to 78 m), and Fishnet bank (61 to 82 m) characterized by the presence of antipatharian whips, deep-water alcyonarian fans, comatulid crinoids, certain species of deep-dwelling fishes, and sparse populations of encrusting coralline algae.

Similar reefs and banks probably have existed on the Texas continental shelf throughout Tertiary time. Exploration philosophy will be dependent on the identification of the proper bank model.

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Shallow Gas Accumulations—Their Origin and Significance for Future Exploration

Large resources of natural gas are present at shallow depths in the northern Rocky Mountains and elsewhere. This gas, predominantly methane, is the product of the immature stage of hydrocarbon generation. The methane is generated by the breakdown of organic matter by anaerobic bacteria and consequently is called biogenic gas. Reduction of CO_2 is the principal mechanism of methane generation under anoxic conditions. The accumulation of biogenic gas is favored by rapid deposition of organic-rich sediments and by the presence of a reservoir or seal either during peak generation or later when uplift and erosion cause exsolution of gases from formation waters. In deep-marine or permafrost environments, the loss of gas is prevented by stabilization of the solid methane hydrate. Ancient gas of predominantly biogenic origin is characterized by the enrichment of the light isotope C^{12} in the methane ($\delta C^{13} < -58‰$) and by large amounts of methane relative to ethane and higher hydrocarbons ($C_1/C_{1-N} > 0.98$). Future exploration for gases of biogenic origin is important for several reasons. Generation of biogenic gas is widespread because it is controlled by biologic activity at shallow depths and is not dependent on factors of temperature and geologic time. Biogenic gas is generated in both marine and nonmarine sediments. The economics of drilling and the increasing wellhead price of natural gas make shallow accumulations an attractive exploration target. Finally, present worldwide reserve figures indicate that similar large resources are yet to be discovered.

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Computer Analysis of Lineaments to Infer Existence of Subsurface Geologic Structures

Surface lineaments ranging from hundreds of feet to several miles in length can be identified through interpretation of high-altitude imagery. Studies of regional extent indicate that the azimuths of the lineaments are in four predominant groups, each group having a predominant direction. These four predominant directions represent regional trends. Of interest are the deviations of individual lineaments from the regional trends. In particular, areas in which the lineaments have, on the average, large deviations from their group-predominant direction represent boundaries of nonregional trends, such as structural or stratigraphic anomalies.

An algorithm and computer program was developed which starts with a map of lineaments, produces a histogram of the lineament azimuths, and statistically defines the four predominant groups and each group's predominant direction. The program determines the deviation of each lineament from its group-predominant direction and produces a contour map of the absolute deviations. The contour map then is used to identify possible subsurface structures.

Good correlation has been exhibited between the contour map and known structural and stratigraphic anomalies.

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Geophysical-Geologic Synergism

No abstract available.

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Oslofjord, Norway: Case Study in Applications of Marine Geotechnology to Sedimentology

Geophysical-geotechnical field work was done in 1962-1963, laboratory geotechnical and geochemical testing of high-quality cores was performed in 1963-1964, and the data were evaluated and synthesized in 1964-1974 for the Norwegian Geotechnical Institute's Oslofjord Project. This investigation will be used as a case study to demonstrate the applications of marine geotechnology to sedimentology. Sediment thickness in the four basins along the axis of the fjord ranged from 29 to 130 m; sediments at depths greater than about 9 to 14 m are Pleistocene age or older, on the basis of carbon-14 dates determined at shallower depths. Sedimentation rates, corrected for consolidation, ranged from 0.9 to 2.5 m/1,000-years. An acoustic reflector in the basins was correlated with the 10,000-11,000 B. P. recession of the glacial ice cap. The overconsolidation ratio ($p_c/\bar{\sigma}_v$) is unity at burial depths greater than 4 to 5 m, indicating geotechnically normal consolidation. Quick (highly sensitive) clays had pore-water salinities of 29 to 38 parts per thousand. Typical nonquick silty clays had the following properties: clay-size 55% < 2 μm; bulk density 1.55 Mg/cu m; water content 86% dry weight; liquid limit 80%; plastic limit 31%; natural shear strength 8.8 kPa; sensitivity 7.2; organic carbon 0.7%; $CaCO_3$ 2.9%; and pore-water salinity 33.5 parts per thousand. The typical submarine clay has higher Atterberg limits compared to the uplifted marine clays adjacent to the fjord. At three selected burial depths, the change of properties along the fjord axis from Oslo south toward the Skagerrak was investigated: at the surface (0.1 m) the pore-water salinity and $CaCO_3$ consistently increased; at 2.8 m only $CaCO_3$ increased; and at 5.6 m both bulk density and $CaCO_3$ increased. Other properties were variable along the fjord axis. The magnitude of bioturbation was assessed using the concept of greatest difference between the minimum and maximum natural-shear strength; the amount of bioturbation was significant at the 2.8 and 5.6-m depth intervals in all of the basins.

