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**ONTARIO SOIL BASELINE SURVEY
ANALYTICAL DATA 1980-1981**

**VOLUME 1
SOIL BASELINE PROGRAM**

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SOIL BASELINE PROGRAM**

**TERRESTRIAL EFFECTS PROGRAM
ACIDIC PRECIPITATION IN ONTARIO STUDY**

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ONTARIO MINISTRY OF THE ENVIRONMENT
NOVEMBER, 1984

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During 1980 and 1981, the collection of soil samples throughout Ontario involved a number of people. This work was accomplished under the coordination of M.A. Griffith (Southern Ontario), T. Spires (Northeastern Region) and W. Carswell (Northwestern Region). The development of an A.P.I.O.S. soils' laboratory and the chemical analyses of all soil samples were undertaken by the Laboratory Services Branch under the direction of A. Neary. The tables that form the bulk of Volumes 2 and 3 were typed by 2001 Word Processing Services .

Volume 1 of this report was written by M. A. Griffith, A.P.I.O.S., Soil Specialist, Phytotoxicology Section, Air Resources Branch. T. Spires of Northern Terrestrial Consultants and P. Barclay, Lakehead University provided most of the information regarding Northeastern and Northwestern Ontario, respectively. All members of the Terrestrial Effects Working Group's Technical Subcommittee assisted in various editing stages of the report, principally D. Griffin, W. McIlveen, D. Dimma, A. Neary and T. Spires.

SUMMARY

The soil baseline program began in 1980 and is part of the Ministry of Environment's Acidic Precipitation in Ontario Study (A.P.I.O.S.). Over 300 locations were sampled in 1980 and 1981 throughout the province. Soil samples were analyzed at the Ministry's laboratory for pH, texture, iron, aluminum organic and inorganic carbon, major nutrient ions and trace metals. The major objectives of the soil baseline program, methods used to sample soils and analytical methods employed are provided in Volume 1. In addition, the effect of acidic precipitation on soils, the glacial history of Ontario, and some theories of soil development are briefly outlined in Volume 1. A uniform data base for soils across Ontario now exists and is presented in Volumes 2 (Analytical Data for Southern Ontario) and 3 (Analytical Data for Northern Ontario) of this report. The analytical data sheets are grouped by region as given in Volume 1, and arranged according to the sampling date. To locate a particular site, the number given on the map in Volume 1 refers to the final three digits of the location code given on the data sheets.

SOIL BASELINE PROGRAM

INTRODUCTION

Acidic deposition comprises all acidifying components deposited from the atmosphere as a result of man-made and natural activities. Sulphur dioxide and oxides of nitrogen undergo complex chemical reactions in the atmosphere to form acidic substances. These acids can be transported over extremely large distances but eventually fall to the ground as dry or wet deposition.

The Acidic Precipitation in Ontario Study (A.P.I.O.S.) was established in 1979 by the Ontario Ministry of the Environment to protect the Ontario environment from the detrimental effects of acidic deposition, based on study findings. One study task is to determine the effects of acidic deposition on terrestrial ecosystems. The soil baseline program commenced in 1980 as the first phase of the terrestrial study.

The effect of acid inputs on the environment depends on the quantity and acidity of atmospheric inputs, and the buffering capacity of the terrestrial and aquatic ecosystems. The effect of acidic precipitation on soil is potentially significant because the soil is the reservoir of plant nutrients and the source of much of the water for aquatic systems. Changes in the soil's chemistry may therefore be reflected in both the terrestrial and aquatic environments. Information on the effects of acidic precipitation on soils is available from effects near point sources of pollution, from experimentation with simulated rain solutions, from natural changes observed in soil over time, and from models and soil forming theories. Anticipated effects of soil acidification include: reduced pH, leaching of basic cations (such as magnesium and calcium) and other exchangeable plant nutrients, reduction in base saturation and cation-exchange capacity, mobilization of soil-bound metals such as aluminum, and changes in biological activity such as decreased nitrification and soil respiration (Bache, 1980).

OBJECTIVES

The principal objective of the baseline program is to establish a uniform data base for soils across the province. This data base 1) provides current data to identify future trends, 2) enables the development of laboratory experiments which define soil sensitivity criteria to acidic precipitation, and 3) provides information required for sensitivity mapping of soils throughout Ontario.

TREND IDENTIFICATION

Baseline data describe the current status of Ontario soils. Trends in soil chemistry are monitored by resampling baseline soil profiles over an extended period and comparing these results to natural background variations in soil properties. Trends will likely vary across the province, depending on site sensitivity and atmospheric contaminant loading.

Little usable historical soil chemical data are available for Ontario. Generally, past soil surveys have been based on aerial photographs and intermittent point checks in the field. Earlier surveys concentrated on agricultural or managed land, and exact sampling locations are unknown. Because a variety of sampling and analytical methods was used, comparison among different surveys done at different times is unreliable. In contrast, the APIOS program attempted to restrict sampling to areas which are, currently, not managed and which offer reasonable access and long-term security. The baseline sites are mapped and the analytical methods are documented.

SOIL MAPPING

A data bank obtained by standardized field and analytical methods for soils associated with major landforms is desirable prior to mapping soil sensitivity to acidic precipitation. Important information which may be necessary when rating the sensitivity of a soil to acidification includes soil pH, cation exchange capacity, base cation content, soil depth, texture, carbonate content and sulphate adsorption capacity. This soils data base will, therefore, be used to prepare a map showing the relative sensitivities of Ontario soils to acidic deposition.

SAMPLING METHODS

SITE SELECTION

A.P.I.O.S. baseline soil sites are, whenever possible, located on presently unmanaged soils. Provincial parks, conservation areas and crown land offering reasonable access and long-term security were found to be the most suitable for baseline sampling.

Site locations are identified by UTM co-ordinates and a sketch map is prepared in the field showing the sampling location in reference to permanent local features. Sufficient detail is included to permit site relocation. The site is also described according to the guidelines in the **Field Manual for Describing Soils** (1982).

SAMPLING PROCEDURE

A pit, approximately 1 m², was dug to a depth sufficient to permit sampling of the parent material. The soil profile was described according to criteria adopted by **The Canadian System of Soil Classification (1978)**. The soil profile was photographed and a sketch was drawn of one of the faces sampled to show major soil horizon boundaries and the positions of stones, root masses, and sampling points.

Beginning at the deepest horizon, duplicate samples, each approximately 1 kg in weight, were collected with a hand trowel from opposite sides of the soil pit and placed in labelled plastic bags. The depth of each horizon was noted. When sampling was concluded, soil horizons were returned to the pit in the reverse order from which they were removed to achieve the least possible disturbance of the sampling site. Thin horizons, particularly bleached horizons beneath the surface layers, proved difficult to sample without contamination from adjacent horizons.

Soil profiles in the Southern and Northwestern Regions were not classified using soil taxonomic procedures, as this was unnecessary for the APIOS study. Classifying the large number of profiles in these areas would have been a very time consuming task. Profiles in Northeastern Ontario, however, were classified according to **The Canadian System of Soil Classification (1978)** (under the direction of T. Spires) as this information will also be used for other purposes.

Present plans call for a re-sampling frequency of approximately once every 5 years for baseline sites in Ontario. New soil pits will be dug adjacent to the original pits. To reduce potential effects of seasonal variations on soil properties, repeat samples will be collected at the same time of year as the original survey.

SOIL SAMPLE PREPARATION AND ANALYSES

To minimize physical and chemical degradation of the soil, samples are spread out on non-metallic trays and air dried for 48 hours within a few days of collection. Dried samples are disaggregated with a porcelain mortar and pestle and passed through a 2 mm sieve. At least 150 g of the < 2 mm mesh fraction is placed in a glass jar and submitted to the Ministry's Toronto laboratory for analysis. A 5 g subsample is thoroughly ground to pass through a 100 mesh sieve (150 µm) and submitted in a glass vial. This fine, homogeneous sample is easily digested and used for analysis of trace metals, carbonates, organic carbon and pyrophosphate and dithionite-extractable iron and aluminum. The remainder of the (2 mm fraction is stored in cardboard or glass containers of suitable size.

