formed the most prolific oil-producing reservoirs of those two periods.

GRAUTEN, WILLIAM F., Consulting Geologist and Oil Operator, Midland, Texas

RELATIONSHIPS OF RESERVOIR FLUIDS IN DELAWARE SANDSTONE STRUCTURES AND STRATIGRAPHIC TRAPS

From the axis of the Delaware basin to the western monocline, the upper Delaware sandstone exhibits a regular progression from gas-bearing structures to oil-bearing structures updip, an example of Gussow's migration theory.

Beginning in western Reeves County, Texas, the monocline has trends of clean sandstone encased in very shaly laminated siltstone. These stratigraphic traps contain such perplexing fluid relationships as water above oil, and gas downdip from oil, both in the same correlative electric-log zone. The writer submits that these phenomena are caused by the entrapment of different fluids in lenses within a sandstone body. "Membranes" with various low permeabilities form the boundaries of the "sub-lenses" and control the migration of various fluids.

HOLMQUEST, HAROLD J., Senior Exploration Geologist, Mobil Oil Company, Midland, Texas

DEEP PAYS IN DELAWARE-VAL VERDE BASINS

The Delaware-Val Verde Basins are a continuous elongate northwest-southeast-trending downwarp extending from Eddy County in southeast New Mexico to Edwards and Kinney Counties in Texas. Deep production consists mostly of petroleum condensate and gas containing substantial amounts of carbon dioxide, and is confined primarily to the Ellenburger Group of the Ordovician; the Devonian; the Morrowan, Atokan, and Strawn Series of the Pennsylvanian; and the Wolfcampian Series of the Permian.

Original water salinity distribution in the Ellenburger and Devonian formations appears to have been highly modified by hydrodynamic movement of meteoric waters in the west, southwest, and south parts of the trough. This flushing, extremely active in early Pennsylvanian, late Permo-Pennsylvanian, and Triassic-Jurassic periods, continues in a minor degree to the present time. Charged meteoric water which introduced carbon dioxide to the subsurface had as its major origin the solution of carbonate and bicarbonate components in the exposed rocks of the Ouachita, Marathon, and Diablo Platform areas. The most likely periods of generation were early Pennsylvanian, late Permo-Pennsylvanian, and during the Tertiary igneous disturbance. Forceful emplacement of carbon dioxide and methane may have occurred in the Val Verde Basin throughout early Pennsylvanian and mid-Wolfcampian folding and thrusting in the Ouachita-Marathon region.

Absence of oil production from the deep zones in the Delaware-Val Verde Basins appears to be the result of two major factors. The first is the hydrodynamic flushing of crude accumulations from all but the deeper and larger closures. This scattering of oil occurred coincident with the major periods of hydrodynamic activity. The second factor is that restored maximum overburden, as well as present overburden in many cases, exceeds the gas-condensate conversion point for Delaware-Val Verde Basin oils. These oils, derived from the Simpson, Woodford, and Permo-Pennsylvanian shales, disassociate into gas-condensate and gas below 14,000, 13,000, and 8,000–9,000-foot depths, respectively.

HUBBERT, M. KING, Shell Development Company, Houston, Texas

GEOLOGY OF SUBSURFACE FLUIDS—PROBLEMS AND RESEARCH NEEDS

Oil and gas occupy the pore spaces of sedimentary rocks in petroliferous basins to the extent of the order of 1 part per 100,000; below shallow depths the remainder of the pore space is filled with water. Hence, oil and gas originate, migrate, and become stably trapped in a rock-water environment.

From an initial state of dispersion elementary volumes of oil or gas are driven by physical forces to positions of concentration and entrapment. The direction of these forces is from regions of higher environmental energy for the given fluid to lower-energy regions; and traps for a given fluid are regions of local minimum potential energy.

The search for oil and gas thus reduces itself to a search for regions of minimum potentials for these two fluids. These, in turn, depend on the density and state of motion of the ambient water as well as on the geometrical configuration of the rocks. Petroleum geology, to the extent that it is to become a rational, rather than an empirical science, must therefore ultimately be based on a comprehensive knowledge of the mutual relations of the rock-water-oil (or gas) complex.

