tary cycles were deposited in the Newark basin formed during rifting events associated with formation of the present-day Atlantic Ocean. Sedimentary cycles consist of laminated black shale, thin-bedded mudstones with sinuous polygonal mudcracks, brecciated mudstones containing angular fragments of thin-bedded mudstone "float" in a red muddy matrix, massive mudstones with abundant millimeter-scale mud aggregates and analcime or dolomite void fillings. Black shale and thin-bedded mudstones indicate a shallowing perennial-lake environment. Other textures found in these cycles have been attributed to subaqueous dewatering mechanisms. Our study suggests that these textures are the result of subaerial exposure and soil-producing processes in an arid environment.

In modern playa deposits, brecciation results from superimposition of mudcracks and mudcrack fillings; massive muds result from repeated wetting and drying, vesicle development, and clay illuviation. Coatings, around grains and void walls, by aligned clays (cutans) and iron oxides are seen in both modern muds and ancient massive mudstones. These microfeatures increase upward in the ancient cycles in the same manner as recent desert soils.

Desert "soils" overlying lake deposits in the Mojave indicate a transition from pluvial Pleistocene modern arid conditions in which sedimentation is slow and sporadic. Similar periods of long, continued aridity may be inferred for the Lockatong, and other similar formations, in Triassic basins along the east coast of North America.

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Near-Surface and Burial Diagenesis of Mississippian Burlington and Keokuk Formations

The Burlington and Keokuk formations (Osagean) in Illinois and Missouri exhibit a complex diagenetic history of multiple episodes of calcite cementation, dolomitization, dedolomitization, chertification, compaction, and minor Mississippi Valley-type mineralization. Geochemical data and plane and cathodoluminescent light petrography define the complete paragenetic sequence.

The earliest widespread diagenetic event was replacement of lime mud by luminescently zoned dolomite (dolomite I). Dolomite I rhombs were later partially replaced by unzoned, luminescently red dolomite (dolomite II). A regional calcite-cemented stratigraphy of 5 luminescent and nonluminescent zones postdates dolomites I and II and predates upper Meramecian deposition. Between the third and fourth calcite-cement zones, minor dedolomitization was accompanied by a third dolomite generation (dolomite III) that syntaxially overgrew and/or replaced dolomites I and II.

Chertification of lime mud began before replacement by dolomite I. Additionally, chalcedony and megaquartz filled voids and partially replaced the first 5 calcite-cement zones.

Two regional compaction events are observed. The first occurred between calcite-cement zones 3 and 4, whereas the second postdates calcite cement zones.

The preceding events are postdated by minor Mississippi Valley-type mineralization, which includes dissolution vugs partially filled by baroque dolomite, sphalerite, pyrite, quartz, and ferroan calcite.

A mixing zone is proposed for dolomite I based on petrographic timing and complementary stable isotope data. Regional variations in luminescent and nonluminescent calcite-cement zones suggest precipitation in ground-water systems with lateral and vertical Eh gradients. Late diagenesis by hot brines is indicated by minor Mississippi Valley-type mineralization and supported by fluid inclusion data and depleted carbon and oxygen isotope values.

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Structural Relations Between Marfa, Marathon, Val Verde, and Delaware Basins of West Texas

The Marfa, Marathon, Val Verde, and Delaware basins and related uplifts formed the major structural elements of the southwestern continental margin of North America during the Paleozoic. In contrast with the relatively simple relationships where the southern Oklahoma aulacogen intersects the Ouachita orogenic belt, structural relationships in the area of these basins are very complex. Various geologic evidence points to an allochthonous Marathon basin. However, a prominent gravity anomaly is associated with the Ouachita system as it extends from western Arkansas through Oklahoma and Texas into northern Mexico. If this anomaly is the signature of the early Paleozoic continental margin, then the location of the Marathon basin with respect to this anomaly suggests lateral displacements have been only on the scale of tens of kilometers. The Delaware basin seems clearly analogous to the Anadarko basin in that it formed as a result of reactivation of a major crustal flaw (not necessarily a rift). This reactivation was a result of the Ouachita orogeny. The Marfa basin is also flanked by a linear gravity high and basement uplift. The relationship of this anomaly to the gravity high associated with the Ouachita system suggests that the Marfa basin may be more analogous to the Delaware basin than foreland basins such as the Ft. Worth and Arkoma. A prominent gravity high that extends into northern Mexico is associated with the Devil's River uplift, and the relationships between this feature, the Val Verde basin, and adjacent structures suggest major deformation on a crustal scale.

