dients and long burial (cooking) times. Yet the heat flows in all areas had been much higher in the geologic past due to volcanism, igneous intrusion, orogeny, metamorphism, and/or uplift and erosion.

Mean random vitrinite reflectance (R_o) is an indicator of organic metamorphism. A plot of R_o versus present temperature from a number of areas that have not undergone major geologic mutilation, increases in tight ($R = 0.97$) linear fashion. Yet burial times for these different areas range from 0.3 to 240 m.y. These same data, when plotted against increasing burial time at constant temperature, do not show the expected trend of increasing R_o values with increasing burial time. Vitrinite reflectance data from a geothermal (rift valley) area with a maximum heating age of 10,000 years, directly overlie the preceding plot, which suggests the time needed for full organic maturation is 10,000 to 300,000 years, a geologic instant. Geochemical data from deep (up to 9 km), high-temperature (up to 300°C) wells having long burial times (up to 240 m.y.), suggest that some geochemical postulates are in error and that time has little effect on organic maturation. It appears that vitrinite reflectance can be used as an absolute paleogeothermometer from 20° to at least 400 + 20°C.

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Cordilleran Overthrust Belt in Southern Canada—Its Regional Tectonic Implications, and Its Role in Hydrocarbon Generation and Entrapment

Palinspastic reconstructions based on balanced sections that are constrained by deep crustal structure, as outlined by seismic refraction, gravity anomaly, magnetic anomaly, and geomagnetic depth sounding studies, show that: (1) the Cordilleran miogeocline, a northeast-tapering wedge of craton-derived sedimentary strata, more than 15 km thick, accumulated outward from the rifted(?) edge of a 35-km thick slab of early Proterozoic continental crust, on a basement of oceanic crust and/or attenuated continental crust; (2) the miogeocline was compressed, detached from underlying crustal rocks, and displaced more than 200 km northeast as two successive collages of small allochthonous terranes from the adjacent ocean basin collided with North America; (3) the overthrust belt is a tectonically prograded shallow accretionary prism that formed during the subduction of the basement of the miogeocline, as supracrustal rocks were scraped off the underriding continental craton and accreted to the overriding miogeoclinal prism; (4) subsidence and molasse sedimentation in the northeastward-migrating foreland basin were a result of isostatic flexure of the lithosphere in response to the weight of the encroaching accretionary prism, and of the molasse itself; and (5) burial of source rocks, and hydrocarbon generation, migration and entrapment are indirect results of the subduction of the lithosphere that formerly lay beneath the miogeocline.

The first collision (Late Jurassic and Early Cretaceous Columbian orogeny) involved outward-verging thrusting and folding on either side of the uplifted core of the miogeocline, and produced a thick wedge of molasse (Kootenay-Blairmore) that extended over the western part of the craton. Mid-Cretaceous granitic plutons truncate Columbian structures. The second collision (latest Cretaceous and Paleocene Laramide orogeny) marked the final phase of convergence during which the reservoir structures associated with northeast-verging listric thrust faults and folds developed in the Canadian Rockies. Source rocks were buried to depths of 13 km under the Lewis thrust sheet in southeastern British Columbia, and 5 or 6 km under the plains, as a wedge of Laramide molasse (Brazeau-Paskapoo) was prograded northeastward in front of the overthrust belt.

Intracontinental transform faulting, involving 450 km of right-hand strike slip on the Tintina-Northern Rocky Mountain Trench fault system, was partly taken up by thrust faulting in the Rocky Mountains south of 56°N lat. during the Laramide orogeny, but during the Eocene it was linked to the en echelon Fraser River fault zone by ductile stretching of the intervening lithosphere. This stretching is expressed, over an area of about 150,000 km^2 in south-central British Columbia and adjacent parts of the United States, at a shallow level, by listric normal faults and Eocene dike swarms, and at a deep level, by boudinage of the whole crust. Supracrustal rocks moved into the necked zones between the boudins as the metamorphic core complexes emerged in northeast-trending domal culminations with K-Ar mica cooling ages of about 50 Ma. A different pattern of regional extension, involving uplift and partial unroofing of deeply buried source rocks in the southern part of the over-thrust belt and adjacent foreland basin, was established in early Oligocene time.

