fore do not yield oily pyrolysis residues. The disappearance of pyrolysis residues from rock samples representing deep-burial and high-temperature histories relative to those which yield good residues at shallower depths and lower temperatures may be utilized to determine the depth of the oil-generating to gas-condensate-generating maturity threshold.

The technique has been utilized to map source-rock distributions and maturity thresholds in the Pennsylvanian of the western Anadarko basin.

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Development of Petroleum Resource Appraisal Methods in U.S. Geological Survey and Role of Appraisal Group in Resource Assessment Studies

In 1973 the Oil and Gas Resource Appraisal Group was originated within the U.S. Geological Survey (USGS) to develop resource appraisal methodology and apply these methods in assessing the nation's petroleum resources on a regional basis. The resource appraisals were published in USGS Circular 725 on the undiscovered oil and gas resources of the United States for 102 geologic provinces. Since this first assessment, the evolution in the development of petroleum resource appraisal procedures within the Resource Appraisal Group has been significant.

The appraisal methods are designed to evaluate all the known geologic and geophysical data available for a prospective petroleum basin or province. Resource appraisals can be made with any amount of data. However, the amount and kinds of data available will determine the method or methods to be used in the appraisal for any basin or stratigraphic unit. Methods will also change with time, as the amount and nature of the information in a specific area will vary with exploration activity and availability of data.

In frontier areas of exploration (where only gross interpretation of the basin geology is available) by applying the principles from worldwide experience for the occurrence of oil and gas it is feasible to use subjective judgment with minimum data to provide an estimate of the potential petroleum resources. More advanced methods employing objective data and statistical analysis are being employed when increased exploration provides an expanded data base. The methods used in making resource assessments are evolving in complexity to the point that we can deal with exploration plays by stratigraphic units within each prospective province. In areas where data are extremely abundant, the choice of methods used may become more a function of the objectives of the resource assessment and the availability of staff for the study. If data and time permit, the ultimate approach for a complete resource assessment is to use as many methods as possible as a means of cross-checking results.

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Geochemical Exploration in Powder River Basin, Northeastern Wyoming and Southeastern Montana

Combined geochemical and geologic information from this structural basin accurately delimited areas and stratigraphic sequences prospective for crude oil and thermal hydrocarbon gases. Using volumetric and performance data for each effective source sequence, quantities of expelled oil and gas were calculated which readily account for in-place oil reserves of more than 6 billion bbl and minor amounts of associated gas.

Oils expelled from Lower and Upper Cretaceous source beds are similar. The Mowry siliceous shale and Niobrara calcareous shale and marl expelled most of the oil indigenous to the basin. A second major oil type is correlated to the remote Permian Phosphoria source area centered in southeastern Idaho. Oil migration paths have been mapped, gathering areas identified, and time of migration determined. Three of five giant oil fields—Salt Creek, Lance Creek, and Bell Creek—are located on separate gathering areas around the basin periphery. Hilight and Hartzog Draw fields are stratigraphic traps paralleling structural strike on the basin's eastern flank, oriented to receive maximum flow of migrating oil.

An Early Jurassic regional migration emplaced Phosphoria oil in upper Paleozoic reservoirs before the basin formed. Expulsion from deepest Cretaceous source rocks began in Eocene time and probably continued into Pliocene time as the expulsion front moved upsection and updip. Laramide structure controlled migration of Cretaceous oil.

Recharge water affected oil preservation. Consequently, temperature and salinity anomalies are commonly associated with accumulations in recharge areas, where two types of bacterial alteration are recognized.

More than 20 mutually supporting chemical and physical parameters from rocks and fluids proved useful in defining prospective areas.

MOMPER, JAMES A., Amoco Production Co., Tulsa, Okla.

Domestic Oil Reserves Forecasting Method and Assessment of Regional Potentials

The forecasts of undiscovered giant oil fields in the United States, beginning with the initial study in 1960, seemingly have predicted subsequent exploration results with considerable accuracy. The probable number of undiscovered giant fields was predicted from the trend in discovery rates during previous decades.

The forecast number of undiscovered giants, multiplied by the average recoverable oil content in discovered giants, approximates the amount of recoverable oil in undiscovered giants. This value is then enlarged by the proportion of recoverable oil discovered in nongiant fields relative to giant fields. The resultant is the total undiscovered resource of new oil, using existing recovery capabilities. The quotient was adjusted upward for anticipated improvements in enhanced recovery technology to obtain the amount of ultimately recoverable oil in all undiscovered domestic fields.

Remaining reserves of discovered oil also were adjusted upward using a similar enhancement value. Based on established trends, future additions to existing reserves resulting from extensions, deeper pool, and

shallower pool discoveries were estimated. The approximate amount of oil that eventually will be produced in the United States (the grand total of all foregoing calculations) compares favorably with conservative predictions.

