same conclusions as for coals. (9) Surface and subsurface continuity of stratigraphic units and paleontologic zones from the central India shield to central Afghanistan and Iran proves that India has been a part of Asia since the latter part of Proterozoic time.

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Geologic Factors Which May Affect Gas Occurrence in Anadarko Basin, Oklahoma

The Anadarko basin in Oklahoma, the Texas Panhandle, and in southwestern Kansas contains many reservoirs which produce commercial quantities of gas with subordinate quantities of oil. The producing formations are Permian; Upper, Middle, and Lower Pennsylvanian; Upper and middle Mississippian; Hunton; and Ordovician. Each of these groupings can be considered a genetic stratigraphic unit in which the depositional and structural history is closely related.

Gas analysis is a powerful tool in the exploitation of a given reservoir. Some reservoirs in the Anadarko basin are blanket-type sandstones in which the analyses will be uniform over a broad area. Gas analyses showing abnormally high BTU values, subnormal formation pressures, or exceptionally high nitrogen content can be producing from a sandstone lens (either channel or offshore bars) or a limited carbonate porosity zone in which there has been no communication of fluids.

Hunton gas analyses show a higher percentage of CO_2 at depth, whereas the BTU values decrease because of the decreasing percentage of gas liquids below 14,000 ft. Pressures in the Hunton, although a little below the so-called normal bottomhole pressures, increase in a fairly uniform manner. The Morrow sandstones are productive over most of the Anadarko basin. Variations in the analyses from these sandstones appear to depend on the depth of production and on the chemical content of the gases. It is evident that many of the anomalous values of the analyses depend on the extent of the local reservoir and its geometry.

Gas analyses are a major factor in the economics of gas production. The Hunton gases along the northern shelf of the Anadarko basin yield high percentages of valuable gas liquids. Other zones yield variable amounts of gas liquids. Nitrogen values are small in all reservoirs except in the Permian where several "noninflammable" gases are reported. In contrast with the Oklahoma and Texas panhandle gas production, helium does not appear to be a factor—only traces to less than 1.0% helium are reported.

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Preliminary Diagenetic Model of Carbonate Beach Sequences

Detailed studies of Cretaceous Edwards carbonate beaches revealed striking vertical sequences of first generation, early diagenetic fabrics which are thought to represent the diagenetic imprint of the original hydrologic regimen on the sediments during and soon after their deposition.

The classic environmental zones of the beach can be recognized in the Cretaceous prograding beach sequences and contain, from top to bottom, the following diagenetic features.

The *backshore zone* contains penecontemporaneous dolomite, dedolomite, montmorillonite-caliche paleosoil zones; all evidence points to a meteoric-vadose diagenetic environment.

The *foreshore zone* contains much moldic porosity, micrite rims on grains, beach rock cemented during deposition by metastable carbonates; all intragranular cements have a low iron content indicating an oxidizing vadose cementation environment. These features indicate the influence of both meteoric and marine hydrologic conditions.

The *lower foreshore zone* is characterized by dominant inversion textures preserving shell structure of original aragonite grains, the notably poor development of micrite rims, the presence of early metastable carbonate cementation (beach rock) and relatively high iron content of intragranular cements. These features indicate reducing phreatic, dominantly marine hydrologic conditions during diagenesis.

The *offshore zone* contains high iron intragranular cements, multiple bored, and inverted bored surfaces. The diagenetic environment was no doubt marine phreatic.

Companion studies of Holocene carbonate beach sediments, rocks, and interstitial water confirm to a remarkable degree, the diagenetic patterns found in the foreshore and upper offshore zones of the Edwards carbonate beaches, which lends strong support to the use of these patterns as a preliminary model of carbonate diagenesis in the beach environment.

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Porosity-Cement-Depth Relation for Minnelusa Sandstones, Powder River Basin, Wyoming

Upper Minnelusa reservoir sandstones of Wolfcampian (Permian) age show a linear reduction of porosity with depth. However, porosity is not a simple function of compaction, but is related also to composition and maximum depth of burial.

Wolfcampian sandstones are fine-grained orthoquartzites that have calcite (and dolomite), anhydrite, and silica cements. From grain-packing studies in thin section, 3 stages of compaction are evident. The first stage is characterized by a linear decrease of effective porosity to 26% at 6,000 ft of maximum depth of burial, during which quartz grains and calcite clasts were compacted. The second stage is characterized by decrease in effective porosity to 10% or less by change of calcite clasts to calcite cement. The third stage of compaction is characterized by a linear decrease of intergranular porosity to 26% at 16,000 ft maximum burial during which quartz grains were compacted and calcite and anhydrite cements were dissolved and replaced by secondary silica. Intergranular porosity includes both voids and cement, as distinct from total and effective porosity.

It appears that permeability is greatly reduced at less than 10% effective porosity at a maximum burial of 12,000 ft and present drilling depths of 10,000 ft. Therefore, this depth may represent economic limits for Minnelusa exploration.

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Island Chains, Aseismic Ridges, and Plate Motions

Transform fault and spreading-rate data have been reexamined and a worldwide synthesis of relative plate motion made. Island chains and aseismic ridges, formed by plate motion over mantle hot spots, show the direction of motion of the plates over the mantle. It has been found that by adding a single constant to this relative motion synthesis, a system of absolute plate motion over the mantle can be established which satisfies the relative motion data and the island chain /aseismic ridge trend data. This evidence is used to support a theory of deep mantle convection whereby plumes rising beneath the hot spots provide the driving force for continental drift.

