T2.7 OFFSHORE GEOLOGY

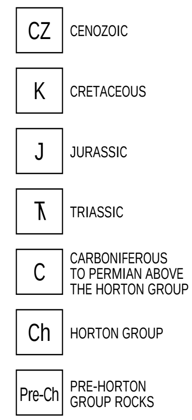
The Nova Scotia offshore covers approximately 40 million hectares and includes parts of Georges Bank, the eastern Gulf of Maine, Bay of Fundy, Gulf of St. Lawrence, Laurentian Channel and the Scotian Shelf and Scotian Slope, which together form part of the continental margin of eastern Canada. (See Region 900 on Theme Regions Map.) The margin evolved subsequent to the rifting of the supercontinent Pangea and the ensuing sediment accumulation in the basins has created conditions suitable for the generation and preservation of oil and natural gas.

The offshore areas of Nova Scotia are important links in the chronology of events that comprise the province's geological history. Accessibility, however, has limited the study of offshore stratigraphy and deposits. Until recently, information was derived from dredge materials from the fishing industry and scattered core samplings. During the last few decades, there has been increasing interest in offshore oil and natural-gas exploration, and more recently, marine mineral potential. The Geological Survey of Canada (GSC) and the Atlantic Geoscience Centre (AGC) support mapping programs for offshore geology, one of which produces an East Coast Basin Atlas Series. There is now a better understanding of the offshore geology and the relationships with marine processes. Topics T2.1–T2.6 discuss Nova Scotia's geologic story. This Topic summarizes the pieces which are in evidence offshore. More detailed information can be obtained from *Geology of the Continental Margin of Eastern Canada*.[1]

GEOLOGICAL SUBDIVISION OF THE OFFSHORE

The offshore is here taken to include all areas adjacent to the province which are covered by water (see Figure T2.7.1). Geologically, the offshore region can be divided into three parts:

1. the Gulf of St. Lawrence (Unit 914) and Laurentian Channel (Unit 932), where Carboniferous sedimentary sequences, similar to those occurring in the Cumberland and Sydney basins and overlying a complex basement of