The following analyses are performed on the samples; pH (in distilled water and in 0.01M calcium chloride, 1:2 soil: solution ratio); NaCl-exchangeable calcium, magnesium, potassium, and aluminum; an estimate of permanent charge cation exchange capacity (by summation of exchangeable cations measured); Na-pyrophosphate and Na-dithionite-citrate-bicarbonate extractable iron, aluminum and manganese; organic carbon (Walkley-Black); total calcium carbonate equivalent (reaction with HCl and CO₂ measurement using a volumetric calcimeter); total nitrogen

(Kjeldahl); total P and/or plant available phosphorus (Na-bicarbonate extractable), soluble S (distilled water extractable, measurement by ICP); soluble SO_4 (distilled water extractable, and measurement by ion chromatography); soluble aluminum (0.01M CaCl_2 -extractable); $\text{HNO}_3/\text{HClO}_4$ -extractable Cu, Ni, Pb and Zn; and texture (% sand, % silt, % clay by wet sieve/sedimentation - pipette analysis). For further information on the analytical methods refer to the Procedures Manual Terrestrial Effects, Acid Precipitation in Ontario Study (A.P.I.O.S.) Report No. 007/83, Ontario Ministry of the Environment.

DEVELOPMENT OF ONTARIO SOILS

HISTORY OF ONTARIO SOIL DEVELOPMENT

Approximately 13,500+ years ago all of Ontario was covered by glaciers (Prest, 1976). As the glaciers advanced, then receded, a variety of landforms common to Ontario today were produced. The history of glaciation is complex and only a simplified account will be presented.

The Laurentide ice sheet which covered Ontario was composed of a number of lobes. Each lobe carried debris from areas far to the northeast or northwest as well as from local sources. The hard bedrock of the Canadian Shield in northern Ontario was stripped of its soil by this ice sheet. Only sterile, polished bedrock plains were left which then received a new cover of shallow till (unstratified deposits of stone, gravel, sand and/or silt) from the glacier.

Much of the original soil on the Canadian Shield was picked up by the advancing glacier and reworked and deposited in southern Ontario as till plains. The glacier often reworked the till to form other features known as moraines (well defined mounds of till) and drumlins (smooth elongated hummocks of till). Glacial meltwater carrying till poured from the edge of the glacier as it receded producing outwash plains. Other fluvial-glacial deposits in Ontario are spillways (channels of old meltwater drainage courses), eskers (snake-shaped ridges of irregularly stratified sand and gravel) and kames or recessional moraines (knobby hills of irregularly stratified sand and gravel).

Ponding of meltwater by the glaciers created lakes where none now exist. The floors of these former lakes and ponds are known as lacustrine plains (clay plain, sand plain). Fragments of glacial lake deposits such as beaches and shorelines, are still noticeable in Ontario.

Bedrock geology contributes little to direct soil development in Ontario although much of the till which forms the parent material of the soil is bedrock derived. The parent material of Ontario soils is generally the debris deposited by the glaciers or their lakes. There is a broad range of indigenous and exotic plant cover in Ontario. Generally the acidic litter associated with coniferous forests enhances podzolization or acidification of soils. Ground vegetation, including lichens and mosses will also affect soil development. Man influences and/or disturbs the development of soils by building roads and urban centres, by felling forests, and by cultivating the land. Atmospheric pollution, including acidic precipitation, may be an additional influence on soil development.

SOIL DEVELOPMENT

A soil consists of layers, known as horizons, of mineral and/or organic matter. These horizons differ in their physical, chemical, mineralogical, and biological characteristics (Joffe, 1949). A soil profile consists of one or more horizons. Leahey (1961) explains that surface horizons contain organic matter derived from plants and organisms. These surface horizons are subject to weathering and leaching of mineral matter more than any other horizon, Below this, a horizon occurs which accumulates most of the material leached from the surface. The lowest horizon comprises the parent material representing the relatively unweathered, bedrock or glacial deposits from which the soil was derived. Soils in Ontario vary widely in the nature and thickness of these principal horizons.

As soils develop they evolve until they reach a slowly changing state. Their development is governed by five main factors: parent material, climate, organisms, topography, and time. The important characteristics of each factor are summarized from Fitzpatrick (1972) and Buol *et al* (1973).

Parent Material

Parent material is the initial state of the soil system (Jenny, 1941). It is composed of mineral material and/or organic matter. Most of the parent material in Ontario are glacial deposits or water-laid sediments (lacustrine). The nature of the parent material is largely responsible for the course of soil formation and the resulting chemical, mineralogical and physical composition of the soil. Many features of the soil are directly related to soil parent material, such as, mineral stability, particle-size, degree of sorting, formation of clay minerals and permeability.

Climate

Climate, through temperature and precipitation, is the principal factor governing the type and rate of soil formation. Temperature affects the weathering of soil minerals, the rate of biological activity within the soil, the decomposition of organic matter and water evaporation from the soil. Moisture entering the soil is derived mainly from precipitation. The differentiation of horizons is largely determined by the movement of moisture in soil and subsequent chemical reactions. Some moisture is retained by the soil but most is lost through drainage or evapotranspiration.

Organisms

Soil and vegetation develop concurrently. Vegetation adds organic matter or litter to the soil surface. Deposits of coniferous needles beneath the tree contribute to local soil acidity while deciduous foliage provides a more base-rich litter. In addition, vegetation cycles and exchanges nutrients with the soil, binds the soil to prevent erosion, and alters the initial form and structure of the soil.

Burrowing mammals and worms mix the soil. Microorganisms such as bacteria, actinomycetes, algae and fungi participate in elemental cycling, production of organic matter, and transportation of material throughout the soil.

Topography

The initial shape, slope and orientation of the landscape is governed by local topography. Drainage patterns, amount of moisture, soil distribution and thickness, and vegetation types are also affected by topography.

Time

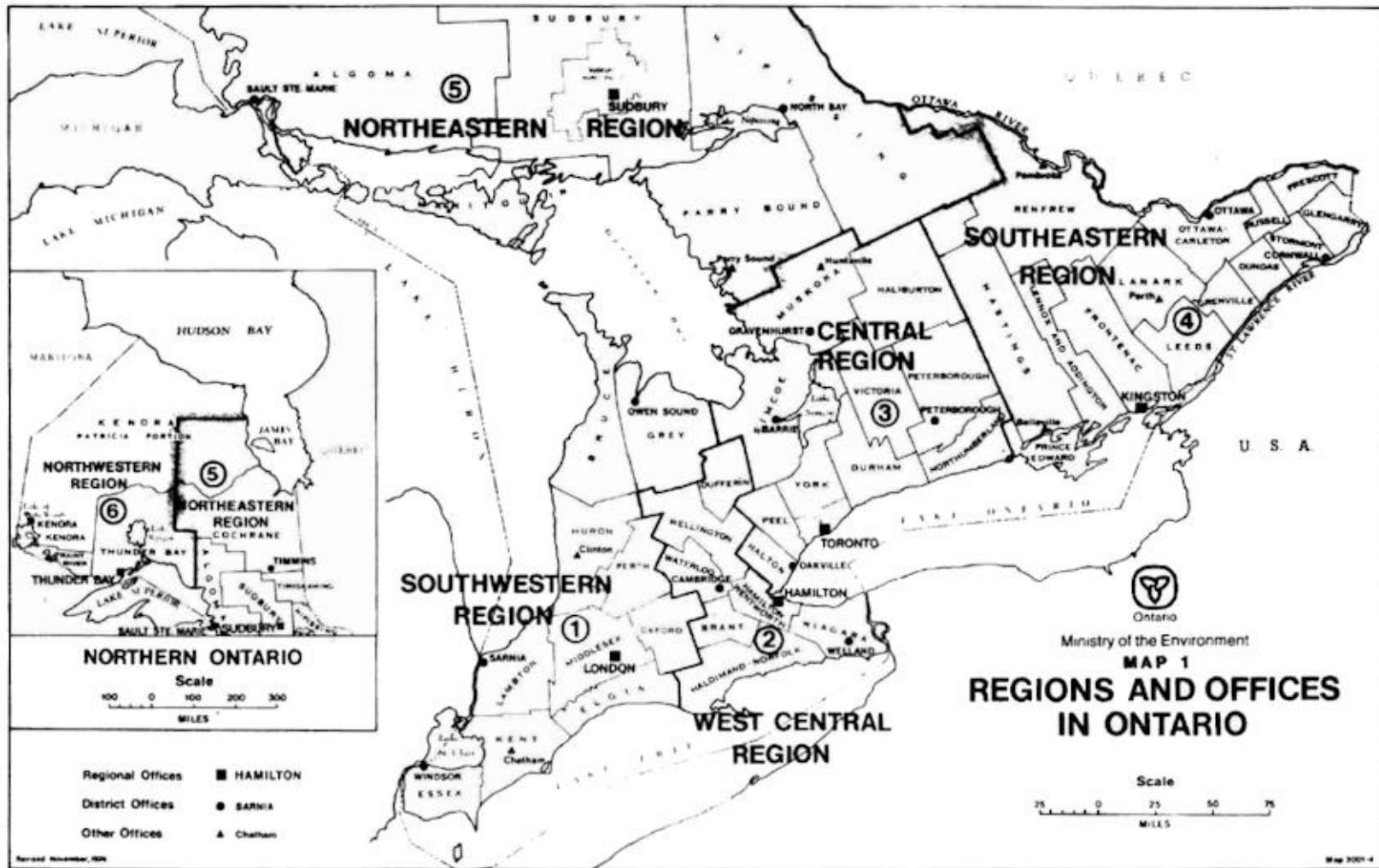
Soil formation is a very long and slow process. Surface horizons may take only a few hundred years to form, while those derived from weathering of primary minerals may take thousands of years to develop (Birkeland, 1974).

