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 ground-water 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 channel deposit for the Upper Devonian Speechley sandstone in Cherryhill field in west-central Pennsylvania. Isopaching indicates the channel trend, showing the geometry of the sand body perpendicular to basin contouring. Cross sections document a downcutting erosional contact with the underlying marine shales. Using a lithologic time correlator above the sand and the erosional basal contact, a GIS map shows that maximum reservoir development coincides with the central channel axis. Thus, the isopach and GIS maps are essentially identical; both confirm the channel trend.

Bedding characteristics, sedimentary structures, and petrology, from 59 ft (18 m) of conventional core, also suggest a turbidite channel. Bedding is predominately massive, and is comprised of incomplete Bouma sequences. Grain size decreases upward. Porosities which average 8%, and permeabilities, which are generally less than 1 md, were reduced by silica and carbonate cements and clays bridging pore throats. Sedimentary structures include shale clasts, erosional basal contacts, and bioturbation.

The combination of various mapping techniques and core interpretation suggest a turbidite channel origin for the Speechley sandstone. This approach may permit predictions for field development and exploratory drilling.

GROAT, C.

Gulf Coast Geopressured Geothermal Resources: The Hard Facts

(No abstract available)

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Geological Constraints on Models for the Late Jurassic-Early Cretaceous (Wealdian) Longroño-Soria Strike-Slip Basin (Northwest Spain)

The Longroño-Soria basin was formed between N60°E-striking, left-stepping, left-lateral strike-slip faults during the Late Jurassic-Early Cretaceous (Wealdian), when as much as 6 km (20,000 ft) of fluvio-deltaic strata accumulated in it. During basin development, the ends of the master faults propagated, increasing fault length and offset. Outside the basin, compressional deformation with superimposed folding was induced near the ends of the master faults. At the same time within the basin, normal faults and depocenters migrated in a direction opposite to that of the propagating master faults. The resulting extension allowed a N130°E-trending, 50-km (31-mi) wide, synsedimentary syncline to develop in the basin fill. This syncline was related to formation of a half graben in the basement. The high rate of subsidence and the high heat flow led to a sequential development within the sediments of water escape structures, hydroplastic-type compaction-related microfaulting, pseudocleavage, and metamorphism—420°C (788°F), 1-2 kb, 100-150°C/km (5.5-8.25°F/mi) gradient.

Our interpretation of the geometry, sedimentation, tectonics, and thermal evolution of the Longroño-Soria basin is based upon 2 mathematical models of strike-slip basins and one analogue model: (1) Rodger's calculations predicting vertical deformation, stress accumulation, and secondary faulting; (2) an unpublished finite element method by Liu that gives stress deviation and accumulation patterns; and (3) microtectonics, which provide a model for stress deviations at the tip of the microfaults and for the geometry of deformation during micro-rhombgraben development. The 3 models show comparable fault geometry and stress patterns, and fit our data from the Longroño-Soria basin.

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Deposition, Diagenesis, and Porosity Relationships in the Glorieta Formation, Keystone (Holt) Field, Winkler County, Texas

Production of hydrocarbons from the Chevron 7C H. E. Lovett well, Keystone (Holt) field, is from the upper part of the Glorieta formation (Leonardian). The field is located near the western margin of the Central Basin platform (Permian basin) on a present-day structural high.

The 116-ft (35.4-m) core contains at least 7 cycles of deposition, which consist, upward from the base, of progradational subtidal, intertidal and supratidal deposits. Supratidal deposits predominantly consist of dolostones with fenestral cavities; sabkha deposits are not represented. Scattered nodules of nonevaporitic anhydrite have been emplaced within subtidally deposited carbonates after dolomitization. Intrabiopelgrapestone grainstones, oointrabiopelgrainstones, intrabiopelpackstones and wackestones, and intrapelpackstones and wackestones are the predominant lithofacies. Dolostone is the predominant lithology.

The cored interval was exposed subaerially several times, and episodes of freshwater diagenesis were interspersed with influxes of dolomitizing and anhydritizing fluids. Most dolostone intervals record the following five stages of diagenesis: (1) early dolomitization; (2) emplacement of nonevaporite anhydrite as cement, replacement or a combination of both; (3) dissolution of anhydrite; (4) precipitation of dolomite cement; and (5) emplacement of second generation anhydrite as cement and replacement. Some intervals contain additional stages of diagenesis including precipitation of the clay mineral dickite and calcite as cements.

The core contains many highly porous dolostone intervals, and 9 distinct pore types are preserved. These include primary intergranular, fenestral, and intrabiotic voids; secondary intercrystalline pores; hollow micrite envelopes; biomolds, oomolds and fractures; and tertiary anhydrite molds. The most abundantly represented pores are secondary intercrystalline and tertiary anhydrite molds.

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Hydrocarbon Maturation in Laramide Basins—Constraints from Evolution of Northern Big Horn Basin, Wyoming and Montana

Thermal and mechanical models were used to quantify the effects of Laramide uplifts and subsequent synorogenic deposition on the hydrocarbon maturation of Cretaceous source rocks in the Big Horn basin. Laramide deformation and resultant sedimentation has clearly affected hydrocarbon maturation of Cretaceous source rocks (Thermopolis, Mowry, Frontier, Cody). Modified Lopatin-type reconstructions suggest that a significant region containing Cretaceous source rocks has been within the liquid hydrocarbon window. The earliest onset of hydrocarbon maturation in the northern Big Horn basin was latest Eocene, with some regions still containing immature Cretaceous source rocks as a consequence of Cenozoic erosion, uplift of the Pryor Mountains, and lack of burial.

Regional geologic features indicate that the basin formed as a result of flexural compensation of an elastic lithosphere during emplacement of the Beartooth and Pryor Mountains, and possibly the Absaroka volcanics. This was determined by 2-dimensional models which predict sediment thicknesses caused by tectonic loading and subsequent sedimentation. Flexural rigidities of 10^{21}-10^{22} newton-meters adequately explain flexural subsidence in the northern Big Horn basin.

The present basin configuration also was compared with a theoretical profile based on geologic constraints. Subsidence models for the present basin profile suggest that Paleocene thrusting of the Beartooth block contributes a majority of the tectonic loading and that Cenozoic erosion has drastically affected the resultant sedimentary sequence (Fort Union and Wasatch). These models, along with stratigraphic reconstructions, can be combined to pinpoint areas of potential hydrocarbon maturation within Laramide-type basins.

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Energy in the Reindustrialization of America

America's future industrial growth will depend on our energy growth, and energy growth depends on the choices we make today. In the petroleum exploration industry our choices are based as much on energy and economic analyses and forecasts as they are on geologic factors. The theme of this convention, "Energy, Economics, Exploration—in Transition," is most timely, for these elements are truly in transition now more than ever before in the petroleum industry's history.

Of critical importance is the role of energy in the reindustrialization of America. Energy supply, in whatever form of fossil fuel or alternate