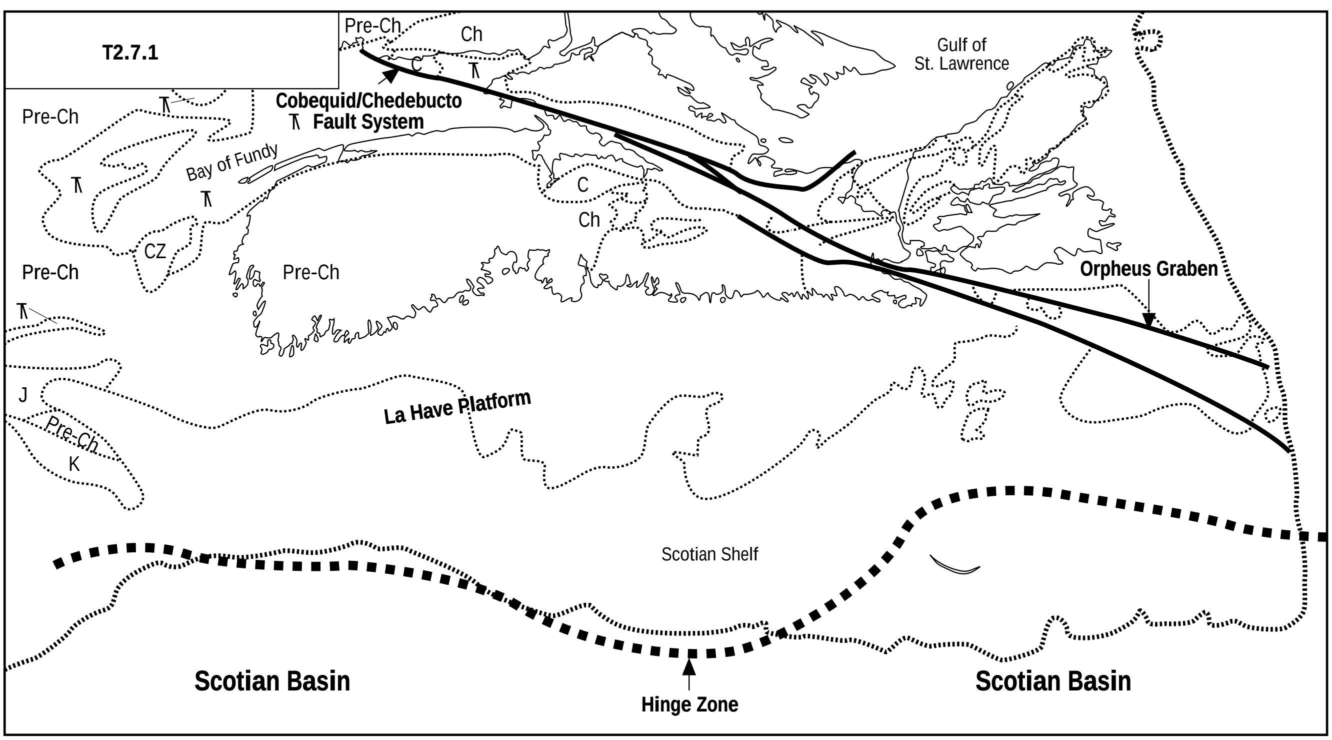


Figure T2.7.1: Structural geology of the Nova Scotia offshore.

Avalon terrane metamorphic and igneous rocks, extend offshore into the larger Magdalen and Sydney basins

2. the Bay of Fundy, where the red Triassic and Jurassic sedimentary strata and basalts that occur in western Nova Scotia, overlying various Paleozoic formations, thicken northward toward the axis of the Fundy Basin (Unit 912)
3. the Scotian Shelf (Districts 920, 930) and Slope (District 940) where the Meguma Group rocks, which extend beneath the continental shelf, are onlapped by Jurassic, Cretaceous and Tertiary sedimentary beds of the Scotian Basin.[2]

The Scotian Basin can be further subdivided into:

(i) an inner area, where the Meguma basement is relatively shallow. This includes the LaHave Platform (District 930) and Canso Ridge (District 920). Its southern boundary is the "hinge zone": a zone of faulted basement blocks which marks a flexure in the crustal rocks between the platformal area and the adjacent basinal area

(ii) an outer area, consisting of a series of interconnected sub-basins containing very thick sedimentary rocks. This is the area of greatest potential for oil and gas discoveries (see Figure T2.7.2).

STRATIGRAPHY

The proto-Nova Scotian landscape has been more or less continuously exposed to erosive forces since the middle part of the Jurassic Period 180 million years ago. Its history from this point is essentially one of denudation rather than deposition, and consequently very little evidence of geological events has been preserved on land.

There are, however, two exceptions. First, at five locations in Nova Scotia, fluvial sediments have been