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Neotectonics, Sea Level Change, and Quaternary Natural Gas Occurrence in Coastal Maine

The glaciated, passive continental margin of northern New England is not a likely location for either tectonic activity or hydrocarbon accumulation, but neotectonic action has played a role in creating favorable stratigraphic traps for natural gas in the Quaternary inner-shelf and estuarine deposits of Maine. During late glacial time (13,000 years B.P.), a marine inundation accompanied ice retreat across the isostatically depressed lowlands of coastal Maine and blanketed the area with marine sediment (Presumpscot Formation) up to 50 m thick. Unloading of the ice led to rapid coastal rebound within a few thousand years, and the former sea floor became emergent to present depths of -65 m. A gullied and weathered lag surface on the muddy Presumpscot Formation marks the regression that followed deposition. Since about 8,000 years B.P., sea level has risen in Maine, and within historic times it has been accompanied by seismicity and subsidence rates up to 9 mm/yr. Examinations of over 1,500 km of seismic reflection profiles and limited coring reveal the presence of abundant natural gas in Holocene sediments filling ravines cut into the Presumpscot Formation during emergence. It appears that the gas is derived from and trapped by mud deposited in estuarine depocenters that migrated landward during the Holocene transgression.

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Disrupted Carbonate Hardgrounds in Shallow Carbonate-Shelf Sediments: Origin and Setting of Tepees and Their Associated Fabrics

Carbonate-sediment surface hardgrounds are commonly disrupted and brecciated. Some of these breccias are the result of repeated episodes of fracturing and fracture fill by sediment and/or cement. Each fracture and fracture-fill phase causes the crust to grow in surface area and crumples it into megapolygons whose anteform margins are called tepees. Fracturing is caused by thermal contraction, water-table movement buoying up the crust, mass movement of sediment, and tectonic events. Tepees are commonly ascribed to tidal flats but, in fact, also occur in many settings that can be determined from their fabric and facies associations. (1) Submarine tepees from shallow, carbonate-saturated water occur in fractured, bedded, marine grainstones with acicular and micritic cements. They contain no vadose pisolites or gravity cements, and the hardground surface is altered and bored. (2) Peritidal tepees occur in fractured, bedded, tidal-flat carbonates characterized by fenestral, pisolitic, and laminar algal fabrics close to the marine water table. Fracture fills include gravity-controlled marine travertine and/or marine and terra rossa sediments. (3) Groundwater tepees form in fractured fenestral, pisolitic, and laminar algal crusts over "boxwork" carbonates at the margin of shallow salinas where periodic groundwater resurgence is common. (4) Extrusion tepees, which are also from salina margins with periodic groundwater resurgence, form in crusts coated with laminated micrite that extend from the fractures downward into dolomitic micrite. (5) Caliche tepees, from continental settings overlying soil profiles, form in laminar crusts with pisolites. Fractures are filled by micritic laminae, microspar, spar, and terra rossa.

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Estimating Unconformity Thicknesses from Vitrinite Reflectance Data

Combining variations of vitrinite reflectance with depth and burial history information enables estimation of the paleoheat flux-time derivative, β. In the presence of an unconformity, the residual r.m.s. fit of the paleoheat flux to the observed data is significantly improved when the unconformity thickness (h) is allowed to be a free variable. A best unconformity thickness that minimizes the residual r.m.s. fit to β can be determined, providing a new method of determining simultaneously paleoheat flux and unconformity thickness.

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Seismic Expression of Catastrophic Slope Failure: Lower Cretaceous Torok Formation, North Slope of Alaska

Seismic geometries in the deep marine Torok Formation illustrate that catastrophic slope failure involving both slope and basin-plain sediments occurred during Early Cretaceous time on the North Slope of Alaska. The magnitude of the failure emphasizes the importance of slumping and sliding as processes of mass transport of sediment in the deep marine environment.

Torok sandstones and shales were deposited on continental slopes, basin plains, and submarine fans. Fluvial-deltaic sands and shales of the Nanushuk Group are the time-equivalent shelf deposits. The Nanushuk-Torok relationship is expressed seismically as offlapping reflectors that record shelf-edge progradation. Slumps and slides are common on Torok slopes where gradients of up to 10° are documented.

The largest such feature, located near Harrison Bay, is 1,500 mi^2 in area and 2,000 ft thick. The disturbed zone is lobate in plan view, wedge shaped in cross section, and thins basinward from a dramatic scarp deeply incised into Torok foreset beds. Seismically, the slide is expressed as a series of remnants of undisturbed or rotated glide blocks that strike parallel with the slump scarp and are encased in chaotically bedded slump debris. Geometric similarities to the Turnagain Heights slide (Anchorage, 1964) suggest block gliding as the mechanism of slope failure.

Because the Torok was initially sand-poor, wells drilled through glide blocks and slump debris encountered predominantly shale. Understanding similar seismic geometries in other slope systems will aid in their evaluation as hydrocarbon traps. Favorable reservoir and trap scenarios include turbidite sands in remnant blocks trapped against slump fill and younger turbidite sands ponded behind remnant topography.

