hydrocarbon-generating potential. Samples of the Woodford Shale were obtained from 18 wells drilled in the Anadarko basin by various operators, and polished sections of the shale were prepared and interpreted by the author while working at the Oklahoma Geological Survey. A minimum of 60 vitrinite reflectance measurements were recorded for each well. The Woodford was sampled at depths of from 5,060 ft (1,542 m) in the northeastern shelf to 20,308 ft (6,190 m) in the deepest part of the basin in Beckham County, southwestern Oklahoma. A systematic increase in mean vitrinite reflectance (mean R_O) with depth was observed. From northeast to southwest across the Anadarko basin mean R_O increased from 0.51 to 2.60%. An isoreflectance map for the Woodford Shale in the Anadarko basin was prepared using data collected during this study. The Woodford Shale should have generated commercial quantities of oil in those areas of the basin where the shale has a mean R_O of from 0.60 to 1.35%. In Kiowa County, Oklahoma, the Woodford Shale was sampled in a fault block bordering the Wichita uplift on the southern boundary of the basin. It has, in this well, an anomalously low mean R_O of 0.48%, possibly due to a shallow depth of burial throughout its history.

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Computer Applications System for Exploration: Offshore China Case History

Pennzoil has developed CASE (Computer Applications System for Exploration) to assist explorationists in mapping and evaluating large, offshore frontier basins. CASE is a user-friendly, interactive, exploration data base and mapping system. It allows explorationists to store vast amounts of data and to retrieve, for any area of interest, various combinations of data sets for mapping, analysis, and display. Geophysical data are routinely computer contoured and drafted on geographic, geological, and geophysical base maps. This technique allows the explorationists to rapidly and uniformly map and evaluate very large areas and to identify prospects for more detailed study.

In addition to seismic time-structure maps, computer-generated regional maps are prepared on depth-structure, isochron, isopach, interval-velocity, average velocity, gravity, and magnetic data. Computer-generated surfaces may be displayed with faults, also using a 3-D isometric presentation, or input to filtering programs.

CASE optimizes the explorationist's time, is cost-effective, and provides management with uniform, relatively high-quality maps for decision making.

Pennzoil developed CASE to evaluate about 80,000 line kms of geophysical data covering over 75 million acres (30 million ha.) in the South China Sea, the largest geophysical group shoot ever. Utilizing this system, a nucleus of about a dozen geologists and geophysicists, with a relatively small support staff, mapped and evaluated the offshore China data in a period of about one year. Case history examples are presented from this unprecedented and highly successful geophysical mapping and evaluation effort.

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Evaporitic Lacustrine Environments of Canadian Plains

The plains of western Canada contain dozens of saline and hypersaline lakes which range in size from small (<1 sq km) prairie "potholes" to relatively large (>300 sq km) bodies of water. The shallowest lakes exhibit playa characteristics, flooding with water during the wet season but drying up during the summer and fall. The sediments of these lakes are composed of a mixed suite of siliclastics, carbonates, and evaporitic minerals. The major detrital minerals are quartz, dolomite, feldspars, and clay minerals. The authigenic carbonate minerals are aragonite, normal calcite, and high-Mg calcite. Evaporitic minerals include mirabilite, thernardite, gypsum, and bloedite.

Spatially, the modern subenvironments in these basins usually exhibit a roughly concentric distribution, with a saline mud flat/sand flat occurring nearest the shore, followed by an ephemeral lake zone, and possibly a perennial lake. Although differing in scale and stage of development from basin to basin, all of the lakes have roughly similar near-surface stratigraphic profiles and facies distribution. The upper 25 to 50 cm consist of a thin (1 to 5 cm) crystalline crust overlying a thicker (5 to 50 cm) layer of mirabilite-thernardite-bloedite mush. Salt crust development, growth of large, euhedral mirabilite crystals, surface desiccation, and mineral dissolution all operate to create an extremely dynamic near-surface environment on a diurnal and seasonal basis. Underlying these upper units is a zone of relatively dense salt crystal with minor mud interbeds. This unit can range in thickness from <1 m to >40 m. Finally, underlying this dense crystal layer is a black, highly reducing, organic-rich, muddy clastic unit with variable salt crystal content.

