gas sand. Through detailed examination of the geology and evaluation of alternative explanations of the waveform changes, successful interpretation was accomplished.

Total gas reserves geophysically discovered to date in the Colony formation are estimated at 110 Bcf.

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Vertical and Surface Seismic Profiles Map Aquifers in Madison Group and Red River Formation, Powder River Basin, Wyoming-Montana

Intensive energy development activity in the Powder River basin of eastern Wyoming has placed heavy demands on the water resources of the state. The U.S. Geological Survey is therefore investigating the water resource potential of the Madison Group and Red River Formation, such water to be produced from depths of 2,500 to 7,500 ft (762 to 2,286 m) to supply some of the needs. The exploration seismograph is a promising tool to aid in well-site selection; under some conditions it can be used to detect porosity development at depth.

In-situ measurements of the acoustic properties of the Madison–Red River interval have been made using vertical seismic profiles in several wells. Surface seismic profiles were then run over the wells. The combination of these results with well-log data and regional geologic subsurface studies gives considerable insight as to commercial quantities of water at depth.

The investigation also has petroleum-exploration significance. Madison porosity development often provides an excellent oil and/or gas reservoir in the adjacent Big Horn and Williston basins.

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Explorable Structures in Old Bahama Channel, North of Cuba

Approximately 3,500 km of reflection seismic profile, augmented by some gravity and magnetic data, revealed five domal structures beneath water depths of 500 m in the western reaches of Old Bahama Channel. Closure crossings span as much as 10 km. Cores of these structures are overlain by up to 400 m of semiconsolidated sediment. Cores may be salt diapirs or subducted shallow-water carbonate blocks or both. The size of these structures and their occurrence in relatively shallow water make them attractive exploration targets at the present time.

Additional seismic characteristics of the semiconsolidated sediments comprising the basin fill are (1) extensive continuity of reflections probably resulting from interbedding of shallow-water carbonate turbidites with pelagic oozes, and (2) crinkling of reflections at depths of several hundred meters which may be a compaction phenomenon. Normal faults are common in the sediments. In some places, related faulting and apparent flowage in the sediments may result from compaction and attendant water loss or from flowage of evaporites deeper in the section.

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Graded Beds as Paleogravimetric Cameras

Physicists over the past century have postulated that the universal constant of gravitation, G, is decreasing with time. Assuming an annual rate of decrease of 10^{-10} parts per year the gravitational acceleration of the earth, g, would have been 22% greater two billion years ago. Distal turbidites occur in geologic deposits as old as 2.5 billion years. Utilizing the relations developed by Scheidegger and Potter, a functional relation between g and measurable characteristics of a graded bed may be constructed. This relation, a "paleogravimeter," was tested in terms of sensitivity to changes in g as well as possible confounding effects such as sediment concentration, density, and grain packing. Only the sediment concentration in the turbidity current had a measurable effect. By utilizing Middleton's result that the transition between "distribution" grading and "coarse-tail" grading occurs at particle concentrations of 30%, a selection criteria can be established for the "paleogravimetric camera." In this respect it is meaningful to measure only beds deposited from currents of the same particle concentration. When this is done the paleogravimetric change can be measured. The paleogravimetric camera can be improved by substituting more realistic relations for Stokes' Law and allowing viscosity to vary as suggested by Roscoe. Preferably however, a purely physical model for sedimentation from a turbidite should be developed in place of the Scheidegger-Potter relation.

BEAUMONT, E. A., Cities Service Co., Tulsa, OK

Retrogradational Shelf Sedimentation: Viking Sandstone (Lower Cretaceous), Central Alberta

The Viking Sandstone in the Joffre-Joarcam area of central Alberta consists of a series of overlapping sediment sheets becoming progressively younger westward toward the paleoshoreline. During the regression at the beginning of Viking deposition, streams meandered across the former shelf surface depositing sand in deltas (today's irregular-shaped reservoirs). An ensuing transgression, punctuated by minor regressions, reworked shoreline sediment deposited during the regressions into linear shelf sand bodies (today's linear reservoirs west of the irregular-shaped reservoirs). During the transgression, the retrogradational nature of the sediment sheets, which contain the sand bodies, was formed.

Well-log cross sections show that the Viking thickens westward, pinches out eastward, and that each sediment sheet contains several northwest-trending shoestring sandstone bodies. Cores of the sandstone bodies and their underlying beds exhibit a coarsening-upward succession of: (1) silty marine shale; (2) intercalated silty shale and rippled sand (locally a structureless bioturbated clayey sand); and (3) glauconitic cross-bedded sandstone. A polymictic pebble conglomerate occurs randomly within this sequence.

