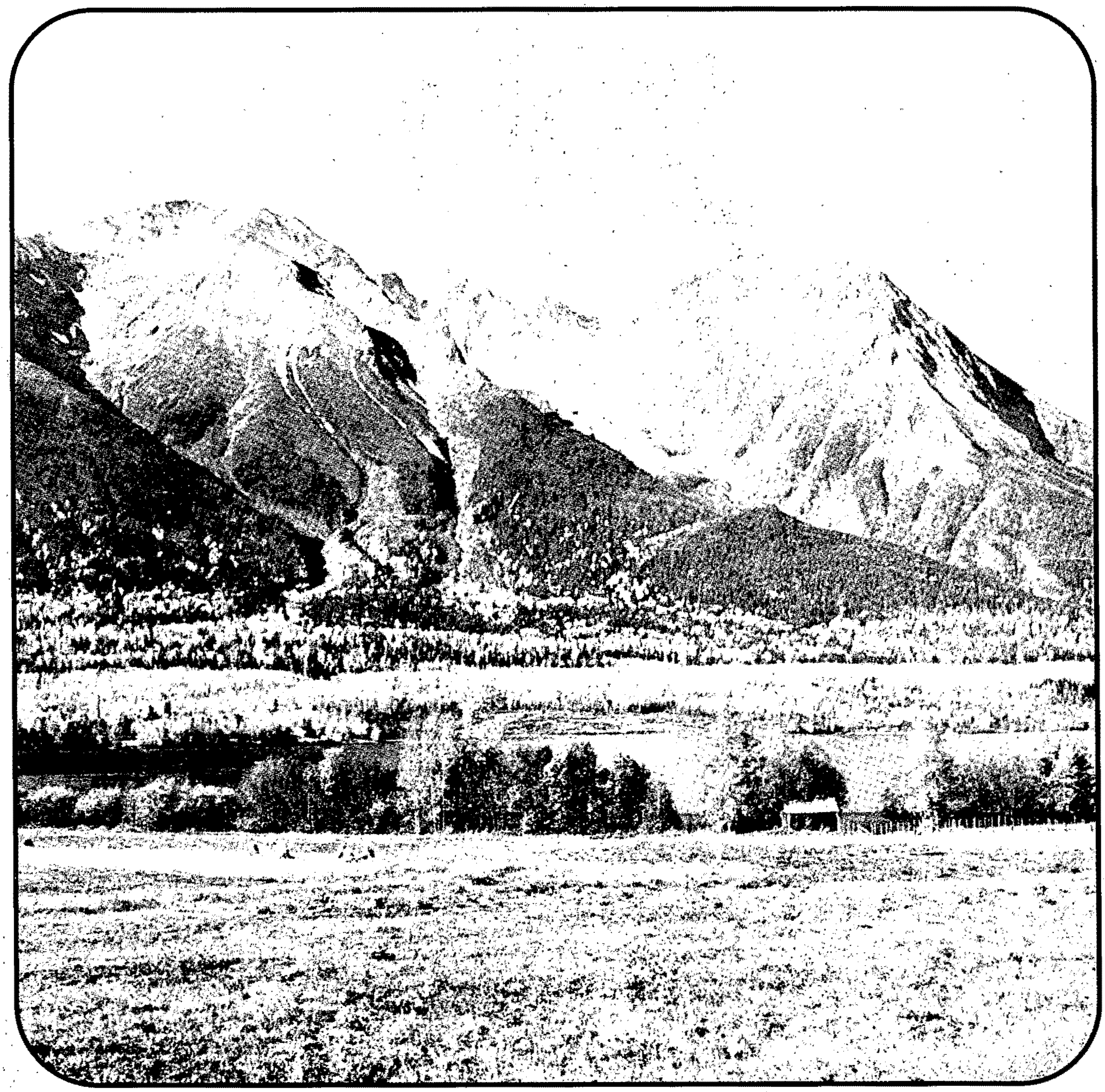
THE SOIL LANDSCAPES OF BRITISH COLUMBIA



Agriculture Canada

Province of British Columbia
Ministry of Environment

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THE SOIL LANDSCAPES OF BRITISH COLUMBIA

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Victoria, B.C.
1978
Reprinted August 1986

Canadian Cataloguing in Publication Data

Main entry under title:
The Soil landscapes of British Columbia

Includes bibliographies.
ISBN 0-7718-8265-3

1. Soils - British Columbia. 2. Landforms - British Columbia. I. Valentine, K. W. G. II. British Columbia. Ministry of Environment. Resource Analysis Branch.

S599.1.B7S64 631.4'9711 CP78-83284-1

LAN 991571.394

First Printing 1978
Second Printing 1981
Third Printing 1986
Fourth Printing 1994

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PREFACE

For a number of years now those of us working with soils in British Columbia have been approached with such questions as "where can I get a book on soils?" or "is there a book on the soils of British Columbia?" The problem was that people like foresters or engineers were trying to use soil survey reports and maps with no background information other than that which could be extracted from the very technical manual on the Canadian System of Soil Classification. Then in about the fall of 1975 it became obvious that we needed similar background information for all the tours through British Columbia that were to be run in conjunction with the XIth Congress of the International Society of Soil Science (Edmonton, Alberta, June 1978). So in the spring of 1976 there was a collective drawing in of breath and the work for this book was started. It is the product of a group effort on the part of many people over the following two years.

Throughout we have adopted a pedological landscape approach. The aim was to describe and explain the variety of soils that are found in the different parts of the province. To do this it was first necessary to describe the regional variation in climate, geology and vegetation because all these factors contribute to the present form of the soil. This has been done in Part 1. Then in Part 2 there is a discussion of what soil is, how it develops, how it is classified, and then a description of the nine main types of soil. Throughout the publication we have followed the 1978 Canadian System of Soil Classification. The principal descriptions of the geographical variation of soil are included in Part 3. For this purpose the province was divided into five regions based on physiography from Holland's 1964 publication on the Landforms of British Columbia. The soil unit that has been described is a "soil landscape". This has been defined as the total ecosystem with which a soil is associated, with emphasis placed on the soil itself. It could be used at any level of classification but here we have used it at the great group level. Lastly in Part 4 there is a brief history of soil survey in British Columbia. This has been included because it is often confusing to someone using soil survey reports and maps why work done in the 1950s does not correspond to work done in the 1960s or 1970s. It is because our survey methods and soil classification have changed through the years. Why and how they have changed is explained here.

We have tried to make the whole publication as readable as possible. Technical discussion has been kept to a minimum. However, some level of knowledge had to be assumed if the writers were to avoid defining every technical word they used. Therefore, we have aimed at the level of a second year undergraduate in earth sciences. This may mean that some parts are a little simple for soil scientists attending the I.S.S.S. Congress in Edmonton. Nevertheless, we hope that they will find something to interest them in the descriptions of the soil landscapes of a very varied and beautiful part of Canada.

A brief comment is also necessary regarding the plant names used. We wrestled with this one for a long while. The problem is that across Canada there is often no single accepted common name for a plant. We decided in the end to follow the recently published inventory of the Vascular Plants of British Columbia by Roy Taylor and Bruce MacBryde (UBC Press, 1977). The section on vegetation includes the scientific name as well as the common name, when it is first mentioned. All other sections use common names only.

This book is the product of a truly cooperative effort. The editors would like to thank the contributors for accepting with patience and responding with alacrity to all the badgering and modifications (suggested and dictated!) that were made over the two year period. There are also many other people who contributed but whose names do not appear on the Contents page. Their efforts are gratefully acknowledged now. Mariette Klassen and Jackie Scales did the typing. Bob Bierman drafted Figure 1.4.1, Alison Brookfield and Angus Weller drafted Figure 3.2.1 and Janet Etzkorn drafted all the other Figures and the black and white Plates. Boyd Porteous supervised the drafting and acted as a coordinator for the final stages. Crenagh Redmond proof read the final typing and located the oblique aerial photographs. Alex McKeague and Jack Shields made constructive suggestions on Part 2, and John Day arranged for the coloured Plates to be produced by the Graphics Unit, Agriculture Canada, Ottawa. Tony Blicq and Bert Farley arranged for UBC Press to provide the soil map of British Columbia from the Atlas of British Columbia (Figure 3.2.1). Roy Taylor checked the plant names and "Mac" MacCarthy undertook the agonizing task of giving the whole thing a final edit to attain some uniformity of english usage. The following agencies are also to be thanked for allowing their personnel to work on the project in addition to their normal duties: the Ministries of the Environment, Agriculture and Forests, Victoria, Agriculture Canada and the Department of the Environment, and the Soil Science Department, University of British Columbia.

Lastly we would like to provide a grain of salt with which to digest the information contained within these covers. Remember it represents only a stage in our knowledge of the soils of British Columbia. As more information becomes available in future years this publication will have to be revised. We look forward to receiving that information, and hope any future editors find it as interesting producing the revised publication as we did in producing this one.

K.W.G.V., P.N.S., T.E.B. and L.M.L.
Victoria, October 1977.

Part 1

The Environmental Factors

1.1 INTRODUCTION

T.E. Baker

Soils and man are products of their environment. Man inherits many of his characteristics from his parents and soils also reflect in their appearance and in the way they function the influence of the parent materials from which they have developed. Changes in the environment also cause differences to develop. All these factors result in the different soils and people we find. Therefore, we can think of soils as individuals. It is important to know what they are like and how they behave within a given environment.

To gain this understanding it is best to consider separately the components which make up the soil environment. Part 1 of this report gives basic information about climate, geology, physiography and vegetation. The remainder of the text describes the types of soils and regional soil landscapes that are found within British Columbia. The province has been divided into five regions based primarily on physiographic divisions as defined by S.S. Holland in a 1964 publication on the Landforms of British Columbia (B.C. Dept. Mines and Pet. Res. Bull. 48). These five physiographic regions are shown in Figure 1.1.1.

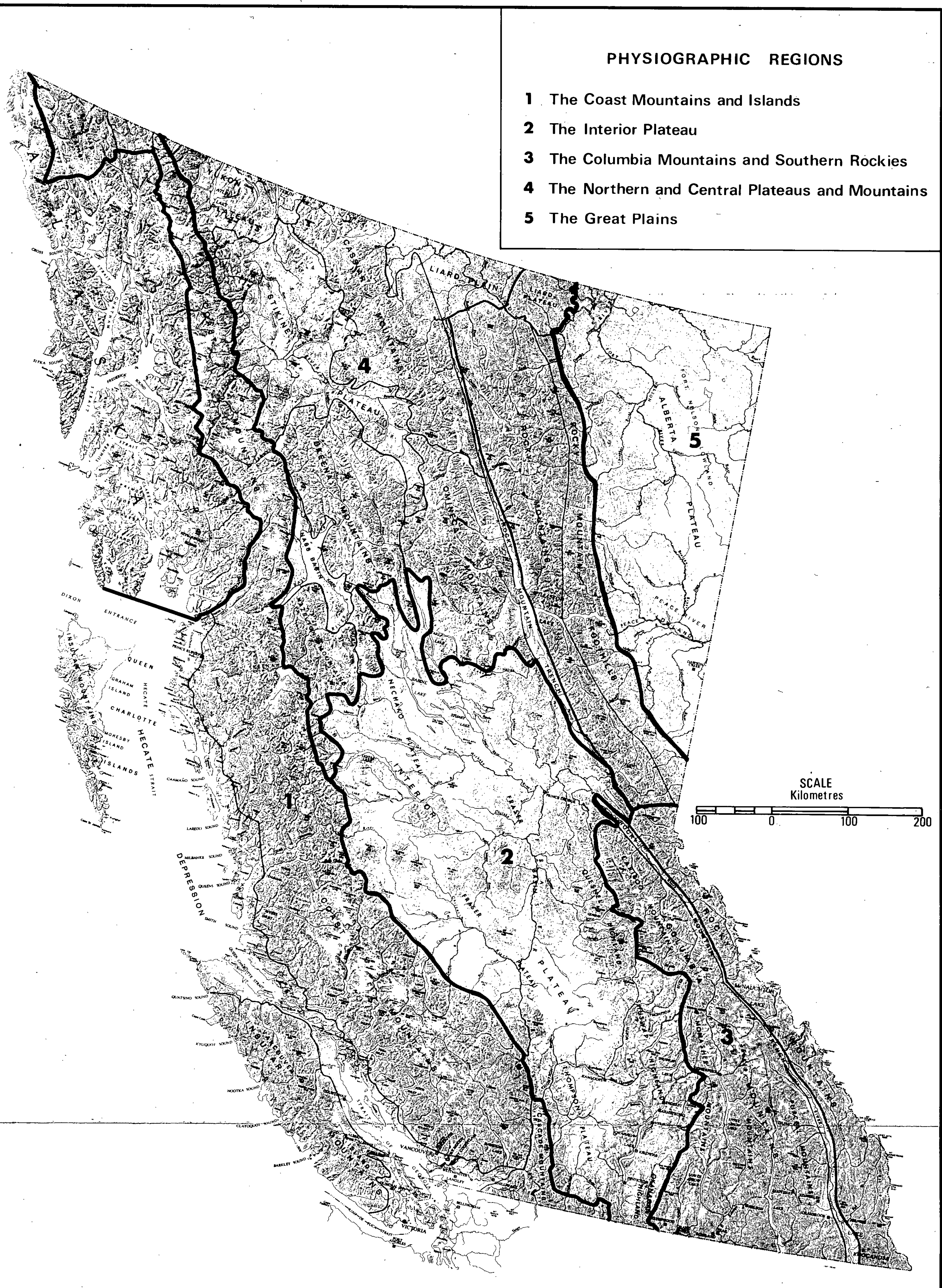


FIGURE 1.1.1 PHYSIOGRAPHIC REGIONS OF BRITISH COLUMBIA

1.2 CLIMATE

D.G. Schaefer

The climate of British Columbia varies enormously from place to place. On the macro-scale, climates associated with the major soil landscape regions (Part 3) are a product of geographical location and large scale topography. On the micro-scale, conditions at the earth's surface are modified by local physiographic factors such as slope, aspect and elevation. Micro-scale climates are also affected by vegetation and the condition of the soil itself through influences on the processes of evaporation and heat exchange.

The latitude of British Columbia places the province squarely in the zone of the westerly atmospheric circulation of the northern hemisphere. Its position on the western side of North America places it in proximity to the vast Pacific Ocean which is an immense reservoir of heat and moisture. The Pacific plays the dominant role in determining the climates of the province.

Innumerable winter storms born over the North Pacific Ocean develop rapidly, move in a northeasterly direction to the Gulf of Alaska and there weaken and die. Frontal systems which break away from the storm centres impinge upon the coastline and there face another major determinant of British Columbia climates; successive large-scale mountain barriers aligned in a northwest to southeast direction. Since these are roughly perpendicular to the mean winds aloft, they determine to a major extent the overall distribution of precipitation and the degree of dominance of Pacific air masses in relation to continental air masses in the various regions of the province. Weather systems carried by the prevailing westerly winds aloft drop considerable moisture as rain or, at higher elevations, as snow, when the air is forced up the west-facing slopes of Vancouver Island, the Queen Charlotte Islands and the Coast Mountains. The wettest climates of British Columbia are found in this zone. On the eastern slopes, the air descends and is heated by compression, causing the clouds to dissipate. The driest climates of the province lie in the valley bottoms in the lee of the massive coastal barrier. As the air again ascends the Monashee and Purcell Mountains, the Cariboo and Cassiar Ranges, and finally the Rocky Mountains, additional moisture is released with the heaviest precipitation falling on the west-facing slopes of each successive mountain barrier.

The mountain ranges are effective barriers to prevailing westerly winds, with particular emphasis on low-level moisture supply; they also block the westward passage of frigid continental Arctic air masses which dominate the winter season east of the Rocky Mountains. While the Great Plains region of northeastern British Columbia lacks this protection, other parts of the province experience varying degrees of shielding from the onslaught of Arctic air, increasingly so as one moves from east to west and from north to south.

In summer, the prevailing westerlies weaken. The climate then comes under the dominance of the large, semi-permanent Pacific anti-cyclone or high pressure centre which expands northward, greatly diminishing the frequency and intensity of Pacific storms and coastal precipitation. In the interior, spring is a season of decreased precipitation. About June, precipitation again increases as an interplay of factors, which include high rates of insolation and late spring surges of cool unstable air, produces strengthened convective activity, resulting in showers and thundershowers. In addition, a number of so-called "cold low" storms normally cross the province en route to the Great Plains. By mid-summer, these normally decline as the Pacific anti-cyclone develops its dominance over western North America.

Having described some of the macro-scale climatic controls at work over British Columbia, the question remains as to the characteristics of the resulting climates of the various soil landscape regions and, more particularly, how these are modified by physiography to produce the meso- and micro-climates that directly influence soil processes. Further, there is the question of the temperature and moisture conditions that exist within the soil layer itself. These are directly related to climatic conditions experienced above ground.

Temperature cycles near the soil surface follow those in the air with only slight lag. Deeper layers experience a much smaller range or amplitude of change with a lag of one or two months at depths of a few metres. Temperature changes penetrate more deeply in rock and wet sand than in wet clay and least of all in dry sand. In any case, temperatures below 5 or 6 m are essentially constant throughout the year. Soil moisture conditions are a function of gains through precipitation or snowmelt waters and losses by runoff and evapotranspiration. A discussion of the classification of soil temperatures and moisture regimes is included in Part 2.3 below.

The following sections deal separately with the five major regions of British Columbia. Table 1.2.1 provides selected climatic data for sites typifying those regions. Table 1.2.2 presents some contrasting values for stations at low and high elevations in certain regions.

TABLE 1.2.1

Selected Climatic Data for Major Soil Landscape Regions: Annual Means

Region	Stations	Precipitation (mm)	Evapotranspiration* (mm)	Snowfall (cm)	Temp. (°C)	Annual Range of Temp. (°C)	Bright Sunshine (Hrs.)
Coast Mountains and Islands	Vancouver Internat'l Airport	1068	490	52	9.8	15	1930
	Pr. Rupert	2415	613	113	7.8	12	1035
Interior Plateau	Summerland	296	295	74	8.9	25	1990
	Pr. George Airport	620	439	233	3.3	27	1865
Columbia Mountains and Southern Rockies	Cranbrook Airport	438	337	178	5.1	27	1800 E
	Revelstoke	1096	485	412	7.2	25	1600 E
Northern and Central Plateaus and Mountains	Dease Lake	394	347	187	-1.2	32	1750 E
	Germansen Landing	525	332	257	0.4	31	1755
Great Plains	Fort St. John Airport	450	383	206	1.3	33	2130
	Fort Nelson Airport	446	380	192	-1.3	40	1900 E

*Mean actual evapotranspiration from Phillips (1976), computed using the Thornthwaite water balance method, assuming a soil storage capacity of 100 millimetres of water.

E-Indicates values of sunshine in hours estimated from climatic maps.

THE COAST MOUNTAINS AND ISLANDS

The marine west coast climates of British Columbia have a relative lack of sunshine, moderate temperatures year round and heavy precipitation, with a maximum in the fall on the North Coast and in the winter on the South Coast. Extensive areas, particularly westerly exposures and higher elevations,

TABLE 1.2.2

Comparative Climatic Data for Selected Pairs of Stations at Low and High Elevation: Annual Means

Region	Stations	Elevation (m)	Precipitation (mm)	Snowfall (cm)	Temperature (^{o}C)
Coast Mountains and Islands	Hollyburn	46	1917	66	10.0
	Hollyburn Ridge	951	2939	811	5.1
Columbia Mountains and Southern Rockies	Trail	433	664	167	8.7
	Old Glory Mountain	2348	735	558	-1.9
	Golden	788	472	204	4.8
	Glacier	1248	1493	970	2.1
Northern and Central Plateaus and Mountains	McLeod Lake	704	629	334	1.8
	Pine Pass	933	2057	1322	0.6

receive in excess of 2500 mm of precipitation, making them by far the wettest parts of Canada. East-facing slopes and lowlands receive substantially less. Snowfall accounts for a small fraction of the annual precipitation near sea level. The mean annual range of temperature (i.e. the mean temperature of the warmest month minus that of the coldest month) in the outer coastal zone is the smallest in Canada at $10^{o}C$.

A distinct climatic zone must be recognized over the southeastern lowlands of Vancouver Island, the islands of the Strait of Georgia and the Fraser River estuary. These areas which lie in the rainshadow of the Vancouver Island Ranges and Olympic Mountains have climates approaching the Mediterranean type in that summers are normally dry and warm with a high number of hours with bright sunshine, defined by a condition in which no cloud screens the instrument from the direct rays of the sun. Mean annual temperatures are the highest in Canada at just over $10^{o}C$. The annual range of temperature of $15^{o}C$ indicates a slightly greater continental influence than on the outer coast. Precipitation amounts at sea level are as low as 650 mm, making this the driest region of the British Columbia coast.

Very different climates are encountered close to those described simply by moving to higher elevations. A transition takes place between moderate, rainy climates and colder, snowy climates. Mean temperatures decline 5^{O}C for every 1000 m increase in elevation. Summers become cool and short. Heavy snowpacks form in the winter and linger into mid-summer. In the extreme case extensive glaciers cover the higher peaks of the Coast Mountains.

The large amount of precipitation on the outer coast ensures that soils there are constantly moist. The small annual range of temperature implies slowly changing conditions within these moist soils. Frost is absent in any but extreme surface layers. Heavy snowpacks insulate soils from frost at higher elevations. In the lowlands surrounding the Strait of Georgia, warming and drying of the soil normally results in a mid- to late-summer moisture deficit estimated to range from less than 100 to about 200 mm depending on the site. Again, winter temperatures are moderate with frost penetration slight and infrequent.

THE INTERIOR PLATEAU

The Interior Plateau lies in the rainshadow of the towering Coast Mountains and Cascades. Precipitation in the semiarid valleys of the south averages as little as 250 to 350 mm annually. In the more open valleys to the north, amounts reach 400 to 600 mm. Over the rolling uplands, precipitation is considerably greater, reaching 750 mm or more. Precipitation is well distributed throughout the year with both a winter and a summer peak.

The continental nature of the thermal climate of the region is revealed by an annual range of temperature of 25^{O}C, double that on the coast. In southern valleys, this is a reflection of hot summers and moderate winters. In the uplands and in the north, it is more a reflection of cold winter conditions. Mean annual temperatures range from 10^{O}C in southern valleys to about 3^{O}C in the north and at higher elevations elsewhere. More than 1800 hr of bright sunshine are received annually over most of the Interior Plateau.

Aridity and summer heat are significant factors affecting the soil in southern parts of the region. Strong insolation makes this particularly true of south-facing slopes where very high soil temperatures can result. Further north and over higher ground, more moisture is available and summer heating is less pronounced. Summer moisture deficits are estimated to range from 400 mm in southern valleys to about 200 mm near Williams Lake and to only 100 mm near Prince George. The season of moisture deficit includes most of April to October in southern valleys, May to September near Williams Lake and June to August near Prince George. Moisture deficits are reduced and the season of deficit is shortened at higher elevations throughout the Interior Plateau. In winter, frost penetrates the soil to varying depths depending on location, depth of snow cover and type of material. In colder areas, frost penetration to a depth of 50 cm is common.

THE COLUMBIA MOUNTAINS AND SOUTHERN ROCKIES

Southeastern British Columbia is an area of great vertical relief with strong climatic gradients. Mountain slopes over which westerly winds must rise receive annual precipitation totals of 1500 to 2000 mm, second only to amounts on coastal slopes. About half of this precipitation falls as snow, leading to the maintenance of glaciers on higher peaks. The narrow valleys of the area are semiarid, receiving 500 to 750 mm, only slightly more than the parched valleys of the southern Interior Plateau.

Mean annual temperatures in the valleys of southeastern British Columbia are close to $5^{\circ}C$ in contrast to values of $10^{\circ}C$ for valleys further to the west. This is because the main valley bottoms are at progressively higher elevations as one moves from the Okanagan Valley to the Rocky Mountain Trench (this is illustrated incidentally in Figure 1.4.1) and because Arctic air readily invades valleys close to the Great Plains. Cold winters and cool summers lead to a mean annual range of $25^{\circ}C$, similar to that over the Interior Plateau. With around 1800 hr of bright sunshine per year, southeastern valleys are less sunny than those to the west which receive in excess of 1900 hr. Fewer hours of bright sunshine are received on higher terrain due to increased amounts of cloud. Sunlight is also significantly reduced on steep, north-facing slopes.

The great range of climatic conditions from the valleys to the mountain slopes of southeastern British Columbia dictate a similarly wide range of temperature and moisture conditions in the soils found there. Moisture deficits of 200 mm or more occur in valley bottoms in the southwestern part of the region. The season of deficit extends from June to September. Further east and north, valley bottom deficits of 100 to 150 mm are common. Over higher terrain, deficits are limited to a few tens of millimetres in July and August.

THE NORTHERN AND CENTRAL PLATEAUS AND MOUNTAINS

The northern interior has long, cold winters and short, cool summers with moderate precipitation which is well distributed throughout the year. Mean annual temperatures below $0^{\circ}C$ in the northern valleys with even lower values on the slopes indicate the severity of the climate. Precipitation in the valleys averages 400 to 500 mm per year. Up to 900 mm fall on much of the mountainous terrain, with more than half in the form of snow. Precipitation increases from west to east, culminating in a distinctly wet area in the Rocky Mountains northeast of Prince George. There the annual precipitation averages from 1500 to 2000 mm, including over 1000 cm of snowfall. It is estimated that an average of 1700 to 1800 hr of bright sunshine occurs over much of the northern interior.

Due to the short summer and the harsh winter, the soils in the region are frozen to considerable depth from late October to mid-April or May. Scattered permafrost exists in some of the most northerly areas. Although evapotranspiration rates are relatively low, the modest amounts of precipitation lead to summer moisture deficits of 100 mm in soils at low elevation sites removed from the Rocky Mountains.

THE GREAT PLAINS

The Great Plains region lies to the east of the Rocky Moutains and, therefore, has the most continental climate of any part of the province. What has already been said of the long, cold winters and short summers of the northern interior also applies here. Since the summers are somewhat warmer east of the Rockies, the mean annual range of temperature exceeds 30°C over most of the area and reaches 40°C in the extreme northeast, which is only slightly less than the greatest range observed in Canada. Annual temperatures average just above 0°C in the Peace River basin and a few degrees lower in the Fort Nelson basin and over higher terrain. Precipitation over the Great Plains is moderate, averaging only 400 to 500 mm per year. Maximum rates occur during the mid-summer growing season, another continental feature of the climate of the area. Solar radiation is plentiful. Fort St. John has an annual average of over 2000 hr of bright sunshine, closely rivalling Victoria as the sunniest location in British Columbia.

