T7.1 MODIFYING FORCES

The coast is a place of constant change. Winds, waves, tides and ice are continually at work, eroding, transporting and depositing the rock, gravel, sand and mud of the shore (see Plate T7.1.1). On the Atlantic Coast (Region 800), waves are the most important environmental agent of change, while in the Bay of Fundy (Regions 600 and 700), tides, and the currents generated by them, are of greater significance. Sea-level rise can also contribute to morphological changes on the coast. Organisms can influence the modifying effects of the physical forces.

TOPOGRAPHY

Landforms that result from these forces depend very much on the bedrock geology, unconsolidated surficial materials remaining from the last glaciation, and sea-level changes in the post-glacial period. For purposes of this description, bedrock can be grouped into resistant and unresistant types. Resistant rocks dominate the Atlantic Coast, except in southern Cape Breton Island, the Bay of Fundy coast west of Cape Split (District 720) and the Antigonish–western Cape Breton Island section of the Gulf of St. Lawrence (Districts 220, 310).

Beaches and marshes in these areas are derived exclusively from reworked surficial sediments, including eroded drumlins, glacial outwash and marine deposits. These beaches and marshes are therefore of limited extent and size. Unconsolidated bedrock outcrops in the Northumberland Strait (District 520), southern Cape Breton Island (Districts 530, 870) and the upper reaches of the Bay of Fundy (District 620) are sources of relatively abundant coastal sediment. Surficial deposits also tend to be more plentiful in these areas. As a direct result, the largest beaches and marshes are found on these coasts.

In the late 1970s, winter storm waves were breaking down the primary sand dune at Rissers Beach, Lunenburg County (Unit 832). Deterioration of the jetty at the west end of the beach by the river was found to be the root cause. The jetty had functioned to support the beach in a configuration which faced the direction of greatest wave energy. When the jetty developed gaps, sand washed into the river at an increasing rate, leaving the beach sand-starved and eroding. The beach was restored by repairing the jetty, in-filling the breaks in the dune with Christmas trees as sand traps, and planting beach grass to help hold the sand in place.

WAVES

Ocean swells from the south and east dominate the Atlantic Coast. This high-energy environment is more pronounced in winter. In the fall, remnants of hurricanes often cross the province and its coastal waters from the southwest. Significant wave height occurring for a 12-hour period once a year varies from 6 m in the Gulf of Maine to 8 m off Halifax and Cape Breton Island.[1]

Waves due to offshore winds have no erosive effect on the shoreline, but even off Halifax (which experiences predominantly northwest and northerly offshore winds in the winter) easterly storm-wind events produce onshore waves which rework exposed glacial deposits along the Atlantic Coast at Hartlen Point (Unit 833) at a rate of 2 m annually. Waves along the Eastern Shore are responsible for reworking sediments varying in size from sand particles to cobbles.[2]

The Atlantic Coast is also exposed to long ocean swells originating from storms at great distance. Swells from the open ocean are not very significant in the Bay of Fundy, nor in the Gulf of St. Lawrence.

Summer winds from the southwest and especially winter winds from the northwest generate waves in the Bay of Fundy. These have combined with the tides to erode wave-cut platforms on west-facing coasts. In the Gulf of St. Lawrence, northeast storm winds generate waves of sufficient energy to erode unresistant bedrock outcrops at 1 m annually.

A noticeable seasonal cycle in wave energy is observed in the Atlantic Ocean, Bay of Fundy and Gulf of St. Lawrence (although the Gulf is protected by ice from December to April). The increased winter wave energy, especially in storm episodes, combs down beaches, removing sand and gravel offshore and destroying the characteristic series of parallel offshore bars. Persistent, but gentler, onshore winds in the summer move the same material shorewards, rebuilding the beaches and bars.