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Inferred Eastern Extent, Overthrust Belt, Central Utah

Structural and stratigraphic relations in the Wasatch Plateau, the Gunnison Plateau, and the northwestern Cedar Hills suggest a new interpretation of the easternmost limit of thrusting during Late Cretaceous foreland deformation in central Utah. Steep to overturned dips in the Upper Cretaceous Indianola Group within this region are interpreted to reflect involvement of foreland basin clastics in thrust-related structures that deformed the flank of the foreland basin. A subhorizontal overlap assemblage of inferred Paleocene age indicates that the post-thrust erosion surface sloped gently eastward into the foreland basin.

Northeast-striking, southeast-facing homoclines of Indianola Group strata rest disconformably on Jurassic beds. However, favorable horizons within the Arapien Shale of the Jurassic sequence served as a zone of regional decollement, along which younger formations were detached and transported eastward with respect to underlying autochthonous units. The decollement zone was deformed internally by multiple thrusts and by east-vergent isoclinal folds subsequently complicated by local diapiric modifications. Most exposures of the Indianola Group are thus wholly or partly allochthonous. Folds involving Indianola strata apparently include: (1) fully detached ramp anticlines associated with subsurface thrust faults that underlie the southern Wasatch Mountains, Gunnison Plateau, and Sanpete Valley; and (2) partly detached frontal anticlines associated with blind thrusts that approach the surface beneath the Sanpete Valley and the western margin of the Wasatch Plateau. Structures inferred locally are consistent with documented patterns of deformation involving foreland clastics elsewhere in the overthrust belt and should influence exploration strategy in central Utah.

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Depositional Styles of Notikewan Member (Upper Gates Equivalent), Fort St. John Group, Northeastern British Columbia

The subsurface Notikewan Member (Spirit River Formation) of the Fort St. John Group is correlative with the upper 60 to 70 m of the Gates Formation in northeastern British Columbia. The basal Notikewan is a thin pebbly transgressive lag deposit overlying carbonaceous nonmarine shales, sandstone, and locally conglomerates of the Gates (Falher equivalent). Overlying the transgressive lag is a 5 to 10 m fining-upward transgressive phase of interbedded sandstone or conglomerate and shale. The sandstones are hummocky cross-stratified and the conglomerates are molded into symmetrical gravel dunes (both features indicate storm processes were common during the transgression). The regressive phase is a 20 to 30-m coarsening-upward sequence showing much less evidence of storm influence. Locally 10 to 20 m thick sandstone channels cut through the shoreline into marine sediments. The precise location of the shoreline is generally difficult to pick, unlike in the underlying Falher cycles. Specimens of *Ostrea* above the channel sandstones suggest a brackish-water depositional environment. The *Ostrea* are a good local stratigraphic marker in the Bullmoose Mountain area, in some places forming banks. Sedimentary structures in interbedded sandstones, siltstones, and shales, and reversing paleoflow directions suggest a low-energy shoreline dominated by tidal flat and, possibly, estuarine processes. Paleocurrent data indicate that shoreline orientation was generally east-west. This is in marked contrast to the high-energy wave dominated shorelines of the Fahler. The upper 20 to 30 m of the Notikewan is nonmarine floodplain and overbank deposits with thin (<1 m) coals, lagoonal shales and siltstones, and rare channels.

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Reef Exploration in Michigan Basin: Problems and Solutions

The integration of all aspects of geology with geophysics is necessary in any stratigraphic exploration program. The Niagara (Middle Silurian) pinnacle reef play in the Michigan basin provides interesting insights into this multifaceted problem.

The Michigan basin is an intracratonic structural basin which has been in existence at least 500 million years. During Niagaran time, tall (up to 700 ft, 213 m) hydrocarbon-bearing pinnacle reefs grew on a ramp or shelf between a deeper basinal area and a nonproductive basin-rimming barrier reef bank. These pinnacle reefs are encased in Salina (Upper Silurian) evaporites and carbonates that effectively act as both seal and source for the hydrocarbons.

