these adds an incremental cost to mineral exploration and development. Water pollution control forces deeper surface casing, pit linings, liquid effluent treatment, and surface-water diversion around many mineral operations. Land restoration includes land leveling, erosion protection, and revegetation. Refuse or tailings disposal, likewise, may require expensive treatment facilities, extensive materials handling, stabilization techniques, and permanent revegetation. Air pollution control may require dust control, stack devices, and prevent the burning of waste. Operators not only face physical problems, but must also consider aesthetics from the viewpoint of ardent environmentalists. The Environmental Quality Act of 1969 can be invoked for any "significant" operation that affects federal lands or agencies. As an example of state control, Wyoming has prepared a 99-page booklet listing its environmental control laws. Determining which state or federal law or regulation applies can be difficult in itself. The mineral industry faces not only the expenses of meeting minimum statutory requirements, but most enlightened operators face even greater costs in their voluntary efforts to be good citizens. Public hearings and citizen-sponsored lawsuits challenging any operation with significant, real or imagined, environmental impact will increase.

Without extensive effort to understand and plan for future problems of land availability and the costs of environmental protection, those problems will limit seriously Rocky Mountain mineral potential.

ROSE, P. R., Shell Oil Co., Denver, Colo.

REEVALUATION OF UNCONFORMITY CRITERIA IN CARBONATE SUCCESSIONS

(No abstract submitted)

SANFORD, E. R., Great Canadian Oil Sands, Ltd., Fort McMurray, Alta.

GEOLOGY AND MINING OPERATIONS OF OIL SANDS AT FORT MCMURRAY

Lease 86, the 4,000-acre tract of land presently being mined by Great Canadian Oil Sands Ltd. is in northeastern Alberta and has estimated recoverable reserves of 490 million bbl of oil.

The heavy viscous oil is found in the Lower Cretaceous McMurray Formation, which is unconformably on the Devonian strata. Several hypotheses have been expounded on the source and origin of the hydrocarbons; however, the lack of positive proof has not led to the acceptance of any hypothesis.

Modern strip-mining operations, high-powered scrapers, and bucketwheel excavators are used by GCOS to deliver the oil sand to the plant site, where a hot-water separation process extracts the bitumen from the mixture of sand, shale, and clay. The bitumen is upgraded to a high-quality synthetic crude in the refinery and delivered by means of a 16-in. pipeline to the Interprovincial Pipeline system at Edmonton for shipment to eastern refineries.

SHOMAKER, JOHN W., New Mexico Bur. Mines and Mineral Resources, Albuquerque, N. Mex.

RECENT COAL DEVELOPMENTS IN SAN JUAN BASIN, COLORADO AND NEW MEXICO

The principal San Juan basin coals are in the Upper Cretaceous Fruitland Formation; smaller reserves of somewhat better quality are found in several formations of the Mesaverde Group. Nearly all are subbituminous A or B, or high-volatile bituminous C, with sulfur content averaging about 0.7%.

Since 1953, when coal exploration began in earnest in the basin, 5 major lease blocks totaling on the order of 2¾ billion tons of potentially strippable coal have been established. Additional areas underlain by perhaps another 2 billion tons are in preliminary stages of exploration. In 1971 the Navajo mine at Fruitland probably will be the largest in the United States.

Of this reserve, about 485 million tons (10%) is committed to electric power generation. Much of the rest, particularly a large lease held jointly by El Paso Natural Gas Co. and Conoco's Consolidation Coal subsidiary, is likely to leave the basin in the form of synthetic liquid hydrocarbons or gas. Gasification and liquefaction technology is moving rapidly, and that, plus availability of major reserves of suitable coal, rising demand for fuels, and increasing availability of pipeline and marketing capacity as gas production declines, seems to indicate the future for the basin. The ultimate reserve would appear to be equivalent to about 14½ billion bbl of oil.

SIMPSON, FRANK, Saskatchewan Dept. Mineral Resources, Regina, Sask.

SEQUENCE ELEMENTS IN STRATIGRAPHIC ANALYSIS OF LOWER COLORADO (CRETACEOUS) STRATA, WEST-CENTRAL SASKATCHEWAN

Sedimentary rocks referable to the Lower Colorado subgroup are fairly well defined in the subsurface as that predominantly argillaceous sequence delimited by the base of the Speckled Shale Formation (Turonian) and the top of the Mannville-Blairmore succession (middle Albian). The sequence exhibits pronounced lateral variation and locally discernible diachronism of sandstone bodies; both the lowermost Joli Fou Formation and the uppermost Big River Formation display a northerly increase in sand content, whereas the lenticular sandstone bodies of the Viking Formation, which separates them over most of the study area, become progressively finer grained on the north, so that the formation may no longer be differentiated.

The Lower Colorado succession may be described in terms of repetition of 5 principal sequence elements, each characterized by the predominance of particular gross lithologies and associated internal sedimentary structures: (1) a mudstone element, including structureless mudstones and mudstones containing lenses and intermittent layers of siltstone; (2) a siltstone element, in which lenticular and wavy-layered siltstones and fine-grained sandstones alternate with structureless mudstones; (3) a silty sandstone element, consisting of sandstones with varying proportions of silt-grade material and thin, discontinuous mudstone interlayers, displaying disruption of flaser layering, due to burrowing activities of organisms, as well as loading and injection phenomena; (4) a sandstone element, which may exhibit dune-scale, inclined laminae, horizontal laminae, ripple cross-laminae, and trough cross-laminae; and (5) a conglomeratic element, with pebbly sandstones, conglomerates, and pebbly mudstones. Subordinate lithologies, such as coquinoidal limestones, sideritic oolites, concentrations of iron sulfides, and accumulations of phosphatic bodies, also are present.