TIDES

With the rapid increase in tidal range and height within the Bay of Fundy, stronger tidal currents are established and the capacity to move sediments increases. Large tides have ranges of 5.1 m at Yarmouth (District 920), 9.3 m at Digby (District 720), 12.6 m at Advocate (District 710) and 16.0 m at Burntcoat Head in Minas Basin (District 620). Currents have been reported in excess of 5 m/s in the Minas Channel.

River estuaries in the Bay are virtually dry at low tide. Stronger currents generated by the flood tide carry fine sediment into these estuaries, which the weaker ebb-tidal currents are unable to remove. This is the origin of sediments which have built, and are building, the marshes at the heads of Chignecto and Cobequid bays. The strongest currents in the main channels carry and deposit sand, forming gigantic sand bodies characterized by sand waves. Particularly conspicuous sand bodies are found in the Avon estuary off Hantsport (Unit 511a), and off Economy Point and in Cobequid Bay west of the Shubenacadie estuary (Unit 913a). This sand is exposed only at low tide.

Tidal range is only 1–2 m in the Northumberland Strait, and at certain times only one tide occurs (see T6.1). In summer, the low tide occurs during the day, exposing beaches and sand bars to the sun's radiation. The incoming tide is warmed as it moves over these sand flats, raising water temperatures to the highest values achieved in Nova Scotia. In winter, the reverse situation occurs: the sand flats are exposed at night and the incoming tidal water is chilled, greatly aggravating the ice conditions.

Tidal ranges of large tides increase westward on the Atlantic Coast from a large tide of 1.4 m at Ingonish (Unit 522b) to 1.95 m at the Guysborough (District 860) and 2.1 m at Halifax (Unit 833). Narrow entrances restrict the tidal influence in Bras d'Or Lake (Unit 916). However, strong tidal currents and barometric tides result in the mixing of fresh and salt water. The largest tidal-current velocities are generated within inlet throats and estuarine tidal channels, and here provide the mechanism for landward transport of sand- and mud-sized sediments into embayments.[2]

ICE

Only in the Gulf of St. Lawrence does sea ice cover large areas of water. Shore ice begins forming in December and by late January covers much of the Northumberland Strait. Not until late March or April does this ice break up and move through the Cabot Strait to the Atlantic. The ice cover is moved by strong winds and, in piling up on windward shores, protects the coast from wave attack, although the ice itself may "raft" material from beaches and marshes. During break-up, strong currents moving ice along the Atlantic coast of Cape Breton Island cause ice scour, removing sediments, vegetation and animals southwards and offshore.

Ice forms in the Upper Bay of Fundy (Unit 913a) from December to April. Drift ice moves with the strong current and transports material which becomes frozen into the flows but may strand with the ebb tide.

Ice forming on mud flats in the Bay of Fundy may protect the coast from erosion by waves and tidal currents. However, the mud flats themselves are heavily scoured by ice, which causes erosion and mortality of benthic organisms.

Local ice forms in bays on the Atlantic Coast but does not produce major changes in coastal landforms.

SEA-LEVEL RISE

All coastlines in Nova Scotia are changing. Rising sea level over the last 15,000 years (see T3.3) has caused the coast to retreat inland, flooding the lower reaches of river valleys, eroding unresistant bedrock and unconsolidated materials to create marine platforms, raising marsh levels, and pushing beaches landwards.

Tide-gauging records for Nova Scotia indicate that the relative sea level has been rising over the past century. Records at Halifax show an average 35-cm rise since 1896. The projected relative rise by 2070 is one metre per century.[3]

The impact of accelerating sea-level rise on the coast of Nova Scotia is extrapolated from evidence of post-glacial coastal changes and from observations of coastline retreat over the last century. Past and current sea-level changes have contributed to the erosion of bedrock shorelines and bluffs, beach retreat and subsequent sediment increase in sheltered inlets and estuaries.

