hydrocarbon migration, which has significant effect on formation-water chemistry. The relationship between hydrocarbon migration and diagenetic minerals may be used as a pathfinder for hydrocarbon accumulation at depth.

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Pennsylvanian Shelf Carbonates, Madera Formation, Taos Trough, Northern New Mexico

The sandy limestones of the Madera Formation differ significantly from shelf carbonates described in other southwestern late Paleozoic basins in that: (1) they were deposited adjacent to an active uplift that provided terrigenous clastics; and (2) no large scale phylloid algal mounds were developed. Prior to deposition of the Madera limestones, early to middle Desmoinesian deltaic deposits derived from the Uncompaghre uplift prograded eastward into the basin. Carbonate deposition was locally initiated on abandoned deltaic platforms, where low relief blue-green algal mudbanks and bryozoan mounds developed.

Carbonate deposition became widespread during a middle Desmoinesian transgression. Hummocky to cross-bedded crinoid grainstone shoals formed on and seaward of the algal mudbanks. These initial crinoid shoals were small and laterally discontinuous. As the shoals prograded and evolved into wave resistant barriers, extensive lagoonal and channeled tidal-flat deposits developed behind them. These low-energy lagoonal facies are characterized by small, low relief phylloid algal bars separated by bioturbated sandy siltstones. Fusulinid packstones filled tidal channels which graded laterally into dasycladacean algal flats. Progradation of the shoals also caused steepening of the platform margin, which led to restricted circulation in the slope/basinal depression. Anoxic conditions developed, and thick black, calcareous shaly siltstones were deposited in the basin. Carbonate deposition on the shelf was then terminated by renewed fluvial activity.

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Evidence for Pervasive Bioerosion of Silica Substrates in a Freshwater Peat Environment

Siliceous particles (30 to 100 μm) collected from freshwater peat deposits in the Okefenokee swamp show extensive effects of bioerosion. When viewed with the SEM these effects include: (1) depressions (similar to those produced by diatoms); (2) perforations (holes 2 μm in diameter); and (3) borings (holes >2 μm in diameter). These features are most likely to be of biological origin because of their smooth surfaces and the consistency of the geometry of the cavities. The delicate nature of the eroded grains dictates that the biological agents responsible must have lived in the peat-forming environment. For example, monaxon sponge spicules have lost as much as half their original mass through hundreds of tubular microborings, rendering them far too fragile for transport. Heretofore, microborings have been observed to commonly occur on carbonate substrates, and in only two cases has bioerosion been reported in siliceous sediments in a marine environment. Our observations show that freshwater organisms are also capable of boring/dissolving silica, and that this form of degradation may play a major role in silicon mobility within peat-forming environments.

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Barra Nova Salt Domes Province, Espirito Santo Basin, Offshore Brazil

The Barra Nova salt domes province, in the Espirito Santo basin, offshore Brazil, bears some resemblance to the interior basins of the Gulf of Mexico. Two main hypotheses try to explain the origin of the Barra Nova salt domes. (1) Since Aptian salt was overlain by uniform Albian platform, salt movement began as a consequence of the general eastward tilting of the basin which caused gravity sliding and the formation of salt pillows. (2) Existence of an uneven sedimentary loading is represented by Upper Cretaceous volcanic flows extending over the area underlain by salt. These volcanics sank into the salt, forming exposed salt masses which were dissolved, causing salt withdrawal and gravity sliding. Continued sedimentation on the evacuated areas induces the formation of salt domes.

The initial salt pillows began forming during the Albian. Before the Maestrichtian, they reached the extrusion/collapsing phase which extended to the Holocene with the salt domes being dissolved on the present sea floor. One of the mapped domes represents an exception, as it seems to be already in the burying phase.

The gravity sliding, originated from halokinesis, was an important factor in the tectono-sedimentary evolution of the Espirito Santo basin from Late Cretaceous on.

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Analysis of Upper Cretaceous Trace-Fossil Assemblages, U.S. Western Interior

Diversity and abundance of trace fossils in strata of the Greenhorn and Niobrara cyclothems of west-central Kansas, southern Colorado, and south-central Utah have been used to quantify trace-fossil assemblages. Recognition of assemblages is based on use of quantitative, semi-quantitative, and binary (presence-absence) data in conjunction with cluster and factor analysis. Although the character of the original burrowing infauna was a primary factor in assemblage composition, the nature of burrowed sediments and diagenesis exerted strong influence on the preserved trace-fossil record. Thus, the present composition of originally similar assemblages may differ among the several lithotypes (sandstone, shale, chalk, limestone) because of variations in depositional and diagenetic processes that affected preservation of biogenic structures. It is suggested that some of the observed differences in these Upper Cretaceous trace-fossil assemblages are more apparent than real.

At present, taxonomic problems relating to trace fossils hinder quantification of the Upper Cretaceous assemblages. Direct application of standard taxonomic conventions could lead to conceptual confusion because the morphology of trace fossils is controlled as much by general behavior of organisms and their specific responses to sedimentologic parameters as by body form. For example, *Ophiomorpha* is known to grade into *Thalassinoides,* some of which developed *Teichichnus*-like form. Furthermore, some *Rhizocorallium* are connected to *Thalassinoides* burrow systems. The first three genera could be synonymized with *Rhizocorallium,* which has priority. A more constructive approach involves erection of suprageneric categories, such as *Rhizocorallium*-group, that would express

the natural relationship of many associated trace fossils.