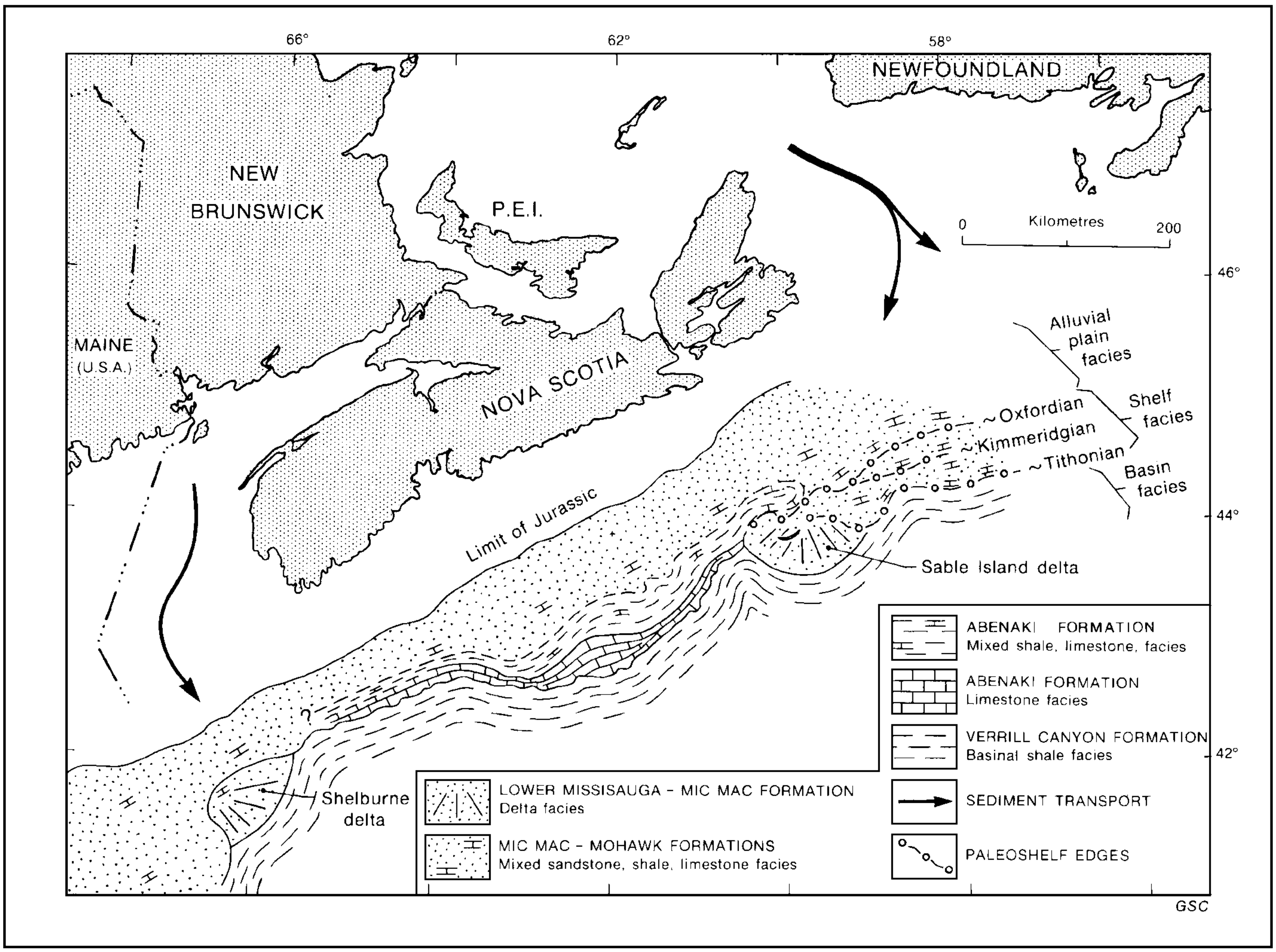


Figure T2.7.2: Generalized facies distribution reflecting depositional environments. Abenaki and equivalent formations, Scotian Shelf.[2]