Despite the peaking of the distribution of precipitation in summer months, high insolation and relatively high temperatures in that season produce sufficient demand for water for evapotranspiration to lead to a significant water deficit. Exposed soil surfaces tend to be warm and dry during mid to late summer, particularly on south-facing slopes. Estimated summer moisture deficits of 150 mm occur in the lower elevation terrain of the region. However, the summer is short. As in other parts of northern British Columbia, cold winter temperatures soon lead to frost penetration to depths of several metres, particularly in the Fort Nelson basin where scattered permafrost exists.

FURTHER READING

Atmospheric Environment Service, Canada Department of Fisheries and the Environment - numerous publications including climatic maps, normals and data summaries.

Details regarding these various data sources are available from the Atmospheric Environment Service.

Bryson, R.A. and F.K. Hare, Editors, 1974. World Survey of Climatology: Volume 11, Climates of North America, Elsevier, New York. 420 pp.

An in-depth volume including descriptive material but with considerable technical detail.

Chapman, J.D., 1952. The Climate of British Columbia, paper presented to the Fifth British Columbia Natural Resources Conference, University of British Columbia, February 27, 1952. 47 pp.

A readable paper presenting basic information on climatic controls but with emphasis on a description of the climates of the regions of British Columbia.

Hare, F.K. and M.K. Thomas, 1974. Climate Canada, Wiley, Toronto. 256 pp.

This text contains sections dealing with basic theory, regional climates, applications and meteorological services along with numerous tables of data. A readable and useful reference.

Phillips, D.W., 1976. Monthly Water Balance Tabulations for Climatological Stations in Canada, DS No. 4-76, Atmospheric Environment Service, Toronto. 6 pp plus tables.

A brief paper describes the method. The complete set of tables (only a selection are included in the paper) provides a valuable source of information on soil moisture surplus and deficit conditions across Canada. Details can be obtained from the Atmospheric Environment Service.

Williams, G.P. and L.W. Gold, 1976. Ground Temperatures, Canadian Building Digest, Division of Building Research, National Research Council of Canada, Ottawa. 4 pp.

A brief paper oriented toward building design which also provides basic information on the behaviour of the sub-surface temperature regime.

The mineralogical composition of a rock determines its susceptibility to chemical weathering, since minerals differ in their resistance to chemical attack.

A geological map of the province (see: Douglas, R.J.W. in Further Reading) shows many different rock types arranged in an intricate pattern. Even on a simplified map (Figure 1.3.1) the outcrop distribution is complex and does not correspond very closely with physiographic regions. Accordingly, in order to avoid duplication, the following descriptions are arranged by rock type rather than by physiographic region. The geology of each physiographic region is shown in Figure 1.3.1 and Table 1.3.1.

INTRUSIVE IGNEOUS ROCKS (PLUTONIC)

These are typically coarse crystalline rocks that in British Columbia range from syenite, through granitic types, to diorite. They occur in a variety of forms ranging from simple stocks, where outcrop area may be tens or hundreds of square metres, to the huge, complex batholith of the Coast Mountains.

Despite variations in mineralogical composition, plutonic rocks tend to be associated with a particular type of terrain. They are relatively resistant to weathering since they are composed largely of durable minerals (quartz, hornblende, feldspar) arranged as a cohesive fabric of interlocking crystals. As a result, slopes on these rocks are generally steep and topography is rugged. Spectacular, glacially formed cliffs survive with little modification, especially in massive or sparsely jointed rocks. Joints, and less commonly, faults, constitute lines of weakness and are followed by cliffs, gullies and major depressions.

However, despite their relative resistance to weathering, some disintegration and decomposition of plutonic rocks inevitably occurs. Mechanical breakdown due to processes such as frost shattering tends to produce relatively large fragments due to the wide joint spacing. Extremely coarse rubble on colluvial slopes and large boulders in till are characteristic of this terrain type. A combination of physical and chemical weathering typically causes granular disintegration. Olivine, pyroxene and calcic feldspar are most susceptible to attack by chemical weathering; crystals of quartz and potash and sodic feldspar are released to form a sandy or gritty residue. Although in most parts of the province the span of post-glacial time is too short for much chemical weathering to have occurred, weathered rock residue of long interglacial periods forms a major portion of the tills and other drift of the last glaciation. Sandy and gritty tills and much sandy outwash are thus associated with areas of coarse crystalline rocks.

1.3. GEOLOGY, LANDFORMS AND SURFICIAL MATERIALS

June M. Ryder

INTRODUCTION

The physical landscape of British Columbia is composed of a great variety of landforms and materials. It ranges from spectacular, soaring peaks in the Rocky Mountains, to alluvial plains in the Lower Fraser Valley and lava plateaus in the central interior. This section describes, and to some extent attempts to explain, the distribution of bedrock types, landforms and surficial materials - unconsolidated sediments that have been deposited in geologically recent time.

The present landforms of British Columbia and the nature and distribution of surficial materials have resulted from the interaction of three factors - rock type, tectonic history and climate. The reaction of bedrock to weathering and erosion influences the character of associated landforms and surficial materials. Tectonic history is the sequence of earth movements that have brought about the gross arrangement and relative elevation of major topographic elements. Climate controls weathering, erosion and deposition (geomorphic processes) and the rates at which they operate. The history of climatic change is also recorded in the landscape.

To discuss the resulting complex physical landscape, physiographic regions are delimited. Each of these consists either of a relatively uniform landscape or a repeated pattern of associated landforms. The landforms within such regions are commonly underlain by related bedrock types and have undergone the same geomorphic history. British Columbia has been divided into five physiographic regions as shown on Figure 1.1.1.

GEOLOGY

The landforms that develop upon a particular kind of bedrock are related to its structural features such as bedding planes, joints, folds and faults, and to its mineralogical composition. Rock structure determines both major landforms and details of the landscape. For example, the straight, steep-sided section of Fraser Valley between Boston Bar and Lillooet is fault-controlled, or the size of rock fragments on a talus slope is related to the spacing of joints and bedding planes on the cliff above. The rate of physical weathering or mechanical disintegration of a rock, is influenced by the presence of lines of weakness and pore spaces that allow water, air and temperature changes to penetrate beneath the surface. Thus, densely jointed rocks such as basalt, or very porous material such as sandstone, are more readily fractured than massive, sparsely jointed granites.

TABLE 1.3.1 Geology and structure of the major physiographic regions.

MAJOR PHYSIO-GRAPHIC REGIONS	PHYSIOGRAPHIC SUBDIVISIONS (HOLLAND)		GEOLOGY AND STRUCTURE
COAST MOUNTAINS AND ISLANDS	Outer Mountain Area	Saint Elias Mountains	granitic and metasedimentary rocks
		Queen Charlotte Mountains	granitic and volcanic (basic and intermediate) rocks
		Vancouver Island Mountains	folded sedimentary and metamorphic rocks with granitic batholiths
	Coastal Trough	Hecate Depression	flat or gently dipping basaltic lavas and sedimentary rocks; a few granitic intrusions
		Georgia Depression	sedimentary rocks with scattered volcanic rocks and Quaternary sediments in Fraser and Nanaimo lowlands; granitic rocks in northeast
	Coast Mountain Area	Coast Mountains	granitic (chiefly granodiorite and quartz diorite) rocks with minor gneiss and schist
		Cascade Mountains	folded metasedimentary and volcanic rocks with granitic batholiths
INTERIOR PLATEAU	Interior Plateau	Nechako Plateau	flat or gently dipping volcanic rocks with a few granitic stocks
		Fraser Plateau and Basin	flat or gently dipping basaltic flows
		Thompson Plateau	flat or gently dipping lavas; sedimentary and volcanic rocks, granitic stocks and batholiths
		Quesnel Highland	schistose metamorphic rocks with minor volcanic and sedimentary rocks
		Shuswap Highland	gneiss and schistose metamorphic rocks
		Okanagan Highland	metamorphic rocks (chiefly gneiss) with granitic intrusions
COLUMBIA MOUNTAINS AND SOUTHERN ROCKIES		Rocky Mountains (south)	folded and faulted sedimentary and metasedimentary (chiefly limestone, quartzite, schist and slate) rocks
		Rocky Mountain Trench (south)	chiefly Quarternary sediments
	Columbia Mountains	Purcell Mountains	folded sedimentary and metamorphic rocks (chiefly quartzite, argillite and limestone) with granitic intrusions
		Selkirk Mountains	folded sedimentary and metamorphic rocks with granitic stocks and batholiths
		Monashee Mountains	folded sedimentary and metamorphic (chiefly gneiss) rocks with intrusions
		Cariboo Mountains	folded sedimentary and metamorphic rocks
NORTHERN AND CENTRAL PLATEAUS AND MOUNTAINS		Rocky Mountain Foothills	folded sedimentary rock (limestone, siltstone, sandstone and shale)
		Rocky Mountains (north)	folded and faulted sedimentary and metasedimentary rocks (chiefly limestone, quartzite, schist and slate)
		Liard Plateau	folded sedimentary rocks
		Rocky Mountain Trench (north)	chiefly Quaternary sediments
	Northern Plateau and Mountain Area	Liard Plain	sedimentary rocks
		Yukon Plateau	folded sedimentary and volcanic rocks with granitic intrusions
	Central Plateau and Mountain Area	Cassiar Mountains	granitic core surrounded by folded metamorphic and sedimentary rocks
		Omineca Mountains	granitic core surrounded by folded sedimentary, metamorphic and granitic rock
		Stikine Plateau	folded and non-folded sedimentary and volcanic rocks with minor intrusions
		Skeena Mountains	folded sedimentary and metasedimentary rocks (argillite, shale and greywacke)
		Nass Basin	sedimentary and volcanic rocks
		Hazelton Mountains	sedimentary and volcanic rocks intruded by small granitic stocks and batholiths
THE GREAT PLAINS	Interior Plains	Fort Nelson Lowlands	flat and gently dipping shale and sandstone
		Alberta Plateau	flat and gently dipping shale and sandstone

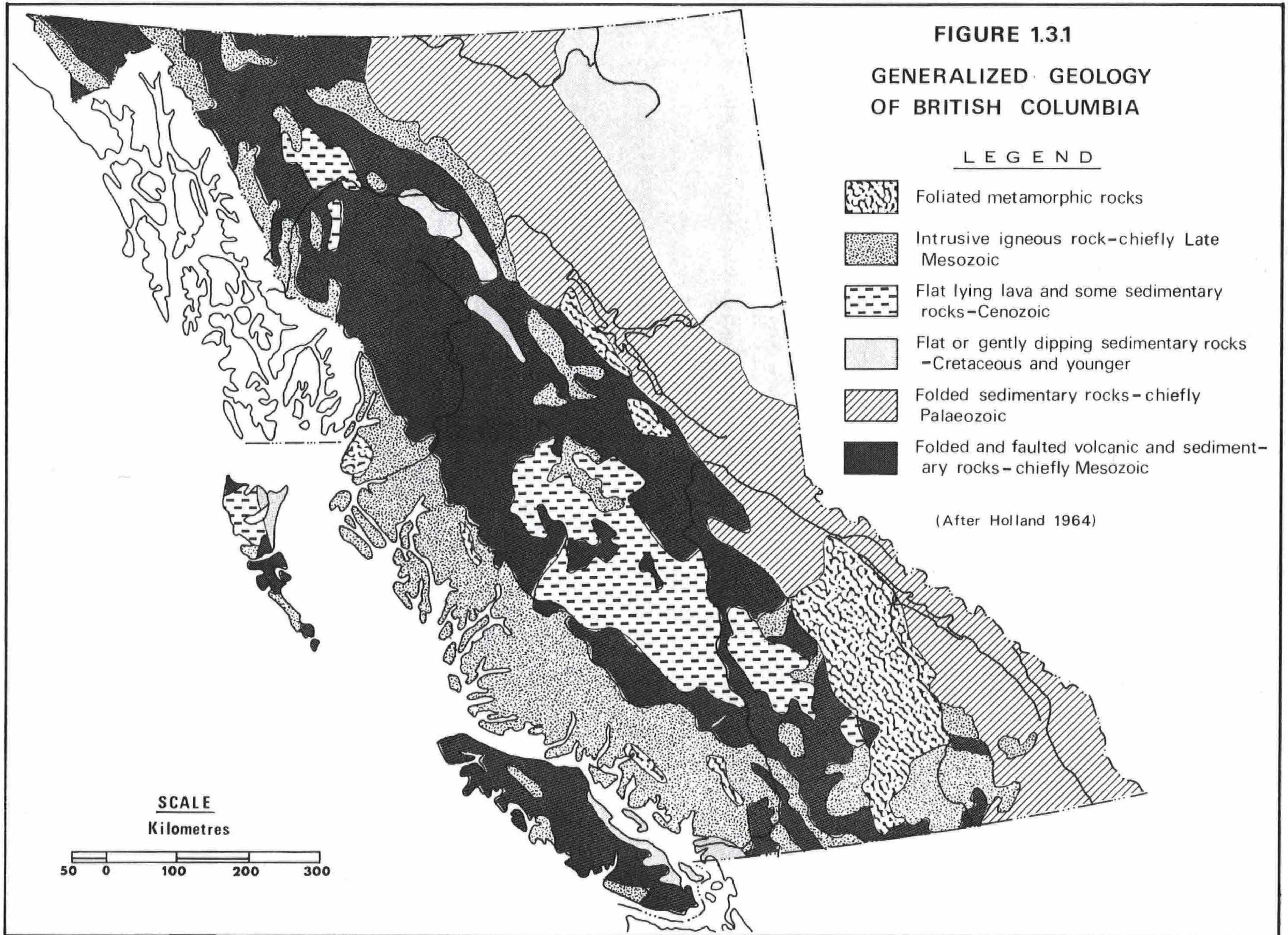


FIGURE 1.3.1

GENERALIZED GEOLOGY OF BRITISH COLUMBIA

SEDIMENTARY ROCKS

The resistance of sedimentary rocks to weathering and erosion depends upon many factors, but of prime importance are mineralogical composition, degree of induration, i.e. the hardening due to cementation, pressure and heat, and the spacing of bedding planes and joints. Poorly indurated rocks, such as clay, mudstone and shale, disintegrate readily and are easily eroded. Well indurated, massive sandstones, particularly quartz sandstones, and conglomerates are relatively resistant to erosion. Limestones generally form upstanding topography and also appear to be relatively resistant.

Horizontally bedded, alternating resistant and less resistant strata give rise to plateau and escarpment, or mesa-like topography. Stepped slopes are also characteristic, with steep "risers" of resistant rock, and gently sloping or flat "treads" of non-resistant strata. Terrain of these types occurs in the Great Plains region of northeastern British Columbia. Where the strata are dipping, asymmetric ridges (cuestas) are formed where the harder rock outcrops. Ridges and intervening valleys run parallel to the strike of the rocks and thus topography has a pronounced "grain" or linearity. Terrain of this type is found in the foothills of the Rocky Mountains.

Physical disintegration of sedimentary rocks produces fragments of a size related to the spacing of lines of weakness in the bedrock. Thus shales, which are thinly bedded, produce small, platy particles that readily disintegrate further. At the other extreme, massive conglomerates may shed huge blocks which survive intact during glacial transport.

Weathering of sedimentary rocks also results from chemical removal by solution or other means, of the cementing agent. Simple disintegration of the rock then occurs, forming a residue that is texturally similar to the original sediment. In British Columbia, products of weathering are mixed with products of glacial abrasion in the surficial materials. Thus, for example, clay tills overlie shales, and sandy tills overlie sandstones and conglomerates. Silica-cemented rocks such as sedimentary quartzites resist this effect and are extremely hard and durable.

In terrain developed upon faulted, folded and steeply dipping sedimentary rocks, there is a strong relationship between rock type, structure, and the ensuing topography. In belts of intense folding and faulting such as the Rocky Mountains, structures are expressed as strongly linear topography. Individual ridges or mountains are commonly asymmetric with steeper scarp and gentler dip slopes; dips of over 45° produce extremely jagged ridges. Prominent cliffs commonly coincide with fault planes or steep bedding planes.

VOLCANIC ROCKS

Topography upon these rock types tends to be similar to that developed upon sedimentary rocks of similar structure. Flat-lying lava flows form plateaus bounded by escarpments and stepped hillsides. Terrain of this type is widespread in south-central British Columbia.

Most of the relatively undeformed volcanic rocks in the province were erupted from fissures and shield volcanos during Tertiary time. Basalts, andesites and pyroclastic rocks (air-fall deposits) are probably most common. The lavas are fine textured and closely jointed. Basalt typically displays regular columnar jointing.

Mechanical weathering of lavas and pyroclastic rocks proceeds in accordance with the arrangement of fracture planes. The presence of open vesicles or spaces left by gas bubbles in many lavas, gives additional opportunities for weathering attack. The physical weaknesses which augment mechanical disintegration also affect chemical weathering. Basalt, consisting of plagioclase feldspar, pyroxene and olivine, is most susceptible, and rhyolite (quartz and feldspar) least susceptible to decomposition. With sufficient time, basalt breaks down completely to clay minerals. The weathering products of lavas are generally fine textured and result from the combined effects of chemical and mechanical weathering.

METAMORPHIC ROCKS

No particular type of terrain can be ascribed to metamorphic rocks in general. Their resistance to weathering and erosion depends upon their individual characteristics.

Many metamorphic rocks such as gneiss and schist are foliated, that is, the minerals are segregated into bands within the rock. As a result, differential weathering may produce linear topographic features as in the Omineca Mountains and Finlay Ranges. Metamorphosed sedimentary rocks such as marble and quartzite commonly retain their original bedding and fold structures which control their topographic expression. Metamorphic quartzites are extremely resistant to weathering and form some of the highest peaks in the Columbia Mountains.

Gneissic terrain occurs in the highlands along the southeastern margin of the Interior Plateau. Weathering products are similar to those of coarse textured igneous rocks of the same composition. Schists occur in the Quesnel Highlands, and elsewhere in association with plutonic rocks; they are broken down relatively rapidly by weathering, and produce strongly linear or stepped topography.

TECTONIC HISTORY

A brief account of tectonic history is necessary here, since the major topographic features of the province are tectonically controlled and many mountainous areas owe their present high elevation to recent uplift, rather than resistance to erosion.

The mountain systems of the province have been built during several episodes of mountain building since late Precambrian time. Successive episodes have tended to emphasize already established structural trends. Two great crystalline belts, the Coast-Cascade Mountains and the Cassiar-Omineca-Columbia Mountains, have been the sites of repeated uplift, deformation and igneous intrusion.

The features of the present landscape emerged during the Cenozoic Era (Table 1.3.2). Folding and thrusting of geosynclinal sediments to form the Rocky Mountains occurred roughly 70 to 35 million years ago. The Coast and Omineca belts also experienced re-elevation at this time. During mid-Eocene time, fissure and shield volcano eruptions produced the first of the two sets of lavas that cover much of the Interior Plateau.

The mid-Tertiary was an erosional interval during which the general outline of present day drainage began to emerge. An erosion surface of 450 to 600 m relief was formed over most of the area lying west of the Rockies. During Miocene time the second phase of vulcanism occurred. There were renewed fissure and shield volcano eruptions and lava spread over parts of the mid-Tertiary erosion surface. The Plateau Basalts, now a prominent landscape feature of the Thompson Plateau, date from this time.

General uplift followed, resulting in differential elevation of the erosion surface and its superposed lavas. It was upwarped along the old Coast and Omineca axes and along the Insular Mountains. The erosion surface constitutes the oldest landform that is preserved today. Over large portions of the Interior Plateau it was modified only slightly by glacial processes. However dissection by rivers has been severe around the plateau margins, whilst in bordering mountains, isolated remnants of flat or gently sloping terrain and accordant summit levels are all that remain. Parts of the upland surface survive on interfluves in the Insular Mountains of central Vancouver Island.

QUATERNARY HISTORY

The geomorphic and climatic history of British Columbia during the Quaternary Period is of greatest significance with regard to present day landforms and surficial materials. Climatic fluctuations during the Pleistocene brought about alternating glacial and longer nonglacial intervals (Table 1.3.2). There is geological evidence for up to four glaciations in British Columbia. However, it is likely that there were additional glaciations for which no local evidence is available, since more complex Pleistocene sequences are preserved in other parts of northern North America.

In British Columbia, sediments that predate the final deglaciation do not outcrop over sufficiently extensive areas to warrant attention here. Accordingly, the following description is restricted to the effects of the last, the Fraser or late-Wisconsin, glaciation and postglacial geomorphic processes. During the Fraser Glaciation ice accumulated in the high mountains of the Cordillera. Glaciers that were several kilometres wide and over a thousand metres deep occupied the main valleys in the mountains. An unbroken ice-sheet covered interior plateaus and thick glacier tongues coalesced along the coast. The Keewatin part of the Laurentide ice-sheet extended into the Great Plains region of northeastern British Columbia. Figure 1.3.2 shows ice-flow directions and other features of the Fraser Glaciation.

The effects of total erosion by all Pleistocene glaciers are widespread, and most apparent on high plateaus and mountains. Several distinct modes of erosion and associated landforms can be identified. True alpine glacial topography is found in mountains that contained glaciers, but were not totally covered by ice; horns, arêtes, and cirques are diagnostic features of this type of terrain. Where mountainous topography was overridden by ice, glacial erosion produced typically rounded summits and ridge crests. Landscapes are commonly found which consist of a combination of these two terrain types where cirques and glacial troughs exist below rounded ridges and summits. Grooved and fluted terrain occurs on plateaus and plains and usually results from both glacial erosion and deposition. In valley and trough areas, erosion was greatest where the valleys were aligned parallel to the direction of ice flow. This was the case in the Okanagan Valley for example, where the bedrock valley floor now lies as much as 200 m below present day sea level.

Fraser ice reached its maximum about 15,000 years ago, when it extended south to 47°N. latitude in Washington State. The subsequent retreat of the ice margin was relatively rapid. The Strait of Georgia and parts of the Fraser Lowland were ice free by 13,000 years ago. Minor readvances of ice into the eastern part of the Fraser Lowland occurred until 11,000 years ago. Major valleys in southern interior British Columbia were ice-free by 11,000 years ago. A Carbon-14 date from peat near a modern glacier terminus in the Coast Mountains shows that ice cover had shrunk to approximately its present extent by 9500 years ago. Sea-level was relatively high at the end of the Fraser Glaciation. As ice retreated from the Vancouver area, for example, sea-level stood at +175 m, and in the Kitimat-Terrace area it was at +230 m during deglaciation. Sediments deposited during the Fraser Glaciation and during the retreat are described below.

HOLOCENE CLIMATE AND GEOMORPHIC PROCESSES

A comprehensive climatic record for Holocene (postglacial) time in British Columbia has not yet been assembled. The information presently available has been obtained chiefly by analysis of pollen from Carbon-14 dated bog and lake sediments. Climatic changes are deduced from the vegetation succession recorded by pollen stratigraphy. Most information comes from the southwest coastal area and adjacent parts of Washington State. No studies have been reported from British Columbia north of a line through the Skeena and Pine Rivers.

Climatic warming occurred rapidly either just before or during deglaciation, and vegetation quickly colonized the newly exposed surfaces. A cold climate, i.e. colder than at present, of one or two thousand years duration is indicated only at sites where the pollen record extends back to the time when ice was still present. There is no record of tundra vegetation. Trees were everywhere a part of the immediate postglacial flora.

There was a relatively warm and dry interval during Holocene time, but its time of occurrence and duration have not yet been precisely determined. There is some evidence for a mid-Holocene "xerothermic" or "Hypsithermal" interval, approximately 3000 to 8000 years ago, which was preceded by cool, moist conditions. However, most recent investigations have indicated that the relatively warm and dry conditions of the Hypsithermal prevailed during the first half of Holocene time, roughly from 10,000 to 6500 years ago (Table 1.3.2).

Cooler and wetter conditions followed the Hypsithermal and lasted until the present time. During this period, minor climatic fluctuations have occurred, and short-lived cool and moist intervals have coincided with temporary expansions of mountain glaciers (referred to as "neoglaciation"). Although these periods of activity are somewhat irregular, in general three episodes of glaciation have been identified at 5800 to 4900 years and 3300 to 2300 years ago and during the last 1000 years (Table 1.3.2). In fact, many glaciers appear to have reached their greatest Holocene extent within the last few centuries.

