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 many paleocurrent data. In simple cases, trough-sets yield bimodal histograms bisected by trough axes (which must be distinguished from other bimodal causes). Asymmetry of troughs or predominance of readings from trough ends produce more complex histograms, which commonly are statistically random (*e.g.*, St. Peter Sandstone; certain Cambrian sandstones, Wisconsin; Meridian Sandstone, Mississippi). Trough-axis plunge azimuths provide a superior paleocurrent indicator; Hamblin's Franconian data and new data from Wisconsin show dispersions half as great as published results for cross-sets only. But oppositely plunging troughs associated in single outcrops and even doubly plunging single troughs discovered in Wisconsin may becloud trough-axis distributions. Double plunges probably reflect both oscillatory (wave?) flow and unidirectional current flow, which produced complex, coalescing, elongate dune forms between which doubly-plunging troughs formed.

Trough cross-stratification has no environmental significance. Long-standing eolian interpretations reflect early recognition of only 1 possible modern analogue, whereas subaqueous dunes with amplitudes up to 65 ft have been known for a century. Cambrian sandstones with complex trough cross-stratification probably reflect submarine dunes affected both by current and oscillatory flow like those of Georges Banks. Paleoslope has little if any influence on orientations of eolian and most shallow-marine cross-stratification; records of "rare" storms may mask "average" conditions. Therefore, independent dispersal indicators (*e.g.*, pebble or mineral trains) should be sought.

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PENNSYLVANIAN FUSULINIDS FROM SOUTHEASTERN ALASKA[1]

Fusulinids of Middle Pennsylvanian age were obtained from 4 sections measured in the west-central part of Prince of Wales Island in southeastern Alaska. Three assemblages can be recognized in ascending order: (1) *Millerella, Nankinella,* and *Pseudostaffella;* (2) *Nankinella* and *Fusulinella;* and (3) *Nankinella?, Fusulinella,* and *Fusulina.* Other Foraminifera including *Bradyina* and *Climacammina* are present in several of the samples. The species present show some affinities with forms from Japan and a close relation with the faunas from the Fort St. James area in north-central British Columbia.

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GEOLOGY AND OIL POTENTIAL OF CANADIAN ARCTIC ISLANDS

The Canadian Arctic Islands sedimentary basin covers an area of approximately 530,000 sq mi, has a land area of 306,000 sq mi, and contains an estimated 900,000 cu mi of sediment. Ultimate recoverable oil reserves are estimated to be 40 billion bbl.

The area consists of 4 major structural provinces: (1) shield-bordering Precambrian shield areas with structural arches extending into the basin, (2) Central Stable region, (3) Innuitian region, and (4) the Arctic coastal plain.

The Central Stable region includes several basins containing relatively flat-lying shelf carbonates of Ordovician-Silurian age, with thicknesses generally 5,000 ft within the basin areas thickening northward to a maximum of 15,000 ft.

The Innuitian region is a mobile belt, characterized by thick sedimentation, that was tectonically active from the Paleozoic to the Tertiary. It is comprised of (a) the Franklinian fold belt, a gently folded early Paleozoic geosyncline, approximately 1,500 mi long, containing up to 16,000 ft of Ordovician and Silurian carbonate, evaporite, and shale; up to 6,000 ft of Lower Devonian clastics; and 16,000 ft of Middle and Upper Devonian strata ranging upward from marine carbonates and clastics to nonmarine clastics; and (b) Sverdrup basin, a NE-SW-trending basin, approximately 600 by 200 mi, containing up to 40,000 ft of post-Devonian to Tertiary strata. Permo-Pennsylvanian rocks are dominantly carbonate and evaporite. The Mesozoic to early Tertiary was dominated by heavy and continuous terrigenous clastic deposition, generally characterized by basinal marine-shale facies and marginal-sandstone facies. The axis of the basin is characterized by numerous evaporite diapirs.

The Arctic coastal plain contains late Tertiary and Pleistocene strata, along the northwest edge of the Arctic Islands, bordering the Arctic Ocean in the position of the present-day continental shelf.

The Arctic Islands sedimentary basin has all the necessary geologic elements conducive to the entrapment of hydrocarbons in prolific quantities. There is a very thick, lithologically varied, stratigraphic succession representing every geologic period, adequate source beds, and abundant potential rocks. There is an abundance of diversified traps—large anticlines, reefs, evaporite domes, faulted homoclines, unconformities, and facies changes. A wide range of hydrocarbon shows, including oil sands, seeps, stain, and bitumen, are present in a large area. The Arctic Islands is an area of outstanding potential for the discovery of large oil fields.

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KEYSTONE VUGS IN CARBONATE BEACH DEPOSITS

Voids that are considerably larger than interstices and therefore termed "vugs" are present in ancient grainstone, in modern beachrock, and in loose carbonate beach sand. They are as large as 10 grains in diameter and are roughly spherical or lens shaped. The roof of the vug resembles a crude keystone arch. Similar vugs can be made in the laboratory by alternately draining and flooding loose carbonate sand in the manner characterizing the swash zone. During the flooding stage, bubbles of trapped air lift grains into the form of a keystone arch, which is stable after the bubble is gone. Keystone vugs in ancient rocks probably will prove to be useful indicators of beach deposition.

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DEEP-SEA DRILLING PROJECT—FUTURE PROGRAM

The Deep-Sea Drilling Project is now engaged in a 30-month program extension which will take the drilling vessel *Glomar Challenger* to the Atlantic, Pacific, and Indian Oceans. Drilling sites have been selected by advisory panels established by JOIDES (Joint Oceanographic Institution Deep Earth Sampling). During the first 18 months of operation the program directed its effort to testing the hypotheses of sea-floor spreading

[1] Publication authorized by the Director, U.S. Geol. Survey.