Absence of primary sedimentary structures in certain units is probably due to bioturbation. Units with high concentrations of burrows near the top suggest rapid deposition. Straight vertical burrows in certain marine sandstones may be insect burrows in barrier-island environments.

Cylindrical, irregular chert nodules are characteristic of most carbonate units. Some nodules are isolated but others coalesce into beds. The carbonate matrix in many places has flow structures around the chert nodules suggesting relatively early lithification of the chert. Some cherty beds contain irregularly cylindrical carbonate bodies. The cylindrical bodies, both chert and carbonate rock, are interpreted as burrow fillings. Burrows filled with material coarser and more permeable than the host sediments were sites of chertification. In beds in which the opposite conditions prevailed, the interburrow material was silicified. Because large burrows with coarse-grained fillings are abundant and in many places penetrate less permeable sediments, they may have functioned as important fluid conduits during early diagenesis.

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Thermal Evolution of Sedimentary Basins Along Atlantic Continental Margins of United States

The subsidence of the ocean floor subsequent to its formation at an ocean ridge can be predicted quantitatively using a simple one-dimensional cooling model and assuming isostasy. The evolution of a passive continental margin is in many ways similar to the evolution of the seafloor. A model for the subsidence and thermal evolution of continental-margin sedimentary basins can be obtained from a similarity solution to the one-dimensional heat-conduction problem. Continuous sedimentation and the subsequent compaction of the sediments are included in the analysis. Good quantitative agreement is obtained with subsidence record obtained from the COST B2 well in the Baltimore Canyon. The present measured thermal gradient is also in good agreement with the predicted value. The thermal evolution obtained is used to predict the petroleum potential of the area. It is found that optimum conditions for the generation of petroleum occur between depths of 6 and 8 km. Petroleum occurrences at shallower depths would presumably require an upward migration of petroleum.

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Fresh Look at Some Ouachita Problems

Numerous new geologic and geophysical data collected in recent years in the Ouachita province by industry, government, and academic institutions allow an updated synthesis of events that shaped the southern margin of North America in the Paleozoic.

Some new key observations include: (1) radiometric data indicate both Devonian and late Paleozoic metamorphic events affected the core areas of the Ouachita Mountains; (2) long-suspected pre-Desmoinesian orogenic uplift that supplied detritus into the foreland basins of the Ouachita system is well displayed on seismic data and has been confirmed by the drill. Weakly deformed Desmoinesian and younger, shallow marine to continental successor basin sediments overlie with angular unconformity the folded and thrusted Ouachita facies rocks beneath the Gulf coastal plain as far south as the Sabine uplift; (3) high-quality field work, especially in Arkansas, has yielded ample data that support a polyphase deformation in the core areas of the Ouachita Mountains. Movements consisted of at least one north-vergent thrust and fold phase primarily of Pennsylvanian age. Initial folding and thrusting were followed (probably in Permian time) by a south-vergent overturning of previous geometries, additional folding and thrusting, and the development of north-dipping cleavage; and (4) plate tectonic reconstructions of the opening and closing of the Iapetus Ocean and the formation and breakup of Pangea have added to the understanding of the events that led to the origin of the Ouachita system. Nevertheless, big data gaps remain.

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Ophiomorpha From Upper Bathyal Eocene Subsea Fan Facies, Northwestern Washington

Trace fossils with a burrow morphology characteristic of *Ophiomorpha nodosa* Lundgren occur in upper bathyal subsea fan deposits of the Eocene in northwestern Washington.

The burrows average 2 cm in diameter and branch profusely. Swollen turnabout chambers occur at branching points. Horizontal burrows are most common at the base of sandstone beds. Burrow walls exhibit surface ornamentation including scratch marks and pellet lining, although most burrows are mud-lined and smooth surfaced. These morphologic features conform to those characteristic of *Ophiomorpha nodosa* Lundgren.

Abundant *Ophiomorpha* burrows occur in the sandstones and associated siltstones of the lower Eocene "Sandstones of Scow Bay" and upper Eocene Quimper Sandstone and Marrowstone Shale, Marrowstone and Indian Islands, northeast Olympic Peninsula.

The burrows occur in a sandstone-shale sequence with sedimentary features characteristic of subsea fan deposition. Lithofacies are classified using Mutti and Ricci Lucchi's 1972 turbidite facies criteria. *Ophiomorpha* occurrences are: 14 in Facies B—lenticular channel sandstones; 68 in Facies C—tabular sandstones with shale interbeds ("classical turbidites"); 17 in Facies D—shales with numerous sandstone interbeds; and 4 in Facies E—shales with few sandstone interbeds. *Ophiomorpha* is most abundant in facies associations consisting of positive megasequences (thinning upward–fining upward) characteristic of channel filling in middle fan-lobe environments.

Paleoecology of foraminiferal assemblages from interbedded shales suggests upper bathyal (200 to 1,200 m) water depths. The in-situ fauna consists of abundant specimens of bathyal hyaline foraminiferal superfamilies (Buliminacea, Cassidulinacea, and Discorbacea), keeled and compressed cassidulinids, numerous species of *Gyroidina,* and bathyal species of *Cibicides.* Forms

characteristic of shallower environments represent a displaced fauna.