Geomorphic processes during the Holocene period have been controlled in part by the effects of Fraser Glaciation and in part by Holocene climatic

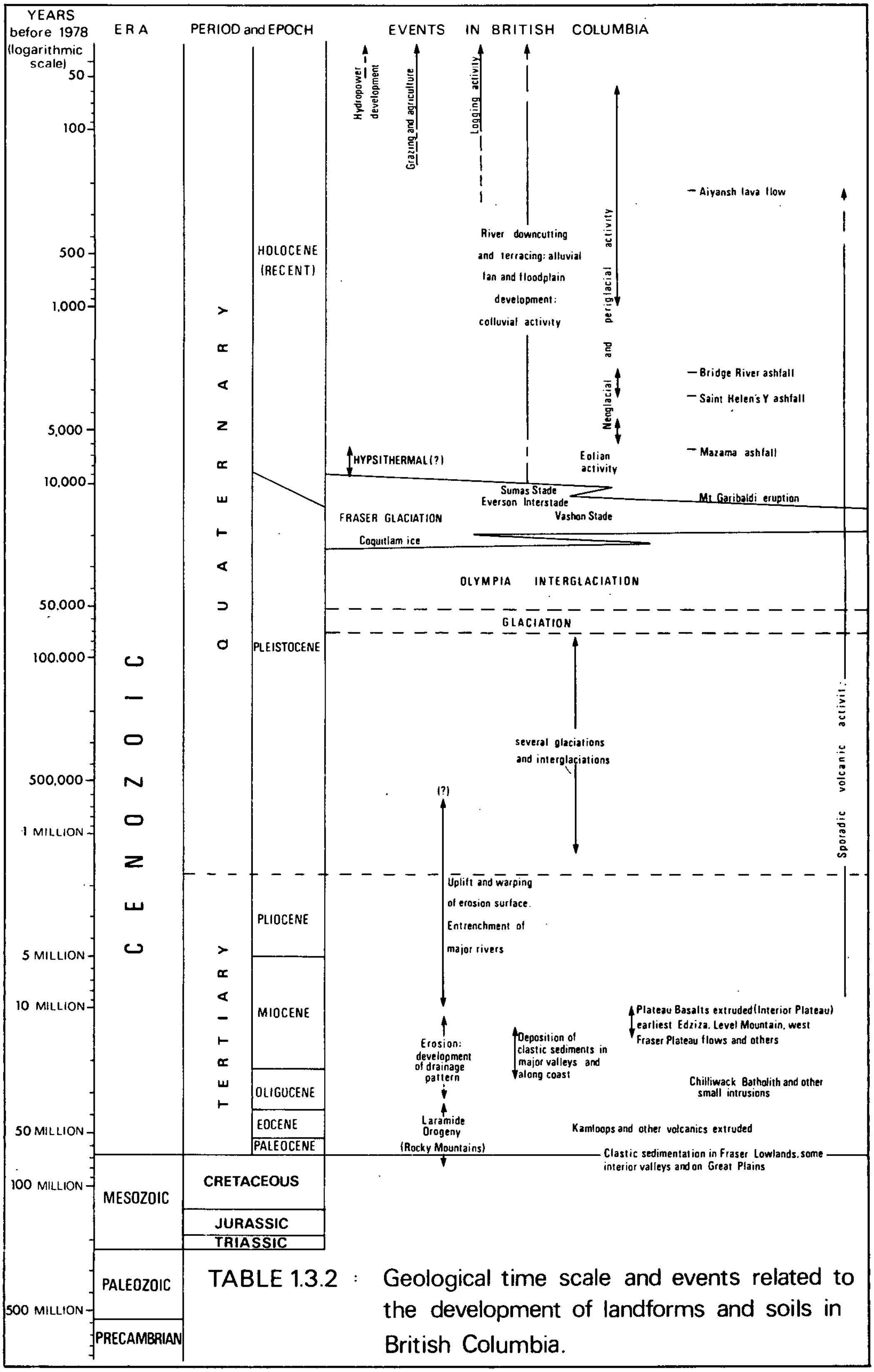


TABLE 1.3.2 : Geological time scale and events related to the development of landforms and soils in British Columbia.

conditions. Immediately following deglaciation there was a period of intense activity when much glacial drift was reworked and redistributed by streams and rivers, and mass wastage processes modified drift deposits on slopes. Aggradation along rivers, alluvial fan deposition, and lacustrine sedimentation occurred at this time. This activity gradually diminished as the supply of easily erodible drift became exhausted. In many valleys postglacial aggradation was succeeded by a phase of downcutting by streams and rivers. Terraces were cut into moraine, fluvial and lacustrine sediments.

With one or two exceptions, the effects of Holocene climatic change are hard to discern in the British Columbia landscape. Increased warmth and dryness during the Hypsithermal period in south-central British Columbia appears to have induced aeolian processes by causing reduction in vegetative cover. Sand dunes in Okanagan Valley and other aeolian deposits have been attributed to this origin. In alpine areas, periglacial and glacial activity seems to have increased during the neoglacial events described earlier.

SURFICIAL MATERIALS AND ASSOCIATED LANDFORMS

Surficial materials that form the parent material of soils were formed during and since the Fraser Glaciation. Drift of this glaciation includes till and fluvioglacial, glaciolacustrine and glaciomarine sediments that were deposited during the ice retreat. Throughout Holocene time, colluvial materials have accumulated on or at the foot of slopes, and fluvial, lacustrine and organic sediments have been deposited on valley floors and in depressions. The physical properties of these materials, their distribution, and the landforms with which they are typically associated are described here.

Morainal materials were deposited directly from glacier ice. They include Pleistocene till and the rubbly deposits of Holocene glaciers. Till is probably the most extensive of all surficial materials in the province. It covers level to moderately sloping surfaces that lie above valley floor areas affected by recent fluvial activity and below rock and colluvial slopes of the alpine zone. Till plains occur where till has infilled irregularities in the underlying surface or covered level surfaces of structural or erosional origin. Drumlins and fluted till sheets are common on plateaus and plains, particularly the Interior and Alberta Plateaus.

Till is a compact, non-sorted and non-stratified sediment which contains a heterogeneous mixture of particle sizes. However, it can vary abruptly from place to place with changes in the nature of source material. Where till was derived from bedrock, its mineralogical composition is related to the local rock (as described earlier). Where till was derived from unconsolidated sediments, it reflects their texture and mineralogy. For example, in valleys of the Thompson Plateau, till consists of rounded pebbles and cobbles in a matrix of sandy silt. The stones come from older fluvial gravels and the fines from older lacustrine silt.

Sandy tills are porous and so water passes rapidly through them. At the other extreme, clay tills tend to be impervious and poorly drained. In addition, impeded drainage may occur where a thin cover of till overlies impervious bedrock.

Fluvioglacial materials are deposited by meltwater either in contact with glacier ice or beyond the ice margin as outwash. Ice-contact deposits vary from well defined kames, kame terraces and eskers to irregular and discontinuous spreads of gravel overlying till. They consist of gravels and sand that may be sorted and stratified. Where bedding is present, it is typically distorted as a result of partial collapse when the supporting ice melted. Kames and eskers tend to be well drained and often constitute the driest, or most xeric, sites within a landscape.

Within British Columbia, ice-contact materials have a wide distribution and are found in most areas with the general exceptions of narrow glacial troughs and the higher terrain of alpine glaciation. Major eskers and esker complexes are found on the Nechako Plateau, Fraser Plateau and Liard Plain. Kames and eskers typically occur in association with meltwater channels on the surface of the Interior Plateau. In areas of higher relief, kames occur in cols or high-altitude through-valleys. Kame terraces form the highest terraces within most valleys.

Proglacial outwash deposits constitute gravel plains or terraces that may be kettled. The material ranges from sand to boulders and is sorted and poorly bedded. Outwash gravels originated as floodplains occupied by braided rivers. In Holocene time old outwash plains have been modified due to changing river regimes and have undergone terracing or have been occupied by meandering rivers. Outwash gravels are forming in present-day proglacial situations along valleys draining from glaciers in the Coast, Columbia and Rocky Mountains.

Outwash gravels are porous and permeable and generally constitute well drained areas unless the water-table lies close to the surface.

Glaciolacustrine materials collected in proglacial lakes during or shortly after deglaciation (Figure 1.3.2 shows the major lakes). They consist of sediment brought into the lakes by meltwater streams. Silt and fine sand are most common but coarser sand and gravel occur close to points of inflow.

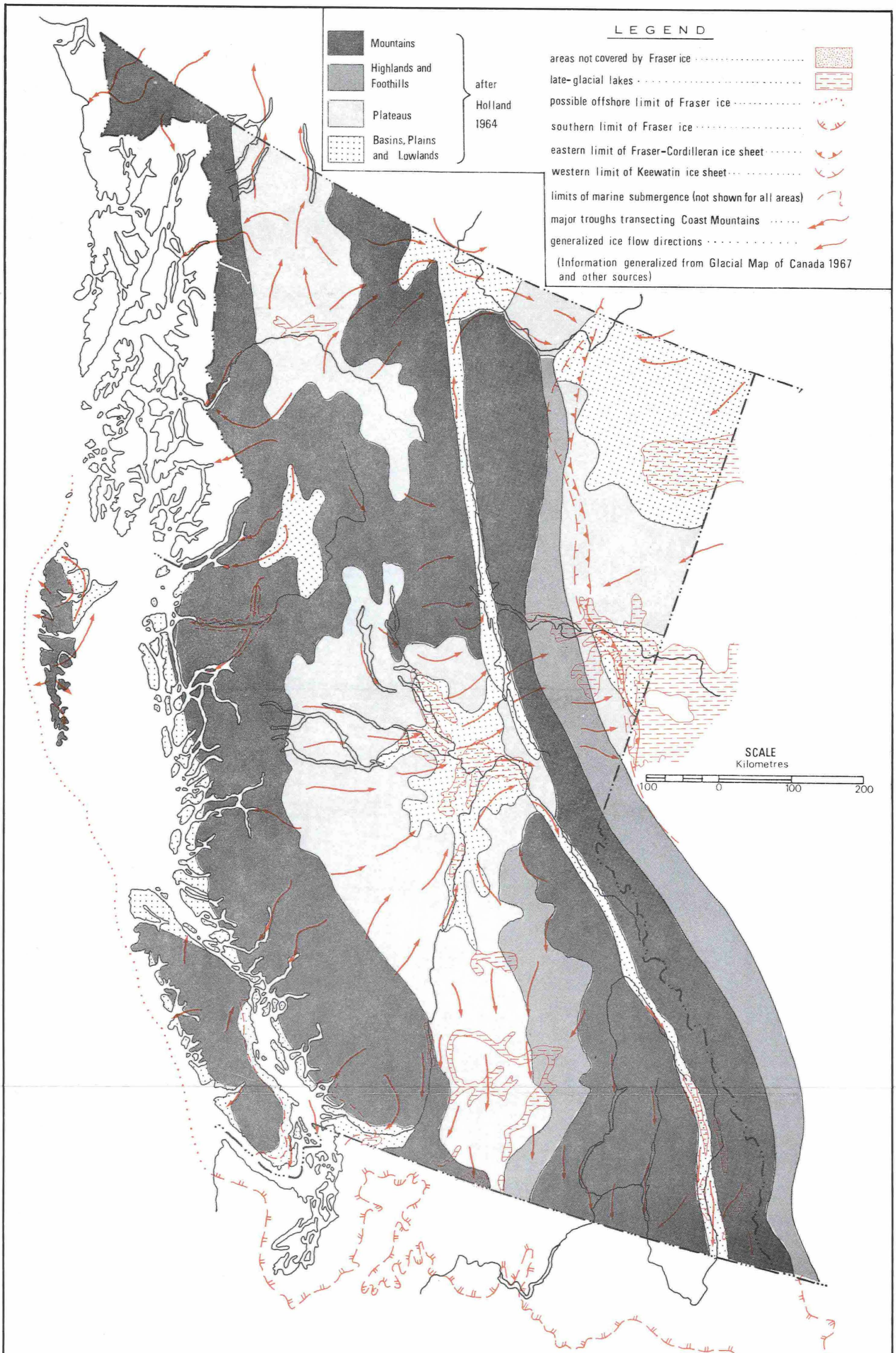


FIGURE 1.3.2 GLACIAL FEATURES OF BRITISH COLUMBIA

Clay-sized sediment can occur locally. Bedding in lacustrine silts and sands ranges from massive to laminated. Where materials were deposited in contact with glacier ice, slumping and settling ensued during melting giving rise to irregular undulating or kettled topography.

In general, the nature of terrain associated with glaciolacustrine sediments depends upon their thickness. In many basins sediments are sufficiently thick that all former irregularities have been masked and the old lake bed now forms a level or slightly undulating surface. Scarps in lacustrine silts tend to be steep with vertical upper sections. Headward erosion of gullies in lacustrine silt is rapid, and where this material occupies large areas, extensive dendritic gully systems may have developed, as for example in the South Thompson Valley near Kamloops.

Near-surface drainage and groundwater movement within glaciolacustrine materials depend upon their texture. Fine silt and clay beds form impervious layers which will reduce infiltration rates if near the surface or cause lateral migration of groundwater in perched water tables at depth. In the latter situation, high pore pressures may develop and cause loss of cohesion resulting in slump and flow failures along slopes. Steep scarp slopes are particularly susceptible to this process. In some places this has been man-induced by addition of extra water, for example from irrigation, on the surface above the scarp.

Glaciomarine materials ("marine drift") were formed during the time of high sea-level at the end of the Fraser Glaciation by the accumulation of particles released from floating, melting ice. It consists of stony, silty clay which is non-sorted and may show faint, irregular stratification. The material is superficially similar to till, but in places contains the shells of Pleistocene marine molluscs. As sea-level fell, the areas mantled by marine drift gradually emerged and were systematically worked over by wave action to form a thin covering of beach sands and gravels.

Water percolation through unmodified marine drift is slow due to its high clay content. Drainage is rapid through beach gravels and sands.

Fluvial materials are transported and deposited by streams and rivers. They consist of gravel, sand, or silt and are generally well-sorted by comparison with most other surficial materials.

In general, floodplains of rivers that have steep gradients and high sediment loads (bedload) tend to have shallow, braided channels and to be underlain by gravelly material. A thin cover of flood-deposited sand may occur away from active channels. Streams of this type occur within steep, mountainous terrain. Floodplains of low-gradient rivers that are transporting fine textured sediment have meandering channels, levees and backwater or back-swamp areas. They are underlain by sand and silt resulting from overbank deposition. Rivers of this kind are found on deltaic floodplains and upstream from lakes, rock sills and other local base-level controls.

Fluvial terraces are underlain by materials similar to those underlying floodplains, but gravels usually predominate and overbank fines are less common.

Alluvial fans are formed where streams emerge from steep, narrow valleys onto flatter ground. Material is deposited here due to reduced gradient and widening of the channel. Material is coarsest, commonly boulder gravel, close to the fan apex, and becomes systematically finer outwards, grading to fine gravels, sand or silt at the periphery. Many alluvial fans are relict features in the present landscape and date from the early post-glacial phase of geomorphic activity.

A delta is simply an extension of a floodplain. Texture of the material within a delta is relatively uniform and depends to a great extent upon the gradient of the river upstream. The delta of a steep mountain torrent will consist of boulder gravels whereas the delta of a low-gradient river will be formed of silt or sand, as for example the delta of the Kootenay River near Creston.

Percolation of water through sand and gravel is potentially rapid due to their coarse texture. Drainage of fluvial surfaces thus depends chiefly upon the depth of the groundwater table. Where this is high, as in the case of deltas and floodplains, areas of impeded drainage will occur, and slightly elevated areas, such as levees, will be relatively dry. The water table is also close to the surface in places on alluvial fans, particularly near the stream and at the fan toe where seepage zones may be present. Seasonal fluctuations in the levels of lakes and rivers will induce variations in the level of the water table in related landforms. Terraces and dissected fans are well drained sites.

Colluvial materials are the products of mass wastage. They include any unconsolidated materials that have lost their original form due to downhill movement, as well as distinctive types of colluvium such as mudflows, landslide deposits and the debris of shattered bedrock.

Mudflows consist of clasts of various sizes surrounded by a "mud" matrix of silt and clay. This mass flows as a viscous liquid when saturated and is capable of transporting large boulders. Colluvial fans consist of stratified sequences of thin mudflows. They tend to be moderately well drained as a result of surface slopes of 5 to 15^{o}, although water percolation through mudflow material is usually slow due to its high silt and clay content.

Landslide deposits vary from fine textured masses of slumped lacustrine silt to huge blocks and rubble of rockslides. They generally form hummocky topography below a steep landslide scar. Fine textured slide deposits are poorly drained and may contain pockets of standing water. There may be seepage zones near the foot of the slide scar. Rockslides are usually very well drained, xeric sites.

Bedrock fragments loosened individually by frost shattering and other weathering processes accumulate as talus slopes or sheets on hillsides. As a result of its coarse texture and steep surface gradients, material of this type is generally very well drained, although seepage sites may occur at the foot of slopes.

Solifluction deposits are widespread in high alpine areas. They consist of water-saturated masses of weathered rock or drift that flow slowly downhill. The high moisture content is derived from melting snow and summer precipitation, and in addition, drainage may be impeded due to underlying permafrost or impervious bedrock.

Eolian materials are wind deposited sands and silts. They form dunes where abundant material is blown along the ground surface and heaped up by the wind, and they form thin layers over older landforms by the settling of airborne particles. Dunes consist of medium to fine sand, whilst eolian mantles consist of fine sand and silt. These materials occur throughout the province, even in the alpine zone, but they are thickest and most extensive on terraces, fans, floodplains and outwash surfaces.

Dunes are generally well drained. The drainage of eolian mantles depends to some extent on the permeability of the materials that they overlie and the associated landform.

Marine materials consist of off-shore deposits of stratified and locally fossiliferous clays and silts that settled from suspension, and shoreline materials of beach sands and gravels that formed by wave action and longshore drift. Terrain underlain by marine clays and silts is usually very gently sloping. Beach gravels and sands occur as low ridges. Drainage on the fine textured off-shore materials is restricted; beach materials are generally well drained.

Organic materials consist of peat that has accumulated in depressions and other areas of high water table. They are most abundant in the northern part of the province in areas such as the Liard Plain, Fort Nelson Lowland, and Queen Charlotte Lowlands. Elsewhere, they are restricted to relatively small areas in rock basins, kettles, floors of glacial spillways, and old channels and backswamps on floodplains and deltas.

CHARACTERISTICS OF THE PHYSIOGRAPHIC REGIONS

For information regarding the geology of these physiographic regions and the relationships between rock type and weathering products, texture of surficial materials, and landforms, the reader is referred to Figure 1.3.1, Table 1.3.1 and the preceding "Geology" section.

COAST MOUNTAINS AND ISLANDS

This region consists of two parallel mountain belts (the discontinuous St. Elias - Insular Mountains and the Coast-Cascade Mountains) and the intervening, largely submerged Coastal Trough. In the mountain belts, summits are highest in the St. Elias Mountains (4600 to 5500 m), Coast Mountains (2500 to 4000 m), and the central part of Vancouver Island (2000 m). The mountain topography is extremely rugged, even in the relatively low Queen Charlotte Mountains (1100 m).

Terrain typical of intrusive igneous rocks and mountain glaciation, both alpine and overridden types, is especially well developed in the Coast and Cascade Mountains. Major linear structures have been excavated by glacial and fluvial processes to form striking alignments and grid-like patterns of valleys and fjords. Ice flowing westwards from the Interior Plateau and northern mountains excavated major low-level troughs across the Coast Mountains. These are now occupied by rivers such as the Taku, Stikine, Iskut, Nass, Skeena, Dean, Bella Coola and Homathko (Figure 1.3.2).

Glacial landforms dominate the St. Elias and Queen Charlotte Mountains. On many islands and coastal areas of the Insular belt, cirques occur at all elevations down to sea-level. Remnants of the Tertiary erosion surface occur as level or gently sloping ridge crests on both island and mainland along the Coastal Trough. The surface lies below 600 m elevation here, but it rises gradually eastwards and westwards towards the mountains. Erosion surface remnants and landforms of mountain glaciation (both alpine and overridden types) constitute much of the Vancouver Island landscape.

The St. Elias Mountains and parts of the northern and southern Coast Mountains still have extensive icefields and glaciers. Rivers draining from these areas have broad gravel floodplains that are free of vegetation and crossed by shifting, braided channels.

Within the mountains, thick drift deposits are restricted to the margins of the floors of major valleys and adjacent hillsides. Floodplains, and in some valleys river terraces, occupy the central part of the valley floor. On most slopes there are extensive bedrock outcrops and accumulations of rubbly colluvium. Relatively gentle mountain slopes may have a thin till mantle. Avalanching is the dominant geomorphic process operating today on steep slopes at intermediate and high elevations. Nivation, solifluction and other periglacial processes are locally important in the alpine areas. Neoglacial moraines occur adjacent to modern glaciers.

Within the lowlands and islands of the Coastal Trough, summit levels are generally below 600 m. Drift deposits are thickest and most continuous here, although there are some large areas of glacially abraded rock surfaces and outcrops of resistant rock types. A uniformly low glaciated rock plain (Milbanke Strandflat) borders the mainland coast along Hecate Strait. Marine drift and associated beach materials cover hilly areas and gentle slopes in the western part of the Fraser Lowland and other coastal areas (Figure 1.3.2). Till and fluvioglacial gravels also form extensive hilly and undulating areas in the lowlands and islands. Fluvial gravels and sands occur as terraces and floodplains along major rivers that cross the coastal lowlands. In Holocene time the Fraser River has formed a major floodplain and delta composed chiefly of sand and silt.

INTERIOR PLATEAU

The Tertiary erosion surface, in places capped by lava flows, is the dominant landscape feature of this region. The degree of dissection of the plateau surface varies from place to place. In the northern two-thirds of the region (Fraser and Nechako Plateaus), large tracts are undissected and comprise flat to gently rolling terrain at elevations of 1200 to 1500 m. The surface is interrupted however, by the entrenched Fraser River and its major tributaries which occupy channels that are 100 to 200 m lower than the plateau surface. Near Anahim Lake, several small mountain ranges (2500 m) are the dissected remnants of late-Miocene shield volcanoes. The Fraser Basin is a low-lying part of the plateau in the vicinity of Prince George, from 600 to 900 m a.s.l.

The southern part of the Interior Plateau (Thompson Plateau) is dissected by the Fraser and Thompson Rivers and their tributaries which flow in steep-sided valleys 600 to 900 m below the plateau surface. Extensive areas of rolling upland surface remain at 1200 to 1500 m, and in places higher hilly areas up to 2000 m are located upon relatively resistant bedrock.

Uplift of the Tertiary erosion surface was relatively great along the eastern margin of the Interior Plateau in the Shuswap, Quesnel and Okanagan Highlands. Subsequently, severe dissection has occurred here, producing relatively rugged terrain with gently sloping erosion surface remnants on ridge crests and summits. Summit levels lie between 1500 and 2000 m, and local relief of 600 to 900 m is typical. Glacial erosion produced rounded ridge crests and steep valley sides. Drift occurs on valley floors and on gentle slopes.

The surface of the whole Interior Plateau is mantled with drift which chiefly consists of drumlins and fluted till. Rock outcrops are not extensive on the plateau surface, although the plateau is bounded by lava cliffs or steep rocky slopes adjacent to the entrenched rivers. Eskers, kames and meltwater channels are numerous. Glaciolacustrine silts occur in many valleys and basins (Figure 1.3.2). Drift is over 100 m thick in some major valleys such as the Fraser and Okanagan. In many valleys this Pleistocene fill has been dissected and terraced during post-glacial downcutting by major rivers.

COLUMBIA MOUNTAINS AND SOUTHERN ROCKIES

This region comprises several parallel mountain belts and intervening valleys. The four mountain belts which together constitute the Columbia Mountains are lithologically and structurally complex (Table 1.3.1). In general, summit elevations range from 2500 to 3500 m, and are lowest south of latitude 50^{o}N. Where summits are high, the mountains are extremely rugged, and where deep valleys flank high peaks, local relief of over 2000 m is not uncommon. Ridges and peaks above 2000 to 2500 m were not overridden by ice and are serrated. Lower summits and crests are subdued and rounded and may have a thin covering of till. Drift is present on valley floors (along with fluvial materials) and on gentler mountain slopes at relatively low elevations. Steeper slopes consist of rock outcrops and rubbly colluvium. Avalanching occurs on steep valley sides at all elevations. Nivation is proceeding in alpine areas, and both active and relict periglacial features occur, such as patterned ground and rock glaciers. The modern glaciers are bounded by one or more strands of neoglacial moraine.

The Monashee, Selkirk and Purcell Mountains are separated by major glacially-enlarged trenches which now contain Arrow and Kootenay Lakes and part of the Columbia River. Drift materials, chiefly till and fluvioglacial gravels, are widespread on the floors and lower slopes of these valleys and alluvial terraces occur along rivers.

The Rocky Mountain Trench is a steep-sided structural depression which lies between mountains of strongly contrasting structures and rock types. It is largely floored with Quaternary sediments. Glacial deposits include till as drumlins, outwash terraces and glaciolacustrine silt. However, Holocene fluvial sediments occupy extensive areas and consist of terrace gravels and floodplain silts, sands and gravels.

In the southern Rocky Mountains, the topography reflects the structural control of underlying folded and faulted sedimentary rocks. Erosional landforms of alpine and valley glaciation such as cirques, troughs and horns are commonly asymmetric where they are cut in moderate to steeply dipping strata. The broadest troughs are located along zones of 'soft' rock. Summit elevations range up to 3600 m and local relief is typically 1200 to 1500 m. The distribution of drift in the Rockies is similar to that in the Columbia Mountains. However, rapid disintegration of the well jointed sedimentary rocks of the Rockies has given rise to much talus development, and to the formation of mantles of rubbly debris over bedrock slopes above timberline. Where bedding is nearly horizontal and along valley sides that parallel the strike of the bedrock, alternating cliff bands and shelves containing talus slopes are a typical landscape feature.

NORTHERN AND CENTRAL PLATEAUS AND MOUNTAINS

This physiographic region consists of a miscellaneous collection of mountains, plateaus and plains, but some generalizations can be made. The plateaus (Yukon, Stikine, and small plateaus within mountain regions) are Tertiary erosion surface remnants displaying varying degrees of dissection by streams with various depths of entrenchment. Plateau surfaces are generally between 1500 and 1800 m, and flat or gently rolling. Where they are warped up to higher elevations, dissection has been more severe. Ice overrode virtually all plateau areas and produced drumlinoid and fluted topography in both bedrock and till. Drift is widespread, and deranged drainage and numerous lake basins provide sites for organic accumulation. Many centres of late-Tertiary and Quaternary vulcanism occur within the plateaus, especially on the Stikine Plateau where the shield volcano of Mt. Edziza (2700 m) and Level Mountain (2100 m), and other volcanic cones are located.

The mountain areas (Skeena, Cassiar and Omineca Mountains) are subdued by comparison with the Coast and southern Rocky Mountains. Summit elevations range between 1800 and 2700 m, and local relief is 900 to 1200 m. Surfaces below 1800 m were overridden by ice and consequently the lower summits are rounded and commonly bear a thin drift cover. Higher areas have all the features of alpine glaciation. Drift is widespread in broad valleys.

The Liard Plain and Nass Basin are areas of low relief and flat or gently rolling topography at elevations of 750 to 1000 m, and below 750 m respectively. There is extensive drift cover with numerous lake basins. Drumlins and fluted terrain in both drift and bedrock are common. Several major esker systems cross the Liard Plain.

The northern Rocky Mountains and Rocky Mountain Trench are essentially similar to their southern counterparts, although there are large areas of relatively subdued mountain topography, for example, in the Hart Ranges. In both the Rockies and the Rocky Mountain Foothills to the east, a strongly linear topography reflects geologic control. The foothills have landforms typical of dipping sedimentary strata with little glacial modification other than a drift cover.

GREAT PLAINS

This area comprises structurally controlled topography with mesas and cuestas, developed on flat-lying or gently dipping sandstones and shales. The sandstones are relatively resistant to erosion and underlie the uplands. Surfaces are generally flat to gently rolling at elevations of 900 to 1200 m on the Alberta Plateau, and below 600 m in the Fort Nelson Lowland. The Peace and Liard Rivers and their tributaries are incised, producing a low relief along valleys of 600 m in the plateau and 150 m in the lowland.

