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STRUCTURAL GEOLOGY IN EASTERN MARGIN OF CANADIAN ROCKY MOUNTAINS

Hydrocarbon accumulations in the foothills at the eastern margin of the Canadian Rocky Mountains are structurally trapped. Exploration for these hydrocarbons requires a prediction of the deep geometric configuration of potential reservoir beds in imperfectly understood areas. This prediction commonly is derived from analogies with the most appropriate of the region's typical structures, a pragmatic approach which is effective because the foothills contain a limited suite of relatively simple structural types: (1) concentric folds (with their attendant *décollement*), (2) low-angle thrust faults (commonly folded), (3) tear faults (generally transverse), and (4) late normal faults (commonly listric). The possible assemblage in a particular area is further restricted because it is a function of the degree of deformation and of the lithology of the deformed rocks. Intensity of deformation increases from east to west.

Regional stratigraphic changes alter the major lithologic units whereas local isopach or facies changes alter the distribution of incompetent rocks within units.

The structural styles are all "thin skinned" as the underlying Archean basement is not involved.

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RECOGNITION OF DEPOSITIONAL ENVIRONMENTS THROUGH THIN-SECTION ANALYSIS OF DETRITAL SEDIMENTS

Petrographic analysis can be a powerful tool in the recognition and delineation of depositional environments of detrital sediments. A study of varied fluvial-deltaic, and interdeltaic environments in the Eocene of the Gulf Coast and the Cretaceous of Montana-Wyoming shows that individual environments may be segregated by applying univariate and multivariate statistical techniques to petrographic data (composition and texture).

These results are supported by data collated from Holocene environments in the Mississippi alluvial valley and delta, and Galveston barrier island. Holocene environments that can be segregated with a minimum of 80% reliability are point bar, natural levee, lake, bay, lower shoreface, middle shoreface, upper shoreface-beach, dune, and lagoon. Consequently, full diameter cores may not be necessary for precise environmental interpretation everywhere in the subsurface. Small samples, such as side-wall cores, taken throughout an interval, may yield significant and reliable environmental information. An example is provided by the Lower Cretaceous Muddy Sandstone of Montana in which the subenvironments of the petroliferous barrier-bar complex at Bell Creek field can be recognized from thin-section analysis and verified by a study of full-diameter cores. The presence of the Bell Creek barrier bar can be predicted through thin-section analyses of sediments in dry holes which surround the bar. If thin-section data are integrated with paleogeographic knowledge of the Lower Cretaceous, the relative position and strike of the barrier system may be ascertained.

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CARBONATE-BANK SEDIMENTATION, EASTERN SHARK BAY, WESTERN AUSTRALIA

A carbonate bank of Holocene age extends for 80 mi (129 km) along the mainland coast of Shark Bay, Western Australia. Development of the bank is attributed in part to the modifying influence of seagrasses on the physical environment. Bank formation under organic cover partly explains the origin of older mound-like bodies of carbonate sediment.

The bank is wedge shaped in cross section, has an average width of 5 mi (8 km) and a maximum thickness of 25 ft (7.6 m) at the seaward margin. For descriptive purposes, the bank is divided into 2 intergradational structural forms—the basal sheet and the submarine levees. More than 50 tidal channels cut across the bank. Seaward advance of the bank has been rapid; estimates of average rate of advance range from 528 ft (161 m) to 754 ft (230 m) per 100 years.

Salinity in sublittoral bank environments ranges from 38 ‰ to more than 55 ‰ (metahaline water type of Shark Bay). Substrates are covered in varying density by 3 seagrass communities.

Bank sediments are biogenic carbonates with admixtures of terrigenous clastics. Sediments deposited under seagrass cover are characterized by skeletal fragments of encrusting foraminiferids and articulate coralline algae from the seagrass epibiota. These sediments may contain up to 30% by weight of fine particles ($<62\mu$), most of which are silt-size skeletal fragments of magnesium-calcite. Intertidal and sublittoral sand-sheet sediments are characterized by "micritization" of carbonate grains, whereas seagrass bank sediments become enriched in Fe and Mn.

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GEOLOGY OF HYDROCARBON OCCURRENCE IN WOODBEND REEFS (DEVONIAN) OF WESTERN CANADA

The Upper Devonian Woodbend reefs of central Alberta contain important hydrocarbon reserves. The discovery of 200 million bbl of oil in the Leduc reef in 1947 launched the modern petroleum industry in Canada.

The generation and capture of crude oil and natural gas in major pools require the associated development, within a depositional basin, of adequate volumes of petroleum source rock, reservoir rock, and strata configurations capable of trapping the hydrocarbons entrained in the fluid systems operative within the basin. The occurrence of the 3 requirements in relatively close proximity within the time-space realm provides a maximum opportunity for major hydrocarbon accumulations to form.

The Upper Devonian Woodbend Group of western Canada provided such an opportunity in central Alberta. It was deposited during a vast southerly transgression of the continent. Many depositional environments were present throughout the great length of the epicontinental basin. Clastic sedimentation dominated the northern "open marine" part of the basin, and shelf carbonates and evaporites were deposited in the shallow seas of the southern part. Biotic and depositional conditions, unique to the basin as a whole, developed along the margins of the carbonate seas. Biohermal reefs formed amid organically rich shale banks and both were enveloped within a short period of time by organically lean, eventually impervious, shale. Source rock, reservoirs, and traps for petroleum were closely associated. Subsequent sedimentary loading brought about maturation, fluid migration, and trapping. The pools were formed before Cretaceous time.

