such a hydrocarbon trap, the updip reservoir seal is created by a zone of porosity destruction due to diagenetic processes associated with the unconformity and the onlap of impermeable red beds of the Jurassic lower Amaranth (Spearfish) Formation onto the unconformity surface.

In 1980, the traditional play concept was challenged at Waskada, Manitoba, with the discovery of significant oil reserves in the top seal. Oil at Waskada field is obtained from 3 stratigraphic intervals in the Mississippian carbonates. Oil migration was not halted at the Paleozoic unconformity, but continued through the unconformity zone until trapped by permeability barriers within the siltstones and fine-grained sandstones of the lower Amaranth Formation.

This discovery has led to a reexamination of the traditional subcrop play and has added a new dimension to exploration in the region. The key to such a subcrop-supracrop play lies in the identification of major paleotectonic structural disturbances in underlying Paleozoic rocks occurring in conjunction with favorable reservoir facies in the overlying top seal. Such traps may presently exist as bypassed pay in other subcrop stratigraphic pools.

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Bahamas: Future Petroleum Province?

The Commonwealth of the Bahamas and its offshore areas, located off the southeasternmost tip of the United States, have experienced only cursory petroleum exploration in the past. Between 1947 and 1971 only 4 wells were drilled; however, the region warrants extensive exploration. New portions of the Great Bahama Bank, where water depths are relatively shallow, have been licensed recently to multinational companies. Recent seismic surveys have indicated encouraging stratigraphic data for much of the Florida-Bahama basin.

This chain of about 700 islands covers approximately 300,000 km^2 (116,000 mi^2) and is characterized by shallow-water carbonate banks that are separated by deep-water channels. Water depths in the Bahamas range from a few meters in the areas immediately adjacent to the islands to as much as 4,000 m (13,120 ft) along the northeast margin of the archipelago.

The Bahamian carbonate platform is underlain by approximately 6 km (3.75 mi) of carbonate and evaporite sediments, making it one of the world's thickest carbonate sequences. Although the presence of reefs, evaporites, and bank carbonates have made the Bahamas an area of scientific interest to petroleum geologists for many years, very little exploration has been conducted in the region.

New seismic surveys of the region, improved drilling methods, and the application of advanced geophysical techniques and geologic concepts improve the probability that this heretofore neglected region could become a future petroleum province.

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Holocene Transgressive Stratigraphy and Sediment Dispersal, Eastern Shore, Nova Scotia

Coastal sedimentation along Nova Scotia's eastern shore is dominated by a rising sea level, restricted drumlin sediment supply, and inherited glacial topography. Evolution of barrier systems follows a 500-1,000 year cyclic sequence of: (1) generation from marine erosion of glacial deposits, (2) transgression resulting from ongoing sea level rise and depletion of original sediment sources, and (3) landward removal following an estuarine retreat path to new sites of reconstruction. The dominant sediment transfer mechanism operating during this transgressive cycle is landward dispersal by tidal inlet, overwash, and eolian process.

Vibrocore, surface sampling, marine geophysics, and underwater photography were used to investigate the potential for eastern shore coastal deposits to be incorporated into the shelf stratigraphic record. High-resolution seismic profiles from the inner continental shelf reveal a lower acoustic unit interpreted as Wisconsinan glacial deposits. Overlying the lower unit is a discontinuous upper unit 1-2 m thick, which occupies topographic depressions and is composed of sand, silty sand, and a coarse gravel lag. Side-scan sonar and underwater photographs show large gravel ripples covering the upper acoustic unit in water up to 30 m deep. The upper acoustic unit is interpreted as the remnants of reworked coastal barriers, drumlins, and till.

Transgressive sedimentation on the eastern shore of Nova Scotia, therefore, conforms to the concept of shoreface retreat. Coastal sediments here are poorly preserved, except in linear shelf valleys, because of a high-energy wave climate and prior landward transfer into tidal deltas, washovers, and associated back-barriers deposits.

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Radiaxial Fibrous Calcite as Early-Burial, Open-System Cement: Isotopic Evidence from Permian of China

The Nanpanjiang basin of south China occupies about 100,000 km^2 in southern Guizhou and eastern Yunnan Provinces and northwestern Guangxi Autonomous Region. The basin contains a thick Paleozoic carbonate sequence overlain by about 3,000 m of Triassic basinal deposits. Permian carbonate rocks comprise a large portion of the Paleozoic strata and form several platforms separated by basins containing dark, thin-bedded limestones, siliceous shales, and cherts. The platform margins are rimmed by sponge or algal reefs.

Radiaxial fibrous calcite (RFC) is the most abundant cement in very coarse sponge or algal debris of Upper Permian reef and fore-reef sediments exposed along the western margin of the Nanpanjiang basin. Small volumes of syndepositional cements, interpreted to have been fibrous magnesian calcites and botryoidal aragonite, predate RFC. Coarse, blocky burial calcite postdates RFC. Evidence that RFC was precipitated during sediment deposition was not found. RFC occurs as isopach layers up to 15 mm thick and exhibits white, gray, and black bands about 1 mm wide. The presence of microdolomite inclusions in these cements indicates that they were originally magnesian calcites. $\delta^{18}O$ of RFC cements are more positive than any of the earlier or later components of the reef and fore-reef facies. Analyses of successive bands reveals the most positive $\delta^{18}O$ near the center of the isopach layers. $\delta^{13}C$ of successive bands reveals generally more negative values toward the centers of layers.

RFC layers are interpreted to have precipitated during early burial of the platform margin while reef and fore-reef sediments were in communication with seawater. Cement layers recorded isotopic characteristics of seawater as platform-edge sediments subsided through the water column at the basin margin. $\delta^{18}O$ of successive bands records cooler water at depth in the basin followed by geothermal warming. $\delta^{13}C$ records increased incorporation of light carbon as the platform subsided through the oxygen minimum zone, followed by a return to normal values at depth.

These data and interpretations suggest RFC layers precipitated very slowly during time spans commensurate with those of subsiding platforms (millions of years). Isotopic characteristics of RFC may not reflect shallow seawater. Rather, they may reflect burial environments where $\delta^{18}O$ is affected by cooler water and $\delta^{13}C$ is affected by biologic activity.

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Practical Use of Inverted Seismic Data

Reliable initial reservoir estimates can be made for a prospect without the benefit of reservoir engineering information. This is done by combining petrophysical data such as sonic, gamma-ray, density, and resistivity logs with inverted seismic profiles and geologic models.

To delineate and appraise the reservoir volume adequately with seismic data, the reduction, processing, and display must be subject to strict quality control. The wavelet must be converted to zero phase, contracted and centered on the reflection coefficient that corresponds to the target beds. The useful spectrum of the data must be as broad as possible to define the geologic boundaries properly. There must be a good estimate of the amplitude spectrum of the wavelet and a successful deconvolution to remove effects of the source signature. Noise maintenance or reduction must precede inversion of seismic data to pseudo-sonic logs. The low-frequency gap in seismic records must be restored deterministically by the use of a geologic model with interval velocities specified. Time-variant processes should be minimized or avoided. A reliable calibration of absolute transit times must be obtained given that the inversion algorithm was stable and satisfied all assumptions involved in its use. Finally, results

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