The use of sequence elements in stratigraphic analysis provides a systematic approach to description of

lithologic variation, an aid to local correlation of sequences, and a basis for environmental interpretation. Type (3) elements are of particular economic importance as the main reservoir rock of the hydrocarbon-bearing Viking Formation.

STARK, PHILLIP H., Mobil Oil Co., Aurora, Ill.

WELL DATA FILES AND COMPUTER—EXPLORATION TOOLS FOR 1970s

Computer processable well data systems in the United States and Canada contain information of more than 700,000 wells. The use of computers to extract, analyze, and display this information is essential for economically efficient exploration where large amounts of data are available.

A systematic approach to exploration using the well data files and computer methods can improve exploration decision making. One case study demonstrates the use of well data files for the analysis of future gas potential in the northern Rocky Mountains. Another case history illustrates file applications that were used to evaluate the Muddy reservoir in the Powder River basin. Data in the Rocky Mountain well data file were used to delineate prospective Muddy trends on which subsequent drilling has discovered more than 250 million bbl of oil.

STARKWEATHER, JACK, Consulting Geologist, Billings, Mont.

COMBINATION FORMULA UNLOCKING LOWER TYLER "POINT BAR" EXTENSIONS IN CENTRAL MONTANA

The lower Tyler Formation of central Montana is oil productive from sinuous, point-bar sands deposited in a Pennsylvanian river channel. These hydrocarbon-bearing bars are hard to locate, and successfully offsetting a discovery is commonly difficult.

Combining the dipmeter with subsurface data and sample cutting studies is a method that will eliminate some dry holes.

Subsurface data indicate the location of the channel, the amount of erosion into underlying beds, and the type of channel fill. Sample cuttings show the type of bar facies found. The dipmeter illustrates the water-sediment transport direction and the deviations of dip within each facies change.

These 3 tools used together will produce a more accurate subsurface picture to determine which offsetting location will produce a field extension.

STONE, DONALD S., and ROGER L. HOEGER, Petroleum Research Corp., Littleton, Colo.

LOWER CRETACEOUS COMBINATION TRAPS IN BIG MUDDY–SOUTH GLENROCK AREA, WYOMING

In the Big Muddy-South Glenrock field area, Natrona County, Wyoming, probably 100 million bbl of oil will be produced ultimately from 3 separate sandstone reservoirs within the Lower Cretaceous section; from oldest to youngest, the Dakota, the lower Muddy, and the upper Muddy. Entrapment of oil in each of these producing zones is the result of updip pinchout or facies change from porous and permeable sandstone to nonreservoir shale, siltstone, or sandstone, assisted by a favorable hydrodynamic environment.

Each of these sandstone reservoirs occupies a flank position around and across the east plunge of the Big Muddy anticline. Isoliths of permeable Dakota sandstone in the producing area and the regional pattern of sandstone distribution, together with the lithologic characteristics of the Dakota sandstones, suggest deposition within northeasterly flowing rivers that drained an incipient Big Muddy uplift and emptied into the sea near Glenrock. Sand delivered to the sea was distributed along a northwest-trending shoreline by relatively low-energy, destructive, marine processes accompanying the upper Dakota transgression. The Dakota pool at Big Muddy-South Glenrock has a continuous oil column more than 2,500 ft in length and an anomalous, inclined oil-water contact.

The lower Muddy sandstone pool also appears to be a single, continuous reservoir with a vertical oil column of at least 2,500 ft. This sinuous sandstone reservoir trends northeast along the southeast flank and around the east plunge of the Big Muddy anticline and has the classic meander morphology of a fluvial river deposit. The physical dimensions of this northeasterly flowing river are comparable with the upper reaches of the present Mississippi River. The influence of probable structural growth along the Big Muddy axis on the radius of meander curvature and depth of the scour channel in the lower Muddy river is particularly evident.

In the upper Muddy sandstone interval 2 nearly parallel sandstone pools trend essentially north-south across the east-plunging Big Muddy axis, and have the typical lithologic and morphologic characteristics of marine shoreline or barrier-bar deposits. Each pool has a vertical oil column of about 1,500 ft.

Regional mapping of the potentiometric surface of the 3 Lower Cretaceous producing intervals and the unusually long oil columns in each of the Lower Cretaceous sandstone pools at Big Muddy-South Glenrock indicate that a favorable downdip hydrodynamic flow must exist in the area of oil accumulation and must be enhancing the oil-holding capacity of the updip barrier zones.

STONE, WILLIAM D., Davis Oil Co., Denver, Colo.

STRATIGRAPHY AND EXPLORATION OF LOWER CRETACEOUS MUDDY FORMATION, NORTHERN POWDER RIVER BASIN, WYOMING AND MONTANA

The Lower Cretaceous Muddy Formation in the Northern Powder River Basin of Wyoming and Montana was deposited during a marine transgression across a stream-dissected surface of the underlying Skull Creek Shale. The transgression occurred over most of the area, but was limited by a prograding delta on the northeast which supplied most of the sand for the area.

The Muddy Formation is divided into 2 units—lower and upper. The lower Muddy was restricted to a system of dendritic channels which were incised into the Skull Creek Shale during a period of emergence. The sands were supplied from the delta on the northeast and transported south by longshore currents. They were deposited principally in a transitional marine and estuarine environment, and are comprised of fine-grained moderately sorted, partly clay-filled quartzose sands.

By the time of deposition of the upper Muddy unit the incised depressions in the Skull Creek topography had been filled largely and the upper Muddy sands were deposited in a complex marine shoreline environment which resulted in offshore bars, barrier islands, beaches, and tidal deposits.