The initial modeling began with an hypothesis based on well logs, COCORP data, and other geologic information. After the subsurface structures were defined, depth and velocity plots were produced. Normal incidence rays were then traced from each horizon to specified shot points. The ray-tracing plot gives a good indication of the quality of resolution one can expect from a particular subsurface geometry. The synthetic profile was produced by first applying a broad-band pulse, then applying a Ricker wavelet to each trace. A gain function was applied to enhance the section for interpretation. Forward seismic modeling in the Anadarko basin enhances interpretation by giving an idea of the seismic resolution one can expect and letting the interpreter test a geologic hypothesis against the seismic profiles.

MEGILL, ROBERT E., Retired, Houston, TX

Exploration—The Past is the Key to the Future

Contrary to conventional wisdom, the history of crude oil prices has been one of volatile swings. Natural gas prices, somewhat more stable, have nevertheless undergone large percentage changes from year to year. Such abrupt changes have caused fluctuations in cash flow and have necessitated the cycles of expenditure evident in the past.

In good times the petroleum industry reinvests almost all of its revenue in finding, developing, and producing oil and gas fields. The reinvestment percentage logically shrinks in poorer times. For exploration alone, the reinvestment rate has averaged 25% since 1944.

Gas discoveries are dominant in new discoveries, and revenue from gas fields is rising as a percent of total wellhead revenue. However, more than half of all revenue is still from oil fields. Revenue is the dominant factor affecting activity. Thus, the ability to forecast future prices determines the ability of the industry to foresee its future.

The petroleum industry's myopic record shows a lack of prescience in the ability to divine future price levels. Any forecast of future activity is limited to the accuracy of the assumptions about revenue.

Given these major uncertainties, a series of forecasts based on several scenarios appears prudent.

MEISTER, EGON MANFRED, PETROBRÁS, Rio de Janeiro, Brazil

Geology of Petroleum in Campos Basin, Brazil

A schematic model of oil generation, migration, accumulation, and alteration is presented for the Campos basin, a sedimentary province covering an area of nearly 31,000 km^2 (12,000 mi^2) offshore southeastern Brazil, where an estimated 1 billion m^3 (6.3 billion bbl) of oil in place has been discovered since 1974.

Source rocks for this oil belong to the Lower Cretaceous Lagoa Feia Formation; oil generation probably started in the Miocene. At that time, a series of local windows opened in the regional evaporite seal at the top of the Lagoa Feia Formation and focused the upward escape of hydrocarbons, mainly along halokinetic fault surfaces. Reservoirs of Albian, Late Cretaceous, and Tertiary age were charged and their porosities enhanced by natural fracturing, solution, and/or grain rearrangement. Original oil (postulated range of 30°-35° API gravity) underwent differentiation by migration, reflected in relative enrichment of aromatics and of the light ^{12}C stable carbon isotope. Alteration of oil by water occurs if one of the two fluids in contact is allochthonous; bacterial alteration is important in low-temperature regimes. Oil entrapment is helped by hydrodynamic conditions, with the intake area of the Paraiba do Sul river delta supposedly playing an important part.

Lopatin-type plots gave the first clue for establishing this model, which takes into account a large number of facts about the basin, such as well and seismic information, clay diagenesis, water and petroleum geochemistry, pressure data, and their geologic field relationships.

MELIM, LESLIE A., Western Washington Univ., Bellingham, WA

Sedimentary Petrology and Depositional Environment of Sandstones of Scow Bay, Indian and Marrowstone Islands, Northwestern Washington

The unnamed middle Eocene sandstones of Scow Bay that are well exposed on the beaches of Indian and Marrowstone Islands, northwestern Washington, document a previously unknown local basement high that shed sediment south onto a subsea fan from the San Juan Islands terranes. The sandstones are lithic arenites with a variety of lithic grains, predominantly volcanic and sedimentary (including chert). Rare quartz-plagioclase plutonic and low-grade metamorphic (mainly chlorite-rich) lithic grains are also present. Quartz and plagioclase comprise most of the nonlithic grains. Rare heavy minerals and potassium feldspar are also present. The San Juan Islands terranes were the source area. Paleocurrent directions obtained from flute casts support this interpretation.

The sandstones are thin to very thick-bedded with minor shale interbeds and at least two 20 to 30-m (65 to 100-ft) thick shale beds. The sandstone beds are commonly structureless, although dish structures, poorly developed parallel lamination, load casts, and shale rip-up clasts are abundant locally. Soft sediment deformation, including slumps, is locally evident. Amalgamation of thinner sandstone beds into very thick (3-5 m, 10-16 ft) beds is common but often difficult to recognize owing to their structureless nature. The exposure along the east coast of Indian Island reveals at least 11 thinning- and fining-upward sequences. The sandstones were deposited as channel-fill sequences on the midfan region of a subsea fan. The thick shale beds were deposited between active channels.

