Geothermal Patterns and Petroleum Traps, Louisiana

Published literature documents varying degrees of correlation between geologic structures and geothermal highs (halos) of several petroleum fields. In conjunction with these fields, additional structures and associated productive trends have been evaluated in order to develop certain predictive criteria. The studies attempted in this regard include structural and stratigraphic traps, rollover anticlines, and salt domes with productive horizons of various ages in Louisiana.

As part of the characterization of the subsurface temperature regime of the regions studied, the following broad generalizations seem to be in order. (1) Geothermal halos observed near faults appear astride the fault, or clearly confined to one fault block or the other. (2) A single geothermal halo in a deep section may be overlain by multiple halos, generally of lower relief, in shallow sections. (3) Geothermal halos associated with deep-seated salt domes are located in the sedimentary section on or near the top of the dome, near the perimeter or on the flanks. Such halos are not discernible on shallow domes. (4) In the interior basin, a salt dome with productive horizons appears to have a geothermal halo of higher relief than those in the vicinity with no petroleum accumulations. (5) Even some petroleum traps, created by sedimentary facies changes with no distinct structural closures, are marked with geothermal halos.

The observed characteristics of the subsurface thermal regimes are generally explicable in terms of thermal properties of rocks and pore fluids and by hydrodynamics.

KUMAR, NARESH, ARCO Exploration Co., Denver, CO, and ROGER M. SLATT, ARCO Oil and Gas Co., Dallas, TX (present address: Cities Service Research, Tulsa, OK)

Deep-Water Stratigraphic Traps in Interior Basins: Examples from Anadarko Basin, Oklahoma

As in modern oceans, there is ample evidence that sands bypassed shelf-edges of ancient interior basins and accumulated in deeper parts of the basins. Although water depths in these basins were never in the abyssal zone, these deposits are today recognizable as "deep-water" sands.

Based on a seismic, subsurface, and sedimentologic study of the Tonkawa Sandstone (Missourian), we have developed a seismic-stratigraphic model for Pennsylvanian sands in the Anadarko basin. Typically, the Tonkawa and other sands are regressive and cyclic and are bounded at the base and top by transgressive limestones. The sands consist of three facies: (1) an upper shallow-water shelf facies, (2) a middle submarine slope-channel facies, and (3) a lower submarine fan-lobe facies. Each sandstone unit exhibits characteristic electric log and seismic signatures and distinctive sedimentary structures and textures. For each depositional cycle, the shelf edge may be formed by a contemporaneous reef, and the break in bathymetric gradient at the base-of-slope may be marked by an older reef. Besides the Tonkawa Sandstone, this model is applicable to the following formations: (1) Springer/Morrow (Springeran/Morrowan); (2) Red Fork (Desmoinesian); and (3) Cleveland and Cottage Grove (both Missourian).

The model predicts that both individual slope sands and submarine fan lobes are potential stratigraphic traps. Associated carbonate banks may also form traps. We suggest that many deep-water traps remain to be found in the Anadarko basin.

KUMATI, SUGAIER M., Mobil Oil Libya Ltd., Tripoli, Libya (S.P.L.A.J.), and JOSEPH M. ANKETELL, Univ. Manchester, Manchester, England

Structural Analysis of Western Sirte Basin, Libya (S.P.L.A.J.)

Examination of surface sediments and tectonic features in the oil-rich Hofra area, western Sirte basin, Libya (S.P.L.A.J.), demonstrates that this area was subject to periodic movement of blocks due to faulting and probably also eperiogenic uplift.

It is here proposed that the faults are the major structures in that it is possible to interpret some, if not all, of the folds as having formed in relation to reactivation of the fault systems. The fault systems may be interpreted in terms of a major "bull-nose" Riedel P Shear structure related to a deep-seated fault along which there was left-handed movement. The faults making up the major bull-nose structure and in particular the Abu Shush fault system display Riedel Shears in patterns indicative of left-handed movement. Abu Shush fault system appears to display a northerly change from styles ranging from those typical of a pre-residual to a peak structural situation. In addition, the post-peak to pre-residual styles typical of the southern part of the Abu Shush fault zone are associated with reversal of stress patterns along a major P zone in the southern part of the Gedari fault zone.

The complexities in stratigraphic relationships resulting from such events may often not be easily recognized in boreholes without exhaustive paleontologic studies, particularly when one considers that most of the unconformities display little variation in dip across the unconformable surface.

