Dives in 240–250 m water depths were made by the submersible *Alvin* in the northwest and central parts of the Wilkinson basin in July 1971. The submersible was instrumented with a probe consisting of a nuclear transmission densitometer, which directly measured bulk density and, indirectly, water content at 0.8-cm intervals, and with a static cone penetrometer, which indirectly measured shear strength at 2.5-cm intervals. The probe was pushed at a constant rate to a maximum depth of 1.45 m by means of a rack and pinion drive actuated by the *Alvin*'s mechanical arm. Three sites, located several hundred meters apart, were occupied on each of the 2 dives.

Previously measured geotechnical properties in the Wilkinson basin, a postglacial sedimentary basin of lutite, indicated relatively uniform areal and vertical (to 3 m below the bottom) conditions. The *Alvin* studies showed a horizontal and vertical heterogeneity much greater than expected. The presence in limited areas of high shear strength strata, not directly correlatable with bulk density or water content, and other apparent small-scale anomalies are not easily reconciled with conventional depositional patterns generally believed present in marine sedimentary basins.

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BEAVER RIVER ANTICLINE AND ITS ASSOCIATED GIANT GAS RESERVE IN CANADA'S NORTHLAND

The Beaver River gas field is located mostly in northern British Columbia at the approximate junction of the British Columbia-Yukon and Northwest Territories boundaries.

The Beaver structure was mapped initially by E. D. Kindle in 1944, while working for the Geological Survey of Canada. Amoco Canada mapped the area in 1955, and as a result of its map interpretation, purchased the Crown lands over the Beaver River structure, as well as several other structures. The discovery well on the Beaver River structure was commenced in 1958 and completed in 1960. The excessive length of time required to drill the well resulted from continued problems, the most serious being a gas blow-out, which resulted in the death of 2 rig hands. A total of 6 follow-up wells has been drilled on the structure, proving a recoverable gas reserve of 1.4 trillion cu ft of gas.

The gas reserve is in an anticline which can be mapped by surface geology and has been confirmed in the subsurface by conventional geophysical methods. The producing zone identified as of Middle Devonian age is a secondary dolomite with fair to good porosity and permeability. The porosity and permeability are improved substantially by fracturing associated with the structural deformation. Exploration in the area of Beaver River, while ideal relative to the standards of the surface geologist, is a nightmare of high costs and problems for the geophysicists and engineers. Access problems due to terrain variations, extreme cold in winter, and muskeg in summer, make normal operations extremely difficult and costly.

The "disturbed belt" of Northeast British Columbia and the Yukon and Northwest Territories undoubtedly holds many more giant hydrocarbon accumulations similar to Beaver River. However, for exploration to flourish in these high-cost areas, exploration incentives are necessary. Reasonable assurance that hydrocarbons when found will get to market with as little delay as possible is a primary requirement. With increasing demand for fuel on the North American continent, Canada's northland gains prominence as a potential supplier. As the demand becomes more urgent, exploration for accumulations such as Beaver River should expand.

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CALCAREOUS ALGAE AND SOME ASSOCIATED MICROFOSSILS FROM ANCIENT WALL REEF COMPLEX (UPPER DEVONIAN), ALBERTA

Nine genera of small calcareous fossils, generally attributed to the algae, are in samples from the Upper Devonian Fairholme Group exposed at the southeastern margin of the Ancient Wall reef complex at Mount Haultain, near Jasper, Alberta. In order of decreasing abundance these are *Renalcis, Sphaerocodium, Girvanella, Keega, Solenopora, Parachaetetes, Vermiporella, Epiphyton,* and *Litanaia.* Except locally, these organisms are of minor quantitative importance. They produced little identifiable loose sediment and their principal rock-forming roles appear to have been as frame-binders and secondary frame-builders associated with the stromatoporoid reef facies marking the edge of the carbonate platform.

The 3 most abundant genera at Mount Haultain exemplify some of the problems of taxonomy and affinity which are common among Paleozoic fossils usually referred to the calcareous algae. *Renalcis, Sphaerocodium,* and *Girvanella* generally are considered to be blue-green algae. *Renalcis* and *Sphaerocodium* differ in both size and form from extant blue-green algae. The branching series of chambers forming the test of *Renalcis* are more characteristic of the Foraminiferida. Its simple wall structure and irregular form suggest an affinity with the Parathuramminacea. The systematic position of *Sphaerocodium* is uncertain. *Girvanella* is a microscopic tubiform fossil reported to range from the Cambrian to the Cretaceous. Its resemblance to the calcified sheaths of several species of extant filamentous blue-green algae suggests that it may be possible to remove it from its conventional position in the artificial group Porostromata, to define its relations to blue-green algal structure and taxonomy more precisely, and to extend its geologic range to the Holocene.

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VALUE OF SEA-BOTTOM AND COASTAL MORPHOLOGIC STUDIES TO OFFSHORE EXPLORATION

Undersea conditions are such as to prevent most of the erosional processes which occur on land. Current erosion and the action of reef-building organisms have a tendency to emphasize tectonic anomalies, rather than to smooth them. Studies of sea-bottom morphology can thus permit recognition of deep-seated structures, saving large expenses in geophysical work. Such studies should include statistical analysis of water depth, as well as various interpretive maps (regional and residual bathymetric maps, sea-bottom topographic contrast maps, *etc.*).

