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Conventional United States Oil and Gas Remaining to be Discovered

Annually, Shell Oil Co. makes a forecast of conventional United States oil and gas resources remaining to be discovered, and differentiates the part of that forecast that will be found in the first and second decades of the future. The primary purpose of these forecasts is for use as a planning tool to aid in deciding the future directions and levels of effort for Shell Oil Co.

A major assessment effort was carried out in 1978 when future estimates were 60 billion bbl of oil and 315 tcf of gas. The annual assessments since then have been done in less depth until this year's major reassessment effort. The results of this assessment will be discussed, the methodology used will be reviewed, and Shell Oil Co.'s use of the results will be discussed to better place the Shell Oil Co. forecast in context with forecasts made by the U.S. Geological Survey, industry, and other forecasters.

RUGGIERO, ROBERT W., Sohio Petroleum Co., Houston, TX, and ALAN J. SCOTT, Univ. Texas at Austin, Austin, TX

Depositional History and Performance of a Bell Canyon Sandstone Reservoir, Ford-Geraldine Field, West Texas

The late Guadalupian Bell Canyon Formation comprises alternating siltstone and fine to very fine-grained sandstone, which constitute economically important, shallow (2,000-3,000 ft, 600-900 m) oil reservoirs in the Delaware basin. In Ford-Geraldine field (Reeves and Culberson Counties), the Ramsey sandstone member, uppermost sand of the Bell Canyon Formation, was deposited in a deep-water, sediment-starved, euxinic basin.

Bottom-hugging hypersaline density currents spilling off the shelf through breaches in the Permian platform margin gouged elongate, subparallel channels into the slope and preexisting Laurentian-type fan.

Occasionally, sand-laden currents flowed through these channels, either scavenging sand stored on the shelf near the channel head or scouring material from intermittent depocenters on the slope. Where the slope gradient decreased significantly, sand was deposited within the channel. Isopach maps how that the distribution of coarser sediment was highly influenced by channel-bottom topography. The back-filling lobate geometry of these flows indicates that the channels were retrograding to a more gentle slope during a late Guadalupian period of high sea-level stand.

After eastward tilting of the Delaware basin in the Tertiary, hydrocarbons migrated updip toward the toes of the lobes and along the western margins of the channels. The reservoir sands are encased in less permeable, laminated siltstone; therefore, the terminal part of the channels provided excellent stratigraphic traps.

The Ford-Geraldine field produces from one of these Ramsey sand-filled terminal channels with original reserves estimated at 110 million bbl of oil. Within this complex trap framework, hydrocarbon distribution in the field is determined by a combination of stratigraphy, subtle structure, and hydrodynamics. Large variations in sandstone porosity and permeability over short vertical and horizontal distances result from: (1) channeling within the larger channel complex, (2) the occurrence of thinly laminated siltstone layers isolating individual sand layers, (3) sandstone pinch-out into siltstone, and (4) the distribution of calcite and authigenic clay cements. Primary and secondary production extracted 22% of the original oil in place. Tertiary production (alternating carbon dioxide and waterflood) is underway. Reservoir characteristics described here must be incorporated into the enhanced recovery model to make valid predictions of tertiary recovery performance.

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Depositional and Diagenetic History of Bodcaw Sand, Cotton Valley Group (Upper Jurassic), Longwood Field, Caddo Parish, Louisiana

Bodcaw Sand contains fine-grained sandstones and siltstones deposited within a barrier-bar-complex. Based on vertical changes in sedimentary structures, texture, and mineralogical composition, upper-, middle-, and lower-shoreface lithofacies in the Bodcaw Sand can be identified. Cross-stratification and low-angle laminations, rarely disrupted by biogenic structures, characterize the fine-grained upper-shoreface sandstones. Middle-shoreface sandstones have undergone extensive reworking by biotic and abiotic factors. Few primary sedimentary structures and early generation trace fossils are preserved in middle-shoreface sandstones. Lower-shoreface siltstones and very fine-grained sandstones contain lenticular and wavy bedding, much of which is disrupted by bioturbation.

Bodcaw Sand has low porosity and permeability. Vertical and lateral variation in porosity and permeability are related to depositional textures and diagenetic fabric of Cotton Valley sediments. Bodcaw Sand has experience a complicated diagenetic history. Compaction, cementation, replacement, and dissolution modified primary rock properties following deposition of barrier-bar sediments. Cementation plays an important role in modification of reservoir properties. Important authigenic minerals identified in Bodcaw Sand include silicates, carbonates, and phyllosilicates. Based upon textural relationships between allogenic grains, authigenic constituents, and pore characteristics, a relative succession of diagenetic events can be interpreted. Two major diagenetic sequences occurred within Bodcaw Sand. Diagenetic events within one sequence included cementation by silica, phyllosilicates, and calcite, as well as, dissolution and replacement reactions. The other sequences primarily involved diagenetic reactions of calcite precipitation, dissolution, and replacement.