MELLO, MÁRCIO ROCHA, GUILHERME DE O. ESTRELLA, and PAULO CÉSAR GAGLIANONE, PETROBRÁS, Rio de Janeiro, Brazil

Hydrocarbon Source Potential in Brazilian Margin Basins

Twenty thousand samples from the Brazilian continental shelf basins were analyzed to characterize and evaluate the hydrocarbon source potential of the areas.

The geochemical evaluation of the rock and oil samples was performed by organic carbon determinations, Rock-Eval pyrolysis, vitrinite reflectance, thermal alteration index, liquid and gas chromatographies, gas chromatography-mass spectrometry, and carbon isotope analyses.

Three source rock systems have been identified: lower Neocomian shales deposited in a continental environment, upper Neocomian shales grading from continental to lagoonal environment, and Aptian shales related to evaporitic and lacustrine sequences.

Upper Cretaceous and Tertiary open marine slope sediments are not considered as source rocks. Locally, these sediments present high organic carbon content but show an extremely poor hydrocarbon yield. Anoxic depositional conditions, nevertheless, can be traced locally along some levels of the Santonian to Cenomanian shales and marls. These sediments are generally immature in the Brazilian margin basins and no oil was generated from this section.

Three oil families were distinguished through oil-to-oil and oil-to-source rock correlations: the lower Neocomian continental type, the upper Neocomian continental to lagoonal type, and the Aptian evaporitic to lacustrine related sequences.

The geochemical studies, together with geologic and geophysical data, provided the basis to display some models for the migration pathways and habitat of oils in the Brazilian margin basins.

MERIN, I. S., and J. R. EVERETT, Earth Satellite Corp., Chevy Chase, MD

Mapping Dikes from Thematic Mapper Imagery: Raton Basin

Analysis of 1:48,000-scale thematic mapper (TM) imagery of a portion of the Raton basin, supplemented with 1:80,000-scale black and white stereo aerial photographs and geologic and topographic maps, shows that many more dikes are present in the basin than are shown on previously published maps. In comparison with the geologic map, this study allowed mapping of a greater number of dikes, and extension, or connection, on refinement of the trend and/or location of many previously mapped dikes. Only a small number of dikes (or portions of dikes) were mapped in the field by previous investigators, for which no evidence was shown on TM imagery, aerial photography, or topographic maps.

Comparison of the TM imagery with the aerial photography reveals that TM imagery may be a better tool for locating dikes. Clearly, smaller objects can be identified and greater detail can be mapped using aerial photography as compared with TM imagery. For example, the photography clearly shows that several dikes are right-laterally offset. These offsets appear on TM imagery only as subtle bends, rather than breaks in the dikes. However, because TM imagery reveals subtle spectral differences that aerial photography cannot, the imagery will display more information. This is demonstrated by nearly twice the number of dikes being mapped using TM imagery than with aerial photos.

MERINO, ENRIQUE, CRAIG H. MOORE, PETER ORTOLEVA*, JEFF JOHNSON, and JIM HETTMER, Geo-Chem Research Assocs., Inc., Bloomington, IN

Computer Modeling and Graphic Representation of Development of Secondary Porosity and Cements in Reservoirs Rocks

We have developed a set of programs for analysis of surface and subsurface data that (1) organize the data to reduce its bulk without violating its integrity, (2) present 3-dimensional graphic representations of the data, and (3) use transport/reaction models to predict the evolution and spatial distribution of secondary porosity and cements. This evolution path and distribution arise through the interaction of flow, diffusion, dispersion, mineral dissolution, and cement precipitation.

These programs are applied to 2 types of reservoir rock: (1) a feldspathic arenite in which feldspar dissolves and calcite cement precipitates, and (2) a limestone undergoing dolomitization.

Knowledge of spatial distribution of porosity and cements derived from these models is valuable in choosing drill-hole sites.

MERRILL, GLEN K., Univ. Houston, Houston, TX, and PETER H. VON BITTER, Royal Ontario Museum, Toronto, Ontario, Canada

Use of Conodont Genus *Gondolella* in High-Resolution Biostratigraphic Zonation of Middle-Upper Pennsylvanian Rocks, Central North America

Several conodont taxa have been suggested for use as biostratigraphic tools in the Pennsylvanian, but each has its limitations. Some are severely restricted paleobiogeographically or paleoecologically. Others existed through a relatively short interval of time, leaving the bulk of the Pennsylvanian column unzoned. Frustratingly, the single most promising group, the *Idiognathodus-Streptognathodus* plexus, has eluded taxonomic treatment that is both phylogenetically sound and biostratigraphically useful.

Gondolella Stauffer and Plummer, 1932 (type-species *G. elegantula*, O.D.), is subject to many of these restrictions, especially geographically and paleoecologically, but offers a highly precise zonation in the rocks where it does occur that can serve as an interim standard for some (mostly Missourian) and a supplement for others (mostly Desmoinesian). Enough occurrences have been amassed to facilitate interregional, and in some cases, intercontinental correlations.

