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 this type of migration. Fortunately for all concerned, these chemical changes can be distinguished from those chemical transformations which stationary petroleums slowly undergo in response to reservoir temperatures and pressures over geologic time intervals.

In contrast to the relatively minor chemical changes that can be attributed to secondary migration, certain petroleums, produced from distinct but narrowly separated strata within a single field or limited geographic area, are markedly different in chemical composition. Other chemical characteristics of this group of oils, however, suggest that they were derived from a common source. The observed chemical differences can not be explained as transformations of the stationary maturation variety. Detailed studies of the compositional differences encountered in such oil sequences imply that these oils must have experienced physical separations of major petroleum fractions prior to or during the migration process. This variety of petroleum segregation, capable of producing major chemical changes, is herewith designated as a "separation-migration" mechanism to distinguish it from the typical secondary migration phenomenon which results in relatively minor petroleum composition changes.

Although the recognition of a new petroleum migration mechanism may appear to further complicate our already strained concepts of petroleum migration and segregation, the existence of a "separation-migration" mechanism is in accord with and a plausible consequence of some of the best-founded hypotheses of petroleum evolution.

THEIS, CHARLES V., Staff Scientist, U. S. Geological Survey, Albuquerque, New Mexico

Ground Water in Southwestern Region

The outstanding generalization about ground water in the parts of New Mexico and Texas in this region is that reserves will be exhausted in a few to several decades at the present rate of use. In nearly all areas development has increased exponentially since 1945. In New Mexico some legal check on exploitation is available in the doctrine of priority; in Texas no legal check exists.

Generalizations concerning the hydraulics of the important ground-water bodies are: most recharge is close to development; the localities of natural discharge are from a few to 100 miles distant; the exploitation of ground water by wells involves either the depletion of storage or a decrease in stream flow to which it is tributary.

The prolific aquifers are unconsolidated deposits of Quaternary and Tertiary age in bolsons, stream valleys, and the High Plains, and limestones especially of Permian and Cretaceous ages.

Bolson aquifers include the interconnected water bodies between the Basin Ranges of southwest New Mexico, the Estancia Valley, Tularosa Basin, and the Dell City areas. River-connected aquifers include the alluvium of the Rio Grande and the alluvium and limestones of the Pecos River and other Texas streams. The development of the Roswell Artesian Basin resulted in the New Mexico ground-water law, upon which the laws of nine other western states are modeled. Saturated brines enter the Pecos in the Delaware Basin.

The Staked Plains contains probably the largest area of ground-water mining, and one of the largest ground-water reservoirs in the United States. Its size made necessary the first application of a non-steady theory of ground-water movement 30 years ago and the widespread mining resulted in 1963 in the first legal determination that ground water is a depleting mineral resource.

The hydrodynamics, development, reserves, and depletion of individual ground-water bodies are given.

THODE, H. G., President and Vice-Chancellor, AND MONSTER, J., Research Chemist, Hamilton College, McMaster University, Hamilton, Ontario, Canada.

Sulphur Isotope Geochemistry of Petroleum, Evaporites, and Ancient Seas

It has now been established that considerable sulphur isotope fractionation occurs in the biological sulphur cycle and that the bacterial reduction of sulphate, which leads to the enrichment of S^{34} in sulphate and its depletion in sulphide, is largely responsible for the wide fluctuations in isotope ratio which occur in marine sediments.

In this regard, present-day ocean water sulphate is remarkably uniform in sulphur isotope content, both in depth and in geographical location at a value of $\delta = S^{34} = +20$ (20 parts per mil enriched in S^{34} with respect to sulphur in meteorites) and provides a base level in isotopic ratio from which fractionation can be reckoned. However, in dealing with ancient sediments and petroleum, we need to know the S^{34} content of the ancient oceans or seas.

Recently (Thode and Monster, 1963) a study of the sulphur isotope distribution in the marine evaporites of some ten sedimentary basins of several continents was carried out. From this study it has been possible to estimate the sulphur isotope ratio for the various ancient oceans and to establish the pattern of change throughout geological time.

The pattern of change for petroleum sulphur appears to be parallel with that for the evaporites and ancient seas. However, the petroleum sulphur is, in general, depleted in S^{34} by about $15^{\circ}/_{\circ\circ}$ with respect to the contemporaneous gypsum anhydrite deposits. This displacement of $\sim 15^{\circ}/_{\circ\circ}$ in the S^{34} content, which is about the isotope fractionation expected in the bacterial reduction of sulphate, is strong evidence that sea water sulphate is the original source of petroleum sulphur and that it is first reduced by bacterial action in the shallow muds before being incorporated into the petroleum. The lack of any sulphur isotope fractionation in the plant metabolism of sulphate would seem to rule out plant sulphur as a major source of petroleum sulphur.

Since the δS^{34} values for petroleum pools in a given horizon, e.g., Devonian (D-2), are fairly uniform over a large sedimentary basin and since these values vary from one horizon to another depending on the S^{34} content of the contemporaneous seas, sulphur isotope studies should be useful in solving migration problems.

WASSERBURG, G. J., Professor of Geology and Geophysics, California Institute of Technology, Pasadena

Origin of Rare Gases in Natural Gases

Studies have been made by several laboratories on the isotopic and chemical abundances of He, Ne, Ar, Kr, and Xe in natural gases from both gas wells and geothermal areas. This work has shown that the rare gases consist of a mixture of two distinct components—atmospheric and radiogenic. These investigations give information on the evolution of natural gas accumulations from considering the dissolved atmospheric components and the production of He^4, A^{40} and Xe from nuclear processes. The importance of solubility phenomena in fractionation of these elements may be approached by using a simple model. Measurements of