must be displayed or printed out so that data manipulations can be reviewed critically.

Having achieved a rigid quality control, explorationists should now feel comfortable with initial reservoir estimates based on these data sets. Financial planning and forecasting can then proceed on a more secure basis earlier in the exploration and development of a prospect.

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Application of Three-Dimensional Computer Modeling for Reservoir and Ore-Body Analysis

Three-dimensional computer modeling of reservoirs and ore bodies aids in understanding and exploiting these resources. This modeling tool enables the geologist and engineer to correlate in 3 dimensions, experiment with various geologic interpretations, combine variables to enhance certain geologic attributes, test for reservoir heterogeneities and continuity, select drill sites or perforation zones, determine volumes, plan production, generate geologic parameters for input to flow simulators, calculate tonnages and ore-waste ratios, and test sensitivity of reserves to various ore-grade cutoffs and economic parameters. All applications benefit from the ability to update rapidly the 3-dimensional computer models when new data are collected.

Two 3-dimensional computer modeling projects demonstrate these capabilities. The first project involves modeling porosity, permeability, and water saturation in a Malaysian reservoir. The models were used to analyze the relationship between water saturation and porosity and to generate geologic parameters for input to a flow simulator. The second project involves modeling copper, zinc, silver, gold, and specific gravity in a massive sulfide ore body in British Columbia. The 4 metal models were combined into one copper-equivalence model and evaluated for tonnage, stripping ratio, and sensitivity to variations of ore-grade cutoff.

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Geomorphic Features of Oregon-Washington Project EEZ-SCAN

During Leg 4 of Project EEZ-SCAN, long-range side-scan sonographs and seismic-reflection profiles were collected off Oregon and Washington, from the edge of the continental shelf to the boundary of the United States Exclusive Economic Zone (375 km from shore). The survey was extended seaward where necessary to include the Juan de Fuca Ridge. The project utilized the British GLORIA side-scan sonar system. The records were slant-range corrected and anamorphosed, and mosaics were constructed at a scale of 1:375,000.

The sonographs display precise geometry of the major geomorphic features of the area: accretionary ridges, submarine canyons, and fan valleys on the continental slope; deep-sea fans and channels in Cascadia basin; and elongate volcanic ridges making up Gorda and Juan de Fuca Ridges. Canyons with gullied walls deeply incise the upper continental slope off Washington. On the lower slope, the regime apparently changes from one of downcutting to one of overbank deposition. Cascadia basin and Cascadia Channel record intricate and complex drainage histories. The channel is not evident as a major feature on Nitinat Fan but becomes more prominent to the south, especially where it crosses Blanco Fracture Zone and enters Tufts Abyssal Plain.

Recent tectonic deformation of oceanic crust in the vicinity of Gorda Ridge is evident in the sonographs. For example, long, linear volcanic ridges flanking the spreading center are distorted and rotated westward at the north end where the Gorda Ridge meets the Blanco Fracture Zone.

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Lacustrine Deposits in Rifted Deep Basins of Yellow Sea

The central Yellow Sea is a typical intracratonic rifted basin that consists of 4 major depressions bounded by aligned listric faults along horst blocks of uplifted basement (Kunsan, West Kunsan, Yellow Sea subbasins, and Central Trough). The depressions are half grabens caused by pull-apart extensional stresses.

Core analysis and micropaleontologic study indicate that more than 5 km of lacustrine sediments were accumulated in the central part of the West Kunsan basin. Two distinctive sedimentary successions are recognized in the core descriptions: alternation of reddish-brown siltstones and sandstones containing evaporites and marlstones, and an overlying progradational sequence including minor limestone beds in the lower part of the sequence. The progradational sequence is interpreted as lacustrine deltaic deposits. Abundant palynofloral occurrence of freshwater green algae, *Pediastrum*, and absence of marine fauna such as dinoflagellates are also supporting evidence for a lacustrine environment. The lithofacies and tectonic framework of the Yellow Sea are very similar to those of Cretaceous lacustrine sediments of the Korea Peninsula onshore and Pohai coastal basin in China.

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Late Paleozoic Foreland Deformation in Northern Mexico: Paleogeographic and Tectonic Implications

Deformation in north-central Mexico reflects the existence of an actively evolving foreland basin during the late Paleozoic. The Pedregosa and Orogrande basins formed the northern extensions of this north-northwest-trending foreland basin, which was flanked on the north and west by several large block uplifts. Deformation along the southeastern margin of the basin, in Coahuila, is postulated to represent part of a foreland fold-thrust belt, while structures in Chihuahua and adjacent parts of New Mexico and Texas are related to basement-involved block uplifts. The unconformities, sedimentation patterns and deformation styles of several localities in Chihuahua, southern New Mexico, and west Texas indicate similar, but not necessarily time-equivalent, deformational histories.