Coastal dunes on Sable Island (District 890) are constantly being reworked, and increased sea-level rise is expected to accelerate this process.[3] The cyclic phases of progradation, stability and retreat, resulting from sea-level changes, waves and tides, have been changing the shoreline of Nova Scotia since the last glacial retreat. If the predictions on sea-level change in the future are right, these processes will continue to modify the coast, possibly at an accelerated rate.[3]

T7.1
Modifying
Forces

BIOLOGICAL COMPONENT

Biological communities have a significant impact on the form and development of the coastline. When salt-marsh grasses and Eel Grass colonize muddy shores, they reduce the wave and current action, leading to the deposition of sediment and the building of more extensive muddy environments. Kelp beds can have a similarly moderating effect in areas exposed to high waves.

Growth of thin films of unicellular algae on the surface of muds can make them more resistent to erosion by slowing the rate of change over what would occur in the absence of organisms. Some sea-bottom invertebrates, such as the amphipod *Ampelisca* and the polychaete *Clymenella torquata*, build tubes out of sediment, and the combined effect can stabilize the sediment. Organisms that feed on sediment sometimes make the bottom more stable by depositing feces, which are more compact and stable than the sediment was before it was ingested.

Rock-boring organisms, such as the clams *Zirphaea crispata* and *Petricola pholadiformis*, tunnel in soft rocks in shallow water and help to break them apart. The shells of clams in some coastal environments form a distinctive feature, and the crushed remains of shells and the skeletons of barnacles can form a distinctive type of sediment called shell hash.

CULTURAL FACTORS

Agricultural and forestry practices have led to significant loads of sediment entering the ocean and resulting in pronounced coastline change, usually in sheltered coastal estuaries. Humans have also had an impact by excavating or in-filling marine areas (the former Halifax City Dump) and by dyking practices begun by the Acadians and continued to the present. The construction of causeways, breakwaters and jetties alters the normal pattern of water movement and sediments transported by water and can create or destroy coastal features such as beaches and tidal marshes (see T12.9).

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Associated Topics

T3.3 Glaciation, Deglaciation and Sea-level Changes, T6.1 Ocean Currents, T6.3 Coastal Aquatic Environments, T6.4 Estuaries, T7.2 Coastal Environments, T7.3 Coastal Landforms, T10.9 Algae, T11.17 Marine Invertebrates, T12.7 The Coast and Resources

Associated Habitats

H2 Coastal

References

1 Walker, R.E. (1976) Wave Statistics for the North Atlantic—1970. Bedford Institute of Oceanography, Dartmouth, N.S. (*Data Series* BI-D-76-3).

2 Boyd, R., A.J. Bowen and R.K. Hall (1987) "An evolutionary model for transgressive sedimentation on the Eastern Shore of Nova Scotia." In *Glaciated Coasts*, edited by D.M. Fitzgerald and P.S. Rosen. Academic Press, San Diego.

3 Shaw, J., R.B. Taylor and D.L. Forbes (1991) "Impact of accelerated sea level rise on the coast of Nova Scotia, Canada." In *The Climate of Nova Scotia; Proceedings from a Symposium, November 19, 1991*. Atmospheric Environment Service, Environment Canada, Dartmouth, N.S.

Additional Reading

• Forbes, D.L., and R.B. Taylor (1987) "Coarse-grained Beach Sedimentation under Paraglacial Conditions, Canadian Atlantic Coast." In *Glaciated Coasts*, edited by D.M. Fitzgerald and P.S. Rosen. Academic Press, San Diego.