RUTLEDGE, ANNE K., and JOHN C. LORENZ, Sandia Natl. Labs., Albuquerque, NM

Facies Relationships and Reservoir Potential of Ohio Creek Interval Across Piceance Creek Basin, Northwestern Colorado

The Ohio Creek member of the Mesaverde Group of Late Cretaceous age grades from a fluvial to a paralic facies from the southern to central parts of the Piceance Creek basin. The Ohio Creek is considered here to be the nonmarine to paralic equivalent of the Lewis transgression to the north. Although it is fluvial in the type area and southern part of the basin, evidence of marine influence in the east central part of the basin includes: (1) zones of abundant logs with large fossil *Teredinidae* burrows, (2) palynological evidence from outcrops at Rifle Gap and the U.S. Department of Energy MWX wells, and (3) marine-type sedimentary structures visible in outcrop. In this east-central area Ohio Creek depositional environments are interpreted as distributary channel and estuarine.

Although the Ohio Creek is highly altered by diagenesis and is an aquifer in some parts of the basin, the equivalent zones are productive of hydrocarbons in the north-central parts of the basin. Continued changes in facies toward a marine environment to the north affected the petrologic characteristics and sand body/reservoir morphology, increasing the reservoir potential of this zone to the north. The variably thick interval is recognizable in the subsurface as an extensive sandy zone with blocky shaped log profiles; it should provide good reservoirs where porosity and permeability are not occluded by diagenesis, and where continuity with surface exposures has not allowed gas escape and water influx.

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Deep Marine Dolomitization, Enewetak Atoll

Dolomite is present 1,250-1,400 m (4,100-4,600 ft) below sea level in Eocene strata of the Enewetak Atoll. Petrographically, the deep Enewetak dolomite postdates brittle compaction of rigid grains in the host Eocene strata. The $^{87}Sr/^{86}Sr$ ratios of these dolomites (0.70865-0.70901) indicate that the dolomites formed mainly between middle Miocene and the present. Because the top of the lower Miocene is more than 900 m (2,900 ft) above the deep dolomitic interval, the dolomite must have formed at a minimum burial depth of 900 m (2,900 ft). Stable oxygen isotope determinations suggest dolomite precipitation from cold marine water. Lower Miocene and Eocene carbonate strata on the atoll are currently in open communication with cold, modern ocean water and probably have been since deposition. At a depth of approximately 1,000 m (3,300 ft), modern Pacific Ocean water becomes undersaturated with respect to calcite but is still supersaturated with respect to dolomite. Therefore, it is proposed that the deep Enewetak dolomites precipitated from cold, deep ocean water (undersaturated with respect to calcite) percolating through the atoll at burial depths of more than 900 m (2,900 ft).

At least 3 factors appear critical for marine dolomitization: (1) waters undersaturated with respect to calcite, but supersaturated with respect to dolomite; (2) permeable limestones; and (3) hydrologic position of those limestones where numerous pore volumes of undersaturated water will be flowing through. In the past, different oceanographic conditions may have caused some ancient seas to have relatively shallow calcite saturation depths. Many ancient dolomites found in atoll and reef-wall settings may have also precipitated in normal marine water.

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Explorationist's Model of a Patch-Reef Trap

A geologic model of a carbonate patch-reef complex is proposed. When applied to subsurface control where wells have been cored, the model is designed to actually position a well location with respect to a stratigraphic trap formed by the patch reef. The model is lithofacies governed and is based upon those facies relationships observed among several Gulf Cost patch-reef examples. The relationship between variations in effective porosity and permeability and the variations in lithofacies appears to be direct, judging from the examples studies. This direct relationship points to the formation of a permeability barrier stratigraphic trap where certain updip and lateral facies changes occur.

Only primary porosity and permeability are considered by the model. The effects of secondary porosity, fracturing, dolomitization, and/or secondary cementation can be considered by a second model applied as an overprint to the first.

Application of the model as an additional exploratory tool in carbonates where reservoir quality is a function of lithofacies distribution can lead to the drilling and discovery of numerous subtle stratigraphic traps.

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Structural Evolution of Val Verde Basin, West Texas

The Val Verde basin is a northwest-southeast trending foreland basin contained within the southern portion of the Permian basin. The Val Verde basin has several large fields, e.g., Brown Bassett and JM, which have a combined ultimate recovery of over 1 tcf of gas. Structurally, the major fields are complexly faulted features related to differential uplift of basement blocks. Vertical and horizontal displacement resulted from a wrench system dominated by northwest and northerly trending faults. Reverse faults associated with the wrench system appear to exhibit characteristics of both high-angle and low-angle faults, as is typical of foreland structures. Tectonism was initiated during the late Mississippian, consequent to Ouachita plate convergence, and continued into the Permian.

