Experimental data support the evolution of carbon dioxide and hydrocarbon gas concurrently with oil generation and demonstrate effective accommodation of oil in water saturated with carbon dioxide and hydrocarbon gas at the temperatures and pressures which are present at depth in source rocks. Oil carried by gas-saturated water migrating from source rocks can be unloaded in and near reservoir traps or enroute to a reservoir by removal of carbon dioxide from the water. This unloading is accomplished by reaction of carbon dioxide with "carbon dioxide-starved" or unconditioned sediments contacted by the oil-bearing water as it moves up faults and permeable strata or by coming out of solution because of low pressure at shallow depths. Carbon dioxide reactions with the source rock matrix have previously been saturated with the large amount of carbon dioxide generated which also provided a surplus to saturate the pore water. After the pore water is saturated with carbon dioxide, the mobilized oil can leave the source rock with water expelled by compaction. In noncompacting situations the hydrocarbons can diffuse over reasonable distances from the source rocks into adjacent permeable beds.

The observed capacity of gas-saturated water to carry oil enables reasonable and available volumes of migrating water to transport and unload enough oil to fill reservoir traps.

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Microbiological Prospecting for Hydrocarbons

Microbiological prospecting falls under the broad category of soil analysis and thus involves the use of near-surface samples. Most of the methods are designed to detect certain types of microorganisms or the products of their metabolism. Because these methods are predicated upon the microbial utilization of uprising hydrocarbons, they detect microseeps. Therefore, their utility resides in determining the presence of subterranean hydrocarbon deposits and in roughly defining the aereal extent of the deposits. Various methods have been patented and numerous field trials have been made, including blind tests and tests conducted prior to drilling.

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Geology of Gu-Dao Oil Field and Adjacent Areas

Gu-Dao oil field is located geologically in the center of Zhan-Hua basin, Bohai Bay hydrocarbon-bearing province, and geographically in the coastal zone of the lower Yellow River valley. Zhan-Hua basin is a Cenozoic block-faulted basin, with an area of 2,100 sq km. The intensive subsidence of the faulted blocks was followed by deposition of thick Tertiary continental strata (the Eocene series itself is as thick as 4,500 m), at a sedimentation rate of 0.127 mm/year. The strong block faulting in the basin led to the formation of buried Paleozoic hills, which controlled many overlapping Tertiary structures. Almost 90 of the known oil reservoirs are in these structures.

Gu-Dao oil field produces from one of the late Tertiary overlapping structures which is cut along the north and south side by two faults striking nearly east-west. These faults controlled the origin and the development of the comparatively intact structure. A long period of faulting caused vertical migration of large quantities of oil and gas, and the formation of a series of multiple pays. The hydrocarbons are distinctly zoned. That is, in the Paleozoic and lower Tertiary rocks, they are high-paraffin crude oil of high wax and low sulfur content. The upper Tertiary rocks contain highly viscous aromatic-cycle alkane crude oil of low wax, high sulfur content, and dry gas occurs in the upper part of the Neogene and Quaternary. The analysis of the data shows that hydrocarbons are derived from the same source rock—the lacustrine lower Tertiary Sha-He-Jie formation—distributed in the depression surrounding the Gu-Dao structure. A secondary reservoir was formed along the faults during the multiple tectonic movement during the late Tertiary, as a result of the upward migration of hydrocarbons from lower Tertiary rocks. Hence the Gu-Dao oil field is a combination of both primary and secondary reservoirs.

The main oil-bearing formation in the Gu-Dao oil field, the upper Tertiary Guan-Tao formation, comprises a set of fluvial deposits, with channel sand bodies as the principal reservoirs. The reservoir extends along the long axis of the Gu-Dao structure, and constitutes the major producing area.

The oil field was discovered in 1968 and full production was begun in 1971. The development policy of water flooding at an early stage, either internally, separately, or quantitatively, was adopted according to reservoir characteristics of high viscosity, sand-out, or differences in pays. A series of measures has been taken to control sand and to reduce viscosity. Although 7 years have elapsed since the beginning of production, present oil production per well is equivalent to that of the early stage, a rising trend in productivity is obvious, and good development effects are insured.

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Carbon Isotope Measurements of Hydrocarbons Adsorbed in Near-Surface Sediment Samples

Geochemical surface exploration for hydrocarbons can be markedly improved by carbon isotope analyses of methane which is adsorbed in near-surface sediments. This technique allows isotopic determinations on samples of 25 μL of methane with an overall $\delta^{13}C_1$ reproducibility of approximately ± 1 part per thousand.

HALBOUTY, MICHEL T., Consultant, Houston, Tex.

