four cycles of sedimentation, producing a multistory fluvial sandstone sequence similar to two- and three-story sand bodies described from the middle Carboniferous of the Donets basin (USSR).

As noted by D. Swann and P. Potter the Highland and other fluvial complexes represent the Michigan River system that flowed across the basin from the northeast for as much as $250 \times 10^6$ years. The long-continued geographic stability of successive, often reestablished, channel courses is evidence of the subsidence history of the Illinois basin, its lack of southern closure, and its relation to the Mississippi Valley embayment.

Certain Pennsylvanian channel sandstones are productive in the Illinois basin, but those of the Highland fluvial complex are not, presumably because of high, uninterrupted permeability, shallow burial, and lack of associated source beds. The multistory sand bodies, however, are accompanied by low-permeability overbank silts and crevasse splays which appear to seal adjacent coals from contact with marine waters and consequent sulfate contamination.

Multistory sands are possible exploration targets in other cratonic basins. They are identifiable by detailed facies analysis, core drilling, and high-resolution seismic surveys.

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Porphyrins in Subbituminous and Bituminous Coals

Chlorophyll and its porphyrin derivatives have been shown to be sensitive markers of organic diagenesis and serve as indicators of maturation. It has previously been suggested that coals of the HVC to HVB bituminous rank are at a maturation stage equivalent to early catagenesis in petroleum source rocks. However, comparisons of the mass spectrometric data of coal porphyrins with that of petroporphyrins result in some striking differences. Coal porphyrins lack carbon numbers above $C_{32}$, do not contain the DPEP (308 + 14n monocyclanoalkano) porphyrin series, and have an irregular mass spectral envelope owing to the predominance of even numbers of carbons ($C_{32}$, $C_{30}$, $C_{28}$) in the 310 + 14n etioporphyrin series. Furthermore, the centroid of the envelope systematically shifts from $C_{32}$ to $C_{30}$ to $C_{28}$ with increasing coal rank. In contrast, petroporphyrins usually have carbon numbers ranging from $C_{36}$ to $C_{25}$ and a broad symmetrical envelope with a centroid at $C_{32}$ or $C_{31}$. Both the DPEP and the etio series are typically present. From the data it is speculated that early chlorophyll diagenesis in coals follows an oxidative rather than a reductive pathway. During early catagenesis, dealkylation of coal porphyrins causes a shift in the centroid to lower carbon numbers. "Transalkylation," the free-radical mechanism by which alkyl groups are randomly added and removed from the tetrapyrrole ring during petroleum genesis, must not be operative in coal porphyrin catagenesis.

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Copper Porphyrins in Deep-Sea Sediments

Copper porphyrins have been isolated from deep-sea sediments collected during six DSDP/IPOD legs. These pigments are present in areas receiving high inputs of terrestrially derived organic matter which is either slowly accumulated, deposited from oxygenated bottom waters, or oxidized before deposition. Such areas include the Cretaceous sediments of the Bay of Biscay, Blake-Bahama basin, and Bermuda; slumped Miocene deposits off Cape Bojador on the west coast of Africa; and lower Pleistocene sediments of the Black Sea. Copper porphyrins are absent from sediments that accumulated under anoxic conditions, of which Cretaceous sediments of the Cape, Angola, and Moroccan basins are examples. Copper porphyrins coexist with products of varying states of chlorophyll diagenesis (chlorins, free-base, nickel, and vanadyl porphyrins) which typically form under reducing conditions. The mass spectral envelope is markedly different from that of nickel and vanadyl porphyrins; copper porphyrins are usually etioporphyrins with carbon numbers of $C_{32}$ to $C_{23}$ and a centroid at $C_{28}$ to $C_{25}$. The DPEP series is usually absent. In contrast, carbon numbers of $C_{32}$ to $C_{30}$ and presence of both the DPEP and etio series are characteristic of nickel and vanadyl porphyrins. Their occurrence with a range of chlorophyll diagenetic products and their distinctive mass spectral envelope suggest that copper porphyrins are derived from a different source. Their association with sediments containing terrestrially derived organic matter which has undergone a period of oxidation suggests that copper porphyrins may be potential indicators of oxidized terrestrial organic matter.

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Atmospheric Circulation and Upwelling in Paleozoic, with Reference to Petroleum Source Beds

Liquid hydrocarbons are formed from phytoplankton deposited in marine sediments. Phytoplankton are not distributed uniformly throughout the ocean surface waters. They are sparse over most of the area of the ocean, but are abundant in zones of upwelling where water rich in nutrients is brought to the lighted surface waters. Locations of these organically productive upwelling zones in the past can be predicted using a combination of paleogeographic and paleo-oceanographic modeling. This provides valuable information on likely times and geographic areas in which oil source beds were deposited.

Upwelling is caused by steady, prevailing winds resulting in divergence of currents or the movement of currents away from landmasses. These winds are parts of major atmospheric circulation systems. Their characteristics depend on latitude, season, and the sizes and positions of oceans and continents, but have a physical basis. They can, therefore, be modeled for past continental configurations, and it follows that upwelling can also be predicted.

