flanks of channel-margin bars; passing upward into argillaceous sands of flood-plain origin. The channels which produced this sequence were up to 45 m deep and many hundreds of meters wide. Where they eroded and reworked the preexisting sedimentary pile, apparently along discrete meander-belt trends, they left behind a sand-dominated sequence that today constitutes some of the thickest and richest oil pay zones in the entire deposit.

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Middle East—Stratigraphic Evolution and Oil Habitat

The post-Hercynian sequence of the Middle East is dominated by carbonate sedimentation on a stable platform flanked on the northeast by the Tethys ocean. Two principal types of depositional systems alternated in time: (1) ramp-type mixed carbonate-clastic units and (2) differentiated carbonate shelves. The first type was deposited during regressive conditions, when clastics were brought into the basin and resulted in "layer-cake" formations. The second type was formed during transgressive periods and is dominated by carbonate cycles separated by lithoclines, time-transgressive submarine lithified surfaces. Differentiation is marked, with starved euxinic basins separated by high-energy margins from carbonate-evaporite platforms.

The tectonic development of the Middle East can be divided into several stages. The first stage, which ended with the Turonian, was characterized by very stable platform conditions. Three types of positive elements were dominant: (1) broad regional paleohighs; (2) horsts and tilted fault blocks trending NNE-SSW; and (3) salt domes. All three influenced deposition through synsedimentary growth. The subsequent stage, from Turonian to Maestrichtian, was one of orogenic activity, with the formation of a foredeep along the Tethys margin and subsequent ophiolite-radiolarite nappe emplacement. From the Late Cretaceous to the Miocene, the platform regained its stability, only to lose it again at the close of the Tertiary, when the last Alpine orogenic phase affected the region, creating the Zagros anticlinal traps.

Source rocks were formed in the starved basins during the transgressive periods. Marginal mounds, rudist banks, oolite bars and sheets, and regressive sandstones form the main reservoirs. Supratidal evaporites and regressive shales are the regional seals. The spatial arrangement of these elements and the development of source maturity through time explain the observed distribution of the oil and gas fields.

The Middle Jurassic to Albian sequence in the central part of the Gulf, around the Qatar Peninsula, provides a well-studied example of the control on oil distribution by the distribution in space and time of mature source beds, effective regional seals, and reservoirs. Oil, tar, and extract typing as well as maturation studies show that the Upper Jurassic Hanifa bituminous limestone is the source for the oil and tar in the Jurassic as well as the Lower Cretaceous reservoirs, the latter reservoirs being only charged where the intervening regional Hith seal is either absent through nondeposition or is breached through faulting. Growth structures draining mature Hanifa kitchens contain sizable accumulations, whereas the Jurassic and Cretaceous reservoirs of the large Qatar dome contain only minor amounts of oil, which can be ascribed to insufficient source maturity and too late closure.

Geochemical and geologic evidence indicates that the tar mats present at the base of many oil accumulations are not the result of biodegradation or early, immature expulsion from the source, but probably the product of gas deasphalting of reservoired oil.

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Late Triassic-Jurassic Paleogeography and Origin of Gulf of Mexico

A step-by-step reconstruction of the paleogeography of the Gulf of Mexico and surrounding areas suggests that the basic structural and stratigraphic framework of the region was established by events during the Late Triassic and the Jurassic. Cretaceous and Tertiary events only accentuated and modified this framework. During the Late Triassic and Early Jurassic, continental conditions prevailed over most of the southern part of the North American plate. Marine deposition was restricted to parts of western and central Mexico that were covered by embayments of the Pacific Ocean. As the supercontinent of Pangea began to crack and break up in the Late Triassic and as the North American plate started to separate from the South American and African plates, tensional grabens began to form. They were filled with red beds and volcanic rocks.

It was not until late in the Middle Jurassic (Callovian) that Pacific marine waters began to reach the Gulf of Mexico area across central Mexico. These marine waters flooded intermittently the preexisting grabens and, between floods, evaporated to produce extensive salt deposits (Louann Salt). The salt varied markedly in thickness according to the rate of subsidence in the grabens. Little or no salt was formed in the intervening high areas. During the Late Jurassic, marine waters from the Pacific progressively covered an increasingly large part of the Gulf of Mexico and surrounding areas as a result of continued subsidence, sea-level rise, or both. Connection with the Atlantic, however, was not established until late Kimmeridgian or Tithonian time.

On the basis of these paleogeographic data, it is possible to speculate that in the Late Triassic and Early Jurassic the Yucatan continental block was located roughly 300 km north-northwest of its present position, and that it was a part of the large North American plate. As the North American plate began to drift northwestward, the Yucatan block seems to have been "left behind." The separation of the Yucatan block from the main North American plate probably started in the Late Triassic, continued slowly and sporadically during the Early and Middle Jurassic, and quickened after the formation of the extensive Callovian salt deposits. By the close of the Oxfordian the Yucatan block had reached essentially its present position, and the Gulf of Mexico had been born.

AAPG RESEARCH CONFERENCE

Temperature Environment of Oil and Gas

Santa Fe, New Mexico, September 13-17, 1981
WM. H. ROBERTS, III, and P. H. JONES, Conveners

Abstracts

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Shallow Geothermal Survey of Durkee Oil Field and Woodgate Fault, Harris County, Texas

This study was conducted northwest of Houston, Texas, in two areas of intensive investigation: Durkee oil field and a nearby segment of Woodgate fault. Temperature measurements made with thermistors at a depth of 2 m revealed temperature anomalies caused by sources at depth and in the near surface.