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Mannville Group of Lloydminster Heavy Oil Fields, Canada—Depositional Overview

A regional subsurface study of 200 cores and several thousand well logs has led to an interpretation of the depositional history for the Lloydminster area of western Canada. Major geologic controls on deposition were tectonism in western North America, a series of northwest-trending ridges formed of Paleozoic carbonates found in the central plains, salt collapse within the depositional basin, and eustatic changes associated with Boreal and Gulfian seas. On the basis of genetic units, the Mannville Group has been divided into three units: lower, middle, and upper.

The lower unit is dominantly a siliceous, fine to medium-grained sandstone which is found in the lows between the northwest-trending ridges of Paleozoic carbonates. The unit is up to 60 m thick with the dominant sedimentary structures being high-angle (30°) cross-stratification.

The middle unit consists mainly of upward-coarsening, very fine to fine-grained, quartzose sheet sandstones, 6 to 10 m thick, associated with a restricted marine microflora and microfauna. A typical sequence begins with a basal bioturbated shaly siltstone and proceeds upward through wavy lenticular sandstones in silty shales, wave-rippled sandstones with mud drapes, wavy-bedded sandstones, and low-angle (0 to 10°) cross-laminated sandstones. This sequence is commonly capped by a coal or gray carbonaceous shale. Although sheetlike in appearance, the lateral continuity of the sandstones is commonly broken by shale or sand-filled channels.

The upper unit is comprised of thick (up to 35 m) lenticular channel fills of cross-bedded, lithofeldspathic or quartzose sandstones which grade laterally into interbedded deposits of current-rippled sheet sandstones, siltstones, mudstones, and coals.

The vertical sequence of environments is interpreted to be: post-Paleozoic incision followed by valley-fill deposition of an aggrading north-flowing fluvial system (lower unit), transgression followed by regressive sedimentation in wave-dominated paralic environments (middle unit), and continued regressive deposition within an areally extensive, north-flowing anastomosed fluvial network (upper unit).

Mannville deposition in the Lloydminster area was terminated by a major transgression which deposited the widespread marine shales of the Colorado Group.

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Integrated Model for Vadose Diagenesis of Carbonate Rocks

The composition, morphology, and distribution of vadose diagenetic features are related to extrinsic and intrinsic factors. Extrinsic factors include the total yearly precipitation, and its seasonal distribution, evapotranspiration, and temperature. These influence the total carbon dioxide supplied, and the relative time during which input (by vadose percolation) and loss (by degassing and evapotranspiration) occur. Intrinsic factors include rock type and composition, porosity and permeability, soil cover, and topography. These influence the rate of water infiltration, and the resulting rate at which descending waters become saturated. The interaction of the two factor groups determines the final character of the zones of vadose diagenesis. There results a land surface-, joint-, or fracture-related zone beneath which descending waters are generally saturated and little solution occurs. Also a zone exists beneath which pore fluids and gasses are unaffected by degassing or evapotranspiration, and within which vadose precipitational fabrics are confined.

As such, the zone of active vadose diagenesis may constitute only a small part of the total zone of percolation, much of the zone being characterized by fluids which pass through without altering their composition (i.e., causing no diagenetic alteration of rock fabric or mineralogy). Furthermore, because of the high wettability of most carbonate grains (in the absence of adsorbed organics), pores in the zone of slow degassing and high relative humidity may not display "typical" vadose meniscus cements, but may instead display coatings and fills of euhedral crystals. Consequently, the absence of vadose diagenetic features is probably the more common case (without indicating a lack of exposure). As such, periods of exposure may only be patchily recorded by the presence of vadose diagenetic zones.