Out of such knowledge, it is seen that the conventional horizontal stratification of gas, oil, and water is true only for the special case of hydrostatics. For the general dynamical case, when the water is in motion, traps for gas and those for oil do not coincide. Furthermore, it is possible for such traps to exist in almost any structural position from the crests of anticlines to the troughs of synclinal basins.

JONES, T. S., Geologist, Union Oil Company of California, Midland, Texas

SMITH, H. M., Research Scientist, Bartlesville Petroleum Research Center, Bureau of Mines, U. S. Department of the Interior, Bartlesville, Oklahoma
In conjunction with WEST TEXAS GEOLOGICAL SOCIETY RESEARCH COMMITTEE

RELATIONSHIPS OF OIL COMPOSITION AND STRATIGRAPHY IN PERMIAN BASIN OF WEST TEXAS AND NEW MEXICO

Analyses of 313 crude oils from Cambrian to Cretaceous formations were studied to correlate the geologic occurrence of these oils with such characteristics as composition by hydrocarbon type (aromatics, naphthenes, and paraffins), content of gasoline and gas oil (determined by distillation and refractometric methods), distillate yields and residuum, sulphur and nitrogen contents, and cloud points.

Five general categories, based on likenesses that may indicate a similar history, include most of the oils, but smaller groupings are also discussed.

AVERAGE VALUES FOR CATEGORIES

Category	S	N	N/S	V_A	V_N	V_P	V_D	*Wax Content*
I	0.16*	0.032	0.21	5.5	7.5	87.0*	84	Med.
II	0.35*	0.059	0.11	8.7	30.3*	61.0	79	High
III	1.77*	0.10	0.057	19.3*	31.4	49.3	73*	High
IV	0.16*	0.125	0.78*	6.1	46.1*	48.0	76	High
V	1.19*	0.140	0.12	6.2*	63.1*	30.7*	63	Low*

S and N refer to weight-per cent sulphur and nitrogen; V_A, V_N, V_P to volume-per cent of aromatics, naphthenes, and paraffins, in the gasoline; V_D to volume-per cent total distillate. *Items of particular interest.

Category I (Ellenburger and Simpson oils). The Simpson shale is considered as a likely source.

Category II (a few Ellenburger and Simpson oils, Fusselman, Devonian, Mississippian, Pennsylvanian, Wolfcamp, a few Yeso oils). Probable sources are dark basinal shales of Woodford, Mississippian, Pennsylvanian, and Wolfcamp age, commonly associated with unconformities.

Category III (Yeso and San Andres oils). These occur commonly now on the Northwest and Eastern shelves where sulphate content is high.

Category IV (Spraberry, Delaware Mountain, some Wolfcamp, and Yeso oils). These are relatively unaltered oils, associated with or derived from basinal shales.

Category V (San Andres, Grayburg, Queen, Seven Rivers, Yates, Rustler, Castile, Cretaceous oils). These oils appear altered; suggested reasons: reaction with sulphur, fresh-water leaching of volatile aromatics, microbial oxidation of wax.

McNEAL, ROBERT P., Senior Geologist, Sinclair Oil & Gas Company, Midland, Texas

Hydrodynamics of Permian Basin

A hydrodynamic study of several stratigraphic units in the Permian Basin shows a regional west to east dip of the potentiometric surface. The Ellenburger and Devonian have closed lows against a part of the Ft. Stockton uplift and against some faults in the general area. The Devonian has a steeper dip of the potentiometric surface in New Mexico than in Texas. The Mississippian has too sparse data to show significant features other than east dip. The Strawn potentiometric surface has steeper east dip on the east flank of the Midland Basin and approaches hydrostatic conditions around the Central Basin Platform. The dip of the Wolfcamp is to the east and north in New Mexico and east and northeast in Texas. The San Andres shows east dip. The Delaware Mountain group has general east dip, but anomalous conditions are suggested in central Reeves County.