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Low to Intermediate Subsurface Temperatures Calculated by Chemical Geothermometers

The concentrations of silica and proportions of sodium, potassium, lithium, calcium, and magnesium in water from hot springs and geothermal wells have been combined into 14 chemical geothermometers that are used successfully to estimate the subsurface temperatures of the reservoir rocks. Modified versions of these 14 geothermometers and a new chemical geothermometer, based on the concentrations of magnesium and lithium, were used to estimate the subsurface temperatures (40°C-200°C) of more than 200 formation-water samples from about 30 oil and gas fields located in coastal Texas and Louisiana, Central Valley, California, and North Slope, Alaska. The new Mg-Li geothermometer, which can be used to estimate subsurface temperatures as high as 350°C, is given by:

$$t = (1{,}900/(4.67 + \log[(C_{Mg})^{0.5}/C_{Li}]) - 273$$

where t is temperature (°C) and C is the concentration (mg/L) of the subscripted cation.

Quartz, Mg-Li, Na-K-Ca-Mg, and Na-Li geothermometers give concordant subsurface temperatures that are within 10°C of the measured values for reservoir temperatures higher than about 70°C. Mg-Li, Na-Li, chalcedony, and Na-K geothermometers give the best results for reservoir temperatures from 40°C to 70°C. Subsurface temperatures calculated by chemical geothermometers are at least as reliable as those obtained by conventional methods. Chemical and conventional methods should be used together where reliable temperature data are required.

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Sketching Cross Sections with a Portable Microcomputer

Computer applications have been carried to the field long ago by geophysicists and their "dog houses." The advent of inexpensive battery-powered microcomputers promises to allow the field geologist to participate in this application. The field geologist may record data directly onto a computer-readable medium and calculate statistics or plot a cross section. A program for routine plotting of cross sections in the field has been developed and field-tested. The program proved to be useful to 30 computer-illiterate geologists on a 6-week mapping project in New Mexico. The program allows the user to control vertical exaggeration and displays the correct apparent dip along the chosen line of section. Cubic-spline interpolation is used to plot both topography and folded bedding planes. The program executes in Pascal on an Apple IIc in a few seconds.

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Regional Cement Stratigraphy and Diagenetic History of Waulsortian Limestones, Eastern Midlands, Republic of Ireland

The Lower Carboniferous Waulsortian Limestones, eastern Midlands, Republic of Ireland, contain 7 distinct luminescent zones in clear calcite cements that overlie inclusion-rich, marine cements in cavities and also fill fractures and aragonite-skeleton molds. The luminescent sequence, which records precipitation from increasingly reducing pore waters, is regionally and stratigraphically consistent over an interval more than 1,200 ft thick. Zone 1 cements are nonluminescent; zone 2 cements are brightly luminescent; and zones 3-7 cements are ferroan with a moderate to dull luminescence. Zone 1 cements (mean $-2.6‰\ \delta^{18}O/+3.3‰\ \delta^{13}C$ PDB) are slightly depleted in oxygen relative to radiaxial-fibrous cements (mean $-1.8‰\delta^{18}O/+3.5‰\delta^{13}C$ PDB) which have a composition that reflects Lower Carboniferous seawater. Zone 4 cements (mean $-4.1‰\delta^{18}O/+3.1‰\delta^{13}C$ PDB) are depleted in oxygen relative to zone 1, whereas zone 5 cements (mean $-11.8‰\delta^{18}O/+1.1\delta^{13}C$ PDB) are extremely depleted in oxygen and somewhat in carbon.

Locally intense dolomitization includes 2 regionally extensive generations of ferroan saddle dolomite. Petrographic relationships demonstrate these dolomite generations were replaced by zone 5 cement. Sulfide mineralization, principally pyrite and sphalerite, occurred after the precipitation of zone 5 cement.

Much of diagenesis occurred during a brief period in the Lower Carboniferous. Zones 1-6 and saddle dolomites are contained in Chadian (upper Osagean), shallow-marine facies overlying the Waulsortian. Fractures filled by zone 5 cements are truncated at the margins of Waulsortian clasts contained in a conglomerate overlying an early Arundian (early Meramecian) unconformity.

In the proposed model, marine pore waters were displaced by oxidizing meteoric waters, which became reducing with shallow burial. Warm brines were introduced during later stages of diagenesis and were involved in late calcite cementation (zone 4?-7), saddle dolomitization and sulfide mineralization.

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Algeria: Structural Evolution and Hydrocarbon Potential of a Complicated Tectonic Province

During most of the pre-Carboniferous, Algeria was part of a stable foreland platform on which a thick clastic sequence was deposited. Caledonian tectonics were primarily epeirogenic, but they established structural alignments that were further reinforced by the much stronger movements of the Carboniferous Hercynian orogeny.

In northern and eastern Algeria, a variable basal sandstone and a thick sequence of Triassic and Lower Jurassic evaporites were deposited over