Recognition of the Eocene *Ophiomorpha nodosa* Lundgren in the subsea fan deposits of the northeastern Olympic Peninsula documents an upper bathyal occurrence for this trace fossil.

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Late Neogene Depositional and Climatic Cycles in Yakataga Formation, Gulf of Alaska

Lithofacies and chronostratigraphic analyses indicate three relatively warm and three relatively cool paleoclimatic intervals within the 5,000-m-thick strata of the lower Miocene through Holocene Yakataga Formation of the Robinson Mountains, eastern Gulf of Alaska. The cycle identified correlates with the widely recognized paleoclimatic cycle of warm middle Miocene, fluctuating late Miocene, cool terminal Miocene, warm early Pliocene, and cool to cold late Pliocene and Pleistocene. Glacial periods, recognized by the predominance of glacial lithofacies associated with populations of *Neoglobigerina pachyderma* s.l., are interpreted for the cool intervals. In the sections studied, the interglacial intervals have little or no glacial deposits.

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Hydrocarbon Potential of Sitkalidak Formation, Eocene Submarine Fan Complex, Kodiak Island Archipelago, Alaska

The middle upper Eocene Sitkalidak Formation is a 4,000-m thick sequence of interbedded sandstone, shale, and conglomerate. The formation crops out along the southeast side of the Kodiak Island archipelago and is believed to underlie the continental shelf for several hundred kilometers along a northeast structural grain. The Sitkalidak Formation, as used here, includes marine sandy flysch previously mapped as Sitkinak Formation.

The Sitkalidak Formation is a complex of submarine fans deposited at mid- to upper-bathyal depths in a northeast-trending structural trough. This trough was probably an accretionary basin located on an oceanic trench inner slope. The submarine fan deposits were subsequently faulted and uplifted during late Eocene subduction along an ancestral Aleutian trench. Emplacement was complete by early Oligocene time as the Sitkalidak Formation is overlain with angular discordance by the nonmarine Sitkinak Formation of Oligocene age.

Sitkalidak Formation sandstones were deposited as quartz-poor and mineralogically unstable feldspathic lithic arenites. Diagenesis has greatly reduced primary porosity and permeability to an average 2.5% ϕ and 0.01 md k (101 samples $-$ $\phi = 1.0$ to 7.5%; k = 0.0 to 1.3 md).

Sitkalidak Formation shales are gray to black silty claystones which contain dominantly terrestrially derived organic matter. Total organic content averages 0.44% (217 samples $-$ TOC = 0.01 to 2.38%), suggesting lean source-rock potential for liquid hydrocarbons. Vitrinite reflectance values average 0.80% (53 samples $-$ $R_o = 0.54$ to 0.92%), suggesting thermal maturity levels sufficient for oil generation.

Despite the presence of thick sandstone sequences and potential structural and stratigraphic traps, the Sitkalidak Formation has a low potential for hydrocarbon production because of the poor reservoir character of the sandstones and poor source potential of the shales.

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The Mississippian System of New Mexico and Southern Arizona

Lower Mississippian rocks of New Mexico and southern Arizona (pre-zone 7 Tournaisian age) are unconformable on rocks of Late Devonian to Precambrian age. Mississippian rocks were deposited during transgression on a surface of low relief. Tournaisian transgression began in southern Arizona, depositing the Escabrosa Limestone and, in southwestern New Mexico, the Keating (207 m), Caballero (18 m), and Lake Valley (180 m) Formations. At the end of Tournaisian time, epicontinental seas flooded southern and central Arizona, depositing the younger parts of the Escabrosa and Redwall Limestones. Osagean seaways extended to central and northern New Mexico depositing Kelly (35 m) and Espiritu Santo (35 m) Formations. The Espiritu Santo consists of subtidal to supratidal quartz sandstone and carbonate rocks. Zuni Highlands and Pedernal Highlands formed two low islands. The end of the Tournaisian is marked by marine regression, regional uplift, and erosion. Major regional marine transgression in early Visean is represented by parts of Escabrosa Limestone of southern Arizona, massive encrinites of the Hachita Formation (107 m) in southwestern New Mexico, basin carbonate rocks of the lower part of the Rancheria Formation (46 m) in south-central New Mexico, and the subtidal Tererro Formation (18 m) in north-central New Mexico. The Cowles Member (10 m) of the Tererro Formation indicates that sedimentation ceased in northern and central New Mexico in late Visean time. In southwestern New Mexico, the Paradise Formation (134 m) represents shallow-marine sediments and ranges from zone 15 into zone 19 (late Visean and Namurian). The Rancheria Formation (69 m) and the Helms Formation (50 m) of south-central New Mexico are deep-water facies of the Paradise Formation.

Pennsylvanian sedimentary rocks in southern Arizona and in New Mexico truncate Mississippian sedimentary rocks of Namurian, Visean, and Tournaisian age.

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Oxic-Anoxic and Carbonate Cycles in Cretaceous Organic Carbon-Rich Marine Strata

Sedimentary sequences of Early to middle Cretaceous