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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