Geologic Significance of LANDSAT data on some Known Giant Fields

If land-satellite data had been available and applied to areas over which giant fields were found, how effective would have been the use of the data in the exploration effort and what kind of useful geologic information would have been generated from the satellite images? This question obsessed the author and prompted the effort to find an answer by obtaining satellite images of

15 existing giant fields in various parts of the world and interpreting whatever geologic data the images provided.

At this writing (December 8, 1978), the study has not been completed, but it seems apparent that the images would have been of considerable value in exploring for and pin-pointing the locations of most of the giant fields under study. Such a conclusion indicates that land-satellite images and remote-sensing data should be a top priority in the search for the future giants to be found in the remaining prospective areas of the earth.

HUBBARD, CLYDE, R. E. SHERIFF, and HOWARD BRISTER, Seiscom Delta Inc., Houston, Tex.

High-Resolution LANDSAT for Geologic Studies

LANDSAT images show large areas under the same illumination conditions and from a nearly constant viewpoint, thereby making it possible to see large but very subtle geologic features. Geometrically corrected images with resolving power as great as the intrinsic pixel size can be displayed in false color with the colors so distributed as to maximize the visibility of features. Evidence of geologic features as portrayed in LANDSAT images is obvious when shown with overlays.

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Prudhoe Bay, a Ten-Year Perspective

The Prudhoe Bay field is recognized as the largest oil field in the United States. The Permo-Triassic reservoirs, estimated to contain reserves of 9.6 billion bbl of oil and 26 Tcf of gas, have overshadowed other known substantial accumulations of hydrocarbons in formations ranging in age from Mississippian to Cretaceous in the general area of Prudhoe Bay. Reservoirs are in the Lisburne carbonate rocks, as well as the Kuparuk River sandstone. Other Permo-Triassic and Cretaceous accumulations are less significant.

Perhaps unrecognized, except in retrospect, is the significance of the planned sequential availability of both federal and state lands on the North Slope beginning in 1958. An 11-year period of land availibility followed a 14-year moratorium. Exploration that led to the discovery in 1968 culminated with the September, 1969, State of Alaska "Billion Dollar Sale."

The post-discovery sequence of exploration, development, and production in the area has been characterized by environmental, social, legal, political, and economic complexity and controversy. Comparison of the status of petroleum exploration today on the North Slope of Alaska with the history of the 1950s through the early 1970s is an object lesson for explorationists.

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Predictions of Oil or Gas Potential by Near-Surface Geochemistry

A near-surface hydrocarbon soil-gas technique developed by Gulf Research & Development Co. has been shown to be capable of predicting whether oil or gas is more likely to be discovered in the prospect area. These predictions are made by using the percent compositions and ratios of methane to ethane and propane. Typical average values are:

	Methane	*Methane/Ethane*	*Propane/Methane (X1,000)*
dry gas	100-90	200-20	2-20
gas-cond.	90-75	20-10	2-15
oil	75-45	10-4	60-500

Intermediate values are expected for many hydrocarbon accumulations.

Extensive studies compiled and reported in the literature have clearly shown that reservoired hydrocarbons contain varying amounts of methane and heavier homologs. Frequency histograms of the sum or ratio of methane homologs illustrate that gas from gas deposits is quite distinguishable from gas in oil deposits. Gases from gas-condensate or combined oil and gad provinces plot intermediate between those of gas or oil only provinces as expected.

Light-hydrocarbon ratios have been used successfully to predict the petroleum potential of a formation by monitoring C_1 to C_5 hydrocarbons from a steam-still reflux gas sampling system during routine mud-logging operations. Individual ratios of the C_2 to C_5 light hydrocarbons with respect to methane have been demonstrated to provide discrete distributions which reflect the true natural variations of formation hydrocarbons between oil and gas deposits. Analyses of these same ratios for soil-gas hydrocarbons yield nearly the same limits for delineation of oil and gas potential. This correspondence with the actual formation gases shows that the upward migration of reservoired light hydrocarbons into near-surface soils represents a viable mechanism, allowing near-surface geochemical exploration techniques to be utilized for prospect evaluation.

Normalized histograms of composition data have been constructed which better represent the actual near-surface hydrocarbon populations.

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Dissolved Hydrocarbons in Coastal Waters of North America

Dissolved methane and propane concentrations were measured aboard Gulf's exploration vessels, the R/V *Hollis Hedberg* and the M/V *Gulfrex*, on the continental margins of North America. Propane concentrations of less than 0.5 nL/L were observed in a majority of the samples in many of the areas studied. This observation is in agreement with open ocean concentrations reported by Swinnerton and Lamontagne. However, in a highly petroliferous area such as the Louisiana offshore, higher propane concentrations are more common with one-third of the samples exceeding 2 nL/L. In the Louisiana offshore, three-fourths of the samples contained