Uplift began in Late Mississippian and culminated between latest Pennsylvanian (in the north) and Late Permian (in the south). The geographic distribution and sequential timing of deformation are consistent with our knowledge of the Ouachita system in the U. S. The distribution of the fold-thrust belt and basement-involved uplifts of the Ouachita foreland in northern Mexico is not only similar to other parts of the Ouachita system but also to portions of the Laramide in the northern Rocky Mountains. These similarities and the distribution of late Paleozoic calc-alkaline igneous rocks in the region suggest that a subduction zone and associated magmatic arc were present in eastern Mexico during the late Paleozoic.

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Western Desert of Egypt: Geology and New Petroleum Exploration Concepts

The Western Desert of Egypt has had a sporadic history of exploration. Production has been continuous since the discovery of the Alemein field in 1967, but the emergence of the Gulf of Suez as a giant oil field province has overshadowed Western Desert production.

Recent discoveries in the Abu Gharidig subbasin, and better quality seismic data from the basin to the north, indicate that there are significant untested structures. A simple extension tectonic model may not completely answer the history of basin evolution. However, by invoking a tectonic model with some wrenching components, both facies and structure can be placed in a coherent regional framework. This new model introduces significant new exploration play concepts.

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Cambridge (UK) Arctic Shelf Programme Palinspastic Map Series

The Cambridge Arctic Shelf Programme has been a team effort since 1975. Its objective has been to summarize Arctic stratigraphy and tectonics. During the last 2 years, palinspastic maps for the whole Arctic have been checked systematically against stratigraphic data and the favored reconstructions are being computerized. The program has been financed

by subscriptions from the energy industry and from time to time selected results have been published. We report palinspastic reconstructions for the present Arctic region through Phanerozoic time with a tectonic commentary.

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Carbonate-Cement Stratigraphy of Burlington Limestone (Osagean) of Iowa: Evidence for Eh Gradients in a Regional Mississippian Paleogroundwater System

Cathodoluminescent petrography of calcite overgrowth cements in crinoidal grainstones from the Burlington Limestone reveals compositional zoning, which suggests that a chemical gradient was effective during cementation. These syntaxial calcite cements have as many as 7 luminescent zones. On the basis of these zones, a regional cement stratigraphy has been established among 22 measured sections within a 5,000 mi^2 area in southeastern Iowa. Overgrowths are interpreted as freshwater phreatic-zone precipitates. Comparison of the characteristic luminescent signature of Burlington calcite cements with cements in underlying Kinderhookian and overlying Meramecian limestones suggest the Burlington formed during, or before, the regional mid-Meramecian (sub-St. Louis Limestone) hiatus.

Early nonferroan calcite cements show a pronounced basinward change in luminescent zoning. Updip cements consist of 4 distinct compositional zones. In contrast, downdip cements contain only a single luminescent zone. Zonal distribution may have formed when cementation occurred along an Eh gradient within a fresh or phreatic-water system during exposure in mid-Meramecian time. Updip recharge areas were characterized by alternating oxidizing and reducing conditions, resulting in a sequence of luminescent (low Eh) and nonluminescent (high Eh) cement zones. Downdip, away from recharge areas, contemporaneous cements have only a single luminescent zone, which formed under continuously reducing conditions. The recognition of Eh gradients that were effective during carbonate cementation enables paleoflow paths to be determined, and aids in the prediction of diagenetic trends.

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Sodium Distribution in Eocene Dolomites from Castle Hayne Limestone, North Carolina

An 11-m section of the bryozoan biomicridite facies of the Castle Hayne Limestone in the Martin Marietta quarry, New Hanover County, North Carolina is locally dolomitized. About 6.5 m below the overlying unconformity, a 1.0-m zone consists entirely of sucrosic dolomite. The percentage of dolomite decreases fairly uniformly above and below this zone, and 3.6 m below the upper unconformity, the unit is undolomitized. The dolomite is nonferroan and occurs as fine anhedral to subhedral crystals. Above and below the zone of maximum dolomitization, the dolomite selectively replaces the micrite matrix. Where dolomitization increases toward a maximum, calcite allochems are replaced.