THE SOIL FORMING ENVIRONMENT IN ONTARIO

A brief description of the bedrock and glacial geology (Chapman and Putnam, 1976; Boissonneau, 1966, 1968 and Prest, 1976), vegetation regime (Hosie, 1979), climate (Brown, *et al*, 1980; Chapman and Thomas, 1968) and man's influence on the soil environment are included in the following section.

Maps depicting the major physiographic features for each of the Ministry's six regions of Ontario (Map 1) with the location of A.P.I.O.S. precipitation stations and baseline soil pits are provided. Detailed soil sampling was done at two A.P.I.O.S. sites at Dorset, in Central Region (Plastic Lake, Blue Chalk Lake) and near A.P.I.O.S. experimental vegetation plots in the Northeastern Region.

The soil analytical data appear in separate volumes of this Report. Volume 2 contains the analytical data for Southern Ontario while Volume 3 contains the analytical data for Northern Ontario. The baseline soil pit numbers given on the maps are incorporated as the last three digits of the location codes given in volumes 2 and 3. Readers should note the number and region of the site of interest, and then look through the appropriate data volume for the region and site number.



Map 1. Ministry of the Environment Regions and Offices in Ontario.

SOUTHWESTERN REGION

The Paleozoic bedrock in this region is flat-lying marine sedimentary shale and limestone of mainly Devonian age (Map 2). Some Silurian age dolomites and limestones occur in the north. The entire area was glaciated and thick deposits of till and lacustrine material were deposited over the bedrock and form the parent material of the present-day soils. Most of the material was probably transported only a short distance, since the majority of rock fragments produced exhibit characteristics similar to the local bedrock. The glacier left many different types of parent materials which produced a region with diverse local physiography (Map 3).

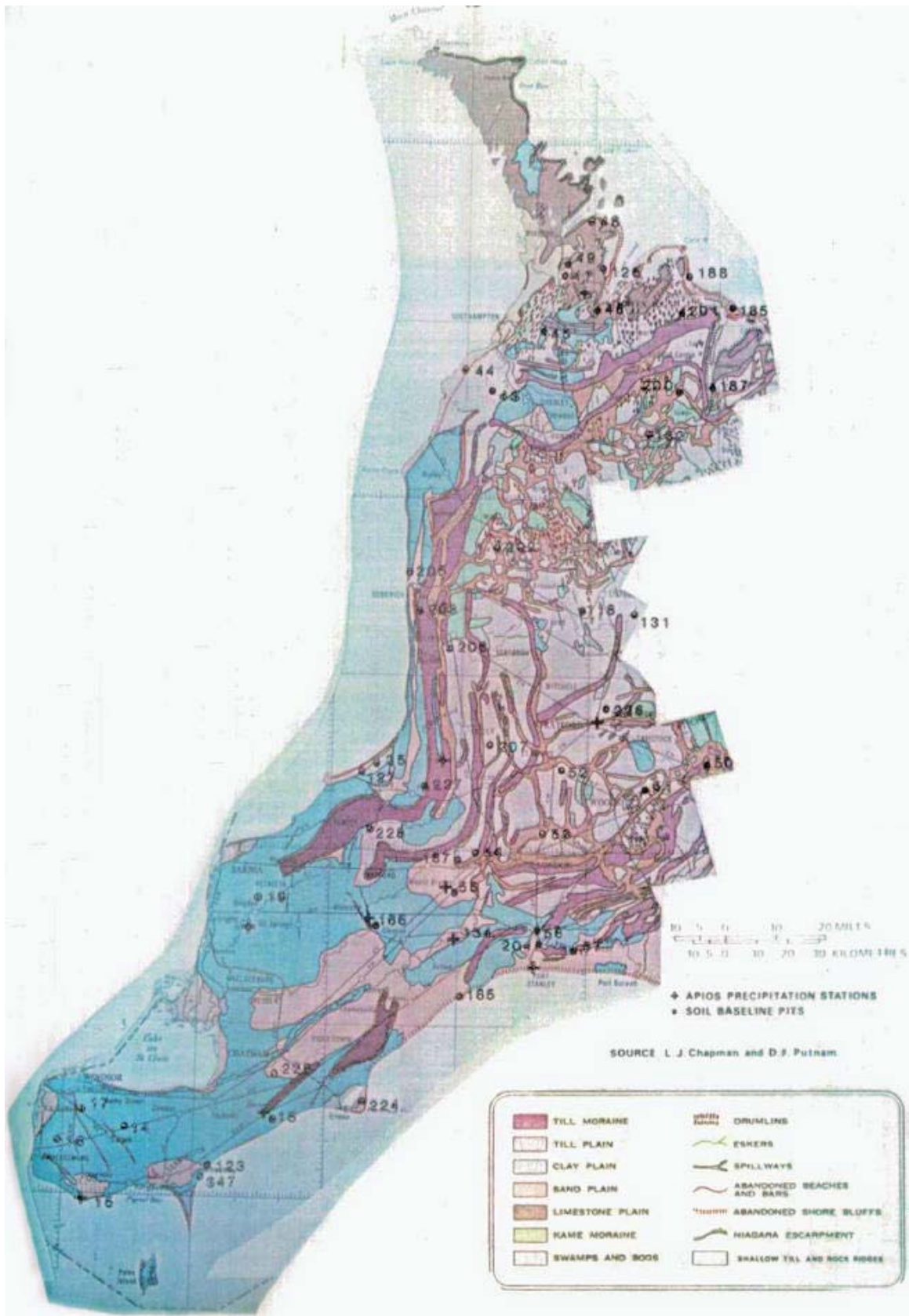
The till plain between Lake Erie and Lake St. Clair was smoothed by stages of Lake Erie during glaciation. Little relief produced poor soil drainage and waterlogged soils. The sand plains directly east were once deltas of the Thames River and glacial Lake Warren, another stage of Lake Erie. The sandy soils of these plains are acidic and very deep.

Along the eastern edge of Lake Huron is a clay plain over calcareous till. Interspersed with the clay plain are two beaches and wave-cut terraces with boulders, gravel bars and sand dunes. This strip of soils is poor for agriculture and much of the farmland has been abandoned.