This region was glaciated chiefly by Keewatin ice from the east. Cordilleran ice from the Rocky mountains extended only a short distance eastwards beyond the Foothills (Figure 1.3.2). Drift was deposited over most of the region, although it is thin or absent from some uplands and ridge crests. Drumlins and fluted till plains are common throughout the area, and a variety of moraine features, pitted outwash and meltwater channels occur in the lowland. Large areas of outwash gravels and sands were deposited by meltwaters draining eastwards and northwards from the Cordilleran ice. These materials now occupy plateau margins adjacent to incised rivers, such as the Fort Nelson and the Hay. Lacustrine sediments of proglacial lakes occur in the Peace River basin and in parts of the Fort Nelson Lowland (Figure 1.3.2). They consist mainly of clay and silt, but grade locally to sands and deltaic gravels.

FURTHER READING

Alley, N.F., 1976. The palynology and palaeoclimatic significance of a dated core of Holocene peat, Okanagan Valley, southern British Columbia. Can. Jour. Earth Sciences 13, pps. 1131-1144.

Describes changes of climate and vegetation that occurred in the dry interior of British Columbia during post-glacial time.

Armstrong, J.E., 1976. Quaternary geology, stratigraphic studies and revaluation of terrain inventory maps, Fraser Lowland, British Columbia. Geol. Surv. Can. Paper 75-1, Part A, pps. 377-380.

An update and summary of Armstrong's work which covers absolute ages, stratigraphy and chronology of Quaternary sediments.

Armstrong, J.E. and W.L. Brown, 1954. Late Wisconsin marine drift and associated sediments of the Lower Fraser Valley, British Columbia, Canada. Bull. Geol. Assoc. Amer., 65, pps. 349-364.

Describes in detail the fossiliferous, till-like stoney clays that cover much of the Lower Mainland. Several hypotheses for the origin of marine drift are discussed and illustrated.

Birkeland, P.W., 1974. Pedology, Weathering and Geomorphological Research. Oxford Univ. Press, 285 pp.

Focuses on the use of soils and rock and mineral weathering to solve problems in Quaternary research that are common to the fields of pedology, geomorphology, sedimentology and stratigraphy.

Clague, J.J., 1976. Late Quaternary sea-level fluctuations, Pacific coast of Canada and adjacent areas. Geol. Surv. Can. Paper 75-1, Part C, pps. 17-21.

Provides an excellent summary and discussion of previously published accounts.

Douglas, R.J.W. (Ed.), 1970. Geology and Economic Minerals of Canada. Econ. Geol. Rept. No. 1, Dept. Energy, Mines and Resources, Canada.

Major work on the geology of Canada. Includes useful chapter on Quaternary geology.

Fulton, R.J., 1969. Glacial lake history, southern Interior Plateau, British Columbia. Geol. Surv. Can. Paper 69-37, 14 pp.

Describes pattern of deglaciations and related development of glacial lakes in the Nicola, Thompson and Okanagan basins.

Fulton, R.J., 1971. Radiocarbon geochronology of southern British Columbia. Geol. Surv. Can. Paper 71-37, 28 pp.

A description of the radiocarbon-dated Quaternary history of southern British Columbia over the past 52,000 yrs.; includes a compilation of dates related to glaciations, post-glacial sea-levels, volcanic ash-falls and post-glacial climate.

Fulton, R.J., 1975. Quaternary geology and geomorphology, Nicola-Vernon area, British Columbia. Geol. Surv. Can. Memoir 380, 50 pp.

An account of Quaternary landforms and sediments in area covered by NTS maps 92I/SE, 92I/NE, 82L/NW, 82L/SW, and accompanied by surficial geology maps at 1:26,720.

Prest, V.K., D.R. Grant, and V.N. Rampton, 1967. Glacial Map of Canada. Geol. Surv. Can.

1:5,000,000 map depicting glacial landforms.

Heusser, C.J., 1960. Late-Pleistocene environments of north Pacific North America. Amer. Geog. Soc. Spec. Pub. 35, 308 pp.

Describes late-glacial and post-glacial climatic, and biotic changes that occurred in coastal regions as interpreted from peat and pollen stratigraphy.

Holland, S.S., 1964. Landforms of British Columbia, a physiographic outline. B.C. Dept. Mines and Pet. Res. Bull. 48, 138 pp.

Physiographic regions are defined and described in terms of their topography, geology, landforms and glacial history.

Mathewes, R.W., 1973. A palynological study of postglacial vegetation changes in the University Research Forest, southwestern British Columbia. Can. Jour. Bot. 51, pps. 2085-2103.

Pollen analysis is used to investigate post-glacial vegetation and climate changes.

Mathews, W.H., 1968. Geomorphology, southwestern British Columbia, pps. 18-24 in Guidebook to Geological Field Trips in Southwestern British Columbia, ed. W.H. Mathews, Dept. Geology, Univ. of British Columbia.

A summary account of Tertiary and Quaternary landform development.

Nasmith, H., W.H. Mathews, and G.E. Rouse, 1967. Bridge River ash and some other recent ash beds in British Columbia. Can. Jour. Earth Science 4, pps. 163-170.

Describes the distribution and time of eruption of post-glacial volcanic ashes.

Tipper, H.W., 1971. Glacial geomorphology and Pleistocene history of central British Columbia. Geol. Surv. Can. Bull. 196, 89 pp.

Describes glacial landforms and Pleistocene history of area covered by NTS maps 92N, 92O, 92P, 93B, 93C, 93F, 93G, 93J. Accompanied by maps of selected glacial features at 1:250,000.

1.4 VEGETATION

R.K. Jones and R. Annas

INTRODUCTION

There is a wide range of vegetation in British Columbia. Along the humid west coast, mid- to high-latitude coniferous "rain forests" occur, whereas many dry interior valleys, in the lee of mountain ranges, have open woodlands and steppe (grassland) communities. In the north, with its cold continental climate, are high latitude northern boreal forests, characteristic of Continental North America and Euro-Siberia. Small areas in southwestern British Columbia in the rainshadows of the Olympic Peninsula and Vancouver Island, have a mild, mediterranean climate which supports open grassy deciduous forests of Garry oak. The mountains provide environments that range from relatively favourable for plant growth at low elevations to most severe and hostile at high elevations. As implied by these few examples the vegetation pattern varies vertically as well as horizontally across the province. Some specific examples of such variations are shown in Figure 1.4.1, and the province-wide pattern of vegetation is shown in Figure 1.4.2.

Although vegetation changes spatially in response to differing environmental and historical conditions, it is possible to discern areas of vegetation which are relatively homogeneous in species composition and physical structure. Such homogeneous areas, which are called plant communities, can be classified and mapped in a fashion similar to soils. On a macro-scale, distribution patterns of plant communities can also be distinguished. It is useful to discuss these vegetation patterns within the framework of some classification system.

Several classification schemes have been developed for the vegetation of British Columbia, each one suiting a particular purpose. This section will use the Biogeoclimatic Zone classification as developed by Dr. V.J. Krajina and his colleagues and students since the early 1950's in the Department of Botany, University of British Columbia.

THE CONCEPT OF BIOGEOCLIMATIC ZONATION

A biogeoclimatic zone is a geographic area having characteristic vegetation with associated animals, soils and climate. Each forested zone is under a broadly homogeneous macro-climate and is characterized and usually named by one or more of the dominant shade-tolerant tree species which are often capable of self regeneration on most of the habitats. Generally, each zone can be broken into subzones which are distinguished by the climax plant association (groupings of several similar plant communities) on a mesic site. This site is the mid-point of the nutrient and moisture range occurring within the subzone; it is therefore not subject to excessive drainage nor to seepage waters and hence the vegetation best reflects the macro-climate.

Each subzone will have a series of communities developed in habitats which are strongly influenced by factors other than macro-climate. These factors may be the result of different soils, drainage, moisture regimes, slope, aspect, and micro-climate to name a few. Thus a subzone may include sites from nutrient-poor ones on sand dunes, to nutrient-rich seepage sites on alluvial floodplains. Additionally, plant communities will often be kept from their climatic or other types of climaxes (edaphic) by such factors as fire, logging, grazing, and flooding. All these factors result in a range of vegetation for subzones and zones. The following discussion is, however, limited to the broader characteristics of the twelve biogeoclimatic zones as proposed by Krajina (Figure 1.4.2).

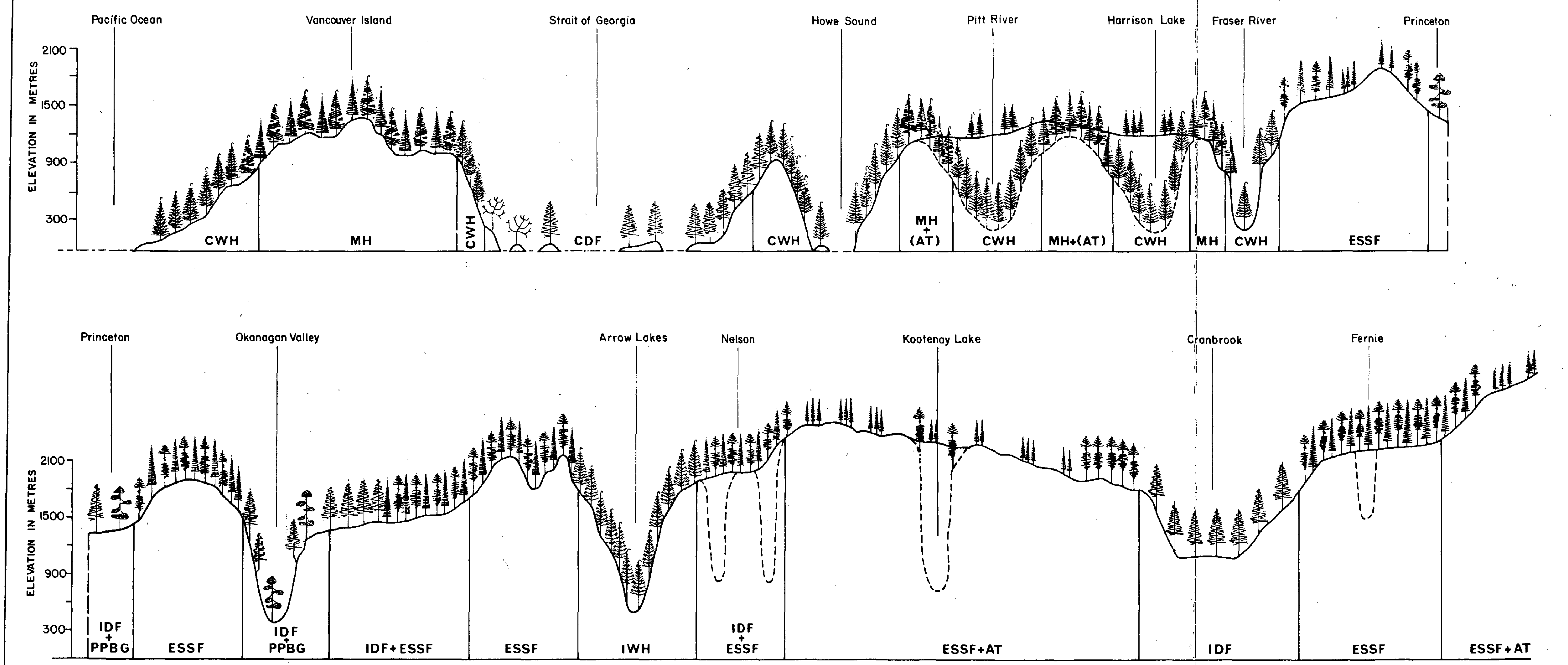
THE BIOGEOCLIMATIC ZONES OF BRITISH COLUMBIA

THE ALPINE TUNDRA ZONE (AT)

The AT zone consists of treeless meadows, slopes, windswept ridges, snowfields, and icefields at high elevations in mountainous terrain. This zone starts at an elevation of 2250 m in southeastern British Columbia but in the cool, moist climate of the northwest, it occurs as low as 900 m. The harsh climate in most alpine environments is a response to increasing elevation or increasing latitude. Thus, alpine and arctic vegetation are very similar.

The alpine is a cold, windy, snowy environment with a very short frost-free period. Many alpine species show specific adaptations for these conditions. Abrasion from wind-blown snow particles damages vegetation by breaking leaf or stem surfaces which compounds the desiccating effect of wind. These are two of the main factors which limit the distribution of trees at treeline. Occasional straggling, prostrate trees, of krummholz form, can be found in relatively protected areas high above treeline.

Adaptations for abrasion and desiccation vary from dwarf forms of woody plants such as the arctic and alpine willows, which are only a few centimetres high, to the development of cushion or mat-like forms of growth which protect most of the plant colony from the wind. Many species on wind-swept slopes and ridges such as moss campion (Silene acaulis) and entire-leaved white mountain-avens (Dryas integrifolia) grow in cushion or mat form.



Biogeoclimatic Zones

CWH	Coastal Western Hemlock	IDF	Interior Douglas-fir
IWH	Interior Western Hemlock	ESSF	Engelmann Spruce-Subalpine Fir
MH	Mountain Hemlock	PPBG	Ponderosa Pine-Bunchgrass
CDF	Coastal Douglas-fir	AT	Alpine Tundra

Tree Symbols

- Western hemlock
- Pacific silver fir (Amabilis fir)
- Mountain hemlock
- Garry oak
- Douglas-fir
- Engelmann spruce
- Subalpine fir
- Ponderosa pine

FIGURE 1.4.1

Biogeoclimatic Zones across British Columbia along latitude 49°30′ N.

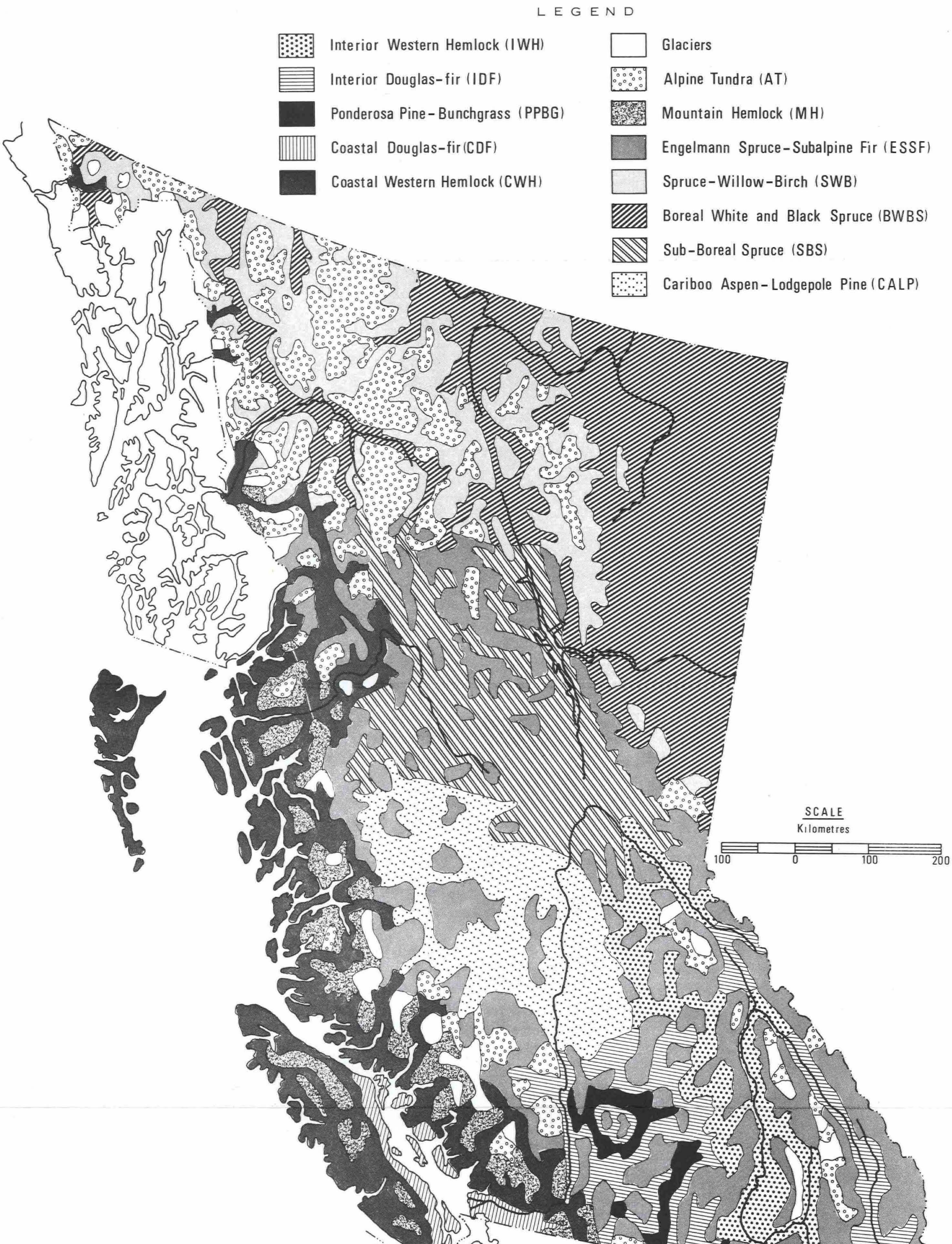


FIGURE 1.4.2 BIOGEOCLIMATIC ZONES OF BRITISH COLUMBIA

Adapted from the Atlas of British Columbia (U.B.C. Press 1978). Original compilation by V.J. Krajina.

Alpine "meadows" occur under moister conditions on flat or gently sloping topography where snow cover lasts the longest. Their vegetative season is short and colourful. A few conspicuous alpine meadow species are Indian paintbrush (Castilleja spp.), lupines (Lupinus spp.), Sitka valerian (Valeriana sitchensis), anemones (Anemone spp.), and arnicas (Arnica spp.). Meadows, especially where dense grass and sedge communities are present, give a very turfy top to the soils.

Alpine heath communities, composed of "mountain heathers" (Phyllodoce spp. and Cassiope spp.) and other members of the heath family such as alpine-azalea (Loiseleuria procumbens) and crowberry (Empetrum nigrum) are very common and sometimes occupy extensive areas.

Under extreme conditions at the highest elevations, only lichens and a few mosses can survive. In certain lower elevation environments of the zone, vascular plants may have difficulty becoming established due to the frequent churning of soils by solifluction.

MOUNTAIN HEMLOCK ZONE (MH)

The MH zone occurs along the Pacific Coast Mountains in a climate of cool, short summers and cool, long, wet winters, with snow cover for several months. At low elevations, up to 900-1100 m in south coastal regions and up to 300 m further north, the forests are characteristically dense and productive. Tree growth becomes progressively poorer with elevation due to the shorter growing season, increased duration of snow cover, and cooler temperatures. The subalpine forests become more open with increasing elevation resulting in discontinuous parkland forests adjacent to the AT zone.

In the lower subzone of the MH zone, mesic habitats are on benches and upper slopes which receive temporary seepage during the early summer. The generally high moisture content and low temperature of the soils result in slow decomposition of litter and a relatively high proportion of organic matter in most soils. Mountain hemlock (Tsuga mertensiana), the most common tree, is particularly well adapted for such conditions, since its roots are shallow and occur principally in organic soil horizons. Pacific silver fir (amabilis fir) (Abies amabilis) and yellow cedar (Chamaecyparis nootkatensis) are the other major trees of the zone, with the yellow cedar generally confined to habitats with abundant moisture.

Dominant shrubs on mesic sites are the blueberries (Vaccinium alaskaense and V. membranaceum) and Pacific menziesia (false azalea) (Menziesia ferruginea). The herb layer is usually not well developed with only five leaved creeping raspberry (Rubus pedatus) and blue-bead Clintonia

(Queen's cup) (Clintonia uniflora) being common. Dicranum spp. and Rhytidiopsis robusta dominate the usually well developed moss layer of mesic sites. On lower and middle slope positions, seepage water is rather plentiful as expressed by a robust understory of small twisted-stalk (Streptopus roseus), deer fern (Blechnum spicant), false hellebore (Veratrum eschscholtzii) and unifoliate-leaved foamflower (mitrewort) (Tiarella unifoliata).

In the parkland subzone, a mosaic of plant communities occurs which grades into the alpine. In basins and depressions, where snow cover remains the longest, a dominant sedge community of Carex nigricans occurs on soils with characteristically turfy surface horizons. Heath communities, typical of the alpine, are also extensive.

THE SUBALPINE ENGELMANN SPRUCE - SUBALPINE FIR ZONE (ESSF)

The ESSF zone lies between the alpine tundra and the lowland forests throughout much of the interior of British Columbia. It is the most widely distributed zone in the province, occurring between latitudes 49 to 57 N and at elevations ranging from 950-1550 m in the northwest to 1260-2250 m in the southeast. The climate is colder, drier, and more continental than that of the MH zone. Trees occurring in the ESSF zone must be able to tolerate relatively severe winters with frozen ground.

Engelmann spruce (Picea engelmannii) and subalpine fir (Abies lasiocarpa) which is also known as alpine fir, are characteristically the dominant climax trees throughout the entire zone. Seral species, such as lodgepole pine (Pinus contorta var. latifolia), are common over large areas after fires, especially in drier regions.

Northern regions of the ESSF zone have boreal and sub-boreal influences; eastern regions have Cordilleran qualities, western portions have coastal transitions, and southern localities have dry continental variants. Not unlike the MH zone, the ESSF zone has elevational gradients in forest cover distribution whereby there are closed forest stands at lower elevations and tree "islands" or parklands in the upper limits of the zone. Unlike the MH zone, it is believed that the clumped tree distribution in the interior subalpine parkland, at least in the drier areas results from heavy snow accumulation which provides favorable moisture for tree growth. Areas between the tree clumps are open and exposed resulting in dry grassland communities.

In the lower elevations of the wetter subzones of the ESSF zone, forests have closed canopies. Even though precipitation is sufficiently high for Podzolic soils (see Part 2.4), productive seepage sites are very frequent.

These have plant species typical of soils containing high moisture and nutrients (e.g. mountain alder (Alnus incana), oak fern (Gymnocarpium dryopteris), Sitka valerian and false hellebore).

In the drier, less productive parts of the zone where Brunisolic soils are common, many species characteristic of dry conditions occur frequently (e.g. kinnikinnick (Arctostaphylos uva-ursi), pine grass (Calamagrostis rubescens), and showy aster (Aster conspicuus)).

THE SPRUCE - WILLOW - BIRCH ZONE (SWB)

This is the third and most northerly subalpine zone in the province. It extends from a latitude of roughly 57° N and stretches well into the Yukon Territory and Mackenzie District of the Northwest Territories. Subalpine and subarctic climates (at higher latitudes) are characterized by severe winters. Moderate snow cover occurs over frozen ground in the southern part of this zone and over ground with permafrost in the northern part. The elevational ranges of the zone in the southeast occur between 1100 and 1700 m and in the northwest between 900 and 1500 m.

The plant communities found in this zone have yet to be studied in British Columbia. Detailed studies in the Yukon region (Ogilvie Mountains) commonly found white spruce (Picea glauca) on rich, well drained soils and black spruce (Picea mariana) on poor, imperfectly drained soils in the lower elevations of the zone. Persistent frosts, common at elevations above 1200 m, strongly affect the continuance of the coniferous trees. In their place, deciduous willow and birch shrubs predominate. The willows, mainly Salix barclayi, S. planifolia, S. pulchra, and S. glauca, prefer habitats with favourable nutrient regimes; habitats with poor drainage and less nutrients are characterized by bog glandular birch (Betula glandulosa). In some valleys subject to cold air drainage from adjacent mountains, the shrub willows and birches will occupy the valley floor as well as the upper elevations of the zone. The spruce forests are therefore bounded both above and below by a shrub subzone.

THE BOREAL WHITE AND BLACK SPRUCE ZONE (BWBS)

The largest occurrence of the boreal forest occurs on an extension of the Great Plains into northeastern British Columbia. It occurs also at the lower elevations of the main valleys west of the Rocky Mountains. The northern continental climate, with its frequent arctic air masses, produces short growing seasons and long cold winters. Discontinuous permafrost is common in northern parts of this zone. This area is situated approximately north of latitude 54° N and at elevations between 165 and 850 m. Forest fires are frequent throughout the zone, maintaining nearly all the forests in an early successional stage.

White spruce, black spruce, lodgepole pine, tamarack (Larix laricina), balsam poplar (Populus balsamifera), common paper birch (Betula papyrifera), and Alaska paper birch (Betula neoalaskana) are the major tree species in the forested regions of the zone. Grassland communities occur along the rivers in the southern Peace River area, and on the steep slopes above the Stikine River in the lee of the coastal mountains. Other than these drier grasslands, the remaining boreal forest is a mosaic of forest and bog communities.

In the gentle topography of the Fort Nelson Lowland of the Alberta Plateau, productive forests of trembling aspen (Populus tremuloides) and to a lesser extent white spruce characterize the mesic habitats as a "fire climax". It is believed that biogenic cycling of calcium by trembling aspen helps to maintain the Luvisolic soils of the area in a relatively high productive state by retarding acid leaching of the soils. Black spruce, a theoretical climatic climax species, produces acid litter which has the opposite effect.

Relatively open pine-lichen forests occur on the driest sites which are generally situated on rapidly drained outwash deposits, but dense black spruce-moss communities develop on imperfectly drained habitats. The most productive forests of this zone occur on rich alluvial sites where white spruce and balsam poplar may reach heights of over 50 m. These sites are among the most productive forests in the Canadian boreal forest.

Northeastern bog communities develop on poorly drained organic soils, characteristic of the gentle topography of the Alberta Plateau. The buildup of organic matter from the bog vegetation tends to insulate ground frozen in the winter, which results in discontinuous permafrost being characteristic of the northerly areas of the zone. Sphagnum fuscum is the dominant peat moss in this terrain.

Black spruce and occasionally tamarack are the main trees occurring on organic terrain, however, they are much reduced in size. Tamarack forms pure stands only in nutritionally rich fen types of environments.

THE SUB-BOREAL SPRUCE ZONE (SBS)

The SBS zone is located roughly in the centre of British Columbia where the climate is slightly less continental than that of the BWBS zone. The winters are shorter in the SBS zone, giving a slightly longer growing season. The elevational range of the zone is between 330 and 950 m in the northwest and up to 1100 m in the northeast.

Upland coniferous forests, composed mainly of white spruce and lodgepole pine, as well as deciduous forests of trembling aspen, dominate the landscape. Although white spruce is the dominant mesic climax species, fire and other disturbances result in a variety of vegetation in circum-mesic sites, including overstocked stands of lodgepole pine or stands of trembling aspen. Subalpine fir (alpine fir) is common in the understory, particularly in the shrub layer.

Lodgepole pine-lichen sites are common on dry, well drained outwash materials and these sometimes cover extensive areas. Subalpine fir and white spruce grow best on seepage and alluvial sites. Black spruce bogs, although fairly common, are never as extensive as they are in the boreal forest.