Acid-soluble sodium ranges from a low of 252 ppm in calcite to a high of 1,500 ppm in dolomite. Microprobe analysis revealed that sodium is concentrated in heulandite-group zeolite. The interlocking nature of the dolomite and zeolite crystals, the euhedral morphology of the zeolite, and the strong positive correlation between percentage of dolomite to sodium concentration suggest that both mineral phases are authigenic and formed penecontemporaneously from an open-system, stratified fluid (Dorag).

Unless the sodium distribution can be documented, these data suggest that whole-rock sodium concentrations in ancient dolomites may not be an accurate indicator for hyposaline versus hypersaline dolomitization. Dolomitization in proximity to the overlying subaerial unconformity has greatly enhanced postdepositional permeability in the micrite facies of the Castle Hayne Limestone. Dorag dolomitization caused by a lowering of eustatic sea level in conjunction with favorable hydrologic and lithologic conditions can have a profound effect on reservoir properties and permeability distribution in ancient carbonates.

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Petrology, Stratigraphy, and Depositional Environments of Burnt Bluff Group in Michigan

Recent discoveries of sizable natural gas deposits (production at least 1 MMCFGD/well) in 3 widely separated areas of Michigan have touched off exploration interest in the lower Middle Silurian Burnt Bluff Group. The Burnt Bluff and Manistique Groups are stratigraphically equivalent to the better known Clinton Group.

Analyses of core samples, outcrop samples, and wireline logs allow for a preliminary reconstruction of facies relationships and depositional environments. Where thickest, in northeastern Michigan, the Burnt Bluff Group can be divided into 3 formations: Lime Island Dolomite, Bryon Dolomite and Hendricks Dolomite. To the southwest the group thins dramatically to a single lithologic unit. The Lime Island and the Hendricks Dolomites represent shallow subtidal facies with abundant large, whole bioclasts of corals, stromatoporoids, and brachiopods. The Bryon Dolomite is a thinly laminated intertidal and supratidal carbonate with desiccation cracks, algal laminae, and anhydrite nodules.

Presently, natural gas production is found only in slightly dolomitized portions of the subtidal bioclastic facies in the Burnt Bluff. Porosity development is the key to production and is primarily solution-enlarged interparticle porosity restricted to the Hendricks and Lime Island Dolomites.

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Sedimentary Basin Thermal Histories Through $^{40}Ar/^{39}Ar$ Analysis of Detrital Microcline

The $^{40}Ar/^{39}Ar$ age spectrum technique has the demonstrated ability to resolve gradients of $^{40}Ar^*$ within crystals resulting from geologic heatings. A practical application of this observation is the analysis of detrital microcline from sedimentary beds to assess the source age of the feldspar, the time of basin heating, and the thermal intensity of the heating event. This intensity of the heating event is available through knowledge of the amount of $^{40}Ar^*$ lost from the sample and the temperature-dependent rate of argon transport within microcline. Both of these parameters are obtained as a by-product of the age spectrum experiment.

Results from a variety of sedimentary basins are encouraging and demonstrate the quality of information available from this technique. $^{40}Ar^*$ gradients in samples from the Basin block of the southern San Joaquin Valley, California, indicate a heating duration of 500,000-1 m.y., which is consistent with the stratigraphy. In conjunction with the present heat-flow data, these results suggest an equilibrium thermal gradient ~7°C/km higher than that presently observed—a consequence of rapid burial. K-spar separates from deep drill holes in the Albuquerque basin, New Mexico, reveal age spectra characteristic of substantial $^{40}Ar^*$ loss. Thermal calculations based on these data indicate a simple conductive history for samples above a present depth of about 6 km, although hydrothermal activity is evident in deeper material. Microcline separates have been obtained from a Kimmeridgian Sandstone (Tartan field, North Sea basin) that has been displaced about 1 km by a normal fault. Age spectra from these samples reveal minor $^{40}Ar^*$ losses of 4 and 6% from the samples in the upthrown and downthrown blocks, respectively. These loss profiles correspond to temperature histories that agree well with the formation temperatures and burial histories estimated for these wells. The subtle contrast in argon loss between these 2 samples suggests that this structure is relatively recent.

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Porosity Evolution and Diagenesis of Smackover Grainstones, Bryan's Mill Area, East Texas

Reservoir carbonates in the Bryan's Mill area of east Texas are ooid-dominated grainstones that occur toward the top of stacked coarsening-upward sequences. Individual grains were coated by isopachous circumgranular cements producing early lithification of the grainstones with retention of a modified intergranular porosity. This was patchily