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Scotian Shelf Geothermal Gradients

In 35 wells drilled on the Scotian Shelf, the thermal gradient averages 2.2°C/100 m, and ranges from 0.6 to 2.9°C/100 m. This gradient is similar to values reported from the southern North Sea, another clastic-sediment province. The general trend is toward higher gradients as the sediments thicken away from the land and approach the edge of the continental shelf, although isolated geothermal highs are present over positive structural elements such as the Sable Island diapiric structure. A thermal low follows the trace of the Cobequid-Chedabucto fault.

The lower limiting isotherm of hydrocarbon generation, 65°C, in the liquid window described by Pusey, is reached at a depth of about 2,380 m on the Scotian Shelf. Optimum temperatures of about 93°C are reached at a depth of 3,600 m. Linear extrapolation to 150°C indicates that the approximate maximum temperature of generation would be reached at a depth of about 6,080 m. If Georges Bank has the same or similar geothermal gradients, the correlative sedimentary section of this hitherto-unexplored area will accommodate fully a similar commercial hydrocarbon liquid window at reasonable depths for exploration and production.

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Combination Entrapment in Smackover Formation at Chalybeat Springs Field, Jurassic of South Arkansas

Chalybeat Springs field, in Columbia County, Arkansas, is a combination stratigraphic-structural trap in an oolitic calcarenite at the top of the Smackover Formation. Production is limited by the combination of a structural nose with flank porosity. Downdip production is limited by water.

The field was found in 1972. Discoveries at Lick Creek, in 1960 and Walker Creek in 1968 enabled revision of stratigraphic concepts that were applied correctly in exploration for Chalybeat Springs. Prior to 1968 the Reynolds oolite of south Arkansas was correlated with the Smackover "B" zone of north Louisiana. Consequently, the absence of structurally closed anticlines along the Lick Creek–Walker Creek trend kept the reservoir hidden. The discovery at Walker Creek revealed the stratigraphic separation between the Smackover "B" zone and the Reynolds oolite and led to the discovery of Chalybeat Springs field.

Jurassic strata of south Arkansas are a progradational sequence of facies involving the Smackover Limestone, Buckner shale and anhydrite, and Cotton Valley clastic rocks. The combination of progradational deposition and contemporaneous structural movements produced the trap at Chalybeat Springs.

Entrapment occurs in an oolitic-calcarenite lens associated with a tilted anticline. Updip from Chalybeat Springs the oolitic calcarenite undergoes a change to quartz sandstone with scattered oolites. Downdip from the field the oolitic calcarenite is replaced by facies transition to a skeletal-lime mudstone. The overlying seal for the trap is anhydritic shale of the Buckner Formation and the floor or underseal is an interbedded limestone and sandstone packet termed the Phelps sand member.

The Smackover "B" zone is an oolitic calcarenite deposited on a beach which prograded seaward. Landward of the beach, red shales with anhydrite nodules were deposited on coastal mud flats. Seaward of the beach, lime muds with oysters and echinoderms were deposited in a marine subtidal environment.

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Geology of Norwegian Continental Shelf North of 62°North

Since 1969 regional geophysical mapping has been undertaken on the Norwegian shelf north of 62°N. Approximately 38,400 km of regional reflection-seismic profiles have been shot. Detailed surveys were made in selected areas offshore from Troms and More.

The Norwegian offshore north of 62°N can be separated into the More-Lofoten and the Barents Sea areas. The More-Lofoten shelf, stretching from 62 to 69°30′N, is separated geomorphologically into three segments. A similar separation also is reflected in the land geomorphology and the structural geology underlying the shelf and slope. The shelf has the characteristics of a passive continental margin. The pre-Tertiary sedimentary rocks are structured into three subbasins.

The Barents Sea is an epicontinental sea with water depths averaging 300 m and a gentle bottom topography. Close to the coast, outside Troms, the transition between sedimentary rocks and basement is marked by a change to a rougher topography. Outside Finnmark the wedgeout of the sedimentary rocks under the sea against the old Precambrian land bed rock is affected by a trench.

The eastern part of the Norwegian Barents Sea is a broad epeirogenic basin but more complex structural conditions are present in the western part. The transition between the Barents Sea and the oceanic Norwegian Sea is marked by a Tertiary clastic wedge. A north-south high complex underlies the wedge. In the north-south basin, east of the high, are several salt diapirs. The basin is bordered on the east by a hinge line. Salt diapirs also are present in the eastern Barents Sea.

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Fusulinacean Provinces of North American Cordillera

The North American Cordillera contains some middle Carboniferous, a few late Carboniferous, and many Permian fusulinacean faunas which belong to two or more contrasting paleobiogeographic provinces and are associated with different depositional settings. The most diverse of these faunas is in massive limestones with ribbon chert and basic volcanic rock and is Tethyan (or tropical). A less diverse fauna is in bedded limestones with clastic sediment rocks and has non-Tethyan affinities; some parts of this fauna are nontropical, others are tropical. In the Canadian Cordillera these two contrasting faunas are distributed in four belts: an eastern non-Tethyan faunal belt along the western edge of the late Paleozoic craton; a Tethyan "Cache Creek" belt; a western non-Tethyan belt; and a westernmost Tethyan