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REQUIREMENTS FOR MONITORING OF INDUSTRIAL DEEP-WELL WASTE-DISPOSAL SYSTEMS

Abstract *in* Am. Assoc. Petroleum Geologists Bull., v. 55, no. 11, p. 2090.

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CONTINENTAL PLATE TECTONICS: NORTH AMERICA

A series of basement weakness zones trending northeast and northwest define a plate framework in the basement rocks of North America. The weakness zones began during the primordial solidification of the crust as a result of differential rotation between the equator and the poles, which created a left-lateral couple in the northern hemisphere.

The northeasterly weakness zones were formed by this hemispheric coupling as major tensional zones which define a series of northeast-trending horsts (Slave and Superior plates) and grabens (Arctic, Churchill, and Appalachian-Grenville plates). The northwest-trending weakness zones developed as faults flanking a major dragfold (Canadian shield) produced by the hemispheric coupling.

As horsts and grabens, the northeast-trending plates became the sites of Precambrian erosion and deposition. They later were deformed during Precambrian orogenies by severe coupling produced by right-lateral simple shear acting upon the northeast-trending weakness zones. The orogenic forces producing the simple shear were provided by periodic opening of the Pacific Ocean, which compressed North America during Precambrian and Paleozoic times.

The opening of the Atlantic Ocean, which began in the Triassic, forced North America west-southwestward over the eastern Pacific and eventually on to the mid-Pacific ridge. This caused the Laramide orogeny, which activated the northwest-trending weakness zones, producing coupling of the northwest-trending plates. The oblique encounter of North America and the East Pacific Rise also produced right-lateral, simple shear phenomena along the continent's western margin.

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SEDIMENTOLOGIC DATA ON ORDOVICIAN-SILURIAN BOUNDARY IN CENTRAL APPALACHIANS

The Ordovician-Silurian boundary in the western Valley and Ridge province is in an unfossiliferous, continental sequence, and has been traditionally placed to separate red Juniata Formation from the overlying white Tuscarora Formation. The systemic boundary, thus based on color differences, has been assumed to represent a time-parallel surface of considerable paleogeographic significance. Detailed field and mineralogic data now indicate that this assumption leads to ambiguities in correlations, and that a new means of defining the boundary is necessary.

Sedimentologic aspects of rocks adjoining the color boundary provide primary control on diachroneity. Westward-prograding and eastward-transgressing fluvial regimes generated a sequence of distinct conglomerate, sandstone, and shale lithofacies recognizable over wide areas and occupying the 3,500-ft interval between datable Upper Ordovician and Middle Silurian fossiliferous marine units. Boundaries based on lithofacies approach more closely than other kinds of boundaries to time-parallel surfaces. The color boundary, for example, fluctuates as much as 400 ft vertically, both parallel with and across depositional strike, irregularly and unpredictably crossing lithofacies boundaries. Zones of constant clay, heavy, and opaque mineralogy within lithofacies are likewise randomly truncated by the color boundary.

These data strongly suggest that redefinition of the Ordovician-Silurian systemic boundary in terms of the newly recognized lithofacies sequence is in order. Such revision depends fundamentally on precise time correlations of specific lithofacies with age-established marine units outside the Valley and Ridge area. In the absence of such rock units and of meaningful ichnofossil data, exact location of the boundary may not be possible.

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DEPOSITIONAL ENVIRONMENTS AND HYDROCARBON TRAPS IN "J" SANDSTONE (LOWER CRETACEOUS), DENVER BASIN, COLORADO

"J" sandstones in northeastern Colorado were deposited primarily in 2 delta systems. The large eastern delta prograded toward the northwest from northwestern Kansas. A smaller western delta prograded eastward between Denver and Colorado Springs.

The eastern deltaic sequence is more than 200 ft thick in places and consists of 3 distinct genetic units, in ascending order, (1) marine delta front of low-energy marine clayey sandstones and clayey siltstones; (2) nonmarine delta plain of alternating sandstone, siltstone, and shale deposited in distributary channels, interdistributary bays, marshes, swamps, natural levees, and crevasse splays; and, (3) transgressive marine of low- to high-energy sandstones and shales.

The western deltaic sequence is up to 190 ft thick and consists predominantly of 1 genetic unit, a nonmarine delta plain, similar to that in the eastern delta. Core and log controls indicate that well-developed lower delta-front sandstones are absent in most areas. Upper marine shoreline sandstones are well developed on the north flank of the western delta.

Eastern and western delta sandstones apparently interfinger in some areas. Sediments of the 2 deltas can be distinguished by mineralogy, because western delta sediments are more mature than eastern delta sediments.

Oil reserves in the southwestern part of the eastern delta total about 250 million bbl. The major part of these reserves is trapped in transgressive marine zones at fields such as Adena, Plum Bush Creek, Little Beaver, and Badger Creek. Some additional reserves are trapped in delta-plain channels. Very little oil has been discovered in delta-front sandstones under the eastern delta plain.

Oil accumulations in the western delta have been found in delta-plain channel sandstones at Peoria, North Peoria, Jamboree, Dull Knife, Hombre, Latigo, Byers, and Bennett fields. Gas has been discovered in the thick upper marine shoreline sandstones at Totem field and south of Totem field.