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Hydrocarbon Exploration in Western Oregon and Washington

Recent discovery and successful development of a gas field near Mist, Oregon, have conclusively demonstrated the presence of commercial quantities of hydrocarbons in western Oregon and Washington. Understanding of the source and reservoir facies of this discovery may help develop additional exploration targets.

Reservoir sandstones of the Mist area occur in the Cowlitz Formation of middle Eocene age (Narizian Foraminifera Stage). The Cowlitz Formation of northwest Oregon and southwest Washington consists of nearshore-marine and brackish-water deposits of massive arkosic sandstone, shale, subbituminous coal, and interbedded basalt. It was deposited as part of a broad marine-deltaic system that extended from southern Oregon to northern Washington during middle Eocene time.

The feldspathic-quartzose sandstone of the Cowlitz Formation has porosities ranging from 14 to 41%, averaging approximately 25%. Permeabilities range from 46 to 8,500 md, averaging approximately 200 md.

Marine shale outcrops of the Cowlitz Formation in Washington contain dominantly terrestrially derived organic matter and have total organic carbon content averaging approximately 0.75%. Vitrinite reflectance values average approximately 0.45% for rocks inferred to have been buried to a depth of approximately 10,000 ft (3,000 m).

Traps, including the Mist gas field, appear to be structural-stratigraphic with reservoir sandstones thinning against plunging basement noses. These traps are complex and masked beneath several unconformities, underscoring the importance of geophysical exploration.

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Tectonics of Monterrey Salient, Sierra Madre Oriental, Northeastern Mexico

The Monterrey Salient formed as a result of uplift in the Mesa Central of Mexico and consequent gravitational sliding of the detached cover to the northeast during the Laramide orogeny. The salient is located south of Monterrey where the Sierra Madre Oriental orogenic belt arcs abruptly from an east-west to a north-south direction. It is composed of a series of arced, doubly plunging, en echelon anticlines, most of which are overturned to the north. Exposed in the area are Upper Jurassic carbonates and terrigenous rocks, and Lower Cretaceous carbonates. The salient also contains a few outcrops of Upper Jurassic evaporites which have flowed to the surface along fault planes. These evaporites, recognized as the Minas Viejas Group, are believed to be the decollement above which the deformation occurred.

A crustal shortening of 50% is calculated in the Monterrey Salient. Most of the shortening is attributed to folding, in as much as surprisingly few major thrust faults have been observed. Field work also demonstrates that structural trends are directly related to buttressing effects of paleohighs and thick sedimentary basins. On the basis of these structural trends and recent stratigraphic studies, the Mesozoic Coahuila peninsula is found to extend in the subsurface farther to the south than has previously been assumed.

Both the stratigraphy and structural style make the Monterrey Salient a classic example of a gravity-induced orogenic belt.

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Evolution of a Fore-Arc Basin, Luzon, Philippines

The Tertiary Central Valley of Luzon is a remarkably well-exposed fore-arc basin, with both the trenchward and arc flanks uplifted and dissected. A study of outcrop geology, drilling results, and seismic reflection records determined the changing geometry of the basin through time, facies distributions, sediment-distribution patterns, and hydrocarbon potential for the basin. The uplifted western flank exposes an ophiolite sequence, pelagic deposits, and deep-sea to shallow-marine clastics that document the emplacement and uplift of the seaward side of the basin. The eastern flank shows nonmarine and shallow-marine volcaniclastic aprons shed off the arc, overlain by reefs, shallow-water clastics, and a progressively deepening slope/basin turbidite sequence.

Basin geometries and detrital mineralogy suggest that the Central Valley formed as an elongate geomorphic feature in the middle Miocene and progressively subsided and filled into Pliocene time. Over 35,000 ft (10,668 m) of sediment accumulated prior to a westward jump of the fore-arc basin to a site nearer to the Manila Trench. The positions of shelf/slope boundaries and prograding deltas can be documented from seismic-stratigraphic analysis. The history of basin formation and relative positions of possible source and reservoir rocks suggest that the Central Valley has undiscovered hydrocarbon potential.

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Destin Dome and Western Florida Shelf

The U.S.G.S. has acquired a network of 1,280 km (800 mi) of common-depth-point seismic data connecting eight wildcat wells north of the latitude of Tampa and tied to the Destin dome area in the northeastern Gulf of Mexico. Line layout facilitates ties to onshore and offshore wells and to the regional multichannel net of the University of Texas. These lines reveal the structural growth of the salt-related Destin dome and a salt pillow with Jurassic and Early Cretaceous growth 30 km (20 mi) south of the Destin structure. Elsewhere in the West Florida Shelf, numerous low relief anticlines are present above basement highs.

Destin dome is a large, west-northwest trending anticlinal structure off northwest Florida. The dome is more than 80 km (50 mi) long and 30 km (20 mi) wide and has relief of a kilometer (3,000 ft) on Lower Cretaceous rocks. The dome appears to be the result of a salt swell that was uplifted during the Late Cretaceous and early Cenozoic. In 1973, 32 tracts (184,320 acres) constituting the eastern half of this structure were leased for $728,000,000. The highest bid lease (near the crest of the anticline) was purchased for $211,997,600 ($36,805/acre). Leases were not offered on the western half of the dome as it lies within a bombing range administered by the U.S. Department of Defense. Structural crests of Lower