Further inland from Lake Huron are calcareous till plains, moraines, spillways, some eskers and drumlin fields. Swamps and bogs occur in depressions.



MAP 2: The Bedrock Geology Of Ontario.



MAP 3. Physiography Of Southwestern Ontario And APIOS Baseline Soil Pits.

The Bruce Peninsula in the north of the region is generally a zone of glacial scour. Apart from some silt beds and a few drumlins, gravel bars and sand dunes, there is little overburden scattered over the gray dolomite. The soils in this area are very shallow and limestone bedrock is often exposed.

Large water bodies greatly modify both the temperature and amount of moisture in this region. This is the warmest area of Ontario and soils may be actively formed for approximately 6-8 months of the year. Precipitation is fairly uniform during the year. The amount of precipitation ranges from 77 cm in the southwest to 97 cm at the eastern edge of the region to the lee of the Niagara Escarpment. The mean duration of snow cover ranges from 50 days near Windsor to 124 days north of London.

The natural forest vegetation (Hosie, 1979) is deciduous in the extreme south. The rest of the region is in the Great Lakes-St. Lawrence mixed forest. Most of the land, has been deforested and used for agriculture at least once.

Pockets of soil that are potentially sensitive to acidic precipitation exist in this region. The acidic sand plains along Lake Erie are one example. Generally the clay soils of this region, although often slightly acidic in the top horizon, possess some degree of buffering due to their texture. The sand and gravel soils of the till plains may also be acidic at the surface but the parent material is usually calcareous and therefore strongly buffered. Ground-water runoff from these soils will likely not be acidic.

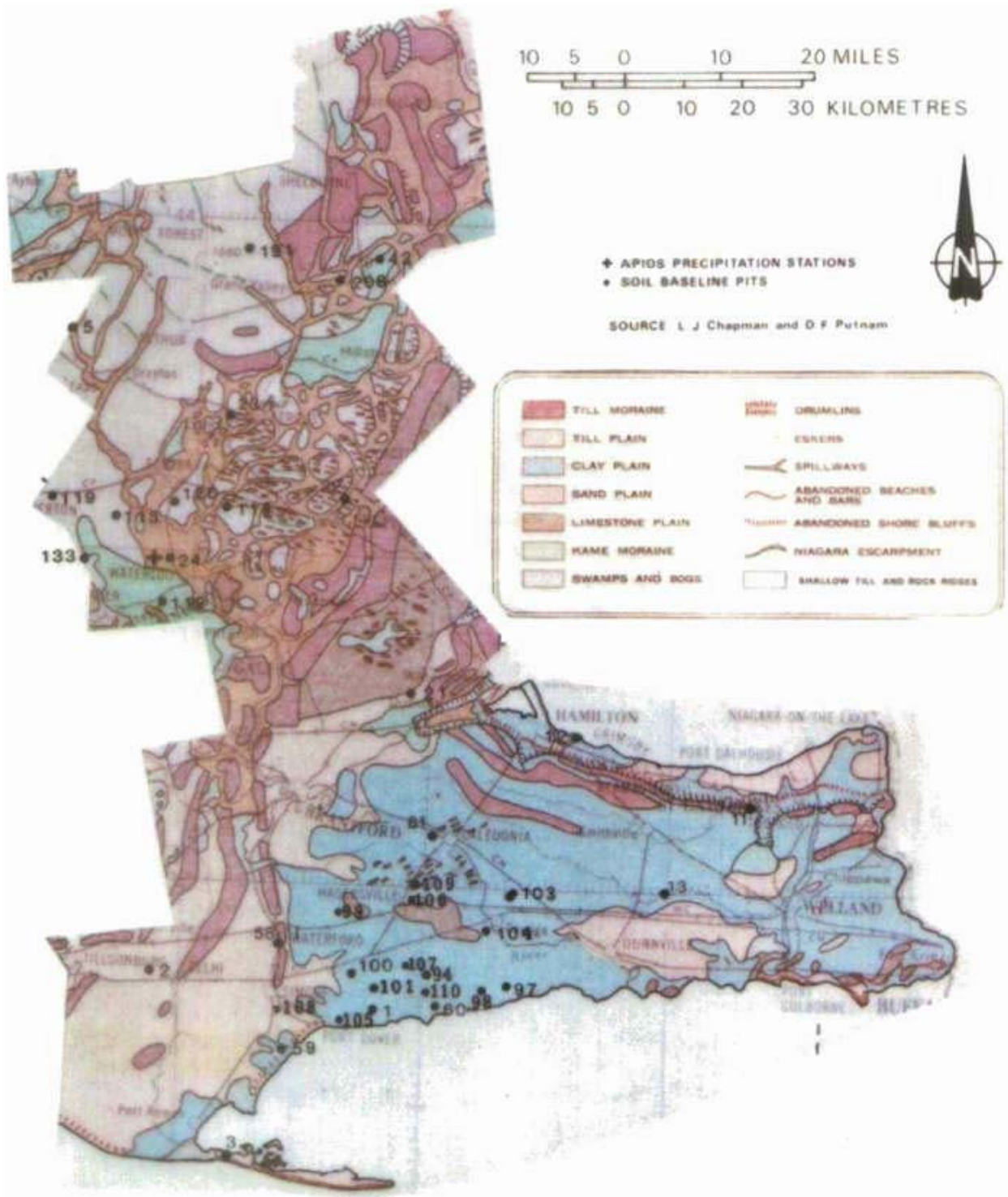
WEST CENTRAL REGION

Most of the region is underlain by Silurian dolomite and shales and Devonian limestones (Map 2). Rapidly weathering Ordovician shale borders the eastern perimeter.

The topsoil of the sand plain in the southwest is easily windblown and poorly buffered. It was once a delta formed by glacial Lakes Whittlesey and Warren. An extensive clay plain rich in silt lies between Lakes Ontario and Erie. These soils were originally deposited by the lakes then reworked by glaciers. Lacustrine beaches, wave-cut terraces, gravel bars and spits are associated with glacial Lake Iroquois between the escarpment and present Lake Ontario (Map 4).

Calcareous till covers the rest of the region to the north. The terrain often is hilly, with morainal deposits, eskers, gravel outwash plains, and sandy kames. Deep gravelly spillways run between fields of calcareous drumlins. Swamps and peatbogs are common in low lying areas throughout the entire region. Organic and waterlogged soils are associated with these wet areas.

The proximity of this area to the Great Lakes greatly modifies the climate. Frost-free days range from 180 in the south to 120 in the north. The average amount of precipitation is 82 cm for the region. The mean duration of snow cover ranges from 75 days in the south to 125 in the north.



MAP 4. Physiography Of West Central Ontario And APIOS Baseline Soil Pits.

The natural forest vegetation (Hosie, 1979) is deciduous in the south bordering Lake Erie and the western tip of Lake Ontario. The rest of the region is covered by a Great Lakes - St. Lawrence mixed forest. The region was settled early and deforested. More recently, there has been rapid urban expansion. As fields are now more prominent than forests, thicker Ah horizons might be expected in the soil.

Although the till at depth is mostly calcareous, the soils which develop on them are often acidic at the surface. In time, acidic precipitation could intensify the acidic nature of the soils and lower the level of the calcareous horizon. The deltaic sands in the south along Lake Erie are already quite susceptible to the loss of plant nutrients due to acidic precipitation. These soils have little organic matter and little natural buffering capacity.