KURESHY, A. A., Staten Island, NY

Large Tertiary Foraminiferal Biostratigraphy, Kirthar Province, Sind, Pakistan

Large foraminifera of Pakistan are chronostratigraphically diagnostic and are the basis for stratigraphic correlation of marine Tertiary carbonate deposits. The sedimentary deposits of Pakistan are divided into three basins, among which the carbonate deposits of the lower Indus basin are very rich in large foraminifera. The lower Indus basin is divided into Sulaiman and Kirthar provinces. The Tertiary deposits of Kirthar province are mainly carbonate with intercalation of argillaceous sediments, designated to Lakhra, Laki, Kirthar, Nari, and Gaj formations, and range in age from Paleocene to early Miocene. The large foraminifera of these deposits are divided into ten distinct foraminiferal zones. These are: (1) Lakra Formation, characterized by *Nummulites muttalii* zone of late Paleocene age; (2) Laki Formation, characterized by *Assilina granulosa* zone of early Eocene age; (3) Kirthar Formation (4) zone, characterized by *Nummulites beaumonti* zone (middle Eocene), *N. pengaroensis* zone (late Eocene), *N. fichteli* zone (early Oligocene), and *N. fichteli/Lepidocyclina* (E) *dilatata* zone (middle Oligocene); (4) Nari Formation (3 zones), *N. fichteli, N. fichteli/Lepidocyclina* (E) *dilatata* zone, and *L.* (E) *dilatata* zone (of early, middle, late Oligocene respectively); and (5) Gaj Formation, characterized by *Miogypsina gunteri* and *M. thecideaeformis* zones (Aquitanian and Burdigalian, early Miocene). The foraminifera are mostly restricted to their respective zones. Post-early Miocene rocks of Kirthar province, Sind, Pakistan, are nonmarine and devoid of foraminifera.

LAMBERT, MICHAEL W., Chevron U.S.A., Inc., New Orleans, LA

Vitrinite Reflectance of Woodford Shale in Anadarko Basin, Oklahoma

The Woodford Shale (Upper Devonian-Lower Mississippian) is a black shale thought to be an important oil-source bed in the Anadarko basin of western Oklahoma. The reflectance in immersion oil (R_o) of first-generation vitrinite particles found in this stratigraphic unit is related to temperature history and thus

hydrocarbon-generating potential. Samples of the Woodford Shale were obtained from 18 wells drilled in the Anadarko basin by various operators, and polished sections of the shale were prepared and interpreted by the author while working at the Oklahoma Geological Survey. A minimum of 60 vitrinite reflectance measurements were recorded for each well. The Woodford was sampled at depths of from 5,060 ft (1,542 m) in the northeastern shelf to 20,308 ft (6,190 m) in the deepest part of the basin in Beckham County, southwestern Oklahoma. A systematic increase in mean vitrinite reflectance (mean R_O) with depth was observed. From northeast to southwest across the Anadarko basin mean R_O increased from 0.51 to 2.60%. An isoreflectance map for the Woodford Shale in the Anadarko basin was prepared using data collected during this study. The Woodford Shale should have generated commercial quantities of oil in those areas of the basin where the shale has a mean R_O of from 0.60 to 1.35%. In Kiowa County, Oklahoma, the Woodford Shale was sampled in a fault block bordering the Wichita uplift on the southern boundary of the basin. It has, in this well, an anomalously low mean R_O of 0.48%, possibly due to a shallow depth of burial throughout its history.

LAMMLEIN, DAVID R., Pennzoil Co., Houston, TX

Computer Applications System for Exploration: Offshore China Case History

Pennzoil has developed CASE (Computer Applications System for Exploration) to assist explorationists in mapping and evaluating large, offshore frontier basins. CASE is a user-friendly, interactive, exploration data base and mapping system. It allows explorationists to store vast amounts of data and to retrieve, for any area of interest, various combinations of data sets for mapping, analysis, and display. Geophysical data are routinely computer contoured and drafted on geographic, geological, and geophysical base maps. This technique allows the explorationists to rapidly and uniformly map and evaluate very large areas and to identify prospects for more detailed study.

In addition to seismic time-structure maps, computer-generated regional maps are prepared on depth-structure, isochron, isopach, interval-velocity, average velocity, gravity, and magnetic data. Computer-generated surfaces may be displayed with faults, also using a 3-D isometric presentation, or input to filtering programs.