THE CARIBOO ASPEN - LODGEPOLE PINE ZONE (CALP)

The CALP zone contains a wide variety of habitats from treeless grasslands along the Fraser River to fairly dense forests in upland areas of the Fraser Plateau. With a climate of cold winters and warm dry summers, the CALP zone occurs at elevations between 510 and 1070 m.

The driest habitats of the zone occur as belts along the Fraser and Chilcotin Rivers where grasses, with their fibrous root system, are able to compete successfully with trees for moisture, resulting in extensive grasslands along these rivers. Adjacent to the grasslands, open forests are frequent, mainly of Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*). The remainder of the zone is characterized by more closed forests of Douglas-fir, white spruce, lodgepole pine, and trembling aspen.

The open range, on the slopes along the Fraser and Chilcotin Rivers, has bluebunch wheat grass (*Agropyron spicatum*) as the dominant climax grass species. In many areas, bluebunch wheat grass is reduced through overgrazing and is replaced by less desirable species. At the lower elevations big basin sagebrush (*Artemisia tridentata*) is especially favoured by overgrazing. The addition of organic matter to the upper soil horizons, through the decay of grass roots, is a major factor in the development of the Chernozemic soils characteristic of these grasslands.

Much of the zone, where Douglas-fir is the climax species, has a well developed herb layer dominated by pine grass which is a major forage species for grazing. Although Douglas-fir is a climax species in the southern part of the CALP zone, extensive areas are dominated by stands of lodgepole pine and trembling aspen which have originated from fire. In the northern part of the zone white spruce becomes the climatic climax species, indicating characteristics very similar to the SBS zone.

THE INTERIOR WESTERN HEMLOCK ZONE (IWH)

This zone occurs mostly in southern British Columbia between the Monashee and Rocky Mountains at elevations between 360 and 1260 m. It is often referred to as the "interior wet belt" since it experiences the highest precipitation of all the interior regions. Its climate makes it the most productive forest zone in the interior. Western hemlock (Tsuga heterophylla), with lesser amounts of western red cedar (Thuja plicata), dominate the few remaining mature forests.

The most common forest association in the IWH zone is a western hemlock-moss association, this also being the mesic or climatic climax association for the zone. In the southern and drier part of the zone, Douglas-fir and, to a lesser extent, western white pine (Pinus monticola) are frequently dominant after fires. On sites subject to permanent seepage waters, western red cedar-western hemlock stands are very common, sometimes occupying large areas. Where the seepage water is close to the surface, cedar-hemlock-devil's club communities are present. Generally Podzolic soils dominate the landscape of the zone. In many respects, the IWH zone is similar to the Coastal Western Hemlock (CWH) zone.

THE INTERIOR DOUGLAS-FIR ZONE (IDF)

The IDF zone occurs in the southern third of the province in the rainshadow of the Coast, Cascade, and Columbia Mountains. Typically, this zone occupies the middle position in the vertical sequence of zones common to dry interior valleys - the Ponderosa pine-Bunchgrass (PPBG) zone occurring at lower and the ESSF zone at higher elevations. The IDF zone lies between 300 and 1350 m in the southeast and 450 and 900 m in the north.

Both open and closed forests characterize the zone. Ponderosa pine (Pinus ponderosa), a seral species, and Douglas-fir, a climax species, form open forests at lower elevations. Here bluebunch wheat grass is one of the most important range species in the steppe-like understory vegetation. Many species characteristic of the lower grassland and arid shrub communities of the PPBG zone occur in these open forests. Grazing activity and fire history tend to determine the composition and pattern of present day vegetation. In general, it is believed that grassland communities are promoted by fire and shrub communities by intensive grazing.

At higher elevations of the zone, the climate is moister and forests become more closed. Pine grass becomes a dominant understory species, replacing bluebunch wheat grass. Closed forest species such as Oregon boxwood (Paxistima myrsinites) and common pipsissewa (Chimaphila umbellata) are more frequent in the wetter parts of the zone with the abundance of pine grass being reduced. Western larch (Larix occidentalis), western red cedar, white spruce, Engelmann spruce, and lodgepole pine are other species frequently found in the zone. Brunisols and Luvisols comprise the major soils of the zone.

THE PONDEROSA PINE - BUNCHGRASS ZONE (PPBG)

This is the driest and warmest zone in British Columbia. (In certain locations it is semiarid.) Located in the southern third of the province, the PPBG zone is distributed along valley floors, the lower slopes of many of the dry interior valleys and in local areas scattered across the interior plateau. The elevational range of the zone varies with aspect but generally occurs between 270 and 750 m. It occupies the lowest position in the vertical sequence of zones common to dry interior valleys (see Figure 1.4.1).

The PPBG zone is believed to be the northernmost extension of the Palouse Prairie found in the intermontane regions of the northwestern United States. Like the IDF zone, the influence of fire and grazing is expressed in the present day vegetation patterns. The vegetative cover consists of a mosaic of treeless bunchgrass steppe and parkland forest.

The high frequency of ground fire in the dry subzone helps to maintain a grassland vegetation including bluebunch wheat grass, needle-and-thread grass (Stipa comata), sand dropseed (Sporobolus cryptandrus) and rough fescue (Festuca scabrella). Most of these species provide good forage for cattle and other livestock. Overgrazing frequently causes a shift from productive grassland communities to communities dominated by sagebrush and other less palatable weed species such as common rabbit brush (Chrysothamnus nauseosus), low pussytoes (Antennaria dimorpha), and brittle prickly-pear cactus (Opuntia fragilis).

The ponderosa pine parkland, the wet subzone, is a discontinuous belt of open forest interspersed with the open grasslands. Ponderosa pine and, to a lesser extent, Douglas-fir are the dominant trees in the subzone. For the most part plant species characteristic of the open grassland form the dominant ground cover.

Alluvial communities along streamsides and on floodplains throughout the PPBG zone are characterized by black cottonwood (Populus balsamifera spp. trichocarpa) and various willows.

THE COASTAL DOUGLAS-FIR ZONE (CDF)

The CDF zone is situated along the south coastal region in the rainshadow of the Olympic Peninsula and Vancouver Island mountains. It ranges in elevation from sea level to 450 m on the east coast of Vancouver Island and from sea level to 150 m on the mainland and Gulf Islands. The zone has a relatively humid, mediterranean climate with warm, dry summers, and moderate, wet winters. Coast Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) is the main climatic climax species on mesic sites.

Under the most extreme coastal rainshadow effects, a dry subzone occurs where Garry oak (*Quercus garryana*) communities are common on rich sites with Pacific madrone (*Arbutus menziesii*) communities being common on poor, rocky, dry sites. The open and colourful grasslands of the Garry oak subzone have interesting soils as a result of the climate and vegetation.

Most of the CDF zone belongs to the wet subzone where Douglas-fir is the most common species, especially on mesic sites. However, many other coniferous species are present. On mesic sites, salal (*Gaultheria shallon*) dominates the shrub layer. The most characteristic soils of mesic sites of the zone are Dystric Brunisols and Humo-Ferric Podzols.

THE COASTAL WESTERN HEMLOCK ZONE (CWH)

The CWH zone is the wettest and most productive forest zone in British Columbia. The humid conditions prevalent in this coastal zone are primarily the result of the continual eastward movement of Pacific air masses. Depending upon the occurrence of a coastal rainshadow, the CWH zone can occupy either the middle or lowest position in the vertical sequence of zones common to coastal British Columbia. The MH zone occurs at upper elevations and the CDF (if it is present) at lower elevations. The zone ranges up to 900 m on windward slopes in the south, up to 1050 m on leeward slopes in the south, and up to 300 m in the north coastal region.

The most characteristic plant associations are hemlock-moss communities. In the drier subzone, coast Douglas-fir is a common successional tree species to the climax western hemlock. In the wetter subzone, Pacific silver fir (amabilis fir) is very common on mesic sites along with the dominant western hemlock.

Plant communities within the CWH zone vary with local topography and slope position. Rock outcrops and areas with well drained, shallow soils, particularly those with southerly aspects, commonly support Douglas-fir, salal, and a carpet of mosses and lichens. Depressional areas and lower slopes, where there is permanent seepage water, maintain a mixed forest of western hemlock and western red cedar with a vigorous understory of ferns.

One of the characteristics of the ecosystems of this zone is the buildup of organic matter in the soils, especially in the wetter subzone. In north coastal regions and on the Queen Charlotte Islands, there is a net accumulation of organic matter resulting from the dampness of the soils and the cool temperatures. This often leads to the development of organic soils and ultimately bogs, even on mesic sites. These bog ecosystems are characterized by poorly growing western hemlock, lodgepole pine, red cedar, and yellow cedar.

FURTHER READING

Biel, Charles E., Roy L. Taylor, and Geraldine A. Guppy, 1976. The Biogeoclimatic Zones of British Columbia. Davidsonii, 7 (4), 45-55.

An account of the biogeoclimatic classification of V.J. Krajina and a short description of each zone.

Krajina, V.J., 1969. Ecology of Forest Trees in British Columbia. Ecology of Western North America, 2 (1), 1-146.

The biogeoclimatic classification with technical descriptions and definitions of each zone and subzone.

Rowe, J.S., 1959. Forest Regions of Canada. Dept. Northern Affairs and National Resources, Forestry Branch, Ottawa. Bull. 123, 71 pp.

A descriptive classification of forests across the whole of Canada.

Taylor, Roy L. and Bruce MacBryde, 1977. Vascular Plants of British Columbia. Botanical Garden, University of British Columbia, Tech. Bull. 4, University of British Columbia Press, Vancouver, 754 pp.

An inventory which has been followed for plant names in this publication.

Part 2

The Major Soils and Soil Processes of British Columbia

2.1 INTRODUCTION

L.M. Lavkulich

In Part 1, the climate, physiography, geology and vegetation ecology of British Columbia were described separately. However, they do not occur separately. They occur together in the landscape and it is their interaction that produces soil on the surface layer of the earth. In fact, pedologists believe that a soil is the result of the so called factors of soil formation, namely parent material, climate, biota (vegetation and animals), topography and time. Every time a factor of soil formation changes so does the soil. It is only through this appreciation that soils can be used to their best advantage to serve mankind. In order to understand and interpret soils, it is necessary to have concepts of processes and classification schemes. In this way soils can be identified, sampled, characterized, mapped and evaluated for specific uses.

The processes resulting from this interaction and the general nature of the soil formed by these processes will be described in Part 2.2. Many different kinds of soils are produced across the landscape of British Columbia as a result of the different intensities of soil-forming processes. An orderly method of labelling each type of soil is necessary so that it can be described, discussed, studied or mapped. For this purpose the Canadian Soil Classification System has been developed over many years. Since climate is so important in the understanding of soils and their properties and management, a Soil Climate Classification has also been evolved over the past several years. The principal features of these two classification systems are described in Part 2.3.

In order to understand and illustrate the processes of soil formation, the relationship among the factors of soil formation, and the application of classification systems to the soils of British Columbia, Part 2.4 provides descriptions, pictures and representative laboratory analyses of the nine main groups of soils (soil orders) found in the province. In this manner soils are related to the landscape, the environment in which they are found and some of their characteristics are described.

2.2 SOIL AND SOIL PROCESSES

L.M. Lavkulich and K.W.G. Valentine

Soil is the naturally occurring unconsolidated mineral or organic material at the surface of the earth which is capable of supporting plant growth. The particular type of soil at any position on the earth is a result of the geologic or parent material, climate, biota, topography and time. These factors of soil formation do not act singly but together in various ways to produce a particular soil. The soil must not be regarded as a passive, inert body on the earth's surface. It is a continually changing system within the total environment.

Soils possess properties that have been inherited from the parent material, for example the amount of stones, mineralogy and thickness. They also have properties and features that are the result of soil processes, including such things as the kind and amount of organic matter, the formation of horizons (layers), new minerals and changes in porosity. For instance the features of a valley bottom soil will be largely inherited from the conditions of sediment accumulation in that part of the valley, whereas the humus content of the topsoil will be the result of the amount of organic litter added to the surface and the balance of the constructive and destructive processes acting on this litter.

Soils have both internal and external properties. The internal properties are often shown as various layers or horizons that are exposed in a vertical cross-section of the soil body. External properties include such attributes as slope and aspect. Soils often grade imperceptibly from one kind to another and occur as a relatively continuous blanket on the land surface of the earth. This continuous blanket is divided into soil classes defined upon the basis of soil properties, many of which reflect processes of soil genesis. Local changes in slope, elevation or aspect are dominant factors in determining changes in soil properties. It is on the basis of the soil's internal and external properties that soil resource inventories are prepared.

SOIL COMPONENTS

Soils are multiphase systems, composed of a mixture of numerous kinds and sizes of mineral grains, organic fragments, air and water. The proportions of these components vary from point to point on the surface of the earth, and from time to time, depending upon the factors of soil formation and the influence of man's activity.

Soil air plays an important role in plant growth and the activity of soil organisms. Its main constituents, as in the atmosphere, are nitrogen, oxygen and carbon dioxide. Various organisms use the oxygen and give off carbon dioxide. The supply of oxygen has to be constantly replenished and this is the importance of adequate pore spaces or aeration within the soil. For adequate aeration approximately 10% by volume of the soil should be occupied by air.

The importance of soil water lies in its roles in plant growth and in the chemical and physical reactions that occur in soils. Water provides the medium by which plants take up their nutrients in solution through their root systems; it may also be considered a plant nutrient itself. Thus water is crucial to plant growth. Molecules of water also play a central role in the chemical weathering processes of hydration, hydrolysis, oxidation, reduction and solution. In physical weathering soil particles and rock fragments are disrupted by the expansion of ice in cycles of freezing and thawing and during wetting and drying. Wetting and drying cycles play an important role in the production of soil structure and in the physical translocation of material such as clay within a soil.

Air and water in the soil have a reciprocal relationship since both compete for the same pore spaces. For example, after a rain or if the soil is poorly drained, the pores are filled with water and air is excluded. Conversely, as water moves out of a moist soil, the pore space is filled with air. Thus the relationship between air and water in soils is continually changing.

The mineral portion of soils is composed of a wide variety of inorganic compounds. The minerals are commonly referred to as primary or secondary. Primary minerals originate from the geologic substrata. They include quartz, feldspar, mica, amphibole and pyroxene. They respond to the environmental factors and in the presence of water and air are altered or weathered. As a result of chemical weathering processes the primary minerals become secondary minerals such as illite, vermiculite, chlorite, montmorillonite and kaolinite (often called the clay minerals) and the hydrous oxides of iron and aluminum. Particle size of the mineral fraction varies widely, from stones (over 250 mm in diameter), through cobbles (250-75 mm), gravel (75-2 mm), sand (2-0.05 mm), silt (0.05-0.002 mm) to clay (less than 0.002 mm). All combinations of these particle sizes can occur in soils, and the expression of the amounts of the various size fractions is called soil texture. Although coarse fragments and sand sized particles play but a small role in chemical processes occurring in soils, they are very important in soil drainage and in the engineering uses of soils. Silts and clays play the most important role in water and nutrient retention as well as the swelling and shrinking properties of soils.

The organic portion of soils results from the accumulation of animal and plant residues added to the mineral soil. It is this organic portion that differentiates soil from geological material occurring below the earth's surface which otherwise may have many of the properties of a soil. Organic compounds undergo decomposition by soil flora and fauna. This process produces humus, the most active and important form of organic matter for crop growth and soil formation. Organic matter is an extremely important constituent of soils, as it is the source of many nutrients necessary for plant growth, it enhances the soil's water holding capacity and its presence favours good soil structure especially in the topsoil.

SOIL PROCESSES

There are four basic processes that occur in the formation of soils, namely additions, losses, translocations and transformations. The two driving forces for these processes are climate (temperature and precipitation) and organisms, (plants and animals). Parent material is usually a rather passive factor in affecting soil processes because parent materials are inherited from the geologic world. Topography (or relief) is also rather passive in affecting soil processes, mainly by modifying the climatic influences of temperature and precipitation.

The various types of additions, losses, translocations and transformations that occur within the soil may be seen in Figure 2.2.1. Most additions occur at the surface. The most obvious ones include solar energy, water controlled by climate, and organic material derived principally from the vegetation.

Losses occur both from the surface and from the deep subsoil. For instance, water is lost by evapotranspiration and carbon dioxide by diffusion at the surface and, on a more catastrophic level, large masses of soil can be stripped by erosion. Materials suspended or dissolved in water are the main forms of losses from the subsoil.

Translocation refers to the physical movement of material within soil. The material can be in the solid, liquid or gaseous form, the movement can be in any direction from and to any horizon. For instance clay, organic matter and iron and aluminum hydrous oxides are commonly moved from the surface horizon to a subsurface horizon. Conversely, in very dry climates salts

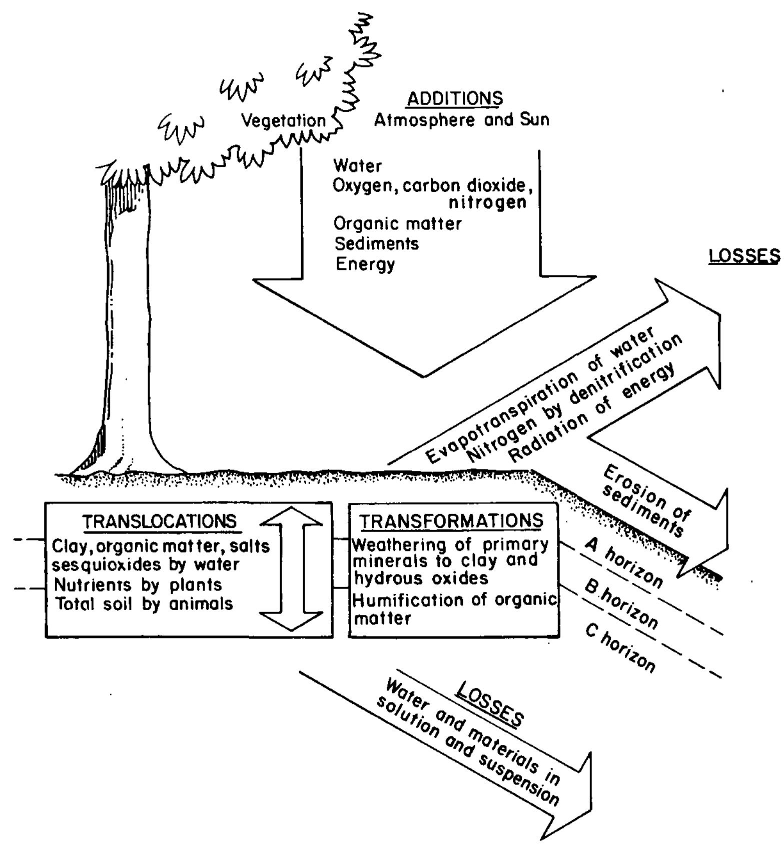


FIGURE 2.2.1 Diagrammatic representation of additions, losses, translocations and transformations involved in soil formation (after Millar, Turk and Foth 1965).

are moved upwards in solution by capillarity, and in very cold climates solid mineral fragments are moved upwards by frost action.

Additions, losses and translocations all involve movement. Figure 2.2.1 shows this movement in two dimensions. Since a soil is three dimensional and most soils occur on slopes, it must be remembered that these movements can occur laterally as well as vertically. Water can carry clay in suspension laterally through a subsurface horizon, or topsoil can move slowly en mass from a surface horizon upslope to form a new surface downslope.

Transformations involve the change of some soil constituent without any physical displacement. Chemical and physical weathering and the decomposition of organic matter are included here.

All these processes occur to a greater or lesser extent in all soils. The properties that characterize one soil are the result of a particular balance among all the processes. Other soils will be different because they have been formed by groups of processes having different balances.

SOIL FORMING FACTORS

Soils are a product of the environment. Often this is illustrated in the form of a mathematical expression, namely:

soil = f (parent material, climate, biota, topography, time)

Although the above expression shows soils to be the function of a number of individual factors, the factors are not mutually exclusive but interdependent. For example, the kind of vegetation found at any one location on the earth's surface is dependent on climate, parent material, topography, time and, in fact, soil. It is obvious that numerous combinations of the factors are possible. This leads to many different kinds of soils, each representing a certain combination of the factors of soil formation. Parent material, topography and time are sometimes referred to as the passive factors of soil formation, as they do not form soils without the active factors of climate and biota.

Parent material may be of two general kinds, organic or mineral. Organic parent materials are formed by biological action where plant and animal tissue is produced faster than it is decomposed. This occurs in cold and wet regions where biological decomposition is very slow. Soil inherits many properties from the parent material from which it forms, for example, the kinds of minerals, particle size and the chemical elements. Thus, parent materials are the building blocks upon which the other factors of soil formation manifest their effects.

Climate is an active factor of soil formation because it governs the amount, distribution and kind of precipitation as well as the amount and distribution of solar energy available at any point on the earth's surface. Biological, physical and chemical processes take place in water, thus the amount of water available leaches the soil, allows nutrients to be obtained by plants and governs the kind of vegetative cover. The form of precipitation, whether rain or snow, is also important in relation to processes which take place in soils. Solar energy, usually expressed as temperature, is an important part of climate because it controls the form of water falling onto the soil surface as well as in the soil. Also as temperature, it increases the rate of reactions, such as chemical reactions, evapotranspiration and biological processes. Wide fluctuations in temperature, especially in the presence of water cause shrinking and swelling, frost action and general weathering in soils. It can be seen that both water and temperature complement each other in changing parent material and affecting the biota on any soil landscape.

Biota is another active factor in soil formation. The kind and amount of plants and animals that exist bring organic matter into the soil system as well as nutrient elements. This has a great effect on the kind of soil that will form. For example forest vegetation tends to accumulate organic matter on top of the mineral soil where it decomposes and adds organic acids to the soil below. This aids in weathering mineral soil particles. Soils under grassland, however, accumulate organic matter within the mineral soil as a result of the extensive root system which dies back periodically. Animals play an important part in soils; in some cases animals ingest soil particles and mix the mineral and organic portions, e.g. earthworms. Other animals tunnel through soils mixing the various components. Similarly, microorganisms have great effects on soils in decomposing organic matter, fixing nitrogen from the atmosphere, and making other soil nutrients available for plant growth. Biota, in conjunction with climate, modify parent material to produce soil.

Topography is often considered a passive factor modifying the effects of climate. Everyone is aware of the effect that aspect, or orientation of the soil surface to the sun, has on the type of vegetation. South-facing slopes tend to be drier than north-facing slopes as the result of higher temperatures. Similarly, as one goes from the valley bottom to the tops of mountains or plateaus the climate becomes cooler. Topography also redistributes the water reaching the soil surface. Runoff from uplands creates wetter conditions on the lowlands, in some cases saline sloughs or organic soils. Thus as a redistributor of the climate features, topography affects soil processes, soil distribution and the type of vegetation at the site.

Finally it must also be remembered that soils develop over long periods and the balance between processes is liable to change in that time. For instance, chemical weathering is likely to be a very important form of transformation when a river sediment is first exposed. But as vegetation slowly becomes established the addition and decomposition of organic matter will become more important and chemical weathering less so.

SOIL HORIZONS

The effect of the processes described acting within the soil is to form different horizontal layers or horizons down a vertical section. Soil horizons run roughly parallel to the surface of the earth and may be composed of mineral or organic material. They differ from adjacent horizons in such properties as colour, structure, texture and consistence. A soil profile is a vertical section down through these horizons to the parent material. Soil horizons are labelled with capital letters to denote the major horizon followed by small letters to denote its particular characteristics. A diagrammatic representation of a mineral soil profile with the designations used in Canada for some horizons is shown in Figure 2.2.2.

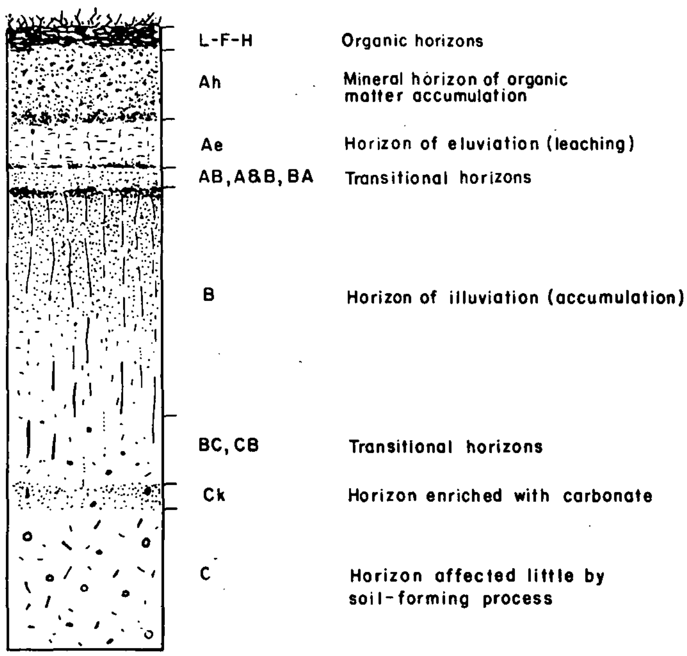


FIGURE 2.2.2 Common horizons in a mineral soil profile. Some profiles may not have all these horizons, but all profiles have some of them.

In mineral soils there are generally three major horizons; A, B and C. The A horizon is uppermost, where the maximum accumulation of organic matter *in situ* occurs and where maximum removal of materials occurs by solution, suspension or erosion. It is also where the largest transfers of energy take place, both solar and biological. This is truly where the action is! The B horizon is where the materials accumulate that were freed in the upper portion of the soil body. There is a close relationship between the A and B horizons. Translocations as well as many biological and chemical reactions take place between them. The B horizon, however, tends to be more stable than the A for short term differences. The C horizon is often termed the parent material. The effects of soil processes have not manifested themselves appreciably and thus the material is little modified.

Small letters are used to modify the major mineral soil horizon letters A, B and C. These small letters denote the predominant properties of the major horizon. Thus h indicates a horizon enriched with organic matter and t indicates a horizon where clay has accumulated. Small letters can be combined; for example, a horizon labelled Bhf indicates that it is a layer within the soil where organic matter, iron and aluminum have accumulated.

Major organic soil horizons are found in two distinctive kinds of environments, well aerated or poorly aerated. In well aerated environments leaves, needles, twigs and branches fall to the earth, accumulate and begin to decompose on top of the mineral soil. The degree of decomposition is important in understanding soil processes, and it is the criterion for distinguishing three horizons L, F and H. L has the least decomposition and H the most with F denoting moderate decomposition. In poorly aerated environments (wet areas) the organic materials also accumulate but their character is different because of the saturated condition. In these areas the horizons are denoted 0. They will be composed mainly of mosses, rushes and woody material.