Further exploration should result in the discovery of additional oil and gas accumulations in delta-plain channel sandstones near the updip edge of the western delta plain. Also, more oil and gas accumulations should be found in the upper marine shoreline sandstones wherever they are well developed.

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EARTH RESOURCE PHOTOGRAPHY—PAYOFF IN SPACE

Spectacular successes in lunar flights and in weather and communications satellites demonstrate presently available technology for obtaining worldwide color photography. The synoptic perspective afforded by satellite photography adds a new dimension to geologic investigation, as demonstrated by interpretations of many photos from Gemini and Apollo flights.

A logical first step in an earth resources program would be a small, automated, short-lived, film recovery stereoscopic color coverage of the entire earth's land area. Among the advantages of such a program are (1) effective geologic interpretation of the data is readily available, (2) obsolete maps could be updated throughout the world, and (3) standards would provide for interpretation of later, more sophisticated data.

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GEOMORPHOLOGY—INTERESTING ACADEMICS OR APPLIED SCIENCE?

A new era for geologic exploration is emerging for 2 basic reasons: (1) exploration methods of the past are simply not adequate to meet the present and future demands of a burgeoning world population with an accelerated appetite for mineral and petroleum resources, and (2) the space age is bringing with it new technology that holds great promise for revolutionizing the exploration techniques of yesterday.

Notable advances in exploration within the past decade have been made in on-the-ground geophysical technology. The new devices have proved effective for accurately detecting deep-seated petroleum structures and buried mineral deposits. However, by their very nature, involving great expense in relation to area analyzed, these are for the most part detailing or focusing tools that must be used selectively in areas having the greatest exploration potential. A prerequisite to their proper and efficient use is the conduct of effective preliminary reconnaissance surveys to localize the areas of most promise.

The greatest hope for meeting the challenge of the future lies in achieving commensurate advances in reconnaissance exploration technology. Broad-scale exploration programs must be planned and conducted from a regional framework of understanding. An integrated exploration concept utilizing a wide and varied range of reconnaissance remote sensing devices offers the greatest potential to achieve the necessary broad perspective.

What is the role of photogeology in general and applied geomorphology in particular for these new exploration programs? For effective reconnaissance exploration, the surface is the place to begin—not only in areas of abundant outcrops and obvious structure, but also in glaciated regions, dense jungles, or featureless coastal plains, areas where the surface has previously been neglected in the search for oil, gas, and minerals. The practical application of geomorphic principles to these problem areas offers interesting possibilities for future large-scale exploration programs.

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FRACTURED SHALE AND BASEMENT RESERVOIR, LONG BEACH UNIT, CALIFORNIA

The Wilmington oil field in the south-central Los Angeles basin has produced oil from fractured basement rocks since 1945. Oil was discovered in a fractured upper or middle Miocene shale and basement reservoir by Thums in the Long Beach unit in March 1968. Oil production is from a southeasterly-thickening prism of fractured black micaceous shale, siltstone, cherty shale, and marly limestone up to 1,385 ft (421 m) thick, and from fractured Franciscan schist. The black shale is correlated with the Palos Verdes Peninsula Altamira Shale of early Mohnian and Luisian age. No definite unconformity has been recognized in the black shale member in contrast to the strong hiatus commonly seen between the upper and middle Miocene in the Los Angeles basin.

The absence in Long Beach unit wells of a thick schist breccia and associated volcanic rocks cored at Seal Beach 3 mi (4.8 km) northeast, indicates a northeasterly source of sedimentation. Correlation with similar rocks across the Newport-Inglewood fault zone suggests a possible 15 mi (24 km) of right-lateral displacement.

The oil is thought to have originated in the shale and to have migrated into an interconnected network of vertical, high-angle and horizontal fractures with migration occurring during several geologic episodes. The fracture system was produced by breakage of the brittle rocks along fold axes and adjacent to the larger faults.

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DYNAMIC RELATIONSHIP BETWEEN ESTUARY HYDRAULICS AND SEDIMENTATION

Flood- and ebb-tide cycles produce differing bedforms, sedimentary structures, thicknesses of sedimentary units, and most important, grain-size distributions. Differences are the result of changes in bed shear, flow regime, and mechanisms of sediment transport.

The salt wedge developed in flood-tide flow produces a stratified estuary with highest flow velocity below the highest rate of salinity change. This relation results in upper flow regime as predicted by the densimatic Froude relation; trochoidal sand waves to 2 m in height are formed. Surface waves and internal waves are seen in the salinity stratification. Ebb flow modifies the sand wave surface, and sediment transport is by ripples and dunes in the lower flow regime. Large-scale planar crossbedding is produced by flood flow; small-scale ripple and dune structures are developed by ebb flow.

The estuary is an effective mechanism for size segregation. Suspension populations are removed by both flood and ebb flows. There is a net inland transport of suspended sediment with deposition on tidal flats and marshes. A single log-normal source population is fractionated into several differing populations by bedload transport, suspension, and recycling during successive tidal cycles. Characteristic log-probability size distributions are developed in different environments.