# T9.1 SOIL-FORMING FACTORS

To some, soil is debris that covers valuable deposits of ore, gravel, gypsum or coal. To others, it is a building material. Still others think of soil as any substance which supports plant growth. These are all valid concepts. Soils are natural, three-dimensional bodies consisting of mineral material, organic matter, water, air and living organisms. The characteristics of an individual soil are the result of soil-forming factors (parent material, climate, topography and organisms) interacting over time.

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The development of soil depends upon the interaction between the following factors: parent materials, climate, topography, living organisms and time.[1,2]

*The distinctive red colour of the soils in the Triassic and Carboniferous lowlands in Regions 500 and 600 is inherited from the local parent material.*

## PARENT MATERIAL



Parent material is the geological material from which a soil is derived. It determines the mineral content and, to a large extent, the particle size of a soil. It influences soil fertility, internal drainage, colour, and the rate at which weathering takes place.

### *Glacial Till*

Most of the soil parent material in Nova Scotia is coarse- to medium-textured glacial till closely related to the underlying bedrock. Where the bedrock is hard and crystalline, the soils tend to be coarse and stony, while soils derived from shaly tills are somewhat finer. Till depth is most commonly one to two metres and rarely exceeds seven metres. However, tills which make up the drumlins between Lunenburg and Canso are thicker and originate further away, perhaps the Bay of Fundy or northern New Brunswick.

### *Glaciolacustrine and Glaciofluvial Deposits*

Glaciolacustrine (lake) and glaciofluvial (outwash, ice contact) deposits occur in association with the till. The lakebed material is somewhat fine in texture and often occurs in depressions, resulting in restricted drainage. Outwash deposits of gravel and coarse sand tend to be rapidly drained.

### *Marine Deposits*

Marine deposits have given rise to nutrient-rich, usually fine-textured soils in estuarine environments. Recent alluvium, material deposited on the floodplains of modern rivers, is also nutrient rich and stone free but is subject to periodic flooding. Organic deposits are found mainly in poorly drained depressions.

## CLIMATE

Climate determines the temperature-moisture regime of an area. This influences the rate of weathering and the amount of leaching that occurs in soils. Climate also influences vegetation, which in turn influences the kind and amount of organic material that accumulates. Nova Scotia's modified-continental climate results in a cool, moist soil environment conducive to the soil-forming process known as podzolization. Organic matter accumulates on the surface and organic acids leach downward, carrying iron and aluminum to a depth of 20–50 cm. This leaves the upper part of the soil very acid and devoid of plant nutrients (see Table 9.3).

## TOPOGRAPHY

Topography affects temperature, rainfall and drainage. On a local scale, level areas collect water, and soils formed on them may be heavily leached, sporadically waterlogged or both. Slopes shed water, which may hinder chemical weathering and slow soil development. The runoff may erode surface layers.

Topography can also be described on a broader scale. For example, the configuration of the Cobequid Hills (Unit 311) results in higher rainfall and cooler temperatures than in adjacent areas. More organic matter accumulates under these conditions and more of it leaches downward.

 

## ORGANISMS

Both plant and animal organisms are abundant in soil. They play an important role in soil chemistry (practically all soil reactions are biochemical) and by physically mixing soil layers. Plant roots bring up nutrients from deeper soil layers, eventually depositing them on the surface through litter fall. The extent of leaching is partly governed by the type of litter. Leaching is greatest under coniferous and moss litter, less under deciduous and least under grass. Most of Nova Scotia's soils have developed under coniferous or mixed-wood forests, which contributes to acid soils, low in nutrient status.

*Under ideal conditions, the earthworm population can be as high as two million per hectare, with a live weight of just over one tonne. This population can process thirty tonnes of soil per hectare annually.*

Organic matter incorporated in the mineral soil helps to develop soil structure, affecting soil aeration, root penetration, moisture storage and drainage. Organic matter also affects the activity of micro-organisms, which in turn play a vital role in breaking down organic matter and mobilizing plant nutrients. Soil organic matter contains a significant proportion of the world carbon supply, an important consideration in balancing the amount of carbon dioxide in the environment.

