appalachian basin. The Huron Member is overlain by a lithostratigraphic marker, the Three Lick Bed. The *Foerstia* Zone has been traced in core and outcrop to the upper part of the uppermost (Clegg Creek) member of the New Albany Shale in the Illinois basin.

Discovery in this widespread continuous biostratigraphic marker at the top of the upper (Gassaway) member of the Chattanooga Shale near the designated reference section in Dekalb County, Tennessee, suggests that the Three Lick Bed of the Ohio Shale does not correlate with the middle unit of the Gassaway Member of the Chattanooga Shale as thought. Field relations indicate that the Three Lick Bed is absent by nondeposition, and starved-basin conditions prevailed into Early Mississippian time in this part of Tennessee. These stratigraphic revisions become significant in a regional synthesis of the anoxic-basin depositional model of OM—rich shale and syndepositional tectonics during Late Devonian time in Tennessee and Kentucky.

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Paleozoic and Mesozoic Stratigraphy and Oil Potential of Western Desert

The depocenter of the Paleozoic basin in western Egypt lies in the northwestern part of the Western Desert. The sediments are primarily terrigenous (with two minor phases of vulcanicity) laid down in an epicontinental sea. The depositional axis of the basin, where thicknesses in excess of 2,800 m (9,200 ft) have been recorded, has a northwesterly trend to the vicinity of the Siwa Oasis. A less well-defined shallower basin with a northerly trend lies to the southwest. The facies show such similarities to those found in the Ghadames and Murzuq basins that the same formational names are applied. Farther east, a possible Paleozoic basin lies in the Abu Gharadig area where 1,300 m (4,265 ft) of sediments were drilled. The limits of this presumed basin are questionable since basement was not reached.

Following the deposition of the Paleozoic section, there was a marked hiatus; the time of Hercynian movements for Permian and Triassic beds is absent. Uplift and the presence of volcanics dated in Permian-Carboniferous time are indicative of Hercynian tectonic activity. Only in Early Jurassic time did the seas again begin to encroach upon the Western Desert area from the Salum basin in the northwest and the Wadi Natrun basin to the east and northeast. This process continued, until by the time of the Oxfordian transgression maximum there was a relatively uniform carbonate cover to about lat. 29°N over the Western Desert.

Further tectonic uplift accompanied by faulting and marine regression is dated from late Kimmeridgian time to the beginning of the Cretaceous, when transgression began once again. The pattern of transgression, however, differs from that of the Jurassic; the two basins, the more westerly Matru basin and the easterly Alamein basin, both have north-northeasterly trends, although by Aptian times they are less clearly distinguishable.

The dominant feature, new in the Western Desert, was the development of an east-west extensional basin, the Abu Gharadig basin, in Cretaceous time. It was bounded on the north (30°N) by the Rabat Abu Rivash ridge, which persisted through the Cretaceous. The trough became less distinctive in Cenozoic times when a further trough, the Tiba basin, developed north of the ridge.

Production from the northern Western Desert until recently has been disappointing. Exploration results from the Paleozoic Section have yielded little, but the existence of a marine section suggests that the area northeast of Siwa still has potential. The thick deeply buried Jurassic marine sequence in the Western Desert may be the source for at least part of the production from Cretaceous horizons in the Abu Ghradig, Alamein, and Razzak oil and gas fields.

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Central Arctic Foothills, Alaska: A Unique Challenge in Frontier Exploration

Chevron U.S.A. has under lease nearly 2 million acres (800,000 ha.) of Arctic Slope Regional Corporation lands in the foothills of the Brooks Range between the Chukchi Sea and Canning River. In the central foothills, between the National Petroleum Reserve-Alaska and the Alaska pipeline, Chevron has conducted extensive field programs and air photo mapping, recorded 3,000 km (1,865 mi) of seismic data, and drilled three exploratory wells.

The Brooks Range foothills are underlain by complex thrust plates and associated foreland folds which contain deformed rocks ranging in age from Devonian to middle Cretaceous. Main thrusting occurred in latest Jurassic to Albian time, corresponding to an arc-continent collision possibly associated with the widening of the Canada basin. First orogenic pulses are recorded by Upper Jurassic turbidites and olistostrome units which reveal a southern clastic source, a major reversal in source direction from older sedimentary units. Lower Cretaceous foreland turbidites show progressive northward migration of underthrusted imbricating plates.

In the thrust belt, the primary reservoir objective is Lisburne limestone and dolomite, Mississippian to Permian in age. Seismic data identify a variety of structural styles of Lisburne plates ranging from complex stacks of imbricates to a single leading-edge plate underthrust by Lower Cretaceous foreland clastic units. Pore space in dolomitic Lisburne is filled with solid bitumen nearly everywhere on the surface in the central foothills, suggesting that extensive amounts of oil have migrated through