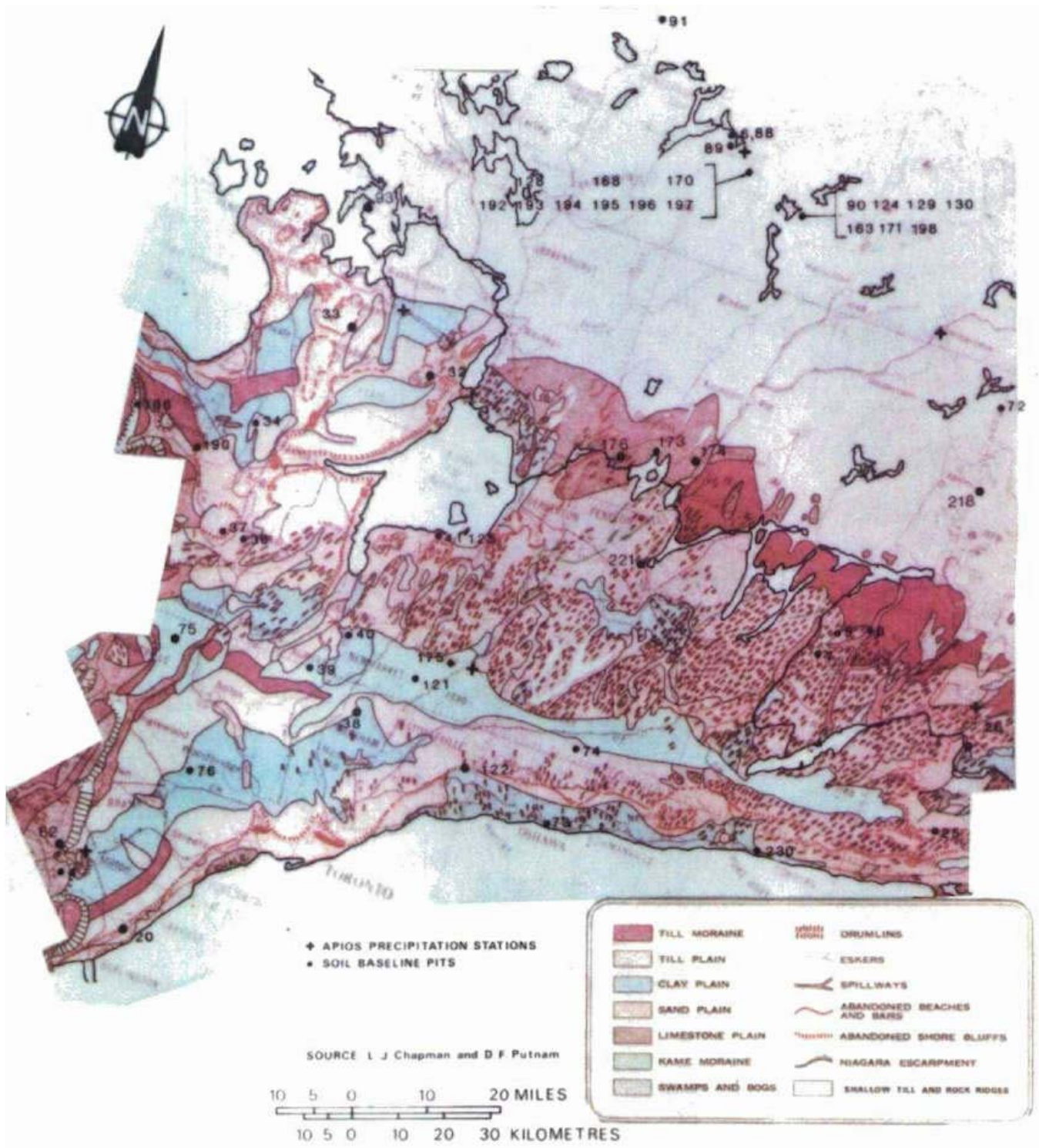
CENTRAL REGION

Silurian shale and limestone border this region to the west. Ordovician shale and limestone bedrock parallel the Silurian rock to the east. Ordovician limestones underlie the majority of the region to the east and north. All of Haliburton, Muskoka and the northern portions of Victoria and Peterborough counties are comprised of Precambrian bedrock (Canadian Shield) (Map 2). It is not uncommon to find large areas of exposed bedrock in this zone.

A narrow, gravelly calcareous shoreline of glacial Lake Iroquois runs parallel to Lake Ontario. Cliffs, beaches, bars and boulder pavements typify the area (Map 5).

A partially drumlinized till plain exists to the north. The till and its associated moraines, drumlins, eskers, and kames are subject to erosion by gullying. Small calcareous clay plains in the area are remnants of temporary glacial ponds or lakes.

North of the till plain are end moraines or kames. The land is subject to erosion. Aeolian (wind-blown) material occurs in pockets throughout the area. Along the northern edge of these end moraines are deep deposits of stratified (varved) lacustrine sediments. The hilly relief of the drumlinized till plain under these lacustrine clays and silts is often evident. There are thousands of highly calcareous drumlins and some gravelly eskers in this till plain near Peterborough. Clay may be found between the drumlins which were likely flooded by glacial lakes.



MAP 5. Physiography Of Central Ontario And APIOS Baseline Soil Pits.

Pockets of deltaic sands and bogs are quite common between Lake Simcoe and Georgian Bay. The till here is formed more from granitic bedrock than limestone. These soils vary from mildly acidic and therefore potentially sensitive to acidic precipitation, to calcareous.

The Shield area, in the northern part of the region, comprises shallow, sandy till and rock outcrops. Noncalcareous sand deposits from Lake Algonquin (Lake Huron, Georgian Bay) are found in this area. There are a few clay plains which are remnants of inland lakes or ponds. Spillways and some moraines are also evident. These noncalcareous sands provide little buffering capacity.

The proximity of this region to Lake Ontario in the south and Lake Huron to the northwest has a moderating effect on the climate. Annual precipitation is fairly uniform, 81-86 cm across the region. Even so, the clay soils are often deficient of moisture in the summer. Along the Lake Ontario shoreline frost-free periods are 1 to 2 months longer (180 days) than inland (120 days). Colder winters and later springs in the north can inhibit soil development.

The region has been so heavily urbanized in the south that little indigenous forest vegetation is left. A narrow band of deciduous forest (mainly birch, maple, black walnut, hickory and oak) occurs along Lake Ontario. The rest of the region is covered by the Great Lakes - St. Lawrence Forest, featuring red pine, eastern white pine, eastern hemlock, yellow birch, maple and oak (Hosie, 1979).

Urbanization, industrial expansion and agriculture have disturbed the natural development of soils in this region. Generally, however, in the till covered areas of the south the soil parent material is calcareous. This calcareous material provides considerable buffering at depth against acidic precipitation inputs. Water moving from the soil to aquatic systems should be mostly alkaline. Carbonate has been found to leach out of the upper horizons of the soils in a cool humid climate. In time, the soil may become acidic. The Leaching of cations may be a natural phenomenon but could also be accentuated as rain pH decreases.

The sandy, often thin soil deposits on the Canadian Shield have the potential to be affected by acidic precipitation with possible adverse effects on surrounding aquatic and forest ecosystems.