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TECTONICS AND STRATIGRAPHY OF DEAD SEA REGION

The Dead Sea rift is a key structural element in a region of tectonic complexity. It is a linear system of faults extending from the Gulf of Aqaba 1,200 km northward to the Taurus Mountains where it veers eastward, and disappears into the overthrust belt. Near the Dead Sea the fault has left-lateral offset of 130 km. The offset diminishes northward. In the Beka'a Valley an eastern branch divides, curves northeastward and loses identity in the Anti-Lebanon and Palmyra folds; a western branch continues northward.

The nature of the fault has been debated for 100 years, but recent exploration in Jordan and Israel provides control for isopach-lithofacies maps which clearly indicate offset strandlines of Cambrian, Triassic, and Cretaceous strata.

Principal movement on the rift occurred in late Oligocene or early Miocene time. The system has been one of weakness since the Precambrian as indicated by a strong north-south joint system in Paleozoic and Precambrian rocks. Offset stream drainage indicates Holocene movement. Oligocene and older rocks spread across northeast Egypt-Sinai without interruption but Miocene-Pliocene strata are confined to a trough in the Gulf of Suez with a meridian width up to 120 km.

The Dead Sea rift is conjugate with the Gulf of Suez–Red Sea block fault (graben) system. The northwest and northeast orientation of these faults is the result of a regional stress couple acting meridionally—the strike of the Dead Sea rift. Marginal foundering increased the width of the Red Sea.

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CLAY MINERAL COMPOSITION OF BEAUFORT SEA SEDIMENTS, ARCTIC OCEAN

Clay mineral composition of the less than 2- and 4-μ size fractions of Beaufort Sea sediments was analyzed by X-ray diffraction techniques. In all except one sample illite is the predominant (51.58–89.46%) clay mineral, kaolinite is present in significant amounts (10.54–42.82%), and chlorite is almost absent. These observations are interesting because of the generally accepted view that kaolinite is a "low latitude" clay mineral and chlorite a "high latitude" one. The presence of kaolinite in the Beaufort Sea is explained by the polycyclic nature of its sediments which have their primary source in kaolinite-rich Mesozoic sedimentary rocks of the North Slope. This explanation is indicated by the large (36.79%) amount of kaolinite in the Colville, the largest river draining from those rocks to the Beaufort Sea. The shore ice, presumably deriving its entrapped sediment from the hinterland, also contains large amounts of kaolinite. It is concluded that a part of this kaolinite is ice rafted to the deeper Beaufort Sea.

The use of clay minerals as a key for the inference of paleoclimates of source rocks on the basis of earlier generalizations may lead to erroneous conclusions, as attested by the present results. For a correct interpretation of paleoclimates it is suggested that clay-mineral data be substantiated by additional data, such as paleontologic and chemical.

Preliminary studies suggest that most illite of Beaufort Sea has formed by illitization of an illite-montmorillonite (?) type mineral.

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TRANSLOCATION OF CHEMICAL CONSTITUENTS AND PEDOGENESIS IN EARLY EOCENE WILLWOOD FORMATION IN NORTHWESTERN WYOMING

Chemical data on a 4-ft red mudstone, in association with intense color mottling, high fossil content, and great lateral extent, indicate the development of a soil (paleosol) within the red-banded, fluviatile Eocene Willwood Formation in northwestern Wyoming. Quantitative analyses of free iron, aluminum, and manganese from a vertical section through the mudstone indicates zones of concentration at the 16–30 in. and 35–42 in. intervals from the top. Mudstone textural analysis indicates increased amounts of fine clay (less than 10 Φ) in the 16–30-in. level. Organic carbon content throughout the profile is unusually high compared with similar Willwood mudstones. Carbonate minerals are essentially absent. The distribution of free aluminum through the profile displays a strong statistical correlation ($r = +.748$) to fine clay distribution, whereas free iron ($r = +.094$), free manganese ($r = -.160$), and organic carbon ($r = +.004$) show essentially no correlation to fine clay content.

Pedogenesis was characterized by organic matter concentration and mobile chemical constituent translocation to lower levels within a parent material of alluvium. Solution and movement resulted primarily from a shallow, fluctuating groundwater table, which produced alternating oxidizing and reducing conditions. Low concentration values and deeper movement of manganese compared with iron may reflect its higher solubility in the reduced state. Mobile ion concentration at the 35–42 in. level probably resulted from minor water table fluctuations directly above an underlying, more permeable sandstone. A significant reduction in the rate of sediment accumulation appears to be the major factor allowing for *in-situ* development of a soil upon the Willwood alluvial plain.

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ORIGIN OF TUFFS IN STANLEY GROUP, OUACHITA MOUNTAINS, ARKANSAS AND OKLAHOMA

Five major tuff sequences (8–120 ft thick) are interbedded with marine graywacke and shale in the 11,000 ft-thick Mississippian Stanley Group. They are present in the basal 1,500 ft and upper 350 ft of the highly folded flysch group. These widespread sequences are thickest and best exposed in the southern Ouachitas, but are traceable to the central Ouachitas.