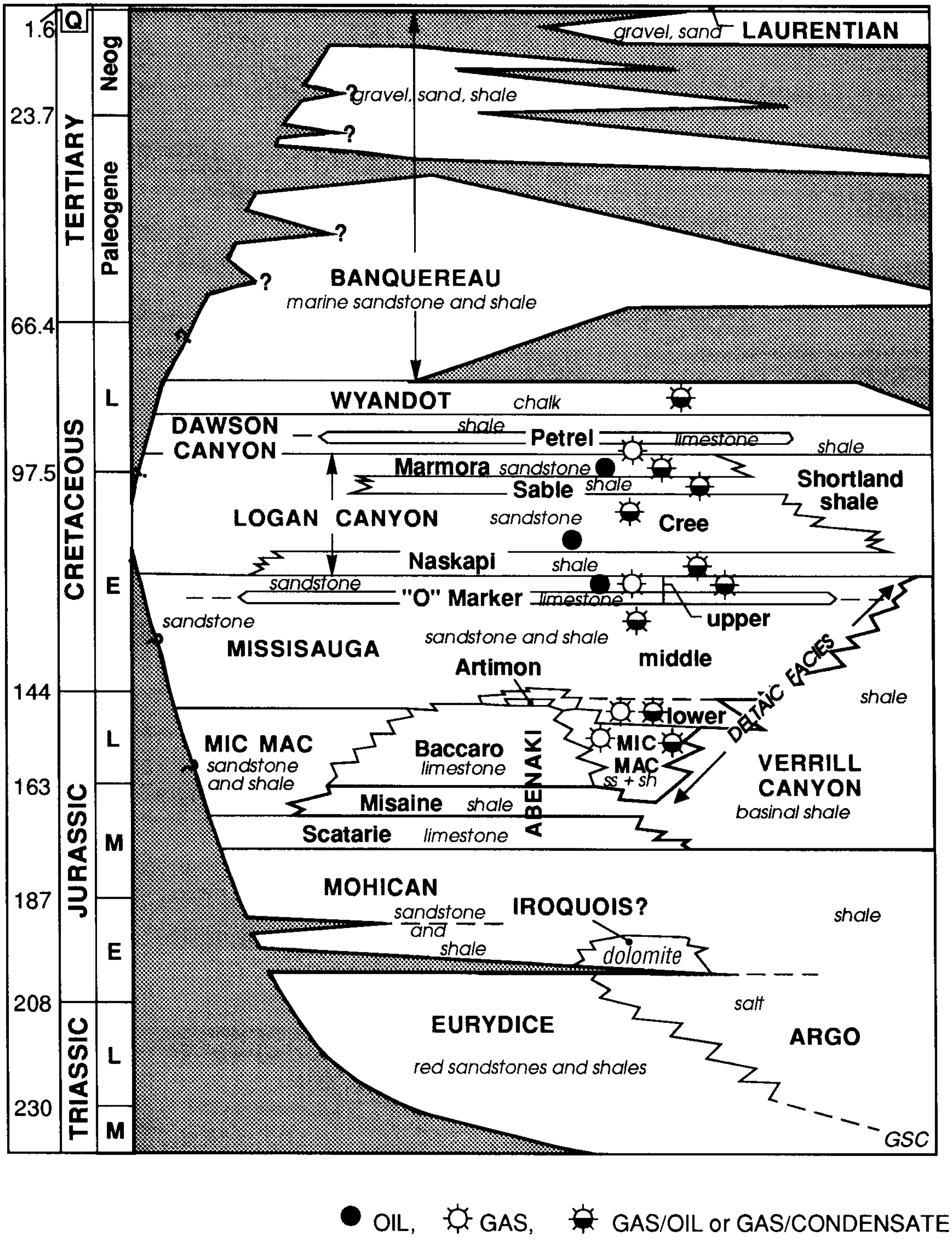


Figure T2.7.3: Hydrocarbon zones of the northeastern Nova Scotia continental shelf.[2]

discovered which contain assemblages of subtropical terrestrial flora (spores) and freshwater algal cysts (dinoflagellates) indicating an early Cretaceous age — ~110–120 million years ago. At another location, a 23-m-thick interval is dated as ~135 million years old. The second exception is the extensive blanket of glacial and glaciofluvial material deposited across all of Nova Scotia during the Pleistocene Epoch, which ended about 12,000 years ago.

This large gap in the geological record can be filled by data from the Scotian Shelf portion of the Scotian Basin. The Scotian Basin extends from Georges Bank in the southwest to the Grand Banks in the east and, in its thickest parts, may contain sedimentary strata totalling 20 km in thickness.[2, 3] There are a number of major structural elements within the Scotian Basin which, depending on their rate of subsidence and hence the amount of sediment accumulation, at present contain relatively thicker or thinner amounts of strata.

There are also several lithostratigraphic units in the Scotian Basin (see Figure T2.7.3). Most hydrocarbon discoveries have occurred in deltaic sediments of the MicMac, Mississauga and Logan Canyon formations.

The edge of the Scotian Basin subcrops Quaternary sediments approximately 30–50 km offshore from the southern coast of Nova Scotia.

This section summarizes the late Triassic, Jurassic and Cretaceous Periods, during which time the offshore area was the focus of significant sedimentation.

Triassic/Jurassic Red Beds and Salt

In the Late Triassic and the early part of the Jurassic Period, much of the Scotian Shelf was an emergent upland, containing a series of isolated to interconnected grabens and half-grabens into which were being deposited red sandstones and shales of the same age as the basal formations in the Fundy Basin. At this time, Nova Scotia was part of the supercontinent Pangea and was situated just north of the equator. Large amounts of salt were deposited into the deeper grabens as a result of the influx of seawater and a generally hot climate.[2]

Middle Jurassic Carbonate and Mud

Two significant changes occurred with the the continued northward movement of Pangea and the initial opening of the Atlantic Ocean in the Early Jurassic. First, the climate became more temperate and evaporite deposition ceased. Second, the broad area of the Scotian Shelf started to subside and land-derived sediments were deposited on top of the salt. These sediments were mainly sands near shore, containing organic matter from the continental land mass, while further offshore carbonates and muds, containing marine organic matter, were being deposited.