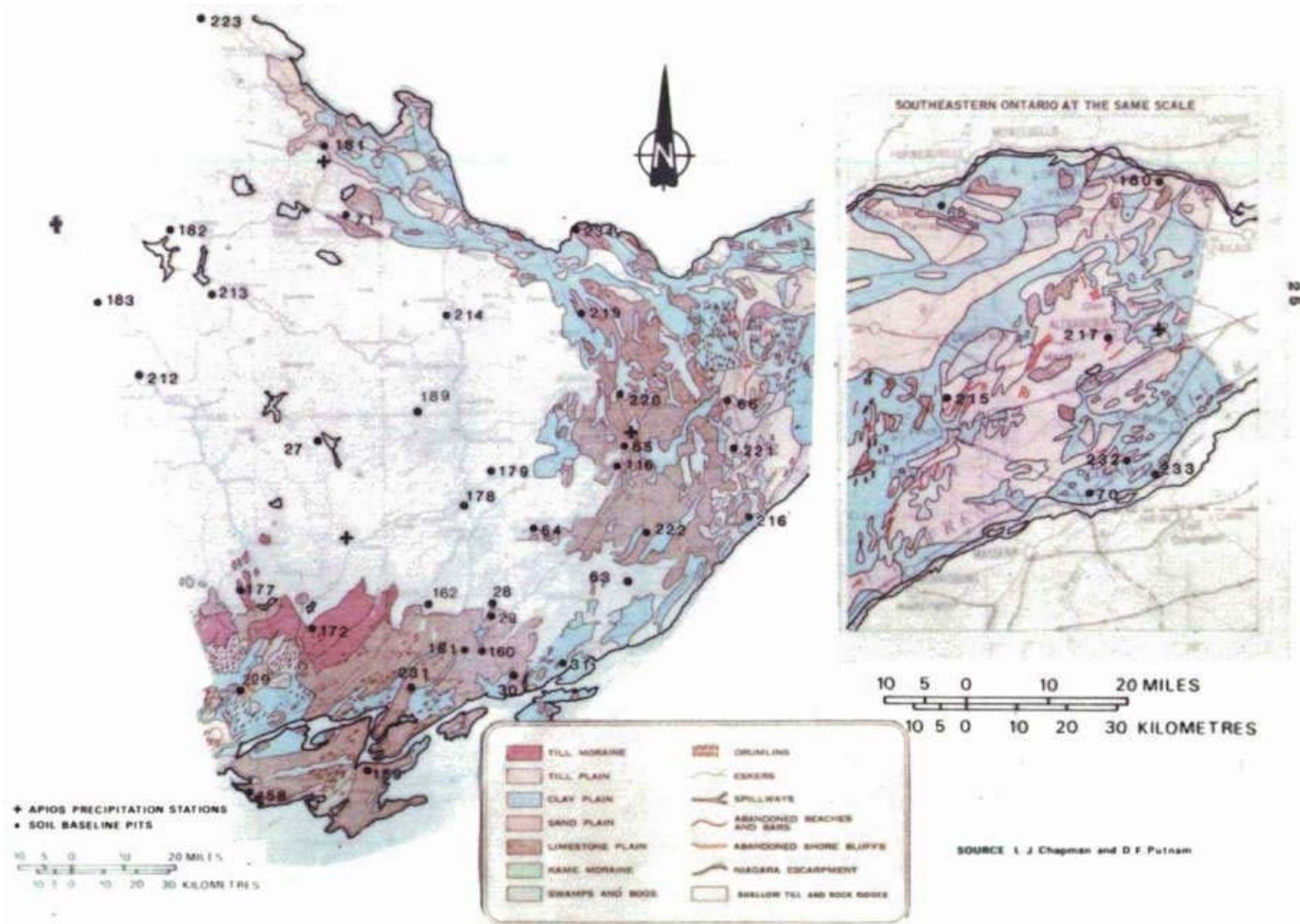
SOUTHEASTERN REGION

The bedrock in the southwest of this region is Ordovician limestone while Precambrian Shield predominates to the north and east. Ordovician sandstones and dolomite occur farther east. The remainder of the region is underlain by different ages of Ordovician shales and limestones (Map 2).

There are areas of active sand dunes and shallow, stoney till in the south (Map 6). Inland, a limestone plain continues to the north and east bordering Lake Ontario. The land is rough and stoney with both limestone and Precambrian Shield rock fragments in the moraines. There are sand and gravel-rich spillways and eskers and a drumlin field. Numerous clay plains occur interspersed over the limestone plain with some sand and gravel shorelines. The slightly calcareous clay plains were formed from freshwater glacial lakes and/or from the marine water of the Champlain Sea. According to Fairbridges (1968) the Champlain Sea formed when the glacier receded to the north of Lake Iroquois and admitted water from the Atlantic Ocean. The sea covered approximately 530,000 sq km in Ontario and Quebec.

The hilly northern portions of the region have thin, sandy, soils with numerous Precambrian rock outcrops. These soils are predominantly acidic in nature. Spillways and sand plains, which are remnants of glacial Lake Iroquois, as well as bogs and swamps, are scattered throughout this part of the Shield.

East of the limestone plain and south of the Shield, the topography is very hilly. Hills of Precambrian Shield rock protrude out of clay left from the Champlain Sea. The clay is slightly calcareous. Bogs are scattered throughout the area. Soils are acidic where drainage is good. Waterlogged soils exist in poorly drained areas.



MAP 6. Physiography Of Southeastern Ontario And APIOS Baseline Soil Pits.

There is an area of level glacial-fluvial sands to the east of Leeds County. The sands were spread out over bedrock and clay by the wave action of the Champlain Sea. As well as beach ridges and sand dunes, some glacial moraines are still evident. This flat area is poorly drained and there are many bogs. The soils are usually gleyed. Although the parent material has some carbonates, these poorly developed soils are mainly acidic.

A low plain bordering the St. Lawrence River to the east of the sands contains drumlins and drumlinoid features. This plain was covered by the Champlain Sea and there are still some clay flats and sand and gravel beaches remaining. North of the till plain is a low, flat, clay plain with the till protruding through in spots. This area is poorly drained and the soils are gleyed.

A large level sandplain to the north was once a delta built by the Ottawa River. This poorly drained soil is 5-10 meters deep and low in carbonates. Stony hills of calcareous till protrude through the sand intermittently. The gleyed soils of this area are generally quite acidic. Bogs are also common in this poorly drained area.

There is a wide range in frost free days, in response to the influence of Lake Ontario in the south and increasing altitude to the north. There are 160 frost free days in the south, compared to only 120 in the north of the region. Precipitation amounts vary as well, with an average of 86 cm in the south and 66 cm in the north, near Pembroke.

The Great Lakes-St. Lawrence Forest region covers the entire region. The principal tree species are red pine, eastern white pine, eastern hemlock, yellow birch, maple and oak. The region was settled in the late 1700's in the south and mid-1800's in the north. Most of the forest was removed for lumber and to prepare the area for agriculture.

The bedrock and parent material in the south is slightly calcareous. However, the cool, humid climate in conjunction with coniferous vegetation moves the soil towards natural acidic conditions by the leaching of bases. Although runoff may be acidic at the soil surface, it will likely be buffered, prior to reaching streams and lakes, where the bedrock and/or parent material is calcareous. The acidity at the soil surface may be altered by acidic precipitation inputs and have an effect on vegetation.

The sand plain in the east of the region is not calcareous and both aquatic and vegetation ecosystems could be affected by acid precipitation where the underlying limestone bedrock is not in contact with runoff. The soils of the Shield area are shallow, naturally acidic, and the bedrock offers very little buffering. Therefore, both aquatic and forest ecosystems are potentially sensitive to acidic inputs on the Shield.