At Durkee oil field, a cool anomaly of about 1°C was found to be caused by a reverse drag fold at a depth of about 6,000 ft (1,829 m). Two warm anomalies of about 1°C were found to be the result of two distributary channel sands at 7,000 ft (2,134 m) depth. Another warm anomaly of about 1°C and perpendicular to the channel sands was found to be the result of a fault intersecting the surface.

Where Woodgate fault possessed a scarp, a temperature maximum was found directly on the scarp. Where no scarp was visible, temperature measurements made at 2 m depth were successfully used to trace the fault and some of its associated fractures. The shape of temperature anomalies on and near the fault were found to be related to the pattern of ground-water flow in the area.

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Exploration Applications of Temperatures Recorded on Log Headings: Theory, Data Analysis, and Examples

Using the least accurate of temperature data types, temperature anomalies, "hot spots" believed to be hydrocarbon anomalies have been defined by application of a new analytical technique. To date, the technique has been successful to a significant degree when applied to known fields using only dry hole data and, in some places, only dry hole data for wells drilled prior to field discovery as initial steps toward before-the-fact analysis. Technique testing by the drill remains undone.

The theory accepted herein is that heat flows from the earth's hot interior toward its colder surface in nature's attempt to establish temperature equilibrium. Three facts are accepted: (1) hydrocarbon fluids have very low thermal conductivities (oil about one-fifth that of water and gas about one-fourteenth that of water); (2) equal heat input elevates the temperature of a largely hydrocarbon fluid volume relative to a laterally equivalent volume of largely water-filled porosity; and (3) there are fewer grams of hydrocarbon fluids to warm than water filling an essentially equal porosity volume.

Hydrocarbon fluids insulate more (fact 1) and their temperatures are elevated more easily (facts 2 and 3) than contiguous waters. Hydrocarbon reservoirs whose heat flow effects are not obscured by the anisotropic effects of adjacent water reservoirs, should be potentially definable temperature anomalies.

The technique formulated involves the following steps: (1) calculation of geothermal gradient values; (2) creation of a geothermal gradient field areally; (3) vector analysis or contouring of created data; and (4) anomaly definition. Technique application to ten fields representative of a range of complexities shows promise for this up-the-odds exploration tool. Results for three examples (Black Lake field, Louisiana; Haverhill field, Kansas; and Salt Creek field, Texas) may demonstrate principal use as a grading method for prospects based initially on classical study.

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Stability of Natural Gas at High Temperatures in Deep Subsurface

The components of natural gas are reactive in the deep subsurface and may not survive under all conditions. The stability of natural gas in reservoirs of various lithologies is studied using a combined theoretical and experimental approach.

A computer program uses real gas data to calculate equilibrium in multicomponent (up to 50), multiphase (up to 30) systems simulating subsurface conditions to 12 km. This program predicts the stability of hydrocarbons in sandstone reservoirs by first considering clean sands and then sequentially adding feldspars and clays, carbonate cements, and iron oxides. All equilibrium compositions have been computed for low, average, and high geothermal gradients; hydrostatic and lithostatic pressures; and with and without graphite. Graphite is present when deep gases are generated by the cracking of oil but is absent in reservoirs originally filled with dry gas. Similar calculations have also been made for limestone and dolomite reservoirs with various combinations of clays, iron minerals, anhydrite, and sulfur, again with and without graphite. Natural gas shows considerable stability in sandstone reservoirs under most conditions, but its concentration in deep carbonates is more variable and tends to a hydrogen sulfide-carbon dioxide mixture except when an appreciable concentration of iron is present. Hydrogen is present at the 1 to 2 percent level for most lithologies.

A multicolumn gas chromatograph is used to analyze inorganic and organic gases released by crushing rock samples in a Teflon ball-mill. Samples from deep wells in the Anadarko basin and southern Louisiana have been analyzed and the gas compositions compared with those predicted from the computer program.

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Subsurface Temperatures, Sacramento Valley, California: Guide to F-Zone (Forbes) Gas Accumulations

A complicated hydrodynamic system exists in the Sacramento Valley. Abnormally high fluid potentials are present regionally owing to regional tectonic forces as shown by previous studies. Certain parts of the Colusa basin in the Sacramento Valley have significant near-vertical fractures which permit the rapid ascent of deep waters under channel-flow conditions, and thus with a minimum loss of fluid potentials. The traps for the erratic F-zone (Forbes) gas accumulations are critically dependent, both laterally and vertically, upon the existence of these high fluid potentials as barriers to gas migration.

Advective water transport occurs along these near-vertical fractures under nearly isothermal conditions. The magnitude of the thermal anomalies caused by this transport is so large that the fracture-high potential features can be detected with conventional maximum temperature readings from well logs despite the considerable error in such values. Well log temperature data are much more readily available than accurate subsurface pressure data. Thus, practical exploration for these elusive gas accumulations is facilitated greatly through mapping the subsurface temperature regimes.

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Geotemperatures of North Sea Basins: Implications to Exploration

The petroliferous North Sea basin is classified as an intracontinental failed-rift basin and should as such exhibit "normal to high geothermal gradients," if relating to the world average of 25°C/km.

An updated, regional, present-day geothermal gradient map