*Most of the parent materials in Nova Scotia are slightly to strongly acid. Newly cleared land in Nova Scotia requires 15–30 tonnes of lime per hectare to raise the topsoil pH to near neutral. The initial treatment is carried out in several stages — all the lime is not added at once. About 500 kg of lime per hectare is required annually to maintain the pH.*

Human activity has had a strong influence on soil characteristics. Some examples are the clearing of forests, stone removal, drainage, tillage, dyking and the addition of lime, manure and fertilizer.

## TIME

The maturity of a soil is usually reflected in the development of distinct layers or horizons (see Figure T9.2.1). Nova Scotia's soils have developed since the glaciers melted 10,000 years ago, a relatively short span of geological time. However, most of the soils can be considered mature, because soil-forming processes have been highly active. Reasons for this include the effects of glaciation breaking down the bedrock to unconsolidated material, the humid conditions and the warm post-glacial period. Soils formed on more recent marine and alluvial deposits are "younger," and exhibit little or no profile development.

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***Associated Topics***

T2.1–T2.6 Geology, T3.1–T3.4 Landscape Development, T4.1 Post-glacial Climatic Change, T5 Climate, T9.3 Biological Environment, T10.1–T10.12 Plants, T11.16 Land and Freshwater Invertebrates, T12.9 Soil and Resources

***Associated Habitats***

H2.5 Tidal Marsh, H2.6 Dune System, H3.3 Bottom Lotic (Rivers and Streams), H3.4 Bottom Lentic (Lakes and Ponds), H3.5 Water's Edge Lotic (Rivers and Streams), H3.6 Water's Edge Lentic (Lakes and Ponds). H4 Freshwater Wetlands, H5 Terrestrial Unforested, H6 Forests

***References***

1 Buckman, H.O, and N.C. Brady (1969) *The Nature and Properties of Soils*, 7th ed. Macmillan, London.
2 Jenny, H. (1941) *Factors of Soil Formation*. McGraw-Hill, New York.

# T9.2 SOIL CLASSIFICATION

Although there are exceptions, the smallest volume of material considered to be an individual soil has a volume of one cubic metre with the shape one metre wide, one metre long and one metre deep. Each individual soil, or pedon, is unique because it has characteristics that set it apart from all other pedons, in the same way that each tree is different from all other trees.

Having set an arbitrary definition of an individual soil, classification according to some preset criteria becomes possible. The criteria can be related to the soil itself, in which case the classification is taxonomic or "natural."[1] Sometimes it is more worthwhile to consider some intended use, in which case the classification is interpretive.[2] A taxonomic soil classification is based solely on soil characteristics, and separations are often made on inferred soil genesis. An interpretive classification is a prediction of how soils will respond to management. Landscape characteristics like slope steepness are usually part of interpretive classifications.

## SOIL PROFILE

Taxonomic systems depend on identifying the horizons or layers exposed in a soil profile. Mineral horizons are labelled A, B or C, starting from the soil surface and working downward. The "A" horizon is a zone of organic-matter accumulation, maximum leaching or both. The "B" horizon is a zone of accumulation. The "C" horizon is relatively unaltered parent material. Organic horizons are labelled "L" (litter from leaves and twigs), "F" (fermented), "H" (humus) or simply "O." Although not a true soil horizon, consolidated bedrock is denoted by "R." Each master horizon can be modified by suffixes to show the process thought to be dominant in the layer (Figure T9.2.1).

## TAXONOMIC CLASSIFICATION

The Canadian System of Soil Classification[3] has five categorical levels arranged in a hierarchy—orders, great groups, subgroups, families and series.

### *Orders*

There are nine soil orders, each reflecting a dominant soil-forming process. Most Nova Scotia soils belong to the Podzolic Order, having iron, aluminum and humus accumulations in the B horizon. Others belong to the Gleysolic Order (wet mineral soils), Regosolic Order (well to imperfectly drained recent alluvium) or Organic Order (accumulations of organic material more 40 cm thick and commonly very poorly drained).

### *Great Groups*

Soil orders are broken into great groups based on differences in the strength of the dominant process. Thus, we have Ferro-Humic Podzols where humus is the major accumulation product of the B horizon and Humo-Ferric Podzols where iron accumulation is dominant.