Geological studies of Niagara and Cayugan paleogeography and regional stratigraphy combined with detailed lithofacies have aided in the mapping of the pinnacle reef trends and the identification of local reef proximity indicators.

Today, seismic data is the major exploration method for actually locating the pinnacle reefs, but major problems had to be overcome before it was an effective tool. Surface topographic features (such as glacial moraines and sand dunes) plus buried preglacial valleys caused severe statics, velocity, and "noise" problems. Judicious application of good basic data processing procedures with particular attention paid to statics corrections, velocity analyses tied to well control, and f-k filtering, commonly solve these data processing problems.

Even though shooting geometry has been optimized to reduce "noise," reflections are often the third or fourth strongest mode on a field record with mode converted shear waves, refractions, multiples, and wave-guided phenomena being stronger. F-k filtering, following the principle of reflection mode amplification (introduced herein), can substantially enhance the signal to noise ratio (reflection to nonreflection ratio).

The variable distribution of the Salina evaporites and carbonates and their irregular solution margins can, however, in places, produce reeflike seismic anomalies. By careful geologic mapping with close attention to facies and lithologic detail and by using simple seismic modeling, the differences between pseudo-reef anomalies and actual reef anomalies can often be distinguished, and the presence of seismic reef proximity indicators can be confirmed with a high level of confidence. The 70% and greater wildcat success ratios maintained consistently by several companies which has allowed them to lead in the exploration of the trend are ample testimony to this.

The final results of careful attention to geologic detail during the entire geophysical analysis, from field acquisition through interpretation, are not only accurate and detailed seismic stratigraphic interpretations, but also cost-effective exploration programs.

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Limitations of Rock-Eval Pyrolysis Assay to Characterize Kerogen

Rock-Eval is a useful new tool to study sedimentary organic matter by pyrolysis and determination of hydrocarbons and CO_2. Certain interpretive and operational aspects of the Rock-Eval technique, however, need to be carefully considered. Rock-Eval S_2 peak or Hydrogen Index (HI = S_2 normalized to organic carbon) is obtained by the flame ionization detector (FID) that responds to carbon-hydrogen bonds, carbon electrons, and carbon mass; thus, the FID response is very nearly the same to benzene, hexane, and six molecules of methane, but the atomic H/C of these molecules varies by a factor of 4. A further problem with the assumption that HI is proportional to H/C is that Rock-Eval does not measure either H_2 or H_2O, both of which are important pyrolysis products. Despite this, Rock-Eval HI is commonly correlated empirically with atomic H/C. Similarly the Rock-Eval oxygen index (OI) measures CO_2 but not H_2O or CO, which are important pyrolysis products. The OI is commonly correlated empirically with atomic O/C. The fact that these two correlations exist probably is due partly to regularities in the pyrolysis mechanisms of kerogen and partly to a predominance of methane from type III kerogen, which accentuates the low HI. These factors are the reason that the HI versus H/C and OI versus O/C plots do not go through the origin but intercept the H/C axis at 0.45 and O/C axis at 0.04. Incorrect classification of kerogen types or interpretation of diagenetic history can result from these OI and HI variations from actual O/C and H/C measurements. Examples of kerogen incorrectly classified as type I and confused evolution paths are documented.

Rock-Eval should be most successful on core samples containing organic matter of relatively uniform composition. Analysis of recent samples, outcrop samples, or a single sample should not be used for unqualified interpretation of kerogen type or evolution path, but it may give useful organic richness and maturity information.

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Application of Depositional Modeling to Coal Exploration, Green River Basin, Southwest Wyoming

Data from over 1,400 coal exploration drill holes, 21 measured sections, and 90 deep mine maps, in conjunction with cursory examination of oil and gas logs and seismic sections, have been used to reconstruct the depositional settings of the Rock Springs Formation in the Green River basin.

From examination of approximately 20 coal seams in the Rock