Examination of depth and behavior of submerged

terraces formed during Pleistocene eustatic movements of the sea might permit detection of minute recent tectonic movements, thus pointing to structures which are still active.

Along continental margins affected by faulting and/or epeirogenetic movements, the study of the coastal morphology might help in delineating ancient drainage patterns, making it possible to predict to a certain extent those areas of paleo-discharge, capable of containing favorable reservoir rocks.

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RECENT DEVELOPMENTS IN PETROLEUM EXPLORATION IN ADRIATIC SEA, ITALY

When Adriatic offshore acreage first was opened for exploration, only part of it was known geologically. The northern part of the sea was known to be an extension of the prolific gas producing Po basin. The central and southern parts were known only as the transition between the Apennine and the Dinarids orogenic belts. Seismic reconnaissance in the Northern Adriatic revealed structural and stratigraphic features similar to the onshore portion of the Po basin. These structures are, in fact, now producing gas from 5 new offshore fields.

The geology of the central-southern part of the Adriatic revealed a more complicated geologic pattern. The Tertiary clastic cover had good seismic response and a very prominent seismic horizon, *C*, indicated several large structures on top of the Eocene-Cretaceous limestone. The reflections below the *C* horizons were very poor and affected by multiples. All the wells located on the horizon *C* features were dry, despite the presence of good oil and gas shows.

The second stage of exploration was begun in 1971. Improved seismic techniques showed disharmonic behavior in the structures below horizon *C*, which is a morphologic paleorelief horizon below the Miocene transgressive deposits. New structures located in the Mesozoic section show convergence of the pre-Miocene horizons. Also, it appears that alongside the Triassic evaporitic basin, younger Yugoslav evaporitic basins of Jurassic and Cretaceous age undergo a facies change in Italian waters. In Italy the sediments are basinal or biostromal with indications of reef development in the transitional belt and porous, prolifically gas-bearing calcarenite along the coast. This new understanding of the geology leads to highly encouraging possibilities for large accumulations in the Eocene and Mesozoic carbonates.

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EXPLORATION AND DEVELOPMENT OF COAL RESOURCES, 1970–1975, AND BEYOND

The growth in coal use in recent years and projections for the future indicate need for an expansion in coal-producing capacity over the next several decades to 3–6 times the present output. Each of the mines contributing to this future production will require the identification and commitment of coal reserves in the ground equal to 30–60 times its annual output. Because of more stringent regulations on quality, especially with regard to sulfur content, large areas will be removed from prime consideration as mine sites until effective means of sulfur-emission control are in use. As a result, future coal exploration efforts will involve, in addition to the determination of quantities, thickness, minability, and heat content of coal deposits, a much more careful analysis and consideration of the chemical makeup and the washability characteristics of each deposit being explored.

Future exploration will be devoted not only to the identification of new sources to meet the growing needs for coal and to replace the reserves being worked out, but also to provide substitute sources for mines now producing coal ruled unsuitable because of its sulfur content. On the basis of published projections, the need for reserves to support new coal mines to supply demand from now to the year 2000 will total somewhere between 60 and 100 billion tons. The lower estimate is based on conventional uses, in which sulfur content has become an increasingly important factor. The higher estimate would provide coal for gasification and liquefaction plants in which sulfur content is less critical. Based on average thickness of coal currently being mined, between 12 and 22 million acres will undergo extensive exploration to provide these reserves.

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EXPLORATION AND DEVELOPMENT OF OIL SHALE AND OIL-IMPREGNATED ROCK, 1970–1975

Most oil shale exploration has been accomplished in the half century prior to 1970. Deposits are delineated, but detailed blocking-out of reserves remains to be done in optimum areas where development is proposed. Eighty percent of thick, rich oil shale is in Colorado, 15% in Utah, and 5% in Wyoming.

Oil-shale development appears likely to begin on federal lands in Colorado, and possibly in Utah, in accord with the program of the U.S. Department of the Interior. Utah is the only oil-shale state having sizable blocks of state lands in optimum areas. Development could begin on these if the question of state entitlement to additional federal lands is resolved promptly. Development of private lands in Colorado and Utah also appears likely. Wyoming lands—federal, state and private—have attracted little development interest. All development to date involves underground mining and above-ground retorting.

Oil-impregnated rock—sandstone and limestone—occurs in 22 states, but few deposits are known in detail. Important deposits are known in 13 states. A concerted mapping program places about 90–95% of the nation's mapped reserve in Utah in deposits totaling 20–25 billion bbl of oil in place.

Deposits in about 11 states have been used for paving and aggregate. None has been exploited as a source of oil, although varied experimental and pilot work has been conducted for this purpose in at least 9 states. Although mining, processing, and refining technology is known and highly developed, unfavorable economics have deterred development. *In situ* methods are largely in an experimental stage. In many deposits techniques used in primary or secondary recovery of conventional or heavy crude oils show promise. Experience in the Canadian Athabasca tar sands deposit is expected to strongly influence U.S. activity.

By 1975, small-scale production of shale oil should nearly be under way in western Colorado and possibly in Utah. From about 50,000 bbl/day of oil in 1976 this