### *Subgroup*

The next taxon is the subgroup, which indicates the degree of conformity to the central concept of the great group. The presence of ortstein layers (iron and organic cementation, usually in very sandy soils), fragipans (clay cementation, usually in medium-textured soils) are examples of subgroups recognized in Nova Scotia.[4]

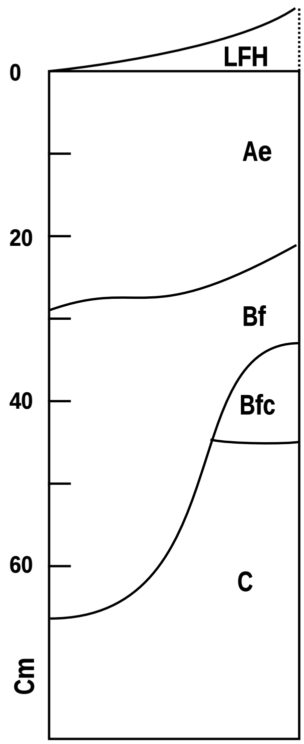
### *Families*

Subgroups are further subdivided into families, based on particle size of the parent material, mineralogy, reaction, depth, and soil climate.

### *Soil Series*

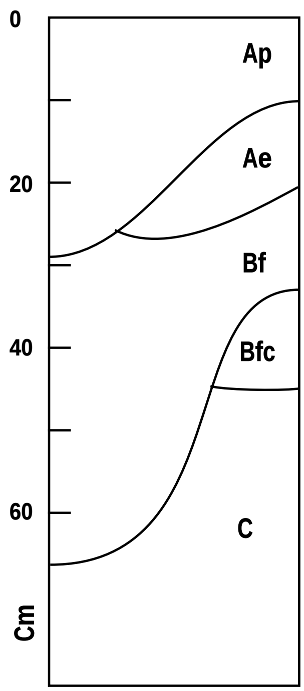
The final subdivision is the soil series, differentiated on detailed features, like horizon thickness. Soil series are given local geographic names, e.g., Pugwash. Soils that have developed from similar parent material but differ because of drainage condition belong to the same catena, e.g., Pugwash–Debert–Masstown or Falmouth–Queens–Kingsville. The series names form the basis of soil-map unit names used in soil-survey reports. However, it is important to distinguish between the taxonomic series, which is "pure," and the map unit, which usually contains soils of different taxa. A generalized soil map of Nova Scotia is shown in Figure T9.2.2.[5]

**Before Cultivation**




| Horizon | Sand | Silt | Clay | Organic Matter | pH | Colour |
|---|---|---|---|---|---|---|
| Forest Humus | — | — | — | 60 | 4 | Black |
| Eluviated | 90 | 7 | 3 | 0.8 | 4.5 | Grey |
| Iron (Fe) Accumulation | | | | 1.0 | 5.5 | Yellowish Red |
| Cemented | | | | 1.0 | 5.0 | Dark Yellowish Red |
| Parent Material | | | | <0.1 | 5.0 | Reddish Brown |

**After Cultivation**




| Horizon | Sand | Silt | Clay | Organic Matter | pH | Colour |
|---|---|---|---|---|---|---|
| Plowed | 90 | 7 | 3 | 2.0 | 6.0 | Dusky Red |
| Eluviated | | | | 0.8 | 5.5 | Grey |
| Iron (Fe) Accumulation | | | | 1.0 | 5.5 | Yellowish Red |
| Cemented | | | | 1.0 | 5.0 | Dark Yellowish Red |
| Parent Material | | | | <0.1 | 5.0 | Reddish Brown |

**Figure T9.2.1:** Cornwallis soil (ortstein Humo-Ferric Podzol) before and after cultivation.

*County and regional soil survey reports are available from the NS Dept of Supply and Services, Information Services, PO Box 550, Truro, B2N 5E3. An index map is available at no charge.*

## INTERPRETIVE CLASSIFICATION

Interpretive soil-classification systems are ratings based on an intended use, the Canada Land Inventory (CLI) for Agriculture being one example. The CLI is a seven-class system, where Class 1 is the best and Class 7 the worst. "Best" is defined as the ability to successfully grow a wide range of commercial crops. As the range of crops becomes narrower, or more inputs are required, or yields become poorer or less reliable, the Class is poorer. There are thirteen subclasses, denoted by a letter, to describe the kind of limitation present. The best soils in Nova Scotia[5] are Class 2 because of adverse climate, denoted by 2C. Common soil limitations in the province are shallow rooting depth (D), stoniness (P), adverse topography (T), wetness (W), lack of moisture (M) and low fertility (F). About 375 000 hectares (7 per cent) of the province has potential for general agriculture as defined by Classes 2 and 3.