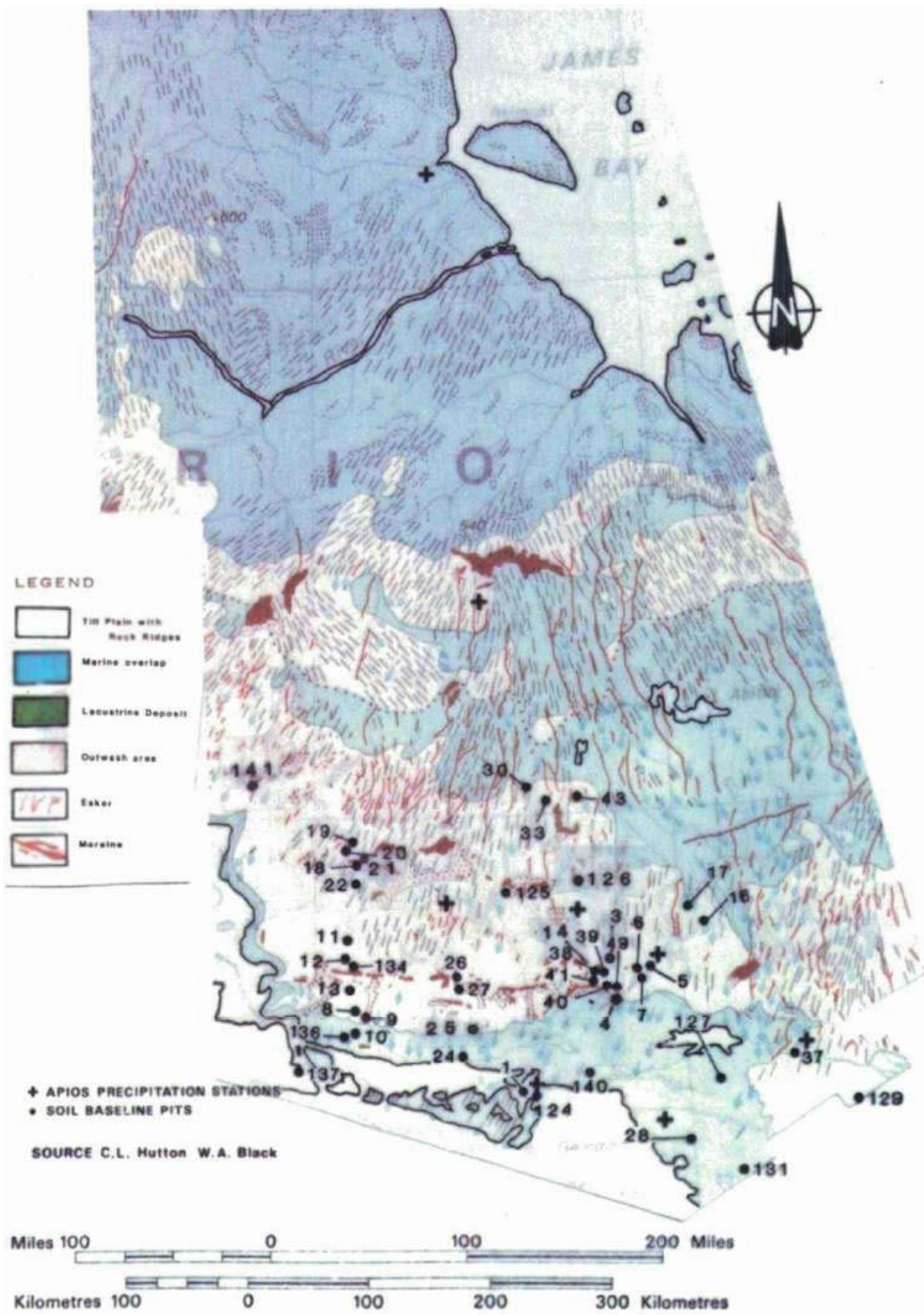
NORTHEASTERN REGION

In many parts of Northeastern Ontario bedrock is either exposed or is close to the surface. The area consists mainly of Precambrian igneous and metamorphic bedrock. Precambrian sedimentary deposits predominate in the eastern part of the region and along the north shore of Lake Huron. Volcanic rocks are also common throughout this area. Ordovician and Silurian limestones are found near James Bay. These limestones have had considerable influence on the soil chemistry of Northeastern Ontario. Limestone bedrock is also present in the New Liskeard area and on Manitoulin Island (Map 2).

According to Boissoneau (1966, 1968), a glacial lake (Lake Algonquin) was formed in the upper Great Lakes basin more than 11,000 years ago. Glacial meltwaters carrying suspended material flowed into this lake and these materials were deposited as the clay plains and sand deltas found in the southern part of the Northeastern region (Map 7).

A sandy glacial till was deposited in those areas not influenced by glacial lakes. However, as the ice front retreated, other glacial lakes were formed. The largest of these is known as Lake Barlow-Ojibway. Carbonate-rich clays and silts were deposited in this lake to form the area now known as the Northern Clay Belt. Sands were deposited in smaller lakes near Chapleau and to the east of Gogama.

In the southern part of northeastern Ontario, acidic soils have developed on the large areas of sandy tills and lacustrine sands. Except for organic soils, many of the soils in areas of lacustrine clays and silts contain substantial amounts of carbonates.



MAP 7. Physiography Of Northeastern Ontario And APIOS Baseline Soil Pits.

The climate of northeastern Ontario is modified by both the Great Lakes and James Bay. The mean annual precipitation varies from 65 cm in the north, to 86 cm in the south and mean annual temperature, from +1°C to +4°C.

The Great Lakes-St. Lawrence forest type predominates in the area bordering the Great Lakes. Red pine, eastern white pine, eastern hemlock, yellow birch, maple and oak are all found in this area. The Boreal forest covers the rest of the region. White spruce, black spruce, balsam fir, jack pine, white birch and trembling aspen dominate the middle of the region while white spruce, black spruce, tamarack and large unforested areas occur in the extreme north.

Although most of the soil types common to Ontario are represented in this region, the majority of the soils are sandy and acidic. Clay soils are associated with glacial lake beds such as the Northern Clay Belt. Sandy soils are more sensitive to acidic precipitation than those which are clay-rich.

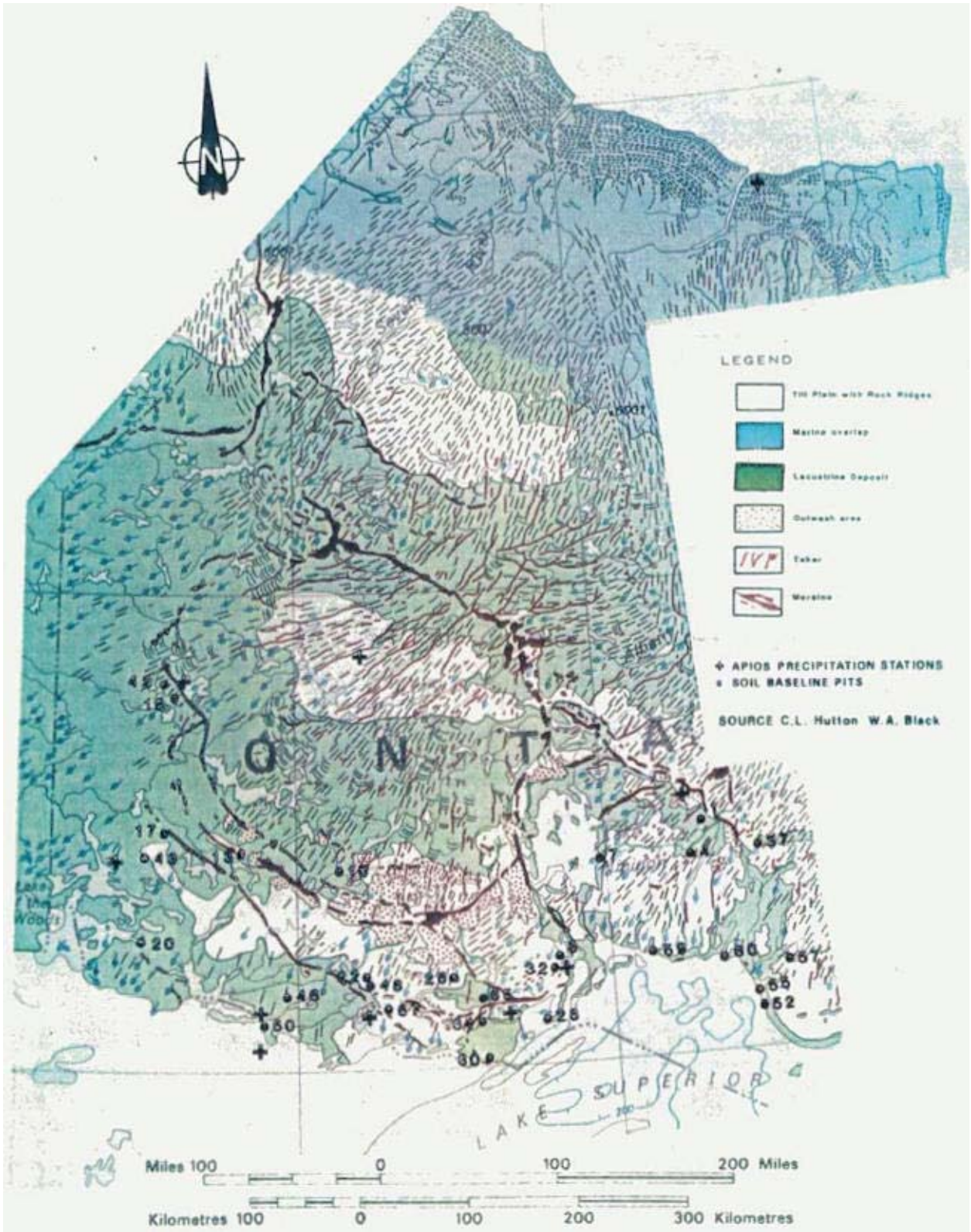
NORTHWESTERN ONTARIO

The Precambrian Shield is the major geological unit in the region and is made up of mostly igneous and metamorphic bedrock. Bedrock formations of Silurian and Ordovician limestones, sandstones, siltstones and shales occur in a block bordering Hudson Bay (Map 2). These rocks are generally high in carbonates and therefore have high buffering capacities.

