from the east that would be expected if the Nemaha ridge and the Cambridge arch-Central Kansas uplift experienced post-Morrowan uplift.

RAUP, O. B., U.S. Geol. Survey, Denver, Colo.

PRECIPITATION OF SULFATES AND CHLORIDES BY MIXING SEAWATER BRINES

Experiments using artificial and seawater brines indicate that gypsum, halite, and sylvite can be precipitated by mixing brines at differing stages of evaporation, as well as by the previously recognized mechanisms of direct evaporative crystallization and crystallization by temperature changes. A modification of existing geologic models is proposed to show how brine mixing might work in an evaporite basin. Conclusions based on the experiments and their relations to the geologic model are as follows:

1. Precipitation of salts can occur in a marine evaporite basin by mixing brines of different composition and specific gravity.
2. Precipitation occurs without further water loss by evaporation.
3. Precipitation can occur from brines that were undersaturated before mixing.
4. Brine mixing could cause different salts to be deposited in different parts of a basin depending on the stage of the evaporite cycle.
5. Sylvite could be precipitated as a primary mineral.
6. Hopper crystals (cubic and tabular) of sodium chloride can form as a result of brine mixing in water of any depth.

READING, H. G., Dept. Geol. and Mineral., Oxford, England

SHALLOW-MARINE ENVIRONMENTS IN LATE PRECAMBRIAN OF FINNMARK, NORTHERN NORWAY

Processes operating in present shallow seas suggest that shallow–marine clastic sediments are the result of 4 types of current: (1) tidal, (2) waves, (3) semipermanent, and (4) river. Usually one or two current types dominate. However, the effect of each type of current depends on whether it is operating under normal (fair weather) or catastrophic (storm or flood) conditions and the grade of sediment available. The Skalnes Sandstone shows the effect of alternating fair weather and storm conditions on a combination of semipermanent and wave currents. Other parts of the late Precambrian sediments of Finnmark show the dominance of river, tidal, and wave currents.

REEVES, R. G., Colorado School Mines, Golden, Colo.

GEOLOGIC ANALYSIS OF REMOTE SENSOR DATA, BONANZA PROJECT

The NASA-supported Bonanza Project of the Colorado School of Mines and Martin Marietta Corporation has as its principal objectives (1) education in the geologic applications of remote sensing, (2) development of techniques for the geologic interpretation of remote sensor data, and (3) specification of the most useful parts of the electromagnetic spectrum for geologic remote sensing. The ultimate goal is to provide a test site over which to calibrate spaceborne remote sensors and from which to extrapolate interpretations of remote sensor data into surrounding areas. Research to accomplish these objectives is carried out in the field in the Bonanza test site (an area of approximately 10,000 sq mi in west-central Colorado) and in laboratories at CSM and MMC. Airborne remote sensor data, including aerial photography, infrared imagery and radiometric data, microwave radiometric data, and radar imagery and scatterometric data are acquired (by NASA) and interpreted. Detailed ground measurements are made during overflights, and extensive ground investigations to assist in the interpretation of the airborne data have been carried out. Measurements include surface and subsurface temperatures, soil moisture, atmospheric characteristics, and incoming solar radiation. Ground investigations include detailed geologic mapping, studies of physical properties of rocks and soils, spectral reflectances of natural materials, and relation of vegetation to geology. To date, the research has added to structural and stratigraphic knowledge of the Sangre de Cristo and Sawatch Ranges and San Luis and upper Arkansas valleys, and to knowledge of structure, rocks, and geologic history of the Bonanza volcanic field.

REX, R., Univ. California, Riverside, Calif.

MINERALOGY OF DEEP-SEA SEDIMENTS FROM CRETACEOUS TE HOLOCENE

The mineralogy of the Cretaceous to Holocene sediments of the Pacific and Atlantic basins has close affinities to present sedimentation patterns. Carbonate sediments dominate equatorial and shallow oceanic areas. Turbidites are common close to continental margins. Siliceous radiolarian and diatomaceous sediments are abundant in zones close to the carbonate compensation depth.

One of the more striking features of the deep sea is the common occurrence of an amorphous metal-oxide basal facies. Many areas of both the Atlantic and Pacific show high iron- and manganese-content sediment facies at, or close to, the contact with basement basalt. This basal facies grades upward into the biogenous and detrital lithogenous overlying sediments. Some areas of the basal facies have high copper and zinc contents, and in other places manganese is prominent. In a few places, this facies is essentially hematitic. The carbonates present in the deep sea include, in addition to calcite and aragonite, dolomite, siderite, rhodochrosite, and ankeritic dolomite. An unusual palygorskite and sepiolite and bentonite associated with dolomite is well developed in the vicinity of the Cape Verde Islands in the eastern Atlantic. Basaltic volcanic glass usually alters to montmorillonite plus a zeolite which is usually phillipsite or clinoptilolite. Erionite has been discovered in the western Pacific for the first time in the deep sea. Biogenous opaline silica dissolves and reprecipitates to form crystobalite cherts. These in turn are recrystallized to form quartz cherts in pre-Cenozoic sediments.

The range of mineral facies available suggests that clay mineral diagenesis is slight but the *in situ* formation of zeolites and clays from recrystallization of volcanic ash is important.

RICHARDS, A. F., and M. PERLOW, JR., Marine Geotechnical Lab., Lehigh Univ., Bethlehem, Pa.

VARIABILITY OF GEOTECHNICAL PROPERTIES OF LUTITE IN WILKINSON BASIN, GULF OF MAINE, AS MEASURED IN PLACE FROM SUBMERSIBLE *Alvin*

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.

RICHARDS, W. B., Amoco Canada Petroleum Co., Ltd., Calgary, Alta.

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.

RIDING, R., Dept. Geol. Sci., McGill Univ., Montreal, Que.

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.

RIGASSI, D. A., Petroconsultants, Geneva, Switzerland

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