Small letters are used in organic soils to denote the degree of decomposition of the organic material. They are used only with 0 for soils of wet environments. For instance 0f would be a horizon with little decomposition and 0h would be one of advanced decomposition. Moderate decomposition is indicated by m.

A full description of major and minor horizon and layer designations may be found in the Canadian System of Soil Classification (see <u>Further Reading</u>).

FURTHER READING

Canada Soil Survey Committee, 1978. The Canadian System of Soil Classification, Agriculture Canada, Queen's Printer, Ottawa.

This publication describes the most recent revision of the system of classifying soils used in Canada.

Millar, C.E., L.M. Turk. and H.D. Foth, 1965. Fundamentals of Soil Science, 4th ed., Wiley, New York. 491 pp.

An introductory soil science text, oriented mainly towards agronomy.

Simonson, Roy W., 1959. Outline of a generalized theory of soil genesis. Soil Sci. Soc. Amer. Proc., 23: 152-156.

The paper upon which the section on soil processes is largely based.

2.3 THE CANADIAN SYSTEM OF SOIL AND SOIL CLIMATE CLASSIFICATION

L.M. Lavkulich and K.W.G. Valentine

A classification system is an arrangement of things made by man to help him remember them and to arrange his knowledge of them into some logical order. A system is needed because a large number of unordered objects cannot be remembered individually and the logical arrangement is needed for reference. A system is also required so that relationships between the various objects can be deduced or inferred, and so that predictions can be made about the objects' properties and behaviour.

SOIL CLASSIFICATION

The Canadian System of Soil Classification which has developed gradually over more than 60 years, attempts to arrange the soils of Canada according to their properties. It is, therefore, a natural or taxonomic system. The different categories are based as much as possible on properties that can be seen in the field. Where this is not possible, or where definite limits of field properties must be set, laboratory measurements are made. For instance the percent carbon content of the A horizon and the percent iron plus aluminum content of the B horizon are both used as criteria for particular soils within the classification. But even where laboratory tests are ultimately necessary, there is usually a field property that can be used as an indication. In the above two cases the blackness of the A horizon would give a clue to the carbon content and the redness of the B horizon can indicate the iron plus aluminum content.

The particular properties that are chosen to differentiate categories are for the most part connected with particular groups of processes because this is the way we think about soils. In effect, therefore, soils are grouped according to how they were formed, that is according to their genesis, because it is the different balances of soil-forming processes that produce the different properties. Although soils are defined on their inherent properties, various groups of soils throughout the system will also be associated with particular environments. Such a taxonomic classification is essential in understanding soil systems as well as in making resource inventories.

Soil varies in thickness over the earth's surface from a few millimetres to several metres, and different soils grade imperceptibly into one another. The minimum depth of soil material that is classified is 10 cm and the smallest three-dimensional unit at the surface of the earth that is considered as a soil is called a "pedon". By definition a pedon is between

1 and 2 m deep and its lateral extension is between 1 and 3.5 m. The actual dimensions depend on the lateral and vertical variability of the soil horizons and upon some other factors such as the depth to bedrock.

The System of Soil Classification for Canada has six levels of generalization or categories as outlined below:

Order - This is the highest level of generalization. The pedons are grouped according to their properties that reflect the nature of the soil forming processes. For example, the total effect of soil processes in the soils of the Chernozemic order leads mainly to the accumulation of organic matter in the topsoil under a grassland vegetation. The number of specific statements that can be made about this category are few; only general statements are possible. Nine orders are recognized, seven for mineral soils, one for organic soils, and one which can contain both.

Great Group - This class is a subdivision of the order and is, therefore, more specific and more precise statements can be made about it. Great groups are based on properties that reflect differences in the strength of the dominant processes or a major contribution of a process in addition to the dominant one. In the Chernozemic order the great groups are differentiated on the basis of the colour of the topsoil. This is an indication of the amount of organic matter that has accumulated. The Brown soils in the driest areas have the least and the Black soils in the coolest and wettest areas have the most. The Dark Gray soils occur near the forest-grassland transition where a secondary process of the leaching of organic matter and clay from the topsoil becomes important. It is the great group that will be used to describe the soil landscapes of British Columbia in Part 3. The classification system down to this level is as follows:

Order	Great Group
Brunisolic	Melanic Brunisol
	Eutric Brunisol
	Sombric Brunisol
	Dystric Brunisol
Chernozemic	Brown
	Dark Brown
	Black
	Dark Gray
Cryosolic	Turbic Cryosol
	Static Cryosol
	Organic Cryosol
Gleysolic	Humic Gleysol
	Gleysol
	Luvic Gleysol
Luvisolic	Gray Brown Luvisol
	Gray Luvisol
Organic	Fibrosol
	Mesisol
	Humisol
	Folisol

Podzolic	Humic Podzol Ferro-Humic Podzol Humo-Ferric Podzol
Regosolic	Regosol Humic Regosol
Solonetzic	Solonetz Solodized Solonetz Solod

Below these first two levels there are three more subdivisions as follows:

Subgroup - A subdivision of the great group that defines the central concept of the great group (Orthic) or certain variations from that concept which are grading towards other orders, e.g. a Gleyed Brown Chernozemic or a Solonetzic Brown Chernozemic, where the normal features of a Brown Chernozemic soil are being modified by the occurrence of excessive water or soluble salts respectively. Special features of the soil profile such as thin iron pans (Placic) or repeated organic layers (Cumulic) are also used to classify subgroups. The subgroup is visualized as having a particular assemblage of horizons and the Canadian System of Soil Classification specifies the horizons that each subgroup category must have, along with others that it may have.

Family - A subdivision of the subgroup which identifies a group of soils that are relatively homogeneous in mineralogy, texture and soil climate as well as genetic soil horizons. Because of the more precise nature of this class many statements can be made about the use and management of the soils in relation to plant growth, hydrology and engineering characteristics.

Series - A subdivision of the family, this is a group of pedons (a polypedon) with horizons whose features such as colour, texture, structure and thickness fall within a narrow range. The pedons have all been developed from similar parent material. This is probably the most important category of soils for consideration of use and management since it applies to real soil bodies - polypedons.

There used to be a further category called a Type based on the texture of the topsoil. This has now been dropped but may be found in some early reports.

The higher classes of the Soil Classification (order, great group, subgroup and family) are especially important in studying genetic relationships, drawing inferences and allowing correlations which are often required for regional studies. The two lower categories are more suited to local and site specific studies and to land utilization programs.

The nomenclature used for the four higher categories is descriptive of either the soil morphology or the kinds of environments in which the soils are found. The soil series, because of its more local character and precise nature, is named after a geographic or cultural feature near the site where the soil was first observed.

SOIL CLIMATE CLASSIFICATION

Climate is an important factor in soil formation as well as being important for biological growth. Climate involves temperature, energy and moisture relationships. It is dynamic with respect to place and time. Most classifications of climate have emphasized the aerial portion of the earth and are interpretations of air temperatures and precipitation distributions. A climate classification is needed that shows the interaction between aerial climate and soil climate. The latter affects root development, plant growth, soil structure, soil behaviour, and the environment for soil flora and fauna. Soil climate is affected by water content, soil depth, surface cover, position on the landscape and the effects of man.

A soil climate classification for Canada has been produced based on temperature and moisture conditions for periods which are significant to plant growth. The distribibion of soil temperature classes and soil moisture regimes in British Columbia is shown in Figure 2.3.1. Soil temperature classes are based mainly on mean annual soil temperatures, the length of the growing season and accumulated degree days. The classes recognized in British Columbia are given in Table 2.3.1.

TABLE 2.3.1

Soil Temperature Classes

Class	Mean Annual Soil Temp. (°C)	Growing Season Days Over 5°C	Degree - days Over 5°C
Very Cold SUBARCTIC	-7 to less than 2	less than 120	less than 555
Cold CRYOBOREAL	2 to less than 8	120 to 180	555 to 1110
Moderately Cold CRYOBOREAL	2 to less than 8	less than 220	1110 to less than 1250
Cool BOREAL	5 to less than 8	over 170	1250 to less than 1388
Moderately Cool BOREAL	5 to less than 8	less than 220	1388 to less than 1720
Mild MESIC	8 to less than 15	200 to 240	1720 to 2220

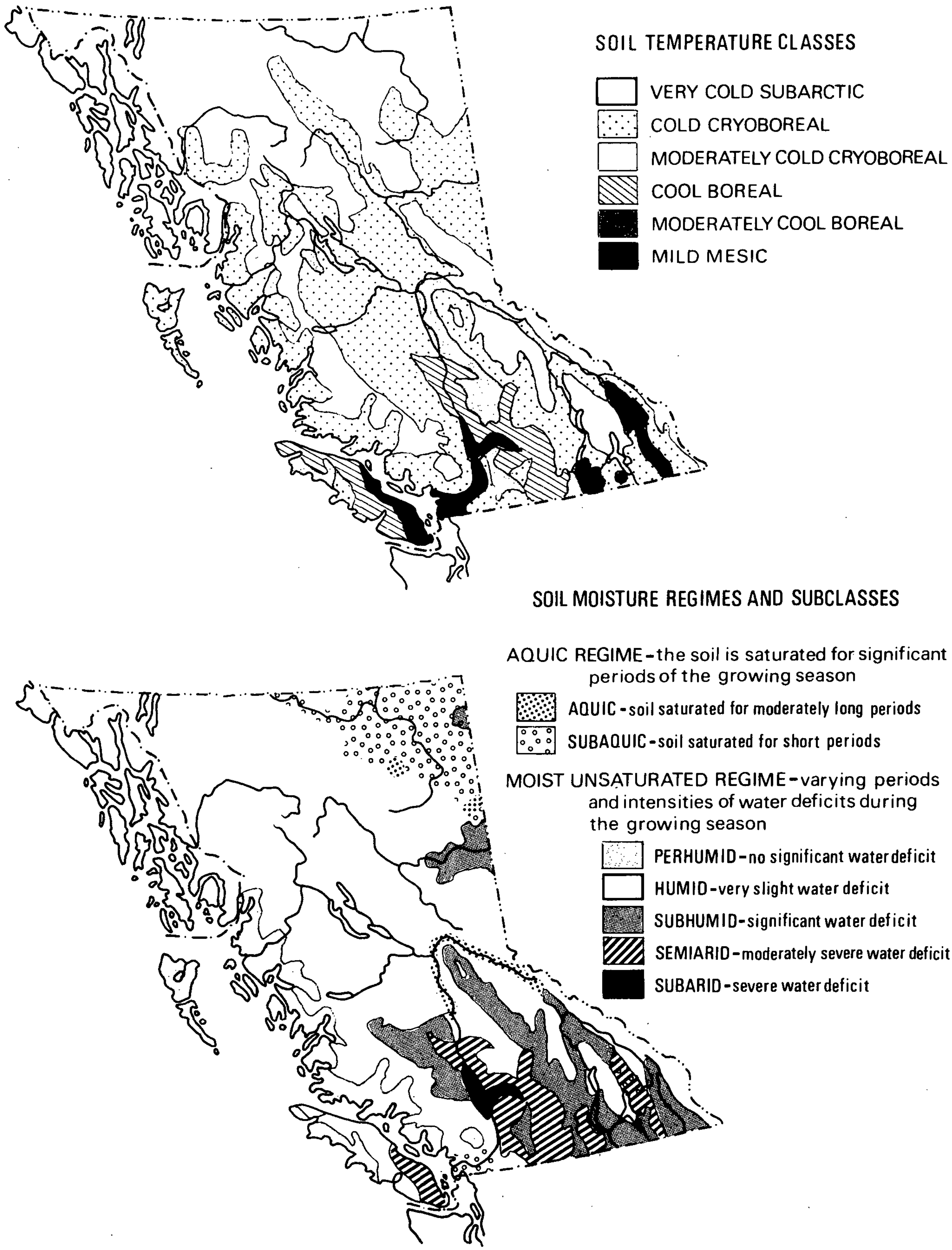


FIGURE 2.3.1 THE SOIL CLIMATES OF BRITISH COLUMBIA (derived from J.S. Clayton et al. 1977)

Moisture classes are recognized on the basis of whether the soil is saturated or not for long periods. For aquic regimes subclasses are separated on the length of time the soil is saturated during the growing season. For moist and submoist regimes the subclasses are based on calculations of intensity and degree of water deficits during the growing season. For a more complete description of soil climates the publication Soils of Canada should be consulted (Clayton et al. 1977 in Further Reading).

SOIL CLASSIFICATION AND SOIL MAPPING

One of the principal uses to which the soil classification has been put is the mapping of soils in the field. The classification system is used to define and label the types of soils that are found in the landscape, and then lines are put on the map to show the boundaries between these different soil landscapes.

Maps can be made to show the geographical distribution of soils classified at any level of the system from order to series. The higher categories will be used on small scale maps where generalizations about large areas are necessary. The lower categories will be more applicable to large scale maps where it will be possible to draw lines round areas which contain soils with a narrow range of properties. In fact, the great group, subgroup and the series have been the categories of classification most often used in mapping. In addition, a special mapping unit called an "association" has also been commonly used.

An example of a small scale map of the soils of British Columbia is that portion of the Soils of Canada map published at a scale of 1:5 million or the map shown in Figure 3.2.1 for British Columbia. Map units delineate areas within which the predominant soils would belong to one great group. Special symbols are overprinted to show areas where excessive water or stones and shallow bedrock cause modifications in the profile typical of that great group.

Formerly, more detailed soil survey maps were published at a scale of 1 or 2 inches to the mile (1:63,360 or 1:31,680). Soil series were used as the mapping unit either singly or in two- or three-fold combination. More recently, soil surveys have been published regularly at a scale of 1:126,720 or 1:125,000 and a special mapping unit that is not a classification category has been used. This is the soil association, made up of a group of soils that occur together in the landscape. Each of these soils will belong to a series but they will differ due to slightly different combinations of soil forming factors. For example, in a rolling landscape there may be a shallow, dry soil on the ridge crests, a well drained, moist soil on the mid-slopes, and a deep, wet soil in the hollows. These would be three series but they could be mapped together as a single soil association. To be grouped as an association, a soil series must have developed from the same parent material under the same climatic regime and usually within the same vegetation zone.

The distinction between a classification category and a mapping unit is important and often causes confusion. A soil association is a mapping unit not a taxonomic category. Great groups, subgroups and series on the other hand are taxonomic categories which may be used as specific mapping units or as components. As formal classification categories they are concepts with specific definitions and limits to their properties. As mapping units they are used to label the range of properties that the predominant soils will have in that area. But it must be remembered that some soils in the map unit will not fit the particular great group or series classification used. The soil mapper or surveyor, will usually try to keep these different soils down to about 15 or 20 percent of the map unit area.

A discussion in greater detail of the types of soil maps and reports that have been produced in British Columbia is included in Part 4.

FURTHER READING

Canada Soil Survey Committee, 1978. The Canadian System of Soil Classification, Agriculture Canada, Queen's Printer, Ottawa.

A complete description of the System of Soil Classification as used in Canada. The publication describes the system as well as giving illustrations of the major soils.

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

An account of the major soils in Canada, their characteristics, distribution and extent. Included are descriptions of soil climate as well as maps of Soils of Canada and Soil Climates of Canada.

2.4. THE SOIL ORDERS OF BRITISH COLUMBIA

K.W.G. Valentine and L.M. Lavkulich

The two previous sections have described the ways in which soils have formed and the method of classifying them in Canada. These discussions have been largely theoretical. It is now time to describe more specifically the types of environment, processes and properties that are associated with the nine major soil groupings - the soil orders - as they occur in British Columbia.

THE BRUNISOLIC ORDER

Soils of the Brunisolic order have undergone only moderate development from the original parent material. Physical, chemical and biological weathering has proceeded far enough to change the morphology of the parent material. There are no drastic translocations or transformations of the material that characterize many of the other orders.

There are a number of reasons for this sort of soil occurring in British Columbia. Firstly in many areas the climate has restricted the progression of soil weathering. Long winters and low temperatures restrict the rate of many of the transformations which constitute soil weathering. This is the reason why Brunisolic soils cover much of the high plateaus of northern British Columbia. Lack of soil moisture also limits transformations such as chemical weathering. Thus Brunisolic soils are also found in the subhumid to semiarid zones of the southern interior.

Secondly, some Brunisolic soils have developed on very coarse textured materials such as fluvioglacial sands and gravels in areas where the climate is not normally a limiting factor in soil development. Because clay-sized particles, the principal active fraction in chemical transformations, make up only a small volume of the total mineral soil, little weathering has taken place. Most of the soil is relatively inert gravel and quartz sand. Moreover the parent material has a low water-holding capacity, so that soil water content is low and thus chemical transformations are further restricted. The droughtiness of these soils means that the vegetation is often limited to open lodgepole pine and pinegrass. Therefore, organic matter additions to the topsoil are limited, and well-structured Ah horizons are thin or absent.

Thirdly, Brunisolic soils are found on very young geological sediments. In this case the time available for soil development since deposition has not been sufficient for anything more than a moderate amount of weathering to have taken place. Many of the soils on the Recent alluvium of the Fraser Valley fall into the Brunisolic order.

Soils of the Brunisolic order are often regarded as being in a transitional stage of development. We think that given time translocations of weathering products will begin within the soil to produce Podzols or possibly Luvisols. The Brunisolic soils on Fraser River alluvium are a probable example. However, there are many areas in British Columbia where Brunisolic soils occur on sediments that have been exposed to subaerial weathering since the ice melted about 11,000 years ago; for example the soils in the semiarid southern interior valleys. In other words it is necessary to decide whether transitional is to mean in the short or in the long term.

The main processes involved in the formation of Brunisolic soils are the removal by leaching of soluble salts and carbonates, the *in situ* weathering of the mineral fraction to form secondary minerals and hydrated iron and aluminum oxides, and the development of soil structure in the finer textured materials that is different from the original structure of the parent material. These are the processes that form the Bm horizon which is diagnostic of Brunisolic soils. In the field it is recognized by its browner or redder colour as compared with the parent material, by its structure and by its lack of major accumulations of any materials translocated from the A horizon, such as clay. A common horizon sequence for these soils would be LFH, Bm, C or Ck.

The great groups of the Brunisolic order are separated on the basis of the presence or absence of an A horizon in which the mineral and organic fractions have been mixed together by soil fauna (an Ah horizon), and on the base status of the soils as shown by the pH. The Ah horizon indicates that there is a net addition of organic matter to the soil and that organic nutrients are available. A high base status shows that the soil can retain inorganic nutrients such as calcium and potassium, or that leaching is limited. The specific characteristics of the four great groups are as follows:

Melanic Brunisol: Thick Ah horizon + high base status (pH over 5.5)

Eutric Brunisol: No or thin Ah horizon + high base status (pH over 5.5)

Sombric Brunisol: Thick Ah horizon + low base status (pH less than 5.5)

Dystric Brunisol: No or thin Ah horizon + low base status (pH less than 5.5)

The Whipsaw soils are an example of a Eutric Brunisol. They have developed on coarse textured fluvioglacial deposits in the southern interior of British Columbia near Princeton. The following abbreviated description is from a profile on a southerly aspect at approximately 600 m elevation east of Wolfe Lake (49^o 26'N, 120^o 18'W).

LF 1 cm of moss, partially decomposed grass and pine needles.

Ah 5 cm of black sandy loam; granular structure; slightly stony.

Bm 20 cm of dark brown sandy loam; coarse granular structure; slightly stony.

BC 15 cm of dark brown gravelly sandy loam; weak blocky structure; very stony.

IIC loose sand and gravel.

Photographs of a Brunisolic soil profile and landscape are included as Plates 2.4.1 and 2.4.2. Chemical and physical analyses from a Whipsaw profile are given in Table 2.4.1. The important points to note from the analyses are the approximately neutral pH all the way down the profile, the lack of clay or Fe + Al accumulation in the Bm horizon versus the Ah and the high percent base saturation dominated by calcium cations.

TABLE 2.4.1

Chemical and Physical Analyses of a Eutric Brunisol
Whipsaw Series

Horizon	Depth (cm)	pH (H_2O)	% Org. C	% Total N	C:N Ratio	Particle Size Distribution % Sand	Silt	Clay	Fine Clay
Ah	0-5	6.5	12.0	0.24	29.1	64.7	29.5	5.8	0.9
Bm1	5-15	6.4	2.9	0.07	24.2	64.6	30.3	5.1	1.5
Bm2	15-25	6.5	1.9	0.05	20.4	70.2	24.5	5.3	1.9
BC	25-40	6.4	--	--	--	--	--	--	--
IIC	40+	6.5	0.6	0.02	15.7	93.1	6.2	0.7	0.8

Horizon	Cation exchange, meq/100 g soil: Capacity	Ca	Mg	K	Na	Base Sat'n %	Fe% (Oxalate)	Al% (Oxalate)
Ah	28.6	16.6	1.9	1.1	0.1	70.0	0.29	0.45
Bm1	12.1	8.6	1.5	0.4	0.1	87.3	0.28	0.20
Bm2	11.6	8.4	2.0	0.4	0.1	93.1	0.35	0.18
BC	--	--	--	--	--	--	--	--
IIC	6.2	5.0	1.3	0.1	0.1	100+	0.48	0.19

These data are taken from Green, A.J. and T.M. Lord. The soils of the Princeton area. B.C. Soil Survey Rept. No. 14, Agriculture Canada, Queens Printer, Ottawa (in press).

THE CHERNOZEMIC ORDER

Soils that belong to the Chernozemic order are associated with a grassland vegetation and a climate which ranges from subarid to subhumid. Some grasslands have shrubs and forbs, and in some areas the soils extend into the forest-grassland transition. The mean annual temperature is usually less than 5.5°C and some part of the soil will be frozen for some time during the winter. However, the most important characteristics of the climate as a soil forming factor are low rainfall, high summer temperatures and high evapotranspiration rates. This inhibits tree growth, limits soil leaching and leads to the accumulation of the decomposition products of the grasses in the topsoil.

The principal areas of Chernozemic soils in Canada are found in the Prairie provinces. But there are also significant expanses of such soils in the valleys and some adjacent plateau areas of the south central interior of British Columbia. The distribution of Chernozemic soils is mainly a result of the climatic limitations to tree growth. These soils are therefore found on a wide variety of parent materials. In valleys they occur on fluvial deposits or terraced lake silts as in parts of the southern Okanagan valley. On plateaus they may occur on till as in the Chilcotin region, and in the very dry interior near Ashcroft they can be found on the colluvium of hill slopes. Local factors such as aspect that affect evapotranspiration are also important. In many areas Chernozemic soils occur on south- and west-facing slopes, with forested soils (usually either Brunisolic or Luvisolic) on north- and east-facing slopes.

The dominant process in the development of Chernozemic soils is the accumulation in the topsoil of organic matter derived from the decomposition of the leaves and roots of the grasses. The organic matter is intimately mixed with the mineral material by its repeated ingestion and excretion by soil fauna. This gives a dark colored surface Ah horizon with well-developed granular structure. The low rainfall means that there is only a limited movement of water down through the soil profile and very little leaching. This means that there will be little movement of clay down the profile and carbonates will tend to accumulate in the C and lower B horizons due to high soil evaporation rates. There will be weathering of primary to secondary minerals in the A and B horizons but there will be little translocation of the products within the soil. A typical but simplified sequence of horizons would therefore be Ah, Bm, Cca.

The four great groups within the Chernozemic order - Brown, Dark Brown, Black and Dark Gray - are differentiated on the color of the surface Ah horizon.

This is associated with organic matter content which is itself a reflection of the aridity of the environment. In a study of a toposequence of Chernozemic soils near Kamloops (see van Ryswyk et al., 1966 in Further Reading) the Brown soils in a subarid environment with a big basin sagebrush plant community had an organic carbon content of 1.12% in the Ah horizon. The Dark Brown soils in a semiarid environment with a needle-and-thread grass - Sandberg's blue grass plant community had a carbon content of 1.75%, and the Black soils in a subhumid environment with a rough fescue plant community had 3.88% organic carbon in the Ah. Dark Gray soils are soils of the forest-grassland transition. They show some characteristics of forest soils such as the Luvisolics. The net accumulation of organic matter is less and there is some translocation of clay from the A horizon to the B.

The Black soils from the above mentioned study near Kamloops are taken as an example of soils from the Chernozemic order. They have developed on moderately coarse textured glacial till at about 950 m above sea level. An abbreviated profile description follows.

Ah	25 cm of black sandy loam, which is friable with platy structure.
Bm	65 cm of dark brown gravelly sandy loam, friable with blocky structure.
Ck	30 cm of grayish brown gravelly sandy loam which is friable with blocky structure and contains carbonates.
C	Grayish brown gravelly sandy loam which is slightly friable with blocky structure but does not contain significant carbonates.

Photographs of a Chernozemic soil profile and landscape are included as Plates 2.4.3 and 2.4.4. Some chemical and physical analyses of the Black soils near Kamloops are given in Table 2.4.2 (page 74). The significant features to note are the high pH throughout the profile, the high cation exchange capacity (C.E.C.), the high organic carbon content of the Ah horizon, and the low C:N ratio. This is a very fertile soil.

THE CRYOSOLIC ORDER

Cryosolic soils contain permafrost close to the surface. This is the feature that sets them apart from all other soil orders. Permafrost, or perennially frozen ground, is found where the temperature of the soil remains below 0^{o}C continuously for a number of years. Under these conditions soil water in the lower part of the profile will remain frozen throughout the summer months, but the upper part (the "active layer") will be thawed. For

PLATES 2.4.1 TO 2.4.6
PROFILES AND LANDSCAPES OF SOILS
FROM THE BRUNISOLIC, CHERNOZEMIC AND CRYOSOLIC ORDERS

2.4.1 Profile of a Brunisolic soil developed in sandy loam over beach sands and gravels in the Nig Creek valley, northern Peace River area (photo A.J. Green).