For detailed study of remaining oil and gas potential in the United States, the country was divided into seven producing regions. Analysis of each region suggested the probable locales of the remaining undiscovered giant oil and gas fields. The favored producing regions in the conterminous 48 states are the Rocky Mountains, Gulf Coast province, and California offshore.

MOORE, CRAIG E., Natural Gas Pipeline of America, Houston, Tex.

Speculations on Basement Mobility in Gulf of Mexico

Since the advent of plate tectonics, we have been faced with explaining the genesis of the Gulf of Mexico. The Gulf basin is the most heavily explored basin in the world, yet concrete evidence relative to its origin has not yet surfaced. Like pieces of a puzzle, major clues in bathymetry, paleobasin margins, and shifting depocenters are coming together to form a picture of the evolution of the gulf. It is reasonable to propose that the Yucatan Peninsula was once in Texas waters. Verification of this hypothesis may vastly expand the hydrocarbon potential of the United States Gulf Coast area. As more geophysical and geologic data are collected, extrapolation of sedimentary facies and the basin axis into the Yucatan shelf and interior may move these speculations into the realm of fact.

MOORE, DAVID G., Deep Sea Drilling Project, La Jolla, Calif.

Submarine Slides

Large submarine slides have long been known to damage structures in nearshore areas where lateral movements or depth changes have abruptly occurred when triggered by earthquakes and/or by periods of rapid deposition off large river mouths. Oldest reports of deep-water sliding are in connection with breaks in submarine telegraph lines. With the introduction of seismic profiling in the early 1960s, sub-seafloor sedimentary structures interpreted as slides have been recorded in many areas. The structures in these records are commonly equivocal and, to prevent misinterpretation, the limitations of the method must be recognized. Knowledge of the environment of submarine slides is equally important. Morphology, seismicity, and sedimentary processes are important in determining the relative stability of slope environments. Superimposed on these are the effects of Pleistocene lowered sea levels which resulted in pulses of sedimentation, overloading, sliding, and erosive turbidity currents. Slides reported in the literature range from rotational slumps off mouths of large rivers, where rapid outbuilding of delta-front deposits over fine-grained impermeable sediments develops excess pore pressures, to massive (over 900 cu km) allochthonous slides of complex structure displaced from an accretionary slope above a subduction zone.

MOORE, T. C., JR., and KAREN ROMINE, Uiv. Rhode Island, Kingston, R.I.

In Search of Resolution

In 1968, when the Deep Sea Drilling Project started, our biostratigraphy was held together almost totally by a single thread—the foraminiferal zonations. In carbonate-rich sediments, these zonations provided an average age resolution of about 6 m.y. in the Cretaceous and about 1.5 m.y. in the Cenozoic. The study of calcareous nannofossils was rapidly advancing at this time and soon "challenged" the Foraminifera for high stratigraphic resolution. Perhaps the biggest impact on biostratigraphy of the material recovered by DSDP has been the development of stratigraphic zonation for the siliceous microfossils. Radiolarian stratigraphy, in particular, has grown from a rough grouping of species with which one could distinguish epochs to a detailed zonation with an average age resolution of about 2 m.y. With this rapid growth in both the number of microfossil groups used in marine stratigraphy and in the degree of stratigraphic resolution, the question arises as to the ultimate resolution that is achievable. Recent work on the upper Tertiary and Quaternary provides a guide to what might be accomplished. The use of many biostratigraphic datums increases the average age resolution to as little as a few hundred thousand years, and the coupling with magnetic and isotopic stratigraphic zonation provides a check on global synchroneity. Development of stratigraphic zonation aided by the determination of fluctuations in abundance of faunal and floral assemblages offers the promise of increasing resolution another order of magnitude; studies of how faunal distribution patterns change with time indicate where such refined techniques may be useful and where they may be misleading.

MORTON, ROBERT A., Bur. Econ. Geol., Austin, Tex.

Characteristics of Shallow Subsurface Faults on Texas Inner Shelf

Faults mapped on the Texas inner shelf from high-resolution sparker profiles show diverse densities, continuities, orientations, displacements, and degrees of recent activity. Potentially active faults either intersect or are near the seafloor at the upper limit of detection on geophysical records, whereas inactive faults are usually overlain by continuous seismic reflectors. Fault characteristics are broadly defined by geologic age, depositional history, and degree of tectonic subsidence. Faults of greatest density and lateral continuity ($<$27 km) are peripheral to the Rio Grande delta, an area of active Holocene deposition. Faults are equally dense and less continuous ($<$16 km) near the Brazos-Colorado delta, whereas presently active faults are rare between the deltas except near Corpus Christi. Faults are least continuous ($<$5 km) and dense along the upper coast which has remained relatively stable during the late Quaternary. Displacements at depths of 150 m range from 3 to 30 m; most displacements, however, are between 3 and 10 m when rollovers are discounted. These en echelon growth