Plate T7.1.1: Eroding drumlin at Lawrencetown Head, Halifax County (Unit 833). The till is eroded and sand transported and deposited in the sand beach/dune system of Conrod Island in the distance. Photo: D. Davis

T7.2 COASTAL ENVIRONMENTS

Like terrestrial and freshwater environments, the coastal environment may be subdivided using biophysical classifications that provide a hierarchical categorization. Coastal landforms (see T7.3) are the smallest of these divisions and have not been systematically identified in Nova Scotia. Regional divisions are distinct and widely recognized as follows:

1. Atlantic Coast: exposed, high wave energy
2. Bay of Fundy: large tidal range, semi-enclosed, more sheltered to wave exposure
3. Southern Gulf of St. Lawrence: micro-tidal, seasonally wave dominated, winter sea ice
4. Sable Island: open shelf environments, exposed high wave energy

Coastal environments have been further subdivided by Owens and Bowen.[1] The following subdivisions are made on the basis of geomorphic and process characteristics :

1. Atlantic Coast
- Northeast Cape Breton Island (Districts 550 and 210)
- East Cape Breton Island (District 530)
- Southeast Cape Breton Island (District 870)
- North Chedabucto Bay (District 860)
- South Chedabucto Bay (District 850 in part)
- Eastern Shore (Districts 830, 840 and 850 in part)
- Western Shore (District 820)

2. Bay of Fundy
- South Shore (District 720)
- Head of the Bay (District 710 in part)
- Minas Basin (District 620)
- Chignecto Bay (Units 532 and 523)

3. Southern Gulf of St. Lawrence
- Northumberland Strait (District 520 in part)
- Antigonish-West Cape Breton Island (Districts 550, 220, 310 and 580)
- St. Georges Bay (District 520 in part)

4. Sable Island (District 890)

Tables T7.2.1–T7.2.3 identify the main characteristics of the first three subdivisions. This approach most closely approximates the land-district level of biophysical classification, characterised by a "distinctive pattern of relief in geology, geomorphology and associated regional vegetation".[1]

SUBDIVISION	GEOLOGICAL CHARACTER	BACKSHORE RELIEF	BEACH CHARACTER	FETCH AND WAVE EXPOSURE	MEAN TIDAL RANGE	SEDIMENT AVAILABILITY
Northeastern Cape Breton Island	Resistant metamorphic and igneous rocks; thin till cover	Upland cliffed coast (5–100 m)	Absent or narrow; coarse sediments	Exposed open ocean coast; ice-free 8 to 9 months	1 m	Very scarce
Eastern Cape Breton Island	Carboniferous sandstone or shale; thin till cover	Rocky cliffs (5–20 m)	Occasional spits and barriers	Exposed ›500 km; ice-free 8 to 9 months	1 m	Scarce
Southeastern Cape Breton Island	Carboniferous sedimentary and metasedimentary rocks; thick till and drumlins	Low rock and till cliffs (10–20 m)	Barrier beaches	Exposed open ocean coast; ice in sheltered areas up to 3 months	1 m	Scarce, but locally abundant
Northern Chedabucto Bay	Carboniferous sedimentary rocks, some resistant volcanics, abundant till	Low rock and till cliffs up 20 m	Spits and barrier; coarse sediments	Exposed in northeast; elsewhere sheltered (›50 km) ice-free 8 to 9 months	1.5 m	Abundant
Southern Chedabucto Bay	Resistant metasedimentary and igneous rocks; fault-line coast; very thin till	Rocky cliffs (3–10 m)	Absent or narrow; coarse sediments	Sheltered (50 km) ice-free 8 to 9 months	1.5 m	Very scarce
Eastern Shore	Resistant metasedimentary and granitic rocks; variable-thickness tills and drumlins	Indented low rocky coast, some eroded drumlins (30 m)	Absent or barriers or pocket beaches in re-entrants; coarse	Exposed open ocean coast, embayments sheltered; ice in sheltered areas 2 to 3 months	1 to 2 m	Very scarce
Western Shore	Resistant sedimentary and metamorphic rocks; thin till deposits	Till or rock cliffs (3–30 m)	Narrow or coarse-sediment barriers	Variable locally very exposed; local ice up to 2 months	4 m	Scarce, but locally abundant

Table T7.2.1: Coastal environments of the Atlantic Coast of Nova Scotia.

