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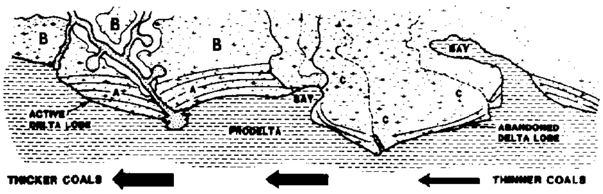
Application of Depositional Modeling to Coal Exploration, Green River Basin, Southwest Wyoming

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

Springs Formation, a depositional model was developed to account for areas of variable thickness in coal accumulation. Coals within the formation developed along lower delta plain, upper delta plain–fluvial or on abandoned deltaic lobes and are referred to as Type A, Type B or Type C coals, respectively.

GENERALIZED RELATIONSHIP OF COAL THICKNESS TO DEPOSITIONAL SETTING



Depositional regression represented by extensive sheet sandstones are inferred to be delta-front deposits which reflect the cuspate to arcuate geometry of wave-dominated delta deposits. Widespread coal deposits up to 22 ft (6.7 m) thick that occur on top of the deltaic sandstones extend for up to 15 mi (25 km) along depositional dip and 36 mi (58 km) along depositional strike. They accumulated in lower delta plain environments as Type A coal seams. Thick coal seams that were deposited in upper delta plain-fluvial environments are less than 20 mi (32 km) in length and are more variable in thickness (1 to 17 ft, 0.3 to 5.2 m). They are referred to as Type B coal seams. Persistent but thin coals, less than 25 mi (40 km) in length and 1 to 8 ft (0.3 to 2.4 m) thick, that occur on top of delta plain–fluvial deposits and that are overlain by sheet sandstones are inferred to represent peat accumulation during delta lobe abandonment and are referred to as Type C coal seams. Coal seam discontinuities, represented by areas of reduced coal thickness or by wedges of sediment producing multiple benches or rider coals, are caused by sediment influx from distributary channels, fluvial channels, and splays. Analysis of the geometries and spatial distributions of coal seams is used to develop a detailed geologic model that can serve as a predictive tool for future coal exploration in this region and in other basins with similar depositional settings.

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Computer-Assisted Exploration in a Deltaic Environment

Oil and gas exploration in a deltaic environment is complicated by apparent erratic sand distribution. The structure and isopachous maps, normally so useful to the explorationist, are often of little use by themselves in locating prospective drill sites. The relationships of source beds, reservoirs, and sealing beds are of far greater importance in identifying prospective areas.

The shallow Wilcox Group in central Louisiana was used in this study. The section is relatively unfaulted and thickens gradually basinward. Several good correlation horizons enabled the study team to subdivide the section into relatively thin intervals and to examine the development of sand distribution through time. These data together with the present-day occurrence of hydrocarbons in these intervals were the primary criteria used in establishing potentially prospective areas.

Due to the large number of wells and the numerous producing zones in the study area, it was impossible to manually generate the statistics, maps, and cross sections needed within a reasonable time. As a result, most graphic and statistical output was generated by the computer.

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Anatomy of the Dolomitized Carbonate Reservoir, Mission Canyon Formation, Little Knife Field, North Dakota

The Mission Canyon is interpreted to be a regressive shoaling-upward, carbonate to anhydrite sequence deposited by a shallow epeiric sea. Upsection most of the formation is of subtidal origin, deposited as: (1) basinal "deeper water" carbonates, below wave base; (2) open shallow marine, which deposited major carbonate cycles of mudstone grading into skeletal packstone/grainstone; (3) transitional open to restricted marine, with minor carbonate cycles of mudstone grading into skeletal wackestone; (4) restricted marine of pelletal wackestone/packstone; and (5) narrow marginal, nearshore marine of skeletal wackestone interbedded with emergent intertidal deposits of skeletal, ooid-pisolitic packstone. Cratonward, the intertidal is interbedded with lagoonal limestones and both overlain by tidal flat to supratidal anhydrite beds.

The reservoir is structurally trapped within a northward-plunging anticlinal nose with less than 100 ft (30 m) of closure. Facies changes create stratigraphic entrapment southward. The seal is the overlying anhydrite beds.

Porous hydrocarbon-bearing beds are isolated within transitional open to restricted marine, restricted marine, and marginal nearshore marine facies. These lime-mud-rich beds underwent replacement by anhydrite to skeletal fragments, which was later leached, and the muddy matrix was dolomitzed to a porous calcareous dolostone.

Thin-section petrography and scanning electron microscopy studies of core samples and relief pore casts reveal four pore types. Pore types include moldic pores and dolomite intercrystal pores; namely, polyhedral, tetrahedral and interboundary-sheet pores, each pore progressively smaller in size. Pore throats are of two major sizes, the largest five times the width of the smallest.

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A Late Cretaceous Submarine Canyon in Brazil: Seismic Stratigraphy

A continuous sequence of gently dipping clastics covers a deep submarine canyon which was cut into Upper Cretaceous sediments and subsequently filled with Tertiary clastics. Conventional seismic work provides some indication of the complex sequence which filled the channel, but the full detail of the depositional history is revealed in detail by inverting the seismic data to produce synthetic sonic logs. The results reveal classic patterns of sedimentation, illustrate several changes which occurred in the source and distribution of sediments which filled the canyon, and map the individual members in close detail.

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Missourian and Virgilian Brachiopod Biostratigraphy, Bird Spring Group at Arrow Canyon, Clark County, Nevada

The Arrow Canyon section of the Bird Spring Group has been proposed as a stratotype section for the base of the Pennsylvanian and of the Permian because of its apparently uninterrupted deposition across those boundaries, extensive invertebrate fauna, nearly total exposure, and readiness of access. Both fusulinid zonation and detailed petrographic studies have already been