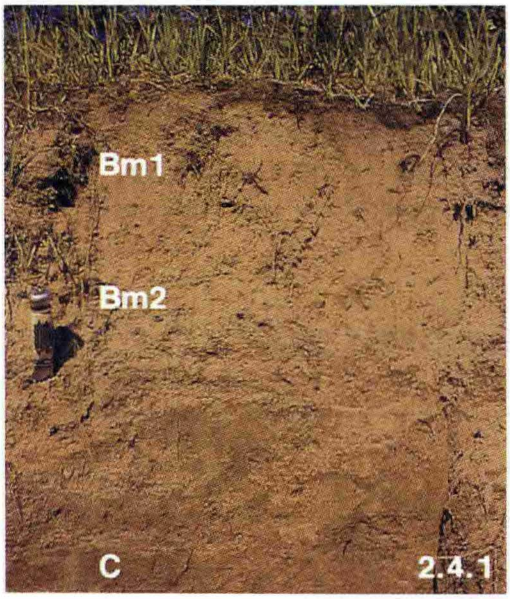
2.4.2 Brunisolic landscape on a fluvioglacial terrace in the Wapiti River valley, northeastern British Columbia. The very coarse gravelly parent materials can be seen in the overturned tree stump. The vegetation is very open lodgepole pine and pine grass.

2.4.3 Profile of a Chernozemic soil developed on moderately fine glacial till near Douglas Lake, southern British Columbia (Photo A.J. Green).

2.4.4 Chernozemic soil landscape at the junction of the Fraser and Chilcotin Rivers, central British Columbia. Dark Brown soils are found on the terrace flats with a needle-and-thread grass community. Brown soils occur on the terrace slopes with bluebunch wheat grass and big basin sagebrush.

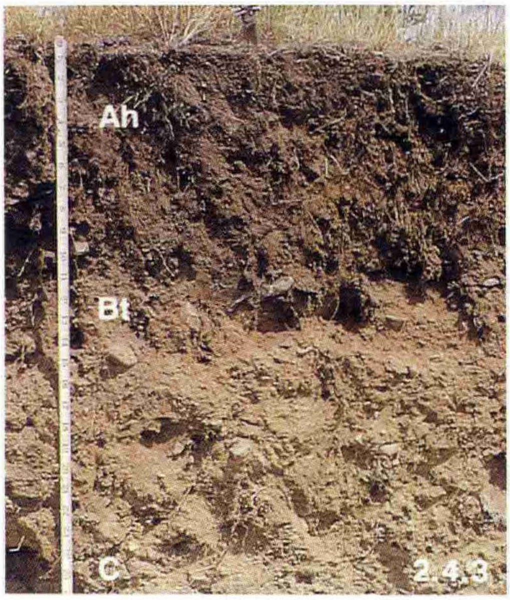
2.4.5 Profile of a Cryosol developed in deep organic matter on the flat very poorly drained Fort Nelson lowland of northeastern British Columbia. The soil was frozen below about 50 cm. Note the scale is in feet.

2.4.6 Cryosolic (Organic Cryosol) landscape in the Fort Nelson lowland. The vegetation cover of these very poorly drained bogs is sphagnum and hypnum mosses, common Labrador tea, bog glandular birch and occasional stunted black spruce and willows. This is the landscape of the profile shown in Plate 2.4.5.



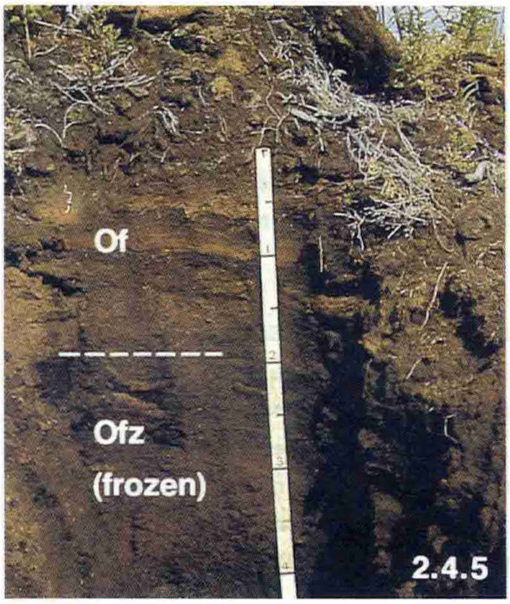
2.4.1


2.4.2

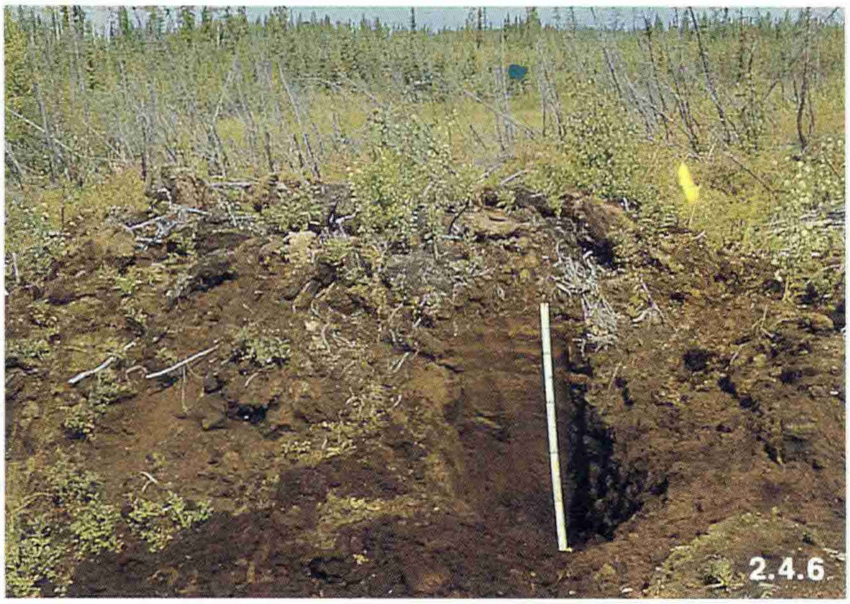


2.4.3


2.4.4



2.4.5


2.4.6

the purpose of soil classification Cryosolic soils either have permafrost within one metre from the surface or if they are cryoturbated (disrupted by frost heaving), they must have permafrost within two metres from the surface.

TABLE 2.4.2

Chemical and Physical Analyses of a Black Chernozemic Soil

Horizon	Depth (cm)	pH (Sat'd Paste)	% Org. C	% Total N	C:N Ratio	Bulk Density (g/cc)
Ah	0-25	7.2	3.9	.49	8	0.97
Bm	25-92	7.3	0.8	.01	8	--
Ck	92-122	8.3	0.3	--	--	--
C	122-142	8.2	0.1	--	--	--

	Cation exchange, meq/100 g soil					Base Sat'n
Horizon	Capacity	Ca	Mg	K	Na	%
Ah	26.4	16.4	5.9	1.9	0.2	92
Bm	16.1	8.1	6.2	1.2	0.1	97

These data are taken from van Ryswyk et al., 1966 (see Further Reading).

The principal areas of Cryosolic soils in Canada are in the far north. British Columbia has two types of landscapes which contain them: firstly the drier peatlands in the extreme northeast within the "discontinuous zone" of permafrost, and secondly the high mountains.

The northeastern corner of British Columbia lies on the southern fringe of the discontinuous permafrost zone. The -1°C mean annual air isotherm is approximately the southern limit of this zone. Permafrost in this area occurs as small isolated patches, usually in peat bogs. The peat moss acts as an insulation and keeps the lower layers frozen in the summer. Permafrost can also occur on north facing slopes and in heavily shaded areas. The peatlands must not be too wet since water effectively melts permafrost.

The occurrence of permafrost in the mountains of British Columbia south of the discontinuous permafrost zone is far less predictable. The principal control is still climatic, but aspect, exposure, vegetation, soil or rock type and the extent of snow cover are also important. The distribution of permafrost is therefore very patchy, but is most common on high north facing slopes which have little or no snow cover. In the mountains and plateaus of northern British Columbia the lower limit is about 1200 m whereas at the 49th parallel it is at about 2000 m above sea level. In the mountains permafrost will be found in mineral as well as in organic soils.

Cryosolic soils have very cold subartic or cold cryoboreal soil temperature regimes. Under such cold environments the rates of chemical and microbiological reactions are slow and transformations within the soils are limited. Mineral soils often have deep organic surface horizons because the low soil temperatures inhibit microbial decomposition of organic matter rather than plant growth. Organic soils are raw and poorly decomposed but transformations and translocations due to physical weathering are prevalent. This is especially true in the active layer above the permafrost where freezing and thawing occurs. As water freezes in cracks it expands. Therefore rock fragments and individual minerals can be broken apart. Also particles are moved within a soil by frost heaving, and in extreme cases horizons can be disrupted and churned.

There are three great groups in the Cryosolic order. They are separated on the degree of disruption of the profile and the type of parent material as follows:

Turbic Cryosol:	mineral soils with disrupted horizons and displaced material, due to cryoturbation.
Static Cryosol:	mineral soils with no disruption of horizons.
Organic Cryosol:	organic soils with no disruption of horizons.

Cryosolic soils in mountainous areas of British Columbia will be mainly Turbic Cryosols with a few Organic Cryosols in the depressions. Little is known about these soils in British Columbia but a description of a soil on a north facing slope at an elevation of 2350 m just north of Banff, Alberta taken in September showed 15 cm of fibric (Of) organic matter and fine humus (Oh) over 25 cm of unfrozen loose fine colluvial rubble over large colluvial fragments which were frozen together (see Ogilvie and Baptie, 1967, in Further Reading).

The Cryosolic soils within the zone of discontinuous permafrost in British Columbia will be principally Organic Cryosols in the peatlands. One of the soils from the Klua complex east of Fort Nelson is taken as an example. It was described and sampled on an exposed road cut north of Clarke Lake (58° 44'N, 122° 29'W). In the bog away from the road cut permafrost was at about 50 cm in late July. An abbreviated description follows:

Of1	30 cm of yellowish brown partially decomposed sphagnum and hypnum moss remains.
Om	55 cm of dark brown semidecomposed moss and leaf remains.

Of2 65 cm of dark brown partially decomposed moss and sedge remains.

Ofz frozen, partially decomposed moss and sedge remains.

Photographs of the profile and soil landscape are included as Plates 2.4.5 and 2.4.6. Some chemical and physical analyses are given in Table 2.4.3. Points to note are the very low pH values, the high organic carbon contents and low bulk densities.

TABLE 2.4.3

Chemical and Physical Analyses of an Organic Cryosol (Klua Complex)

Horizon	Depth (cm)	pH ($CaCl_2$)	% Org. C	% Total N	C:N Ratio
Of1	0-30	3.9	54.8	0.89	61.6
Om	30-85	4.3	47.2	0.88	53.6
Of2	85-150	5.4	52.8	1.68	31.4
Ofz	150+	5.9	52.9	2.42	21.9

Horizon	Bulk Density (g/cc)	Water Holding Capacity %	Fibre %
Of1	0.16	1656	87
Om	0.28	696	54
Of2	0.16	1060	73
Ofz	--	--	82

These data are taken from Valentine, K.W.G., 1971. Soils of the Fort Nelson area of British Columbia. B.C. Soil Survey Rept. No. 12, Canada Dept. Agric., Ottawa.

THE GLEYSOLIC ORDER

Soils of the Gleysolic order are saturated with water for long periods of the year and their profiles show evidence of reducing conditions. Reduction in the chemical sense is caused by a lack of oxygen. The water excludes air from the pore spaces, and the microorganisms rapidly use up any oxygen in the water, causing anaerobic reducing conditions. The transformations of the mineral fraction by chemical oxidation and the decomposition of the organic fraction by aerobic microorganisms are severely curtailed. For the rest of the year Gleysolic soils may be well aerated and aerobic weathering proceeds. Only in the extreme cases of almost permanent saturation are the soils raw and relatively unweathered with deep accumulations of organic matter on their surfaces.

These soils occur throughout the province wherever water is retained in the soil profile for long periods. They are associated with a wide variety of other soils and there is a continuous gradation from the Gleysolics to the well drained soils with which they are associated. The principal reason for their occurrence is restricted drainage due to topography. Wherever water is added to the soil faster than it drains away Gleysolic soils develop. This may be in depressions, on very flat plains or at the foot of slopes. For example, many depressions in the hummocky topography of the Cariboo plateau contain Gleysolic soils. There are also large flat plains in northern British Columbia that are covered with Gleysolic soils, and in mountain regions these soils tend to occur on the lower sections of many slopes in what is known as the receiving position. Other factors also contribute to their development. Fine textured parent materials will restrict soil drainage. For example, much of the northeastern plains is underlain by very fine marine shales which further restrict soil water movement on this flat landscape. In many of the large river floodplains in British Columbia saturation from a prolonged high groundwater table causes Gleysolic soils to develop. Heavy rainfall especially in the coastal region produces Gleysolic soils even on gentle slopes that elsewhere in the province would be better drained. Frozen layers or impermeable soil horizons can also lead to saturated soil conditions.

The lower portion of the profile of a Gleysolic soil is saturated for most of the time. Consequently the lower B and C horizons often have a dull gray colour derived from reduced ferrous iron compounds. Above this the soil is seasonally aerated and patches of bright reddish brown mottling occur where ferrous compounds have been oxidized to ferric iron. The surface horizons often have an accumulation of poorly decomposed organic matter because the action of microorganisms is restricted by the low temperature and lack of aeration.

A typical Gleysolic soil profile has LFH, Bg, Cg or LFH, Ah, Bg, and Cg horizons. Under conditions of prolonged saturation the drier organic LFH surface horizons of leaves, twigs and grasses will be replaced by an O horizon of mosses and sedges derived from wetland vegetation.

The great groups of the Gleysolic order are separated upon the basis of the presence or absence of an Ah horizon with organic matter accumulation, or upon the presence or absence of a Bt horizon with clay accumulation. The names of the great groups and the details of their properties are as follows:

Humic Gleysol: thick Ah and no Bt horizon.

Gleysol: thin or no Ah and no Bt horizon.

Luvic Gleysol: Btg horizon.

The Cowichan soils from southern Vancouver Island are an example of soils from the Gleysolic order. They have developed on fine textured marine deposits in the depressions of a gently undulating landscape. They are poorly drained and the marine clay is only very slowly permeable. The following is an abbreviated description of a Cowichan soil.

L 3 cm of undecomposed grass, leaves and needles.

H 3 cm of dark brown well decomposed organic matter.

Ah 20 cm of very dark brown clay loam with granular structure.

Ae 15 cm of brown silt loam, with faint mottling and blocky structure.

Btg 25 cm of pale brown, hard, prominently mottled silty clay.

Cg pale brown silty clay, prominently mottled with a blocky structure.

The Cowichan soils are Luvic Gleysols because they have a Btg horizon with clay accumulation (see Table 2.4.4). Other features to be noted are the high organic carbon content of the Ah horizon and the presence of the Ae horizon from which clay and bases have evidently been translocated. A Gleysolic soil profile and landscape are illustrated in Plates 2.4.7 and 2.4.8.

THE LUVISOLIC ORDER

Soils that belong to the Luvisolic order are formed under deciduous, mixed deciduous-coniferous, boreal forest or under mixed forest in the forest grassland transition zone. Their parent materials are generally neutral to slightly alkaline and they usually occur in areas having more effective precipitation than do the Chernozemic or Brunisolic soils. In other words they are found in areas which either have higher rainfall or lower temperatures with less evapotranspiration. Therefore leaching of soil constituents and weathering are more intense than they are in Chernozemic or Brunisolic soils.

Luvisolic soils cover a large portion of the province. They are found over much of the south and central interior in areas of humid or subhumid soil moisture regime. This region is in the lee of the perhumid coast mountains with their Podzolic soils, and is further north or at higher elevations than the semiarid or subarid areas of the Chernozemic and Brunisolic soils. Another large area of Luvisolic soils occurs east of the Rocky

Mountains in the northeast of the province. They are formed on a wide variety of fine to medium textured sediments, but not often on coarse textured materials.

TABLE 2.4.4

Chemical and Physical Analyses of a Luvic Gleysol
(Cowichan Series)

Horizon	Depth (cm)	pH (H_2O)	% Org. C	% Total N	C:N Ratio	Particle Size % Sand	Silt	Clay
H	3-0	5.0	29.2	0.89	32.8			
Ah	0-20	5.2	6.4	0.36	17.8	27.9	41.0	31.0
Ae	20-35	5.2	0.5	0.05	10.0	25.1	50.0	24.9
Btg	35-60	4.9	0.9	0.06	15.0	11.1	43.1	45.8
Cg	60+	5.8	0.4	0.03	13.3	13.1	49.9	37.0

Horizon	Cation exchange, meq/100 g soil Capacity	Ca	Mg	K	Na	Base Sat'n %	Bulk Density (g/cc)
Ah	33.5	8.1	5.5	0.7	0.4	43.7	0.84
Ae	9.9	2.0	2.2	0.2	0.2	46.4	1.59
Btg	23.7	9.2	7.5	0.3	0.6	73.5	1.52
Cg	24.8	13.3	8.2	0.2	0.9	91.1	1.47

These data are taken from Day, J.H., L. Farstad, and D.G. Laird, 1959. Soil Survey of Southeast Vancouver Island and Gulf Islands, British Columbia. B.C. Soil Survey Rept. No. 6, Canada Dept. of Agric., Ottawa.

The dominant process in Luvisolic soils is the translocation of clay-sized mineral particles in suspension from the A to the B norizon. These form thin shiny layers of clay on crack faces and down pores. They are called clay skins and it is this Bt horizon which distinguishes Luvisolic soils from the soils of other orders. It can be an important horizon in the soil since the clay can accumulate so much that root and water penetration is restricted. These soils can be very wet in the spring. Other processes are the addition of organic matter to form LFH horizons on the mineral soil surface, the weathering of the mineral fraction in the A and B horizon and the leaching of soluble salts and calcium carbonate into the C horizon. This gives an accumulation in the C horizon which may be detected in the field by applying a few drops of hydrochloric acid and observing the effervescence. A common horizon sequence for these soils would be LFH, Ae, Bt, Cca, Ck.

There are two great groups within the order; the Gray Brown Luvisol and the Gray Luvisol. The Gray Luvisol is the one most common in British

Columbia. There is little or no incorporation of organic matter into the top of the mineral soil so that it does not have an Ah horizon. It occurs in cool subhumid climates. The Gray Brown Luvisol has so far been recognized only in parts of the lower Fraser Valley. It has an Ah horizon and is most commonly found in the mild, humid climate of the St. Lawrence Lowlands in eastern Canada.

The Tyee soils are an example of a Gray Luvisol. They have developed on loam to clay loam glacial till on the Cariboo plateau near Williams Lake. The following abbreviated description is from a profile near Williams Lake airport at about 920 m above sea level (52° 13'N, 122° 3'W).

LFH	3 cm of partially and well decomposed grass, needles and roots.
Ae	15 cm of light gray sandy loam with weak granular structure.
Bt	38 cm of brown loam with strong blocky structure and clay skins on peds.
BC	25 cm of pale brown gravelly loam with weak blocky structure.
Ck	greyish brown gravelly loam with calcium carbonate.

Photographs of a Luvisolic soil profile and landscape are included as Plates 2.4.9 and 2.4.10. Table 2.4.5 contains chemical and physical analyses of the above profile. The points to note from the analyses are the moderately acid pH of the A and B horizons and the alkaline pH of the Ck horizon, the low organic carbon content, the low clay content of the Ae and the build up of fine clay in the Bt horizon.

THE ORGANIC ORDER

Soils in the Organic order are composed mainly of organic matter. Most of them have developed under highly saturated conditions. They are different from mineral soils because they develop by being built up through the progressive accumulation of organic material as plants die and are succeeded by others. Under these saturated conditions the action of the microorganisms and macro soil fauna that chew up organic matter and help in the production of humus is severely restricted. This results from low temperatures and a lack of oxygen. Once again we have an example of a particular soil formed by a particular balance of processes. Organic soils occur where dead vegetation accumulates faster than it is decomposed. Where the soil is saturated for only part of the year organic soils will grade into mineral Gleysolic soils with only a thin surface accumulation of organic matter.

TABLE 2.4.5

Chemical and Physical Analyses of a Gray Luvisol
(Tyee Series)

Horizon	Depth (cm)	pH* ($CaCl_2$)	% Org. C	% Total N	C:N Ratio	Particle Size Distribution % Sand	Silt	Clay	Fine Clay
L-H	3-0	4.7	--	0.43	--	--	--	--	--
Ae	0-15	4.5	0.5	0.04	12.5	48.7	44.8	6.5	1.6
Bt	15-48	5.6	0.4	0.03	13.3	38.0	46.4	15.6	12.6
BC	48-73	6.2	0.2	0.03	6.7	42.5	33.1	24.4	6.0
Ck	73+	7.3	0.1	0.02	5.0	44.7	33.2	22.1	5.7

Horizon	Cation exchange, meq/100 g soil Capacity	Ca	Mg	K	Na	Base Sat'n %
L-H	48.0	23.9	5.0	1.4	0.2	63.5
Ae	8.2	3.0	1.0	0.2	0.1	52.2
Bt	24.0	14.2	7.8	0.6	0.1	94.5
BC	19.4	12.2	6.5	0.5	0.1	99.4
Ck	15.4	22.9	4.3	0.3	0.1	100+

* For the details of the analytical methods used see McKeague, 1976, in Further Reading.
These data are from the unpublished soil survey of National Topographic Sheet 93 B SE by W. Scott.

The most common type of organic soil throughout British Columbia is one that has developed in depressions in the landscape. Water drains into these depressions and the soil is saturated for most of the year. In most cases these hollows in the landscape were lakes immediately after the ice melted. They have gradually filled in with vegetation and their surfaces have built up. The characteristics of organic soils are controlled by the hydrology of the area (the amount and quality of the water) and the vegetation that is or has been growing on them. Over much of the central interior the surrounding mineral subsoil is highly calcareous. Water in the depressions is thus neutral to alkaline. The organic soils are relatively nutrient-rich and the vegetation is mainly sedges, willows and bog glandular birch. The organic material is moderately well decomposed.

On the coast the mineral materials are more acid and there is a higher rainfall. The organic soils are also acid; they are poorly decomposed and consist mainly of moss peat.

Another form of raw acid peat is found on the plains of northeastern British Columbia. The flat topography and fine textured parent materials lead to saturated surface conditions. The cold climate produces subarctic or cryoboreal soil temperatures and a very slow rate of decomposition of

PLATES 2.4.7 TO 2.4.12
PROFILES AND LANDSCAPES OF SOILS
FROM THE GLEYSOLIC, LUVISOLIC AND ORGANIC ORDERS

2.4.7 Profile of a Gleysolic soil developed on clay loam glacial till in the Nig Creek valley in the northern Peace River area of British Columbia (photo A.J. Green).

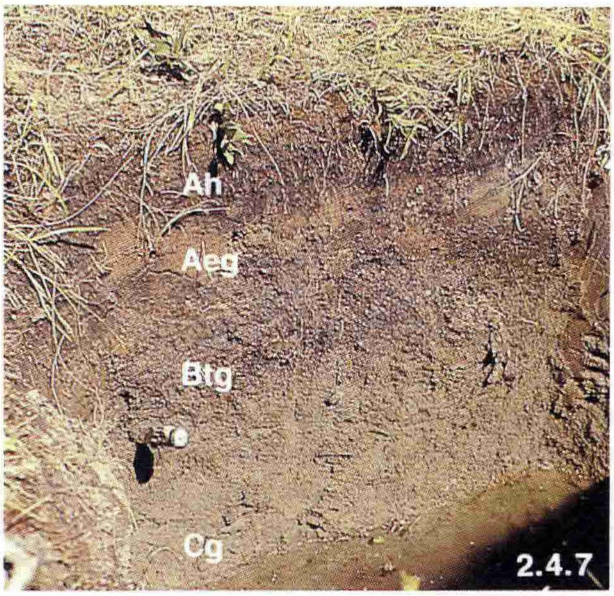
2.4.8 Gleysolic landscape in the Bridge River valley near 100 Mile House, central British Columbia. The Gleysolic soils occur on the imperfectly drained floodplain below the terrace. Sedges, sea-side arrow-grass and willows grow on them.

2.4.9 Profile of a Luvisolic soil developed on clay loam glacial till near Fort Nelson, northeastern British Columbia (photo J.H. Day).

2.4.10 Luvisolic landscape west of Quesnel, central British Columbia. Douglas-fir and lodgepole pine form a relatively open tree cover. Soopolallie and pine grass form the groundcover. White spruce is regenerating under the main tree canopy (photo T.M. Lord).

2.4.11 Profile of an Organic soil developed on a deep accumulation of organic matter in a depressional meadow south of 100 Mile House, central British Columbia.

2.4.12 Organic soil landscape on the Cariboo plateau south of 100 Mile House, central British Columbia. These organic meadows develop in the very poorly drained depressions of the hummocky plateau surface. Sedges, sea-side arrow-grass and mosses are the main plants growing on them. This is the landscape of the profile shown in Plate 2.4.11.


Ah
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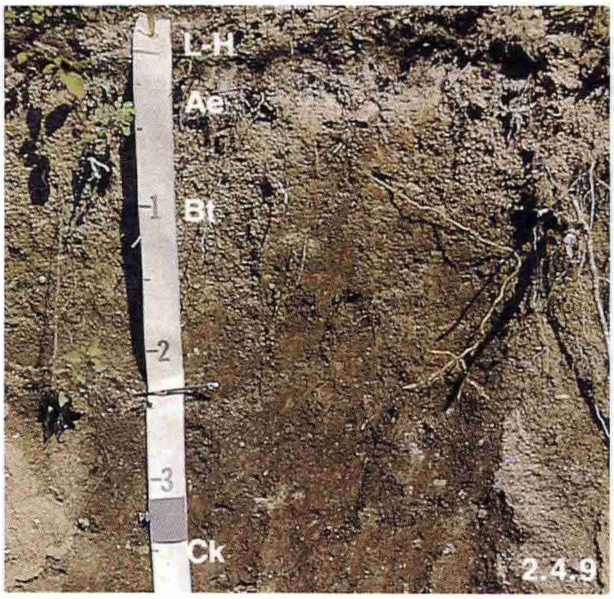
2.4.8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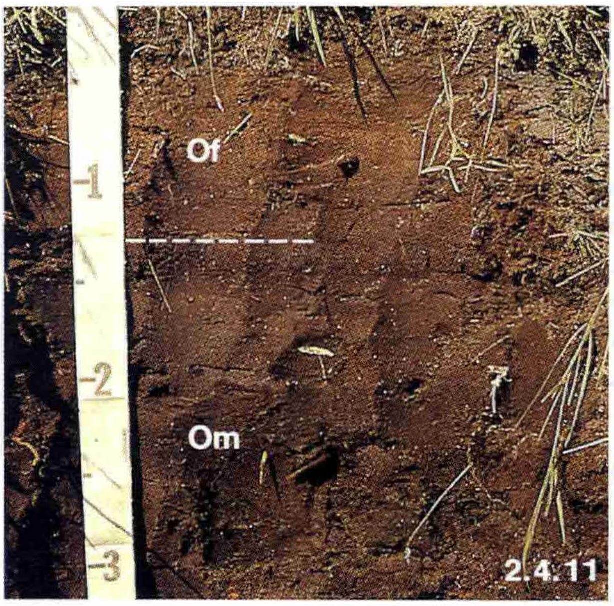
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2.4.11


2.4.12

organic matter. Much of the soil water is from snow melt and few nutrients drain from the surrounding mineral soil. Hence there are vast areas of poorly decomposed acid sphagnum peat or muskeg. Black spruce, tamarack and soopolallie also grow on these soils.