Desmoinesian gondolellids are known from 9 stratigraphic units in the Illinois basin and 5 from the Mid-Continent, and 5 zones are recognized. Distribution is relatively uniform, and zonation of this part of the column is almost total. This zonation is less detailed than the contemporary *Neognathodus* zonation, but it is a valuable supplement to it. The most dense concentration of *Gondolella*-bearing units is in the Mid-Continent Missourian where 15 units have produced gondolellids. These and the 6 Illinois basin units can be assigned to at least 6 zones, totally contiguous in the lower Missourian, less so upward. The Virgilian cannot be completely zoned, but the 2 productive Mid-Continent units are assigned to different zones.

MESCHER, P. K., and J. C. POL, ARCO Exploration Co., Denver, CO

Environmental Significance of Pisoliths, Mississippian Madison Formation of the Williston Basin, Bottineau, Renville, and McHenry Counties, North Dakota

Pisoliths from the Mississippian Madison Formation of North Dakota originated in an agitated, shallow-water marine environment. Evidence for this interpretation includes: (1) association of pisoliths with ooliths and marine fossils; (2) well-rounded clastic pisolith morphology; (3) vertical facies succession in core from open-marine facies through the pisolith-oolith facies band into lagoonal and intertidal facies featuring fenestral fabrics and possible tepee structures; (4) upward-shallowing cycles with reverse grading, submarine hardgrounds, and desiccation features.

Madison pisolites (pisolith-rich carbonate) differ markedly from those set forth by Dunham as indicators of vadose, caliche soil conditions: (1) they lack fitted polygonal structure; (2) they have large amounts of primary pore space or cemented pore space; (3) they contain no peds (soil components); (4) no evidence of rooting is visible; (5) no classic "caliche" horizons are present; (6) only minor occurrence of vadose cements postdate pisolith initiation, development, and deposition; (7) no evidence for replacement of parent rock was observed.

Similar evidence was used by Esteban, and Esteban and Pray, to show that the "type" Capitan Formation pisoliths were not formed by caliche soil-forming processes. Pisoliths and pisolites should be viewed in relation to other carbonate allochems, sedimentary structures, and diagenetic fabrics to determine their origin and environmental significance.

METZGER, WILLIAM J., and ADERBAL C. CORREA, Conoco, Inc., Denver, CO

Regional Facies Distribution and Tectonic Evolution of Appalachian and Ouachita Thrust Belts

A series of 12 tectonic and lithofacies maps representing critical periods of the evolution of the Appalachian-Ouachita orogen were compiled from published sources and interpretation of seismic and subsurface data. The distribution of sediments supports the concept of multiple deformation that resulted from the collision and accretion of small plates or irregular margins of larger plates with North America.

During the Eocambrian and Early Cambrian, a series of rifts developed within the craton subparallel to the continental margin of the Iapetus Ocean. Ouachita sediments were deposited in this rift zone along the southern margin of the craton. However, the rift zone did not persist in the Appalachians, and the sediments in that belt were deposited along the continental margin.

In the Middle Ordovician, the extensional regime continued in the Ouachita belt while compression associated with plate collision began in the Appalachians. The northwest-southeast-trending boundary between these areas persisted throughout the evolution of the orogens. The sedimentary records indicate that the initial compressional deformation in the Ouachita belt began during the Late Mississippian, and the final phase of deformation in the Appalachians was initiated slightly later, during the Early Pennsylvanian.

Structural features associated with thrusting basin sediments over foreland areas were controlled to a great extent by the presence or absence of buttresses. The Ouachita Mountains area provides the best illustration of contrasting structural styles along the thrust belt. Elsewhere along the thrust belts the evidence is either covered by younger sediments or altered by a complex tectonic history.

MEYER, RICHARD F., U.S. Geol. Survey, Reston, VA

Resources of Small Oil and Gas Fields

In presently known small oil fields, a remaining recoverable reserve of about 3,100 million bbl appears evident. As much as 2,000 million bbl remain in place in abandoned small fields, of which at least 500 million eventually may be recovered through redevelopment or, in a few cases, mining. Reserves of oil in stripper wells amount to about 5,200 million bbl. Research on only 2 basins, Gulf Coast and Permian, indicates that, should a high rate of drilling activity persist into the future, at least 10,000 million bbl more in small fields could be anticipated in the United States. This suggests that a total of at least 19,000 million bbl of oil in small fields remains to be recovered in the future in the United States.

Gas from presently-known small oil fields should account for more than 17 tcf, nearly all nonassociated. In addition, at least 67 tcf of gas and nearly 2,000 million bbl of condensate will come from small, nonassociated gas fields. It is not known how much gas, as compared with oil, will be found in small fields as a result of future exploration. The amount will be substantial.

An enormous exploration effort will be required to yield this petroleum. The aggregate return is substantial, but because it is from a collection of small fields, it will not be possible to optimize exploitation in the same way as for a similar amount of petroleum from a few large fields.