Other interpretive classifications are based on growing a single crop (like alfalfa), or are for a single use (like septic filter fields). These classifications follow similar rules to CLI but the criteria and class limits change depending on critical values specific to the intended use.

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***Associated Topics***

T12.9 Soil and Resources

***References***

1 Cline, M.G. (1949) "Basic principles of soil classification." *Soil Sci.* 67.
2 F.A.O. (1974) Approaches to Land Classification." S*oil Bull.* No. 22. Rome, Italy.
3 Agriculture Canada Expert Committee on Soil Survey (1987) *The Canadian System of Soil Classification,* 2nd ed. Agriculture Canada (*Publ.* 1646).
4 Smeck, N.E., and E.J. Ciolkosz, eds. (1989) "Fragipans: Their occurrence, classification and genesis." *Soil Sci. Soc. Amer.* (24).
5 Hilchey, J.D. (1970) Soil Capability Analysis for Agriculture in Nova Scotia. (*Canada Land Inventory Report* No. 8).

***Additional Reading***

• Beke, G.J., and J.D. Hilchey (1978) "Soils of the Appalachian Region." *The Geosciences in Canada, 1977.* Annual Report and Review of Soil Science, Canadian Geoscience Council. (*Geological Survey Paper* 78-6).



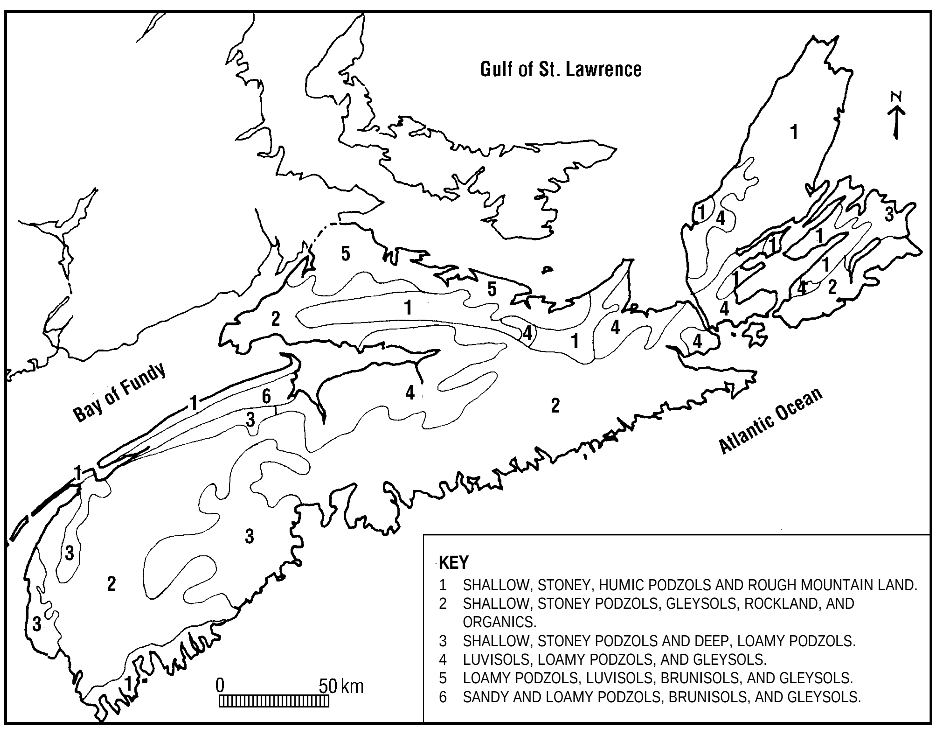


**Figure T9.2.2:** A generalized soil map of Nova Scotia.

# T9.3 BIOLOGICAL ENVIRONMENT

Soils are the foundation of terrestrial ecosystems. They support plants, shelter a variety of animals and micro-organisms, regulate the movement of water, and are where most organic material is decomposed. The greatest amount of biological activity occurs in the A horizon, or “topsoil.” The abundance and diversity of living things in the soil are influenced by factors including acidity, type of leaf or needle litter, soil texture and soil moisture. Soil offers a relatively constant environment; it lacks the wide daily or seasonal temperature fluctuations of the atmosphere.