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Exploration Strategies as Integral Part of Corporate Strategic Planning

With rising exploration costs, recent stabilization of world oil prices, and local surpluses of natural gas, the "bloom is off the sage" for just finding hydrocarbons as an exploration strategy. Now the explorationist must tie his exploration strategies to his company's strategic planning or, in smaller companies, to their long-term goals and objectives. Without these considerations, the company's exploration efforts will not be successful over the long term. The explorationist must now realize that exploration is a business, not merely a function.

There are two critical areas that need to be defined to combine exploration strategy and strategic planning. The planners' strategic criteria must be consistent and reasonable. Criteria should be designed so that the explorationist can clearly understand his responsibility. The explorationist will need to define his exploration environment. Questions like the following should arise in the explorationist's mind. Should I be exploring in this basin? What field sizes are left to be found? What is a realistic chance of wildcat success for a specific prospect, play, or basin? What mix of prospects will give my program a realistic chance of success?

Recent techniques and methods are available tools for defining the exploration environment. In the mature domestic areas, historical digital data bases can be used to describe the present environment and can project future environments. From these environments, along with geologic considerations, geophysical input and physical restraints such as capital and lease position, an exploration strategy can be created that will be compatible with the company's strategic planning.

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Facies Relationships and Paleoenvironments of a Tide-Dominated Delta—An Estuarine-Barrier Complex in a Mesotidal Setting, Upper Cretaceous, Drumheller, Alberta

The transition between the Bearpaw and Horseshoe Canyon Formations (100 m thick) near Drumheller represents an upward-coarsening deltaic sequence. A detailed field sedimentologic investigation of these rocks has led to the recognition of several distinct lithofacies. In stratigraphic order, the lithofacies of the subaqueous part of the delta are: (1) an offshore bar cross- and hummocky-stratified sandstone, (2) a prodelta marine shale and siltstone, (3) a distal mouth-bar shale, (4) siltstone and sandstone with *Chondrites*, and (5) a proximal mouth-bar sandstone and minor shale with *Teichichnus*, *Rhizocorallium*, *Lockeia*, and other burrows. The subaerial part of the delta and the interdeltaic shoreline sediments consist of 15 lithofacies that can be grouped as follows: estuarine distributary channel; barrier; back-barrier; tidal inlets; tidal channels and flats; peat swamp; and middle to upper delta-plain meandering rivers and overbank complexes. Trace fossils associated with these are: *Teredolites* borings, *Ophiomorpha*, *Teichichnus*?, *Cylindrichnus*, *Palaeophycus*, *Asterosoma*, and *Anemonechnus*?. Vertical lithofacies transitions suggest a few transgressive episodes. This sequence was deposited in a mesotidal, embayed shoreline, where a system of meandering distributary channels formed estuarine, tidally dominated deltas flanked by mesotidal barrier-island complexes. Minor transgressions of the sea interrupted the generation of a simple prograding sequence and resulted in formation of very complex facies relations.

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Facies Control of Carbonate Reservoir Properties

The relation between the depositional and diagenetic facies within a carbonate reservoir may affect the success of a secondary-recovery project in terms of the residual oil saturation following displacement of oil by water. Recognition of facies control on the evolution of porosity and permeability aids in the prediction of reservoir performance. Displacement tests, performed on vugular carbonate cores, illustrate this point.

Strongly wetting countercurrent imbibition tests, conducted on full-diameter cores from the Meekwap field in Alberta, reveal the effects of secondary porosity on the displacement of a nonwetting oil phase. In *Amphipore* sp. wackestones, dolomitization and dissolution of *Amphipore* segments have produced a random distribution of small moldic pores that are matrix connected. During water-wet displacement tests, poor displacement efficiency is realized in the high moldic porosity wackestones. Visual observations indicate that the nonwetting oil phase is preferentially trapped in the moldic pores. Reef-core boundstones, composed of a laminar stromatoporoid and algal assemblage, have a pore structure dominated by tabular vugs linked by vertical fractures. In contrast to the moldic pore system, displacement efficiency is maximized in the high porosity intervals as buoyancy forces allow oil to migrate through the vug-fracture system. Visual differentiation of the end-member pore systems will allow the development of a reservoir model that can predict oil recovery within various depositional facies within the reservoir.

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