500 m (1,640 ft) of deltaic deposits dispersed westward into the Central basin. These onlapped the basin margins in response to initial high rates of subsidence along the flank of the shear zone. Late Paleocene uplift and increasing transpression along the shear zone is recorded by a drainage reversal and about 2 km (1 mi) of easterly offlapping deltaic deposits.

In western Spitsbergen, deformation of late Paleocene through Eocene age represents the culmination of transpression and is characterized by thrusts, asymmetric folds, and steeply-dipping reverse faults producing approximately 10-15 km (6-9 mi) of crustal shortening.

Farther west, the Eocene to early Oligocene Forlandsundet Graben, and probably other smaller basins, originated after the climax of transpression, possibly during collapse of the uplifted axis of the orogenic belt. Although the Forlandsundet Graben contains a true vertical thickness less than 3 km (2 mi) of fan-delta to submarine fan deposits, its apparent thickness greater than 5 km (3 mi) suggests basin migration during increasing transtensional conditions. Extensional deformation of the graben sequence heralded the transition of the Svalbard margin from a sheared to a rifted regime. From 36 Ma, Spitsbergen was uplifted, and deep (> 5 km, 3 mi) rift basins developed along the new continental margin.

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Interactive Geologic Modeling

Improved success in finding hydrocarbons and minerals depends on developing geologic models from seismic, gravity, and magnetic data that most closely approximate real-world settings. Although data processing remains the chore of mainframe and minicomputers, interpretations and modeling of geologic and geophysical information now are best accomplished on personal computers because these computers afford the explorationist maximum freedom to shape and fine tune geophysical evaluations. Three case histories use the GEOSIM geophysical modeling systems to delineate exploration targets.

The first example is Silurian Niagaran reef trends in the Michigan basin. Here, differences in seismic reef anomalies result from variations in carbonate-evaporite stratigraphy encasing the reefs, reef geometry, and reef reservoir parameters. These variations which influence real seismic-response differences can be successfully matched using appropriate geologic models in generating synthetic seismic reef anomalies.

The second example applies gravity and magnetic data to seismic modeling of a Wyoming coal field. Detailed seismic stratigraphy helps locate those portions of the field having multiple seams, although it does not resolve individual economic zones. Gravity data do identify pinchout margins of multiseam zones and pinchouts between principal coals. Magnetic data are then used to delineate the burn (clinker) margin.

Seismic modeling of subtle stratigraphic traps is the broader area of exploration interest contained in the first 2 examples. In the third, successfully modeled and tested examples of lateral changes in deltaic facies and of faulted, unconformity-bounded continent-margin sequences are shown to be successful guides to reinterpretation of seismic data.

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Foraminiferal Biostratigraphy and Paleoenvironments of Eastover Formation (Late Miocene), Virginia

Foraminifera from 50 samples taken from the Eastover Formation (Miocene) in Virginia are used in a study of biostratigraphy and paleoecology. The Eastover Formation contains two members: the lower Claremont Manor Member, a clayey, silty, poorly sorted, fine-grained sand which contains abundant foraminifera; and the upper Cobham Bay Member, a well-sorted, shelly, fine-grained sand that contains less abundant foraminifera.

Planktonic species are used to establish a biochronology of the Eastover, while benthic species are used to interpret paleoecology, using the distribution of modern foraminifera as a basis. Evidence of changes in environments through time and varying sea margins is searched for by examination of samples taken from vertical sections and samples taken from different geographic locations within the study area. Additional evidence of paleoenvironments is gained by a grain size analysis of sediments from the formation. Synthesis of this information allows for reconstruction of the geologic history of the Eastover Formation in terms of environments changing through time and space.

Cluster analysis and canonical variate analysis are used to clarify differences in foraminiferal content between and within the two members and to identify the taxa which cause such differences. Analysis of this type is helpful in revealing any foraminiferal assemblage zones present as well as quantifying data derived from the study.

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Heat Flow as an Indicator of Regional Ground-Water Migration in Great Plains

Heat-flow and temperature-gradient measurements indicate a correlation between subsurface structures, regional ground-water flow, and heat flow in the Great Plains. Throughout the province, thick Cretaceous shales act as confining layers to aquifers, e.g., the Dakota (Cretaceous) and the Madison (Mississippian), which flow generally eastward in accord with the declivity of the plains. The vertical component of groundwater flow on the margins of the Denver, Kennedy, and Williston basins evidently exceeds the thermal diffusion rate in the confining layers overlying the aquifers, and causes significant disturbances in the surface heat flow. Heat flow along the eastern margin of the Denver basin in Nebraska may be about 50% higher than normal due to the water flow; the effect in the Kennedy basin in South Dakota and Nebraska may have doubled the surface heat flow. The Williston basin has anomalous heat flow on its eastern margin and may also show effects of intrabasin structures such as the Nesson anticline. These ground-water systems constitute a significant low-temperature geothermal resource that is estimated to exceed 20×10^{18} J of energy. Recognition of this geothermal resource and accurate estimation of the amount of available energy is best achieved by heat-flow studies. For example, estimates of geothermal resources in Nebraska based on heat-flow data and bottom-hole temperature data differ by 80%.

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Three-Dimensional Seismic Monitoring of Enhanced Oil Recovery Project

The 3-D seismic survey technique has been used to monitor the progress of an enhanced oil-recovery project in which production is stimulated by in-situ combustion driven by injected gas. A baseline 3-D data volume was recorded previous to the initiation of the combustion program. After combustion had been allowed to proceed for some time, the 3-D survey was repeated. Since the basis for tracking the effects of the combustion process is comparison, great care was taken to duplicate field geometry, recording parameters, and data processing. VSP data were also recorded to locate precisely the target sand reflection time and character.

Previous to the analysis of the 3-D data, synthetic traces were generated from well log data modified in several ways to simulate the effects of the combustion process. The target sand is characterized seismically by an impedance contrast due to low density. The predicted changes in reflection character are primarily due to changes in density caused by increased gas saturation. Complex trace attributes were computed to examine amplitude and other waveform changes. Comparison of preburn to postburn data shows differences that can be explained by increased gas saturation.

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Depositional Environment and Reservoir Characteristics of an Upper Devonian Sandstone in the Appalachian Basin, Cherryhill Field, Indiana County, West-Central Pennsylvania

The Appalachian basin is referred to as the birthplace of the oil and gas industry. Drilling has occurred since the Drake discovery well in Titusville, Pennsylvania, in 1859. Applying new tricks in an old basin is one way to help meet tomorrow's energy needs.

An isopach map, cross sections, genetic increment strata (GIS) map, core studies, and subsurface well logs suggest a gas-productive turbidite