main untested, but most lands acquired at the 1964 sale have been quitclaimed. Although source rocks are distributed throughout the section, a lack of permeable reservoirs has been discouraging. Despite the negative aspects, the writer believes that the area has much exploratory potential. Another industry exploration cycle is anticipated in the not too distant future.

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PALEOECOLOGIC ANALYSIS OF SOME MIDDLE DEVONIAN FOSSIL AGGREGATIONS

Fossil clusters in the Ludlowville Shale near Buffalo, New York, are nearly circular in bedding-plane outline and plano-convex (convex down) in cross section, the dimensions being about 1 m across and 2 cm thick. The clusters contain several brachiopod species and less abundant bryozoans, trilobites, crinoids, ostracods, bivalves, gastropods, and solitary corals. Their consistent presence across a considerable geographic area and their high diversity suggest that they are an *in situ* "life" assemblage, but their shape and distinct boundaries may be interpreted as evidence that they are not an *in situ* "life" assemblage.

The spiriferid brachiopod *Ambocoelia umbonata* was sampled quantitatively in successive 0.5-cm layers within the fossil clusters. Shell distortion, shell fragmentation, and valve ratios illustrate no vertical trends. Therefore these phenomena must be related to factors that have acted uniformly throughout the clusters. Consistent trends in shell disarticulation, shell position, shell density, and pyrite content are related to factors controlling cluster development. This relation, together with random beak orientations and bimodal size-frequency distributions, favors a biologic origin. The clusters apparently record establishment and succession of organisms on a soft substrate.

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SHALLOW SHELF SEDIMENTATION IN ROCK RECORD—INTRODUCTION TO SYMPOSIUM

A shelf is defined in *Webster's Third International Dictionary* as "1 a : a thin, flat, usually long and narrow piece of wood or other material fastened horizontally at a distance from the floor (as on a wall or in a frame) to hold objects"; and "2 : something resembling a shelf in form or position."

"Something resembling a shelf" in the contemporary geologic scene cannot be well defined. For example, modern continental shelves are defined in different ways by hydrographers, by geographers, and by geologists. Some describe the continental shelf as a surface marginal to continents and lying between the strandline and that place where the sloping surface of the lithosphere steepens toward a deeper part of the ocean basin, regardless of water depth. Others define the shelf as that surface between sea level and a particular depth (commonly 100 fm), irrespective of steepening of the surface. Still others apply the term "shelf" to surfaces formed under the control of erosional, depositional, or structural agencies, or by various more specific biologic or sedimentologic agencies. In most cases, a surface so defined displays the same topographic habit for a distance in either direction from the strandline. With so many apparent variations, can any consensus definition of "shelf" be established within the geologic community?

The presumably representative *AGI Glossary* and the pertinent literature demonstrate that the term "shelf" is applied to any shallow marine sediment. Examples include deposits formed in a great range of physical and tectonic environments. Among these are continental shelves, broad shallow intracontinental basins (epeiric seas), "stable shelves" at cratonic margins, shallow intracratonic basins, and various types of geosynclines. Physical environments in which shelf deposits form are neritic, littoral, and paralic.

For the purpose of this symposium, "shelf" is used in a broad sense. Shelf sediments are subaerial and submarine sediments which were deposited on a relatively shallow, uniformly, gently sloping surface which includes the marine-land interface of the strandline. The zone of shelf sedimentation as here defined is terminated landward and seaward by a perceptible change in the slope and topographic character of the depositional interface.

The purpose of this symposium is to bring together various contemporary viewpoints on shelf sediments. To this end authors representative of the various schools of thought and subdisciplines of shelf studies have been invited to contribute basic papers related to the geology, biology, and chemistry of shelves, or papers illustrating "typical" shelves from various parts of the rock record. It is hoped that such an enunciation of principles and examples will bring into focus the parameters that have controlled sediment accumulation in shallow seas associated with the continental masses and will lead to the construction of reliable theoretical models for their interpretation.

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MINERAL RESOURCES OF NORTHERN ALASKA[1]

Recent production tests near Prudhoe Bay on the Arctic coast show that northern Alaska is a potential major oil province. This potential was first recognized when oil seeps were reported in 1900. By 1930 favorable structures and rocks were known. During exploration of Naval Petroleum Reserve No. 4, gas was discovered in Lower Jurassic rocks at Barrow, oil in Lower Cretaceous rocks at Umiat, and gas in Upper Cretaceous rocks at Gubik. Now oil and gas have been found in Triassic and Mississippian rocks at Prudhoe Bay.

The oil-bearing section consists of Mississippian through Lower Jurassic shelf deposits derived mainly from a northern source, and of up to 20,000 ft of Jurassic and Cretaceous geosynclinal deposits derived mainly from the south.

The Jurassic and Cretaceous Colville geosyncline is bounded on the south by the Triassic and upper Paleozoic rocks of the Brooks Range and on the north by a rise in the pre-Mississippian(?) basement to a depth as shallow as 2,500 ft near Barrow. The stratigraphy of the geosyncline is characterized by northward regression of intertonguing marine and nonmarine detrital sedimentary rocks shed from a southern orogenic source. The structural complexity of the geosyncline

[1] Publication authorized by the Director, U.S. Geological Survey.

decreases northward from the mountain front. Twenty anticlines have been tested, and favorable reservoirs in the Cretaceous seem to be limited to narrow nearshore facies.