Atmospheric circulation and upwelling maps for seven stages in the Paleozoic, using new paleogeographic reconstructions, show that upwelling zones of each stage are related to regions with source beds of that age. Although upwelling does not automatically result in source beds and all source beds do not occur in ancient upwelling zones, knowing the past areas of upwelling and abundant phytoplankton productivity is vital for assessing the potential richness and extent of possible oil source beds.

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Facies, Environments, and Development of Tuxpan-Tecolutla Carbonate Platform, Gulf Coast, Mexico

In the Cretaceous Tuxpan-Tecolutla carbonate platform in the subsurface of the Gulf of Mexico, sedimentologic and stratigraphic data were obtained from the study of 35 wells drilled in the El Abra Formation both onshore (Golden Lane and central platform) and offshore.

Three main depositional complexes are recognized: lagoon, reefal environment, and oolitic banks. Each complex includes several microenvironments.

Dolomitization proceeded episodically in the lagoon. The last phase, showing a northern displacement of the central depression, was associated with the formation of evaporites. Several bentonitic beds are interlayered with the generally massive limestone of the El Abra Formation; some could be traced laterally and are used as marker beds for El Abra deposition.

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Ichnology of Labrador Group (Lower Cambrian) in Southern Labrador

Rocks assigned to the Labrador Group record deposition during initial phases of the lower Paleozoic transgression onto the eastern continental margin of North America during late Early Cambrian time. In Labrador the group comprises two formations; the lower one, the Bradore Formation, is a series of conglomerates, sandstones, and minor siltstones; the upper one, the Forteau Formation, is a series of siltstones, shales, fossiliferous limestones, and reefs.

The Bradore Formation, interpreted on the basis of physical sedimentary structures to be a series of tidal-dominated, nearshore, sand shoals, is almost devoid of body fossils. The presence of an abundant soft-bodied infauna is, however, demonstrated by prolific *Skolithos* as well as numerous *Monocraterion* and *Dolopichnus* and minor forms such as *Lingulichnus, Stipsellus*, and *Cruziana.*

The Forteau Formation comprises a series of patch reefs rich in archaeocyathids surrounded and buried by interreef skeletal limestones, siltstones, and shales. In contrast to the underlying Bradore, these rocks are extremely rich in body fossils. Correspondingly, the interreef beds are replete with ichnofossils including *Chondrites, Cylindrichnus, Monocraterion, Monomorphichnus, Paleophycus, Planolites, Rusophycus, Skolithos,* and *Teichichnus.* These forms suggest that the environment of deposition was relatively shallow and that sedimentation was slow and continuous.

We have also discovered numerous traces in the fine-grained sediments which floor growth cavities within the reefs, suggesting that mobile organisms either inhabited the cavities or at least were transient through them.

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Sediment Dispersal at Fort George Inlet, Florida

Fort George Inlet is located in northeastern Florida, 0.9 km north of the St. Johns River. The geomorphic history of Fort George Inlet is characterized by migration.

The pattern and rate of sediment dispersal were established through fluorescent sand tracing, tidal-current measurement, and bed-form mapping. Morphologic changes were determined utilizing nearshore and beach profiles established in 1923 and 1974, as well as air photos, hydrographic surveys, historical maps, and coastal climate data.

Fort George Inlet partially intercepts the southerly littoral drift (estimate of 190,000 $m^3$/year based on SSMO data) and deposits sediment along Little Talbot Island and Wards Bank, altering the hydrodynamic system in the study area. In the past, accretion at Little Talbot Island (average rate of 142,880 $m^3$/year) forced Fort George Inlet south at an average rate of 36 m/year. However, in 1961 the direction of inlet migration was reversed and is now northward at a rate of 21 m/year. Sediment intercepted by Fort George Inlet is producing a recurved spit extending north from Wards Bank. The expansion and encroachment of this spit into the inlet throat are believed to have initiated the reversal in migration direction. Analysis of aerial photographs indicates that inlet migration occurs sporadically during severe storms.

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Genesis, Occurrence, and Causes of Sediment Distribution in Inner Reefs of Mombasa, Kenya

Though quantitative statistical analysis of skeletal carbonate sediments is under a cloud of uncertainty, the results thereof, in conjunction with copious field observations, elucidate the causes of sediment distribution in and adjacent to the Mombasa, Kenya, reef/platform complex and aid definition of hydrodynamic and ecologic environments. The recent surface sediments have been analyzed to determine their textural and genetic composition. They are made up of two components: biogenic carbonate material (molluscan debris, coralgal, *Halimeda* and Foraminifera) and fluvio-terrigenous quartz (from the pre-Quaternary of the immediate hinterland).

The fringing reef is divisible into a northern and southern sector by the Ras Iwa Tine promontory. Four sediment populations are present which are distinct in skeletal origin, textural composition, and position on the reef. Sediment samples close to the berm abound in *Halimeda* fragments, whereas the carbonate fraction on the outer platform (1 km away) and the channel are dominated by molluscan fragments.