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PETROLEUM RELATED TO MIDDLE AND UPPER DEVONIAN DELTAIC FACIES IN CENTRAL APPALACHIANS

Strata of the Devonian deltaic complex are preserved in 110,000 sq mi of the Appalachian basin. Petroleum production occurs only in the western half, principally in higher permeability sandstone, but some in prodelta dark shale. Oil is produced from Upper Devonian strata only in the westernmost part of the basin. Absence of petroleum production in the east presumably is because hydrocarbons have escaped from Ridge and Valley province outcrops. Sedimentary properties can be extrapolated to the subsurface to better understand the factors controlling petroleum occurrence.

The deltaic clastics were derived from an eastern quartzose source in the latitude between New York and Virginia. Depositional patterns of petroliferous sands resulted from gradual infilling of a subsiding basin, interrupted by rather abrupt eastward transgressions, which produced nearly synchronous, winnowed sands traceable across many counties.

The oldest prodelta sediments (Needmore Shale) were derived from the Baltimore area. Immediately after the Tioga volcanic event prodelta deposition spread abruptly westward nearly to the Ohio River. Cazenovia Stage deltaic siltstones and sandstones occur in Pennsylvania and New York. In late Tioughnioga Stage the zone of winnowing extended to West Virginia (Clearville Siltstone) with terrestrial redbeds accumulating in the Catskill Mountains. Early in the Taghanic Stage hundreds of feet of abrupt eustatic sea-level rise or basin deepening shifted the shoreline scores of miles eastward.

Throughout the rest of Late Devonian time the shoreline encroached generally westward with fairly sudden eastward shifts of tens of miles during times of sea-level rise. These shifts isolated 5 distinct clastic pulses in the outcrop region during the Finger Lakes and Cohocton Stages. In the western area younger sands of the Cassadaga Stage and Bradford Stage were deposited during winnowing accompanying shoreline shifts. Maximum westward encroachment of the subaerial Catskill delta was in the Bradford Stage, followed by Early Mississippian transgression which produced the Pocono Group sandstones.

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TIDAL-FLAT EROSION AND SEDIMENTATION BY ICE, ST. LAWRENCE ESTUARY

The action of ice on the shores of the St. Lawrence estuary has been studied since 1964. Shore ice in that area is a powerful agent of erosion and sedimentation. Annually, millions of tons of sediments from clay to boulder size are removed and carried by ice. Erosion of muddy tidal flats and salt marshes is especially significant; a peculiar sedimentary facies results. The St. Lawrence is one of the best sites to study the geologic action of ice because of the presence of (1) relatively large tidal flats, (2) high tidal range and strong tidal current, and (3) ice during a minimum of 4 months.

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1970s—NOW OR NEVER DECADE FOR MINERALS AND FUELS

In characterizing the 1970s as the "now or never" decade for meeting the challenge of environmental quality, President Richard Nixon has established a monumental goal for America and American industry. Looking only at the projected demands for metals, nonmetals, and fuels during the next 10 years we can see that achieving that goal and, at the same time, assuring our people continuing adequate supplies of minerals and energy at reasonable costs will take all the ingenuity—all the innovative ability—that our mineral and fuel industries can muster.

Not only must our ability to find new deposits of minerals and fuels at greater depths and in alien environments be significantly extended, but we must devise far better methods for extracting, processing, and utilizing these essential raw materials. National concern for environmental quality can be expected to govern virtually every facet of mineral exploration and development in the decade we have just entered.

Skilled, highly motivated, and intensively trained manpower represents an urgent industrial need. National concern only now is beginning to focus meaningfully on this critical aspect of the problem and, although the hour is late, there are indications that it may not be too late for the solutions we so desperately need.

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TECTONIC CONTROLS ON LATE PALEOZOIC SEDIMENTATION IN WESTERN WEST VIRGINIA

Tectonic patterns had a significant influence on the late Paleozoic Berea, Loyalhanna, and Pittsburgh-Sewickley sandstone units in western West Virginia. The depocenter was in the southwest during Early Devonian Berea deposition, southeast when the Mississippian Loyalhanna (Big Injun) sands filled submarine valleys, and northwest during Late Pennsylvanian when the Pittsburgh and Sewickley (Monongahela Group) deltaic sandstones were deposited.

Western West Virginia tectonically was on a relatively stable platform west of the Appalachian trough. Relative rates of supply and subsidence in the trough influenced the major changes in regional paleoslopes. Shallow downwarped axes on the platform oriented perpendicular to the trough also exerted a subordinate but important tectonic control on sedimentation. Characteristics of shallow-water deposition are shared by the Berea, Loyalhanna (Big Injun), and Monongahela sandstone units. However, the interpreted submarine valley-fill depositional environment of the Loyalhanna (Big Injun) is considerably different from the deltaic environment suggested for the Berea and Monongahela sandstones.

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LIMITATIONS IN PALEOCURRENT ANALYSIS OF TROUGH CROSS-STRATIFICATION

More than 50% of cross-stratification is trough type. Its complex geometry accounts for large dispersion in