Pre-geosynclinal rocks are at drillable depths near the edge of the Brooks Range and on the basement rise. Folding and overthrusting make the Mississippian to Triassic rocks along the mountains difficult to evaluate without intensive subsurface exploration. In the north, geophysical data suggest that the basement rise trends southeast from Barrow and may even be an arch with northward regional dips offshore. Recent private exploration resulted in test wells on two presumably separate structures along the trend of the rise. Reservoir rocks between the Upper Triassic and basement were penetrated by the Colville well, and produce oil and gas in the wells at Prudhoe Bay. These Triassic terrigenous clastic and Mississippian carbonate rocks are part of a sequence of deposits that seem to transgress regionally northward across an unconformity and regress southward away from the source. Additional reservoirs on the rise may be present if Devonian(?) carbonate rocks, that discordantly underlie the Mississippian at the front of the northeastern Brooks Range, are preserved below the unconformity.

Transportation facilities necessary for the development of large petroleum resources in northern Alaska will make the development of the extensive coal deposits there more likely and will improve the potential of known phosphate and rich but limited oil-shale deposits.

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RECOGNITION OF ALLUVIAL-FAN ENVIRONMENTS IN STRATIGRAPHIC RECORD

Alluvial fans are orogenic deposits whose geometry is influenced by the rate and duration of uplift of the adjacent mountains and by climatic changes.

Three longitudinal shapes are common. A fan may be a wedge that is thickest (or thinnest) near the mountains, or it may be lenticular.

An alluvial fan may consist of water-laid sediments, debris-flow deposits, or both. Water-laid sediments occur as channel, sheetflood, or sieve deposits. Main stream channels commonly are backfilled with coarse-grained sediments. Sheets of finer grained sediments are deposited downslope from the channel. The fine-grained sediments may be cross-bedded, massive, or thin bedded; the coarse-grained sediments may be imbricated, massive, or thick bedded. Sieve deposits consist of intertonguing lobes of very permeable gravel.

Debris flows are poorly sorted and may have graded bedding or preferred particle orientation. Boulders weighing many tons may be present in an unsorted matrix. Mudflows are fine-grained debris flows. Platy fragments are oriented parallel with the bedding in low-viscosity flows. In high-viscosity flows, fragments are oriented vertically, and normal to the direction of flow.

Individual beds may be traced for long distances along radial sections, and channel deposits are scarce. Cross-fan sections reveal beds of limited extent that are interrupted by cut-and-fill structures, which are most common near the fan apex.

Logarithmic plots of the coarsest 1-percentile and median-particle size make patterns which are distinctive of fan environments. Sinuous patterns indicate tractive-current environments. Rectilinear patterns indicate mudflow environments.

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DEEP-WATER DRILLING—SIGSBEE SALT DIAPIRS

(No abstract submitted)

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FORAMINIFERAL DENSITIES AND ENVIRONMENTAL VARIABLES: USE OF STATISTICAL MODELS TO EXAMINE ESTUARINE ENVIRONMENT

Many environmental variables have been suggested to explain species distributions. However, species distributions generally cannot be evaluated statistically because of inadequate sampling procedures. The purpose of the present study is to outline a method of analysis using statistical models.

A pilot study in the Choptank River, Maryland, indicated that *Elphidium clavatum* density decreases progressively upstream, whereas *Ammobaculites exiguus* and *Ammonia beccarii* densities change very little. From this pilot study, three stations were selected for detailed analysis.

Four foraminiferal samples were taken monthly at each station for a year. Temperature, salinity, oxygen, and chlorophyll *a*, *b*, and *c* were measured each month at every station. A general multiple regression-analysis of variance model was constructed containing 21 parameters for environmental variables, station differences, overall periodic differences, and interaction of station and periodic differences. This model was compared with several containing fewer parameters. Restricted models containing 15 parameters sufficiently accounted for observed species densities in each example.

The set of environmental variables is significant at the 95% level for all species, but none is significant individually. However, relatively large values of regression coefficients for chlorophylls, especially *b*, suggest that food (amount and kind) is important in determining species densities. Each species exhibits periodicity, and for each, periodicity differs at the three stations.

Results indicate that the use of statistical models permits greater understanding of relations between foraminiferal species and environments. Such understanding will be of great value in paleoecology.

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DELINEATION OF SOME OUTER DELTAIC PLAIN SUBENVIRONMENTS BASED ON SEDIMENTARY PROPERTIES IN VERTICAL SECTION

A small wedge of detrital sedimentary rocks (deposits of the outer part of a deltaic plain) was investigated to delineate subenvironments. The rock unit (Middle Pennsylvanian age) is as thick as 40 ft and occupies an area of about 300 sq mi in western Pennsylvania, where intense strip mining provides excellent continuity of outcrop. Criteria for defining rock subfacies are vertical sequences of bed-thickness properties of sandstone and siltstone, together with minor sedimentary structures and fossil content—in brief, those properties observable in smaller exposures or subsurface records.

Lateral relations of the vertically defined rock subfacies, exposed in continuous cut faces, delineate