Late Jurassic Deltas

By the Late Jurassic (~160 million years ago) there were a variety of depositional environments south of Nova Scotia. South of southwestern Nova Scotia, a delta was developing at the mouth of a river system draining the Bay of Fundy–Gulf of Maine and adjacent regions. East of this feature, a narrow (10 to 20 km wide) carbonate shoal extended almost to where Sable Island is today, before being cut off by a second deltaic complex forming from a distributary of the ancestral St. Lawrence River (see Figure T2.7.2).

Woody material, which was washed in and buried within the deltaic sands and muds, is the principal source for the gas reserves around Sable Island. The water depth increased rapidly seaward of these features, and basinal shales, siltstones and fine-grained sandstones were deposited. These deltaic and basinal facies are important as potential source and reservoir rocks for crude oil and natural gas.[4,5,6]

Cretaceous Deltas

The southward retreat of the shoreline during a marine regression in the latest Jurassic and early part of the Cretaceous resulted in the development of fluvial and deltaic sediments on top of the Jurassic basinal sediments in the central part of the Scotian Basin, near Sable Island. A series of lesser marine transgressions and regressions occurred during the middle part of the Cretaceous, which resulted in the deposition of alternating source and reservoir beds. The whole sedimentary sequence was covered by fine muds during the Late Cretaceous, when seawater once more invaded the shelf and created deepwater conditions in the basin area.

Late Cretaceous/Early Tertiary

The later Cretaceous and early part of the Tertiary was a period of generally high sea level, with shoreline occasionally close to present day. By the late Tertiary, there was a general regression and the progradation of coarse clastics across the shelf.

Recent Deposits

During the latest phase of geological development on the Scotian Shelf, sediment banks have been built out along the edge of the continental shelf. The final veneer of glacial deposits, including moraines, was deposited as the Wisconsin ice sheet retreated.

CULTURAL FACTORS

Offshore areas of Nova Scotia are considered to be viable areas for hydrocarbon exploration and development (see T12.3).

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Associated Topics

T2.2 The Avalon and Meguma Zones, T2.6 The Triassic Basalts and Continental Rifting, T3.1 Development of the Ancient Landscape, T3.4 Terrestrial Glacial Deposits and Landscape Features, T3.5 Offshore Bottom Characteristics, T12.3 Geology and Resources

Associated Habitats

H1.1–H1.2 Offshore, H2.1–H2.6 Coastal

References

1 Keen, M. J., G. L. Williams, eds. (1990) *Geology of the Continental Margin of Eastern Canada*. Geological Survey of Canada. (Geology of Canada No. 2) (also Geological Society of America, The Geology of North America, vol. I-1).

2 Wade, J. A., and B. C. MacLean (1990) "The geology of the southeastern margin of Canada, Part 2—Aspects of the geology of the Scotian Basin from recent seismic and well data." In *Geology of the Continental Margin of Eastern Canada*, edited by M.J. Keen and G.L. Williams. Geological Survey of Canada. (*Geology of Canada* No. 2) (also Geological Society of America, *The Geology of North America*, vol. I-1).

3 MacLean, B. C., and J. A. Wade (1992) "Petroleum geology of the continental margin south of the Islands of St. Pierre and Miquelon, offshore Eastern Canada." *Bulletin of Canadian Petroleum Geology*.

4 Mukhopadhyay, P. K. (1989) Cretaceous Organic Facies and Oil Occurrence, Scotian Shelf. Geological Survey of Canada (*Open File* 2282).

5 Mukhopadhyay, P. K. (1990a) Evaluation of Organic Facies of the Verrill Canyon Formation, Sable Subbasin, Scotian Shelf. Geological Survey of Canada (*Open File* 2435).

6 Mukhopadhyay, P. K., and J. A. Wade (1990) "Organic facies and maturation of sediments from three Scotian Shelf wells." *Bulletin of Canadian Petroleum Geology* 38.

Additional Reading

• Grant, A. C., K. D. McAlpine and J. A. Wade (1986) "The continental margin of eastern Canada: Geological framework and petroleum potential." In *Future Petroleum Provinces of the World*, edited by M.T. Halbouty. American Association of Petroleum Geologists (*Memoir* 40).