Middle and Upper Permian strata are not present in the central and southern Val Verde basin. Appreciable amounts of Permian sediment were eroded prior to deposition of Cretaceous strata, thus, Cretaceous rocks unconformably overlie Wolfcamp sediments. Restored estimates for vitrinite reflectance data indicate a minimum of 8,000-10,000 ft (2,400-3,000 m) of Permian rocks have been eroded. Therefore, in the central and southern portions of the basin, Paleozoic rocks are inferred to have occupied depths several miles deeper than present. Vitrinite reflectance values for Ellenburger (Ordovician) rocks at Brown Bassett are approximately 1.8 to 2.0% R_0. Ellenburger reflectance values increase to the south and southeast to values greater than 4.5% R_0. The most southerly wells also have reflectance depth trends which show a break in gradient within Wolfcamp sediments (9,000-10,000 ft, 2,700-3,000 m). The change in gradient suggests a thermal event contemporaneous with the basin's rapid downwarping and Wolfcamp deposition.

Any exploration in the basin, therefore, must recognize the unique relationships between structural timing, structural position, depth of burial, thermal pulses, and hydrocarbon mobility for a large portion of the Val Verde basin.

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Gulf of Mexico Plate Reconstruction by Palinspastic Restoration of Extended Continental Crust

A number of recently published Gulf of Mexico plate reconstructions are strikingly dissimilar. There are no sea floor magnetic lineations, and the sizes and shapes of the continental blocks are not well-defined. Perhaps the only common feature of the several reconstructions is that they ignore the role of continental crust extension during rifting.

In this study, total tectonic subsidence analysis was used to estimate the mount of crust extension in the Gulf of Mexico to determine its effects on the proposed plate reconstructions. This involves the calculation and mapping of the sediment-unloaded basement depth from observations of the basement depth, water depth, and sediment compaction properties. The well-known depth-age relation for oceanic crust and a model for the subsidence of extended continental crust allowed within the limits of available data the identification and mapping of crust type and the amount of extension of transitional crust.

The zone of extended continental crust under the northern margin of the Gulf is extraordinarily wide, more than 800 km (500 mi) in a cross section through east Texas. The zone of extended crust to the south is much narrower, about 150 km (90 mi) on the margin of the Yucatan Block. Palinspastic restoration shows that the total 950 km (590 mi) of extended and thinned continental crust corresponds to 490 km (300 mi) of continental crust of original thickness. Therefore 460 km (280 mi) of crustal extension occurred during rifting and prior to ocean crust formation. The 460 km (280 mi) of extension along this cross section, and the results of similar calculations on other cross sections, must be accounted for properly when reconstructing the prerift configuration of the Gulf of Mexico.

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3-D Seismic Interactive Interpretation of Complex Stratigraphic Environments: An Example From Grayson County, Texas

Interactive interpretation of 3-D seismic data is now an effective tool for mapping complex stratigraphic targets on land. Slicing a 3-D seismic cube through a single reflector provides an insight into complex stratigraphic environments.

A case study from Grayson County, Texas, is used as an example. Production from the lower Davis sands of the Atokan series was established in the Southmaud area in 1978. Further development of the field led to a success ratio of only 50%. Stratigraphic complexity of the fluvial to deltaic environment made reservoir prediction and placement of offset wells difficult. A 6-mi^2 3-D survey was shot for the purpose of mapping the sand distribution. Acquisition and processing costs were less than the cost of one dry hole. The producing sands were a difficult seismic target. Resolution of these sand bodies was in question due to their vertical and horizontal extent as well as their small reflection coefficients.

The interpretation was completed in eighteen hours using Gulf's Interactive Seismic Interpretation System (ISIS). Only one well was used initially to identify seismic horizons. Structural mapping was completed using dual polarity, random vertical lines, and isotime slices. Stratigraphic interpretation was done with discrete amplitude coloring to take advantage of seismic tuning effects. Stratigraphic slices revealed the distribution and thickness of the reservoir sand. Geological features interpreted include a meandering channel with point-bar buildups, a distributary complex, and erosional or nondepositional areas.

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Hydrocarbon Resources of United States Arctic

In April 1980, the National Petroleum Council, an advisory committee to the Secretary of Energy, was requested to estimate, among other directly relevant matters, the oil and gas resources of the United States Arctic regions. The evaluation was based on a review of publicly available information and a survey of the study participants. The results are a composite of anonymous estimates of 20 industry representatives.

As of August 1980, 16.5 billion bbl of recoverable oil and oil-equivalent gas had been discovered on the North Slope. An additional 44 billion bbl of undiscovered, recoverable oil and oil-equivalent gas are estimated for the United States Arctic. Of these, 24 billion bbl may be oil and the remainder will consist of 109 tcf of gas and natural gas liquids. These undiscovered resources constitute as much as 40% of the total undiscovered recoverable oil and gas remaining within United States jurisdiction.

A 1% chance exists that the undiscovered recoverable oil and oil-equivalent gas could exceed 99 billion bbl. Of 10 highly prospective areas,