SUBDIVISION	GEOLOGICAL CHARACTER	BACKSHORE RELIEF	BEACH CHARACTER	FETCH AND WAVE EXPOSURE	MEAN TIDAL RANGE	SEDIMENT AVAILABILITY
South Shore	Resistant Triassic basalt dyke; parallels coast	Low rocky coast or cliffs, up to 30 m	Absent or narrow cobble beach at high-water mark, with wide intertidal platform	Sheltered (50 km)	6 to 10 m	Very scarce
Head of the Bay	Resistant conglomerates, basalts or granites	Cliffed coast, up to 200 m	Absent or large pocket beaches, pebble/cobble on beachface and mud overlying coarse sediment in intertidal zone	Exposed (50-100 km)	10 m	Scarce, but locally abundant
Minas Basin	Triassic sandstone and shales, or unconsolidated glacial deposits	Cliffs, up to 30 m	Wide, intertidal mud or sand flats on rock platform, pebble-cobble beach at high-water mark, marshes in sheltered areas	Very sheltered (›50 km)	›10 m	Abundant
Chignecto Bay	Permo-Carboniferous sandstone and shale	Cliffs, up to 20 m	Wide, intertidal mud flats on rock platform, pebble/cobble beach at high-water mark, extensive marshes in sheltered areas	Very sheltered (›50 km)	›10 m	Abundant

Table T7.2.2: Coastal environments of the Bay of Fundy, Nova Scotia.

SUBDIVISION	GEOLOGICAL CHARACTER	BACKSHORE RELIEF	BEACH CHARACTER	FETCH AND WAVE EXPOSURE	MEAN TIDAL RANGE	SEDIMENT AVAILABILITY
Northumberland Strait	Sandstone and shale	Unresistant low relief; till, rock cliffs (3–10 m)	Barriers, spits and intertidal bars; mixed or fine-grained sediments	Very sheltered (<50 km) ice-free 7 to 8 months	1 to 2 m	Scarce
Antigonish	Deformed sedimentary, metasedimentary and igneous rocks	Resistant rocky upland cliffed coast (5–100 m)	Absent, or narrow gravel-boulder beaches	Very exposed (>300 km) ice-free 7 to 8 months	‹1 m	Very scarce
St. Georges Bay	Metasedimentary and sedimentary rocks	Low relief; till, rock cliffs (2–10 m)	Narrow, or spits and barriers; mixed sand-gravel beaches	Sheltered (50 km) ice-free 7 to 8 months	1 m	Scarce, but locally abundant

Table T7.2.3: Coastal environments of the Southern Gulf of St. Lawrence, Nova Scotia.

The Atlantic Coast of mainland Nova Scotia has been further subdivided by Munroe.[2] He identified twelve morpho-dynamic units. One distinctive unit included the large salt marshes of Lobster Bay, Little River and Cheboque harbours along southwest Nova Scotia (in Unit 831). In these long, shallow estuaries, large tides penetrate the gently sloping valleys of rivers such as the Tusket, Annis, Chebogue and Argyle. Drowned drumlins and rock outcrops dot the outer parts of these bays. Another distinctive area is the Baymouth barrier-beach system east of Halifax Harbour to Owl's Head (west of Ship Harbour, Unit 833). Drumlins in this area provide an important anchor for the barriers, as well as an important source of sediment for beach formation.

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Associated Topics

T2 Geology, T6.2 Oceanic Environments, T6.3 Coastal Aquatic Environments, T6.4 Estuaries, T7.1 Modifying Forces, T7.3 Coastal Landforms

References

1 Owens, E.H., and A.J. Bowen (1977) "Coastal environments of the Maritime Provinces." *Maritime Sediments* 13.

2 Munroe, H.D. (1982) Regional Variability, Physical Shoreline Types and Morphodynamic Units of the Atlantic Coast of Mainland Nova Scotia, edited by R.B. Taylor, D.J.W. Piper and C.F.M. Lewis. Geological Survey of Canada. (*Open File* 725).