> *Most plants prefer soil that contains about 5 per cent organic matter, 25 per cent water, 25 per cent air, and 45 per cent soil mineral particles by volume.*

## SOIL CLIMATE

Soil climate is the integration of those aspects of atmospheric climate which most affect the environment of soil flora and fauna. One soil-climate classification (Figure T9.3.1) is based on soil-temperature and soil-moisture regimes during the year.[1]

The sheltered Annapolis Valley (District 610) has a Mesic temperature regime, while the rest of southern Nova Scotia is moderately cool Boreal to mild Mesic. The northern part of the province is moderately cool Boreal, with the exception of the Northumberland Shore and southern Cape Breton, which are cool Boreal. The rest of Cape Breton is moderately cold Cryoboreal.

Most of the province is Perhumid, meaning that the soils are moist all year. The Annapolis Valley and parts of the central lowlands are humid and experience slight moisture deficits in the growing season.

## FOREST HUMUS FORMS[2,3]

Coniferous trees drop a needle litter that is not readily digested by most micro-organisms, so it decomposes slowly and accumulates on the soil surface. The primary decomposers of coniferous forest litter are fungal organisms. Their decomposition by-products are strongly acid and usually create an environment adverse to earthworms. Thus, little of this raw humus, or mor as it is called, is mixed with the mineral soil. Infiltrating water is made more acidic by its reaction with the by-products of fungal decomposition. The resultant soil solution readily leaches out plant nutrients and other bases.

The litter from hardwood trees is more readily digested by soil micro-organisms and is usually higher in nutrients than conifer litter. As a result, hardwood litter is more easily decomposed and incorporated into the mineral soil, forming partly decomposed humus called moder. Bacteria tend to replace fungi as decomposers, and there tends to be