Submerged deposition on a shelf tens of miles from the paleoshoreline is documented by: (1) marine shale enclosing the Viking; (2) no consistent landward-seaward facies changes; (3) abundant glauconite; (4) an

"offshore" trace fossil assemblage; (5) coarsening-upward sequence of lithologies; and (6) position with respect to the strandline facies. Scarce evidence, such as coal partings and plant fragments, from irregular-shaped fields seems to be inconsistent with deposition offshore. All evidence, however, along with the shingling of the sediment sheets can be explained by retrogradational shelf sedimentation. Modern sediments of the New Jersey shelf are analogous.

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Depositional Facies, Geometry, and Genesis of Upper Cretaceous Mid-Shelf Sand Complex—Sussex Sandstone at House Creek Field, Powder River Basin, Wyoming

At House Creek, cores of the producing Sussex zone reveal a coarsening-upward marine sequence beginning with silty shale and ending with a conglomeratic sandstone. Producing sandstone, 36 mi (58 km) in length, rarely exceeds 1 mi (1.6 km) in width and has an outward "shoestring" appearance. However, distribution of producing and nonproducing sand shows that the thickest part of the complex is immediately southwest of the producing trend and that the sand complex is geometrically asymmetrical—about 17 mi (27 km) across.

The sand zone appears asymmetrical also with respect to sand facies. On the steeper northeast side, the sand complex maintains a sanding-upward profile. In contrast, on the gentler sloping side the facies sequence merges into a single widespread facies. This asymmetry has made possible development of an E-log model for the sand zone.

Deposition of Sussex sand in the House Creek area may have been 50 to 100 mi (80 to 161 km) from the general shoreline in water depths of 50 ft (15 m) or greater. The Sussex zone forms the marine "topsets" of a major basin-filling wedge of fine clastic sediments which prograded from the northwest.

We have difficulty in explaining how sands and gravels in this depositional setting were transported great distances offshore by shelf processes alone. A suggested analog, the Atlantic shelf ridges formed during post-Pleistocene transgression by shoreface erosion and being restructured by the shelf hydrologic regime, is unacceptable because regression and shoreface retreat cannot be documented for the Sussex at House Creek. A model proposed here combines up-coast regression, shoreline retreat, and along-shelf transport. The model emphasizes wave-generated unidirectional currents transporting sediment southerly along or oblique to shelf isobaths.

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Fractional Preservation of Transgressive Coastal Lithosomes on Atlantic Continental Shelf

Migration of coastal environmental lithosomes across the continental shelf is a response to the latest Quaternary rise of the sea. Preservation of fractions of the transgressive sequence is dependent on depth of erosion, which is a function of impinging wave energy, sediment supply, resistance to erosion, and rate of relative sea-level change. Materials deeper in the column have a greater potential for preservation. The relative sea-level curve for Delaware, based on C^{14}-dated basal peats, rises smoothly from 25 m below present from 10,000 years B.P. to the present at a decreasing rate with time. Shells and peats 9,000 to 10,000 years old on the shelf are 40 m deeper, suggesting an east-southeast shelf tilt, tectonically or hydro-isostatically induced. Sea-level rise results in rates of coastal retreat of 10^2 m/year for 10,000 years B.P., 10^1 m/year for 5,000 years B.P., and 10^0 m/year at present. In a model of constant volume of net erosion per unit length of coast, a much smaller depth of erosion applies early in the transgression, allowing a greater preservation potential. Changes in wave climate, sediment supply, and downwarping across the shelf also apply. Recovered sediments, seismic profiles, and recognized morphic features indicate better preservation of shoreline elements on the outer shelf, and more planing off and reworking on the inner shelf. Similar analysis of Delaware Bay indicates that it too follows such a model, in changing from a dendritic fluvial system to a broad estuary.

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Drilling for Methane Gas in Fishers Peak Area, Las Animas County, Colorado

In July and August 1978, two holes were drilled in the Raton basin 12 mi (19 km) southeast of Trinidad, Colorado, for measuring methane gas in coal beds. The sites are near the Morley mine, where the presence of abundant methane gas had been reported during mining operations.

The principal objective was the Morley coal, located just above the Trinidad Sandstone. The geology, drilling procedures, coal beds encountered, tests for gas, and experience gained are described. The amount of methane, although lower than expected, is consistent with the correlation of coal rank to gas yield. The coal is classed as high volatile A; the ratio of fixed carbon to volatile matter is 1.69.

Strong shows of methane are known in other parts of the basin where thicker, more consistent coal sections of higher rank occur. Such localities will most likely prove the importance of the region for methane gas production by future exploration and drilling.

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Devonian Reefs Exposed Along Central Cantabric Coast, Northern Spain

In sea cliffs along the central zone of the Cantabric coast, near Cabo de Peñas, Asturias, the Peran Member of the Candas Limestone (Middle and Upper Devonian) appears in two stratigraphic sections situated near the towns of Peran and Luanco respectively. Faunal assemblages consist of alternations of compact biostromes with units of diversely populated marls. These interbedded deposits reveal that different organisms and mor-