The ice began retreating from southern parts of this region about 12,500⁺ years ago and some ice may have been present in northern areas as late as 5,000⁺ years ago (Prest, 1976). The entire area, therefore, has been much affected by glaciation and the effects are obvious (Map 8). These include exposed bedrock and other areas covered by glacial till and various water lain materials.

The area adjacent to Hudson Bay was scoured and abraded by the glacier and depressed by the weight of the ice. When the ice sheets receded this area was inundated by the Tyrell Sea for several thousand years. This has resulted in a mostly flat plain covered with marine deposits of clay, silt, sand and gravel. Other features include moraines, eskers, and even raised beaches as far as 270 km inland. Many of these glacial and marine deposits are derived from the sedimentary bedrocks of this area and have a high cation exchange capacity.

Once the glacier began to recede, large temporary freshwater lakes were formed. These glacier-fed lakes were present in this region for a period of about 4,000 years, from about 12,000 to 8,000 years ago. Lake Agassiz was formed in the west, and Duluth-Minong-Houghton Lakes in the Superior Lake Basin in the centre.



MAP 8. Physiography Of Northwestern Ontario And APIOS Baseline Soil Pits.

These lakes resulted in various features such as raised beaches, sand and gravel ridges and wave-cut bluffs. More importantly, however, are the large lacustrine deposits of sand, silt and clay that have resulted in flat areas sometimes suitable for agriculture (at Thunder Bay, Dryden, and Fort Frances) and which also produced some of the better forest soils. Extensive aeolian (wind blown) deposits of fine sands and silts also are present in areas such as Lac des Mille Lac, northwest of Thunder Bay. Considerable areas of organic peat soils have been deposited in poorly drained areas of the Shield.

The climate of the Northwestern region is continental. It is modified in the north by Hudson Bay and in the south by Lake Superior. In the coldest month, January, the temperature isopleths run from west to east and the mean daily temperature varies from -25°C in the north to -13°C in the south. In July, the warmest month, the trend is not north to south, but northeast to southwest, and in the northeast the mean is 12°C increasing to 19°C in the southwest. The area has cold winters and cool to warm summers. Precipitation patterns are more complex, with the lowest precipitation in the northwest (32 cm) and the highest in the southeast (90 cm). Most precipitation occurs as rain, but about one-third to one-half may fall as snow. The lowest mean maximum snow depths, 32 cm, are in the west, while the greatest, 76 cm, are in the east.

There is a gradient of vegetation in the region from almost treeless, tundra-like vegetation on the shores of Hudson Bay to a well developed, mixed conifer-deciduous forest in the south. Soils, while very important in the local distribution of plants, are seen as less important in plant distribution than climate on a larger scale. In the south of this region the Great Lakes-St. Lawrence Forest association is most prominent. It contains a number of hardwood tree species not found in the Boreal forest such as sugar maple, Manitoba maple, bur oak and much more white elm, black ash and red maple than are found to the north. The Boreal conifer forest predominates in the centre of this region.

This forest is a dynamic successional forest resulting from forest fires, which occur about every seventy to one hundred years, and more recently from logging. Various patterns develop after fires and logging, which produce an enormous mosaic of different-aged stands with different species compositions. Generally, though, black spruce is the dominant tree on thin acid soils of upland areas and also on inorganic soils of poorly-drained lowlands. Jack pine is widespread on well-drained gravel and sandy acid soils. On sites of undifferentiated glacial till, white spruce, balsam fir, white birch and trembling aspen are common tree species.

A number of shrubs, herbs, bryophytes, and lichens are also common constituents of these forests. Bordering Hudson Bay is a forest-tundra section with patches of stunted trees, usually black or white spruce, and open tundra-like areas of lichen heath, fens and bogs. In addition, there are huge areas of swamp, fen, bog and muskeg. On better drained sites trees such as spruces, balsam fir, trembling aspen, balsam poplar, and white birch occur.

The soils in the northern part of the region, around Hudson Bay, are mostly organic or waterlogged. In the Canadian Shield there are many rock areas devoid of soil. Most of the region, however, contains acidic sandy soils with clay-rich soils in the old glacial lake beds. The thin, sandy soils are more sensitive to acidic precipitation than the clay-rich, moderately buffered soils.

REFERENCES

- Bache, B.W. The Sensitivity of Soils to Acidification. *In: Effects of Acid Precipitation on Terrestrial Ecosystems*, T. Hutchinson and M. Havas (eds.) 1980, pp. 569-572.
- Birkeland, P.W. Pedology, Weathering and Geomorphological Research. Oxford Press, London, 1974, 285 pp.
- Boissonneau, A.N. Glacial History of Northeastern Ontario: I. The Cochrane-Hearst Area. Can. J. Earth Sci., 3, 1966, pp. 559-578.
- Boissonneau, A.N. Glacial History of Northeastern Ontario: II. The Timiskaming-Algoma Area. Can. J. Earth Sci., 5, 1968, pp. 97-109.
- Brown, D.M., McKay, G.A. and Chapman, L.J. The Climate of Southern Ontario. Study number 5, Environment Canada, 1980, 67 pp.
- Buol, S.W., Hole, F.D. and McCracken, R.J. Soil Genesis and Classification. The Iowa State University Press, 1973, 360 pp.
- Canada Soil Survey Committee, Subcommittee on Soil Classification 1978. The Canadian System of Soil Classification. Can. Dept. Agri. Publ. 1646. Supply and Services Canada, Ottawa, 164 pp.
- Chapman, L.J. and Putnam, D.F. The Physiography of Southern Ontario, 2nd edition, 1966, Ontario Research Foundation, 386 pp.
- Chapman, L.J. and Thomas, M.K. The Climate of Northern Ontario. Study number 6, Dept. of Transport, 1968, 58 pp.
- Clayton, J.S., Ehrlich, W.A., Cann, D.B., Day, J.H. and Marshall, I.B. Soils of Canada, Volume 1, Soil Report, Research Branch, Canada Department of Agriculture, 1977, 243 pp.
- Fairbridges, R.W. The Encyclopedia of Geomorphology, Reinhold Book Corporation, New York, 1968, 1,295 pp.

- Fitzpatrick, E.A. An Introduction to Soil Science. Oliver and Boyd Pub., 1972, 176 pp.
- Hosie, R.C. Native Trees of Canada, eighth edition. Fitzhenry and Whiteside Ltd., 1979, 380 pp.
- Hutton, C.L. and Black, W.A. Ontario Arctic Watershed, Environment Canada, 1975, 107 pp.
- Jenny, H. Factors of Soil Formation, McGraw-Hill, New York, 1941, 281 pp.
- Joffe, J.S. Pedology. Pedology Publ., New Brunswick, N.J., 1949, 662 pp.
- Leahey, A. The Soils of Canada from a Pedological Viewpoint. *In: Soils in Canada*. R.F. Legget (ed.). The Royal Society of Canada, Spec. Pub. 113, 1961, pp. 147-157.
- Ontario Institute of Pedology, Field Manual for Describing Soils, 2nd ed., 1982, 38 pp.
- Prest, V.K. Quaternary Geology. *In: Geology and Economic Minerals of Canada, Part B*. R.J.W. Douglas (ed.), Geological Survey of Canada, 1976, pp. 675-764.
- Webber, L.R. (ed.) Ontario Soils. University of Guelph, Ministry of Agriculture and Food, Pub. 492, 1975, 54 pp.
- Webber, L.R. and Hoffman, D.W. Origin, Classification and Use of Ontario Soils, University of Guelph, 1967, 58 pp.