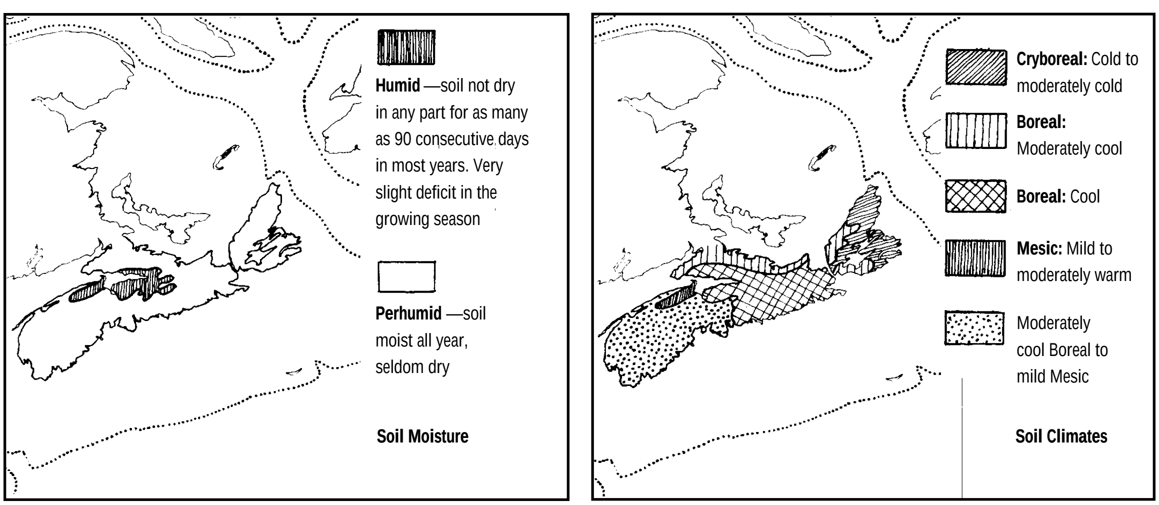


**Figure T9.3.1:** Classification of soil climate based on soil-temperature and -moisture regimes.

a larger diversity of soil fauna. Under less-acid, more nutrient-rich soil conditions, hardwood litter is consumed and incorporated into the mineral soil very quickly by earthworms, producing intimately mixed, humified humus called mull. In Nova Scotia, true mull is not common and is mainly found on the North Mountain (District 720) or on the Cobequids (Unit 311), where the bedrock is more basic.

Mor, moder and mull are terrestrial humus forms, found on rapidly to imperfectly drained sites. Humus forms developed on poorly drained sites are divided into two classes. Organic horizons are called peaty mors and are transitional to soils of the Organic Order. Anmoors are associated with soils of the Gleysolic Order, where the humus has been incorporated into the mineral soil.

*Soil organic matter helps to strengthen soil structure, holds moisture (2.5 times its weight in water) and is a source of plant nutrients.*

## RESTRICTING LAYERS

Most Nova Scotia soils have a layer that restricts rooting depth, water movement or both. In addition to bedrock (see T2), some restricting features are ortstein layers, fragipans and basal till.



### *Ortstein Layer*

An ortstein layer consists of organic matter cemented with illuviated iron, aluminium oxides and organic matter. Ortsteins are permeable to water but not to plant roots. It has been suggested that ortsteins are associated with change from a wet to a drier soil moisture regime. The cementing may be caused by desiccation and resultant oxidation. Ortsteins are most commonly found in coarse-textured upland and highland soils, particularly the Ferro-Humic Podzols, which feature substantial leaching of organic matter to the B horizon. Ortsteins are found extensively in the barrens of southwestern Nova Scotia (District 440) and on the Cape Breton plateau (Districts 210 and Region 100). A typical ortstein is often found in soils of the Lydgate series—a Gleyed Ferro-Humic Podzol common in Shelburne County (Unit 841). The surface drainage is fairly rapid, but the fine, thick organic surface layer retains moisture over long periods. The dark-brown, strongly mottled ortstein layer is found at a depth of about 30 cm. Where forested, Lydgate soils usually support only spruce. Large areas are covered with heath vegetation. Other soils which often develop ortstein layers are Nictaux, Cornwallis, Somerset, Hebert, Bayswater and Gibraltar.

### *Fragipan Layer*

A fragipan is a layer of silt and sand cemented by clay and low in organic matter. It has a platy structure and is brittle when moist and extremely hard when dry. A well-developed fragipan cannot be penetrated by roots and is only slightly permeable to water. Fragipans are particularly associated with lowland soils on glacial tills of medium to coarse texture, e.g., the Debert series in Unit 521. The fragipan usually begins between 30 and 60 cm from the surface and is 5–15 cm thick. Drainage is restricted and tree throw is frequent because of shallow rooting.

### *Basal-till Layer*

Compact till, with or without an overlying fragipan, is a common feature of the lowland regions of Nova Scotia. From a plant growth point of view, the characteristics of basal tills are similar to fragipans: high bulk density, and low permeability to roots, water and air. Queens and Debert soils have developed on material overlying compact till. There are several reasons offered to explain the compacted nature of the till.[4] One theory is that the bottom part of the glacial debris, the basal till, was compacted by the weight of the glacier and present-day soils developed in the overlying ablation till that melted out of the glacier. Another explanation is that the low calcium content of the parent material, coupled with a moist climate, led to poor soil structural development, which, in turn, led to restricted drainage, further inhibiting structural development, and so on, in cyclical fashion.

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### *Associated Topics*

T5 Climate, T9.1 Soil-forming Factors, T9.2 Soil Classification, T10.9 Algae, T10.10 Fungi, T11.16 Land and Freshwater Invertebrates

### *Associated Habitats*

H6 Forests

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1 Clayton, J.S., W.A. Ehrlich, D.B. Cann, J.H. Day, and I.B. Marshall (1977) *Soils of Canada*. Agriculture Canada, Research Branch, Ottawa.
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