CASE optimizes the explorationist's time, is cost-effective, and provides management with uniform, relatively high-quality maps for decision making.

Pennzoil developed CASE to evaluate about 80,000 line kms of geophysical data covering over 75 million acres (30 million ha.) in the South China Sea, the largest geophysical group shoot ever. Utilizing this system, a nucleus of about a dozen geologists and geophysicists, with a relatively small support staff, mapped and evaluated the offshore China data in a period of about one year. Case history examples are presented from this unprecedented and highly successful geophysical mapping and evaluation effort.

LAST, W. M., M. EGAN,* and T. SCHWEYEN, Univ. Manitoba, Winnipeg, Manitoba, Canada

Evaporitic Lacustrine Environments of Canadian Plains

The plains of western Canada contain dozens of saline and hypersaline lakes which range in size from small (<1 sq km) prairie "potholes" to relatively large (>300 sq km) bodies of water. The shallowest lakes exhibit playa characteristics, flooding with water during the wet season but drying up during the summer and fall. The sediments of these lakes are composed of a mixed suite of siliclastics, carbonates, and evaporitic minerals. The major detrital minerals are quartz, dolomite, feldspars, and clay minerals. The authigenic carbonate minerals are aragonite, normal calcite, and high-Mg calcite. Evaporitic minerals include mirabilite, thernardite, gypsum, and bloedite.

Spatially, the modern subenvironments in these basins usually exhibit a roughly concentric distribution, with a saline mud flat/sand flat occurring nearest the shore, followed by an ephemeral lake zone, and possibly a perennial lake. Although differing in scale and stage of development from basin to basin, all of the lakes have roughly similar near-surface stratigraphic profiles and facies distribution. The upper 25 to 50 cm consist of a thin (1 to 5 cm) crystalline crust overlying a thicker (5 to 50 cm) layer of mirabilite-thernardite-bloedite mush. Salt crust development, growth of large, euhedral mirabilite crystals, surface desiccation, and mineral dissolution all operate to create an extremely dynamic near-surface environment on a diurnal and seasonal basis. Underlying these upper units is a zone of relatively dense salt crystal with minor mud interbeds. This unit can range in thickness from < 1 m to > 40 m. Finally, underlying this dense crystal layer is a black, highly reducing, organic-rich, muddy clastic unit with variable salt crystal content.

LAWTON, TIMOTHY F., WILLIAM R. DICKINSON, and WILLIAM S. JEFFERSON, Univ. Arizona, Tucson, AZ

Inferred Eastern Extent, Overthrust Belt, Central Utah

Structural and stratigraphic relations in the Wasatch Plateau, the Gunnison Plateau, and the northwestern Cedar Hills suggest a new interpretation of the easternmost limit of thrusting during Late Cretaceous foreland deformation in central Utah. Steep to overturned dips in the Upper Cretaceous Indianola Group within this region are interpreted to reflect involvement of foreland basin clastics in thrust-related structures that deformed the flank of the foreland basin. A subhorizontal overlap assemblage of inferred Paleocene age indicates that the post-thrust erosion surface sloped gently eastward into the foreland basin.

Northeast-striking, southeast-facing homoclines of Indianola Group strata rest disconformably on Jurassic beds. However, favorable horizons within the Arapien Shale of the Jurassic sequence served as a zone of regional decollement, along which younger formations were detached and transported eastward with respect to underlying autochthonous units. The decollement zone was deformed internally by multiple thrusts and by east-vergent isoclinal folds subsequently complicated by local diapiric modifications. Most exposures of the Indianola Group are thus wholly or partly allochthonous. Folds involving Indianola strata apparently include: (1) fully detached ramp anticlines associated with subsurface thrust faults that underlie the southern Wasatch Mountains, Gunnison Plateau, and Sanpete Valley; and (2) partly detached frontal anticlines associated with blind thrusts that approach the surface beneath the Sanpete Valley and the western margin of the Wasatch Plateau. Structures inferred locally are consistent with documented patterns of deformation involving foreland clastics elsewhere in the overthrust belt and should influence exploration strategy in central Utah.

LECKIE, DALE A., McMaster Univ., Hamilton, Ontario, Canada

Depositional Styles of Notikewan Member (Upper Gates Equivalent), Fort St. John Group, Northeastern British Columbia

The subsurface Notikewan Member (Spirit River Formation) of the Fort St. John Group is correlative with the upper 60 to 70