The potentiometric surface of all units mapped is approximately the same regionally, in spite of the wide differences in elevation and location of the outcrops and subcrops. However, locally there are many variations. Tilting of the hydrocarbon accumulations is a significant factor in a few fields. Vertical and horizontal pressure relationships around faults and subcrops, vertical and lateral continuity of oil, relative permeability to oil, and other hydrodynamic conditions can be critical factors to be considered in exploration in the Permian Basin.

The quality of drill-stem-test instrumentation and programming in the Permian Basin needs to be improved to furnish the pressure data that should be available to the industry.

NOLAN, THOMAS B., Director, U. S. Geological Survey, Washington, D. C.

Mineral Fluids and America's Future

Subsurface mineral fluids and the substances recovered from them constitute a major part of the value of all minerals produced in this country, increasing from about 48 per cent in 1946 to 58 per cent in 1961, not including ground water. Each mineral fluid has its own preferred habitats, and finding new sources will require ever-increasing knowledge of geologic principles and processes.

The predicted annual demand for petroleum and natural gas by the year 2000 is three to four times present domestic production. This increased demand must be balanced by increased rate of production from known fields, by new discoveries, by increased imports, or by synthetic products extractable from coal and oil-shale deposits, or by utilization of other energy sources.

Other natural gases that come from subsurface reservoirs include helium, carbon dioxide, and hydrogen sulphide. Helium is in particular demand because of its unique physical and chemical properties; its geologic habitat is becoming better known.

About one-sixth of the country's present water supply comes from ground water. In some areas withdrawal exceeds recharge, but in other areas withdrawal can be increased greatly without exceeding potential recharge. Currently about one-third of the ground water withdrawn is not being replaced. The behavior, quality, and quantity of both surface and ground water are geologically closely interrelated. Increasing water usage will require improved scientific and legal coordination.

Subsurface saline waters pose a threat to some fresh-water supplies; but with improved conversion techniques saline water can provide additional fresh water. Some fossil brines are now rich sources of valuable chemicals and other brines are potential sources.

Development of geothermal energy from subsurface thermal water and steam has begun, and further exploration will increase the power output. Recovery of valuable chemicals dissolved in some geothermal fluids is being considered.

New uses for low-value fluids include "fluidizing" solids for easier transport and handling, and "solution mining" of low-grade ores.

PEEK, CHARLES A., Operations Geologist, AND HARBISON, ROBERT R., Senior Geologist, Pan American Petroleum Corporation, Midland, Texas

Bakke Field, Andrews County, Texas

The Bakke field is a multi-pay field located adjacent to the town of Andrews in central Andrews County, Texas. The areal extent covers approximately nine sections, or about 5,700 acres. The producing zones are in Ellenburger and Devonian strata, where oil accumulation is controlled by structural closure with a well defined oil-water contact, and in Pennsylvanian and Wolfcamp zones, from structural-stratigraphic traps with no definite oil-water contact. The gravity of the produced crude generally increases from the Wolfcamp downward with the exception that the Ellenburger has slightly lower gravity than the Devonian. Viscosity is greatest in the Wolfcamp and Pennsylvanian and least in the Devonian and Ellenburger pays. The produced water shows the greatest salinity in the Wolfcamp and decreases to the Devonian, which is only slightly salty. There is a slight increase in the Ellenburger salinity.

SILVERMAN, S. R., Senior Research Associate, California Research Corporation, La Habra, California

Migration and Segregation of Oil and Gas

The mechanisms and extent of oil and gas migration have long been controversial subjects among petroleum geologists. Acceptance of proposed "primary" migration mechanisms, which involve the initial transfer of oil or gas from source rock to reservoir, is further complicated because several of these hypotheses require that petroleum formation occur during the primary migration stage. "Secondary" migration, which refers to the movement of oil and gas from one reservoir position to another, is better understood because geochemists have shown that petroleums undergo small but measurable changes in chemical composition during