Finally, a rather different form of organic soil is found on the west coast mountains under the dense forests. In this case an enormous amount of needles, twigs, wood and bark accumulates over the very thin soils or directly on bedrock. This material is not quickly broken down and forms a thick spongy organic surface. These organic soils are different from the others because they are not saturated, they can occur on slopes and ridge crests and are composed of forest debris, not bog debris.

The great groups within the Organic order are separated on the degree of decomposition and the kind of plant material, and the degree of saturation, as follows:

Fibrisols: saturated, poorly decomposed. These soils are found in the northeast and on the coast.

Mesisols: saturated, moderately decomposed. These soils are found in the central interior.

Humisols: saturated, well decomposed. These soils are occasionally found in the central interior and on the coast.

Folisols: rarely saturated, forest debris over thin mineral layers or rock. These soils are found in the coast mountains.

The frozen soil from the Klua complex described under the Cryosolic order is made up of fibric organic matter. The upper horizons would be typical of the unfrozen Fibrisols of northeastern British Columbia.

The Rail soils are a Mesisol from the central interior. They have formed from the gradual infilling of lakes that occupied the depressions in the hummocky surface of the plateau. The following is an abbreviated description of such a soil taken in a meadow just south of 100 Mile House (51° 33'N, 121° 18'W). The vegetation is principally sedges and sea-side arrow-grass with some moss. The meadow had been partially drained and the water table was at about 40 cm in July.

Of 3 cm of poorly decomposed moss and sedge remains.

Oml 76 cm of brown fairly well decomposed sedge and moss remains.

Cm 3 cm of light gray volcanic ash.

Om2 55 cm of dark brown moderately well decomposed sedge and moss remains.

Photographs of the profile and the meadow forming the organic soil landscape are included as Plates 2.4.11 and 2.4.12. Some chemical and physical analyses are given in Table 2.4.6. Note the lower fibre content and higher pH values and higher total nitrogen values than the Klua soils. The Rail soils will be more productive.

TABLE 2.4.6

Chemical and Physical Analyses of a Mesisol (Rail Series)

Horizon	Depth (cm)	pH ($CaCl_2$)	% Org. C	% Total N	C:N Ratio	% Fibre	% Ash	Bulk Density (g/cc)
Om1	3-79	6.9	50.9	2.94	17.3	57.7	12.2	0.118
C	79-82	7.3	1.7	0.35	4.8	--	97.1	--
Om2	82-147	7.0	47.1	2.77	17.0	67.4	18.8	0.129

Horizon	Cation exchange, meq./100g soil Capacity	Ca	Mg	K	Na	Base Sat'n %	Water Holding Capacity %
Om1	163.2	61.7	103.5	1.5	6.0	100+	930.6
C	2.6	9.0	2.2	1.3	2.2	100+	--
Om2	102.8	46.4	64.8	1.5	6.5	100+	1113.9

These data are taken from Sneddon, J.I. and H.A. Luttmerding, 1967. Organic Soils Tour, British Columbia section, mimeo rept. 48 pp.

THE PODZOLIC ORDER

Soils of the Podzolic order have been formed under subarctic to cryoboreal and perhumid to humid soil climates. Their parent materials are mostly coarse textured and well drained. They contain much silica and few bases such as calcium or magnesium carbonate. The vegetation growing on them is usually coniferous forest, but some Podzolic soils develop under heather.

Under these conditions there is an abundance of water moving through the soil during the year. Chemical and biological transformations are intense in the upper horizons. Organic matter is decomposed and primary minerals are broken down releasing iron and aluminum in the non-calcareous soil environment. These three weathering products are readily moved out of the A horizon and into the B in the porous parent materials. It is the accumulation, in various combinations, of organic matter, iron and aluminum in the B horizon that is the distinguishing characteristic of Podzolic soils.

Podzolic soils have a striking appearance. There is a black LFH organic litter layer on the surface under which the top of the mineral soil is light gray. This is the Ae horizon from which bases, organic matter, iron and aluminum have been translocated. There is little left apart from silica silt and sand. The B horizon is in sharp contrast: a reddish brown layer enriched with organic matter, iron and aluminum, the colour becoming more yellow with depth. A typical horizon sequence would therefore be LFH, Ae, Bhf, Bf, BC, C.

There are some variations of this classic podzol profile in British Columbia. In many areas of coastal forest there is no bleached Ae horizon in the profile. The addition of organic matter to, and the weathering of iron and aluminum in, the upper mineral horizon is so great that despite the heavy leaching there is no net depletion to form an Ae horizon. In other areas the organic matter simply masks the Ae horizon under moist field conditions.

Many of the Podzolic soils of the west coast mountains have compacted horizons in the subsoil. These may be at various depths, have varying thicknesses and contain different cementing agents. They are given different names - ortstein, placic, duric or fragic - according to their morphology and mode of origin. They have the common effect of restricting root penetration and permeability.

Over much of southern British Columbia, especially in the mountains, volcanic ash makes up a significant proportion of the topsoil. As it weathers the ash releases large amounts of iron and especially of aluminum. When the iron and aluminum are translocated into the B horizon a Podzolic soil profile is produced. This can happen in areas that do not have a typically high rainfall, nor dense conifers nor a generally acid bedrock. The profile has been formed because the parent material was able to supply large quantities of moveable iron and aluminum. The result is an example of comparable soils being formed in two different environments where the lack of one factor is compensated for by the excess of another.

There are three great groups in the Podzolic order. They differ according to the relative amounts of organic matter and iron plus aluminum that have accumulated in the upper B horizon as follows:

Humic Podzol: accumulation of organic matter and little Fe to give a Bh horizon. These soils occur in wet environments such as the coastal forests or at high elevations inland.

Ferro-Humic Podzol: accumulation of organic matter and Fe plus Al to give a Bhf horizon. These soils occur under humid coniferous forest conditions on the west coast where there is often a thick ground cover of moss.

Humo-Ferric Podzol: accumulation of Fe plus Al and little organic matter to give a Bf horizon. These soils occur in less humid or cooler areas than the other two great groups such as the eastern side of Vancouver Island or the subalpine forests of the interior.

The following soils from the east side of Vancouver Island are used as an example of a Humo-Ferric Podzol. They have developed from glacial moraine derived from granodiorite bedrock. The vegetation cover is Douglas-fir, western hemlock and western red cedar with a dense ground cover of salal. The following abbreviated description is of a well drained soil on a 20% slope at an elevation of 730 m above sea level in the Dunsmuir Creek valley (49^{o} 02'N, 124^{o} 16'W).

LFH 8 cm of reddish black semidecomposed needles, leaves and roots.

Ae 10 cm of brownish gray sandy loam, very friable with no structure.

Bfcc 15 cm of yellowish red sandy loam with blocky structure and small concretions.

Bm 40 cm of yellowish brown sandy loam with blocky structure and faint mottling.

C Olive gray sandy loam, massive and hard.

Table 2.4.7 contains chemical and physical analyses of the above profile. The points to note are the low pH and base saturation values and the differences in Fe plus Al content of the Ae and Bf horizons. Plates 2.4.13 and 2.4.14 show a Humo-Ferric podzol and a Podzolic soil landscape respectively.

TABLE 2.4.7

Chemical and Physical Analyses of a Humo-Ferric Podzol

Horizon	Depth (cm)	pH* ($CaCl_2$)	% Org. C	% Total N	C:N Ratio	Particle Size % Sand	Silt	Clay
Ae	0-10	3.6	1.6	.02	76.2	66.9	30.1	3.0
Bfcc	10-25	4.7	1.8	.03	51.5	53.0	45.4	1.6
Bm	25-65	4.9	1.0	.02	48.1	65.6	32.3	2.2
C	65+	5.2	0.8	--	45.0	59.9	37.7	2.4

Horizon	Cation exchange, meq/100 g soil Capacity	Ca	Mg	K	Na	Base Sat'n %	Fe% (pyrophosphate)	Al%
Ae	6.7	.7	.2	.2	.1	15.5	.03	.04
Bfcc	10.9	.2	.1	.1	--	3.4	.20	.50
Bm	8.1	.2	--	.1	--	3.8	.09	.40
C	3.9	.2	--	.1	--	8.1	.01	.09

* For details of the analytical methods used see McKeague, 1976, in Further Reading.

These data are from an unpublished Ph.D. thesis - personal communication, D. Moon, Dept. of Soil Science, University of British Columbia

THE REGOSOLIC ORDER

Soils of the Regosolic order do not have a B horizon and may lack even an A horizon. They occur in all parts of the province, but rarely, except in the high mountains, do they extend over large areas.

Regosolic soils are very weakly developed for a variety of reasons. They may have developed on very young geological materials such as river alluvium or coastal beaches. They may be found in unstable situations such as constantly eroding slopes or shifting sand dunes. But probably their most common occurrence, and the one about which we know least, is in the mountains. In the very cold and sometimes relatively dry regions above the well-vegetated alpine meadows but below the snowline there are large expanses of rock debris. Little vegetation grows here and frost action continually disrupts the surface materials. There is little chance for strong soil horizons to develop and Regosols abound.

Two great groups are recognized in the Regosolic order according to whether or not there is an accumulation of organic matter at the surface to form an Ah horizon.

Regosol: little or no organic matter, only a C horizon.

Humic Regosol: significant accumulation of organic matter to give Ah, C horizon sequence.

The Chemainus soils on Vancouver Island are an example of a Humic Regosol. They have developed on very young fluvial deposits in the floodplains of river valleys. Their texture and drainage vary according to their position on the floodplain. These floodplains were the first areas to be logged so the vegetation is mixed, with western hemlock and western red cedar in some areas and second growth maple, red alder, western sword fern and willows in others. The following is an abbreviated description of a Chemainus soil:

H	3 cm of very dark brown well decomposed leaf litter.
Ah	10 cm of black silt loam with granular structure.
C	50 cm of grayish brown stratified silt loam.
IIC	stratified sands and gravels.

Some chemical and physical analyses for the Chemainus soils are given in Table 2.4.8. These analyses are typical of a young, fertile, floodplain soil but must not be regarded as typical for Regosolic soils as a whole. Since these soils can develop in a wide variety of environments, their chemical and physical characteristics may also vary widely. Their diagnostic feature is a lack of profile development, rather than a particular combination of chemical and physical characteristics.

A profile of a Humic Regosol from the San Juan River valley on Vancouver Island is shown in Plate 2.4.15. This is on a gravel bar associated with the Chemainus soils. A Regosolic landscape in the valley of the Fraser River is shown in Plate 2.4.16.

TABLE 2.4.8

Chemical and Physical Analyses of a Humic Regosol
(Chemainus Soils)

Horizon	Depth (cm)	pH (H_2O)	% Org. C	% Total N	C:N Ratio	Bulk Density (g/cc)
Ah	0-10	6.2	10.8	0.75	14.4	0.76
C	10-60	5.9	1.4	0.09	15.1	1.02

Horizon	Cation exchange, meq/100 g soil: Capacity	Ca	Mg	K	Na	Base Sat'n %
Ah	49.44	30.00	8.40	0.66	0.18	79.5
C	13.37	7.60	1.40	0.32	0.28	71.9

These data are taken from Day, J.H., L. Farstad, and D.G. Laird, 1959. Soil Survey of Southeast Vancouver Island and Gulf Islands, British Columbia. B. C. Soil Survey Rept. No. 6, Canada Dept. of Agric., Ottawa.

THE SOLONETZIC ORDER

These soils contain a high proportion of exchangeable sodium or sodium and magnesium salts in their B horizon. This distinguishes them from all the other orders, gives their profile a particular appearance, often limits vegetation to the most salt tolerant plants only and restricts their use considerably.

Solonetzic soils are found in two separate areas of British Columbia for two different reasons. In the southern part of the province they occur in semiarid to subarid areas where there is high evaporation and restricted drainage in the depressions of rolling topography. This situation is usually found in valleys for instance near Merritt and Kamloops or on the lower parts of the plateaus such as around 70 Mile House. Soil water drains into these depressions from the surrounding country bringing with it calcium, sodium and magnesium salts in solution. The water evaporates instead of draining away into the groundwater, leaving an accumulation of these salts in the soil. In the northern part of the province is an area of saline soils in the Peace River region. Here the salts result not from the interaction of climate and topography but from residual salinity in the parent materials. Many of the shales, siltstones and mudstones that form the bedrock were originally laid down in a sea and consequently have retained a high salt content. The vegetation cover is usually restricted to salt tolerant grasses and forbs. Trees sometimes grow on marginally saline soils which are beginning to lose their salts through leaching.

The dominant process then is the accumulation of sodium and magnesium salts in the B horizon. It must be emphasized that in most saline soils calcium is still the predominant cation in the soil but the increase of sodium and magnesium from negligible to moderate amounts causes them to affect the soil morphology. When the soil gets wet the sodium causes the soil aggregates to break down into individual particles. The clods are not stable and there are no structural cracks down which water can move. The soil, especially the B horizon, becomes an impermeable sticky mass. On drying the B horizon becomes extremely hard and columnar structural blocks develop. The production of these distinctive columns is probably also enhanced by the expansion of water in the cracks when it freezes in the winter. In most Solonetzic soils there is also a translocation of salts, and to some extent, organic matter from the A to the B horizon. The A horizon therefore becomes less saline and more acidic with time and dark clay and organic matter coatings are deposited on the outside of the structural columns in the B horizon.

There are three great groups in the Solonetzic order. They differ according to the degree of leaching of salts and clay from the A to the B horizon as follows:

Solonetz: very little leaching, clear boundary between the Ah and Bn horizons.

Solodized Solonetz: leaching of salts and clay has produced an Ae horizon between the Ah and Bnt.

Solod: leaching is very advanced. There is a loss of salts from the B as well as the A horizon so that the columnar structure is breaking up, and the Bnt reverts to a Bt horizon.

Most saline soils in British Columbia have undergone a considerable amount of leaching and are Solodized Solonetz or Solods. The Murdale soils in the Peace River area are an example. They are classified as a Solod developed on saline and calcareous clayey glacial moraine. The vegetation cover is trembling aspen, willow, rose, saskatoon and grasses. The following abbreviated description is from a soil 13 km north of Fort. St. John (56° 21'N, 120° 49'W).

LFH 4 cm of partially and well decomposed organic matter.

Ah 7 cm of very dark brown gravelly clay loam with granular structure, very friable.

Ahe 5 cm of dark gray gravelly clay loam with granular structure, friable.

Ae 7 cm of pale brown gravelly loam with platy structure.

AB and BA 16 cm of transition horizons of pale brown gravelly clay with blocky structure.

Bt 25 cm of very dark gray gravelly clay with coarse blocky structure that breaks down into very hard smaller blocks.

BC 24 cm of a transition horizon of dark gray gravelly clay.

Csk dark gray gravelly saline clay with carbonate accumulation and gypsum concretions.

Chemical and physical analyses of this profile are included in Table 2.4.9. There are a number of features of this soil that mark it off from any of the other soils listed in this section. In the Csk horizons the pH value, sodium and magnesium content and electrical conductivity are all high. The magnesium content remains high throughout the profile. The sodium con-

PLATES 2.4.13 TO 2.4.18
PROFILES AND LANDSCAPES OF SOILS
FROM THE PODZOLIC, REGOSOLIC AND SOLONETZIC ORDERS

2.4.13 Profile of a Podzolic soil developed on glacial till in the West Kootenay area of southeastern British Columbia (photo J. Jungen).

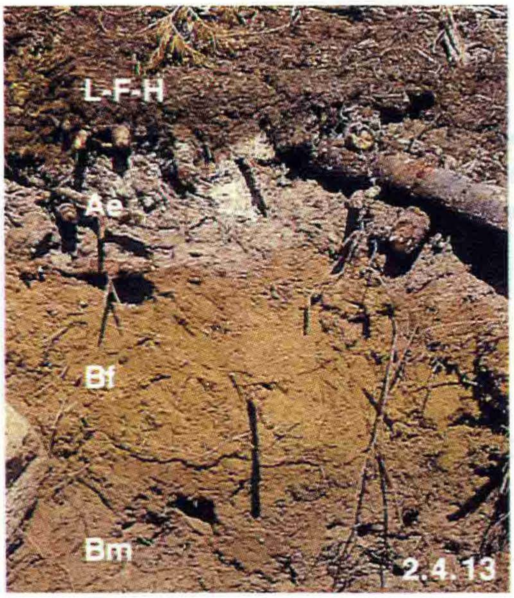
2.4.14 Podzolic soil landscape in the Nanaimo Lake area of eastern Vancouver Island. The main trees are western hemlock, Douglas-fir and western red cedar. Salal and vaccinium form the main shrub cover (photo J. Jungen).

2.4.15 Profile of a Regosolic soil developed on fluvial sands and gravels in the floodplain of the San Juan River valley on Vancouver Island, British Columbia.

2.4.16 Two examples of a Regosolic landscape in the Fraser River valley near Dog Creek, central British Columbia. There are Regosolic soils on the steep banks in the middle distance (1) because erosion constantly strips away surface horizons as they develop. The gravel bar in the centre of the photograph (2) contains Regosolic soils, because the materials are very young. They have only just been laid down by the river.

2.4.17 Profile of a Solonetzic soil developed in silty lacustrine deposits in the Bridge Creek valley near 100 Mile House central British Columbia.

2.4.18 Solonetzic soil landscape in a depression of hummocky glacial till near Osoyoos, southern British Columbia. The centre of the depression is so saline that no vegetation grows and a white salt crust accumulates (1). Desert salt grass grows round the edges of the depression (2) (photo R.K. Jones).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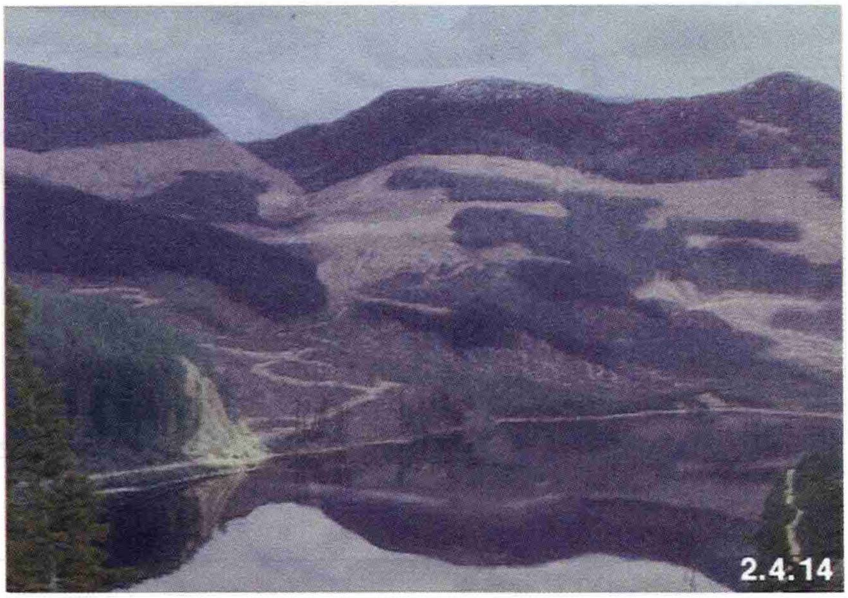
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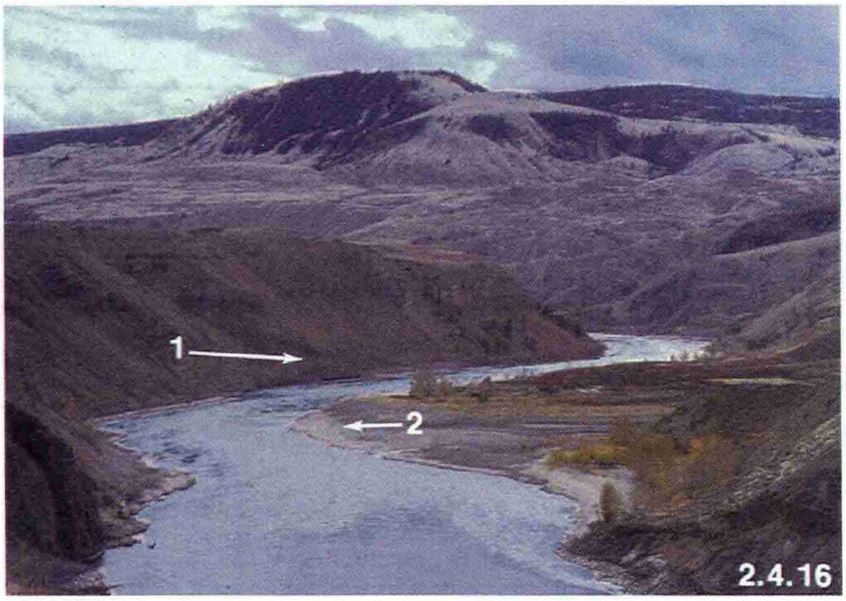
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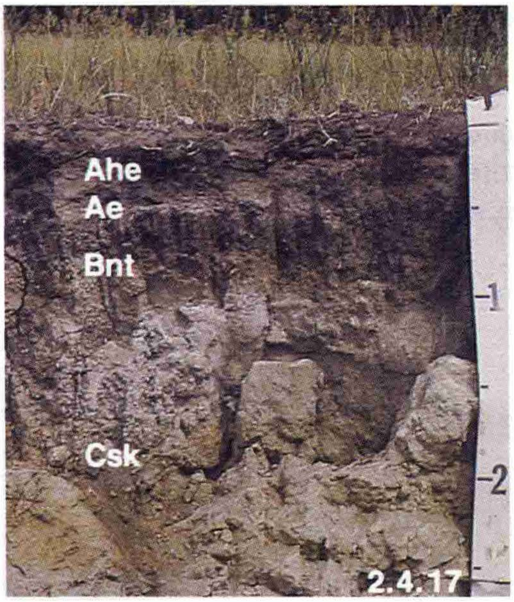
Ahe
Ae
Bnt
Csk
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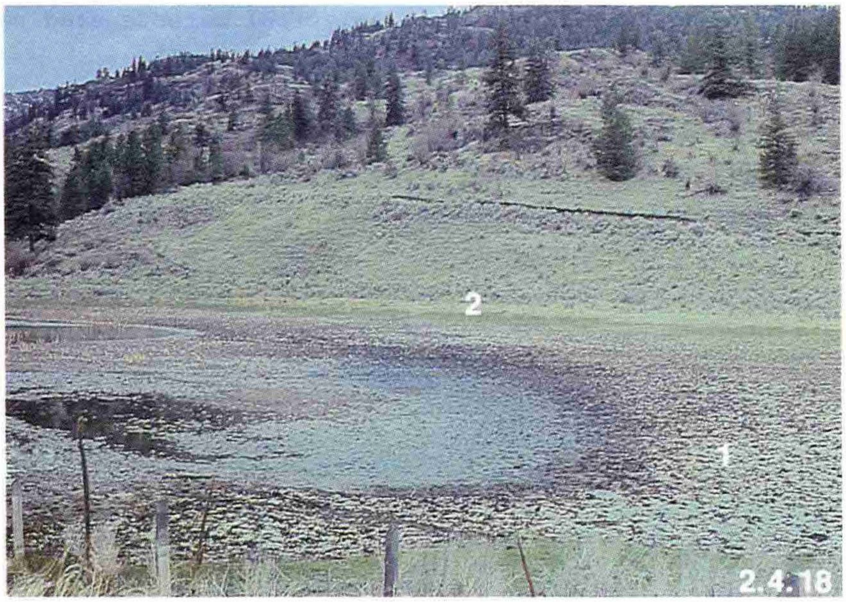
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2.4.18

tent of the B horizons is high but it is low in the A horizons and the pH and electrical conductivity drop markedly in the B and A horizons. Plates 2.4.17 and 2.4.18 show a Solod profile and a Solonetzic soil landscape respectively.

TABLE 2.4.9

Chemical and Physical Analyses of a Solod
(Murdale Series)

Horizon	Depth (cm)	pH* ($CaCl_2$)	% Org. C	% Total N	C:N Ratio	Particle Size Distribution % Sand	Silt	Clay	Fine Clay
Ah	0-7	5.9	8.1	0.88	9.2	15	50	35	14
Ahe	7-12	4.9	2.7	0.30	9.0	16	52	32	14
Ae	12-19	4.4	1.0	0.11	9.1	21	54	25	7
Bt	35-60	4.7	1.1	0.11	9.1	15	36	49	23
BC	60-84	5.8	--	--	--	16	38	46	20
Csk	84+	7.0	--	--	--	14	42	44	19

Horizon	Cation exchange, meq/100 g soil Capacity	Ca	Mg	K	Na	Base Sat'n %	E.C. mmho
Ah	34.0	26.4	8.7	1.4	0.0	100+	--
Ahe	26.7	9.8	6.7	0.7	0.1	64.8	--
Ae	15.3	3.1	3.3	0.2	0.3	45.1	--
Bt	28.9	5.3	14.3	0.5	2.5	78.2	0.4
BC	24.5	6.8	16.1	0.5	2.4	100+	1.4
Csk	21.8	29.6	17.5	0.5	3.0	100+	5.2

*For the details of the analytical methods used see McKeague, 1976, in Further Reading.

These data are derived from a profile sampled and described for Soil Tours Nos. 7 and 15 (Peace River Region) 11th Congress, International Soil Science Society, Edmonton, 1978 - personal communication, T.M. Lord, Soil Research Institute, Vancouver.

FURTHER READING

Brown, R.J.E., 1967. Permafrost in Canada. Map 1246A, Geol. Surv. Canada, Ottawa.

This map shows the distribution of continuous and discontinuous permafrost in Canada, and discusses its causes.

Canada Soil Survey Committee, 1978. The Canadian System of Soil Classification. Agric. Canada, Queen's Printer, Ottawa.

There are introductory descriptions of the environment and genetic concepts associated with each order in this classification.

McKeague, J.A., 1976. Manual on Soil Sampling and methods of analysis. Soil Research Institute, Agric. Canada, Ottawa, mimeo, 212 pp.

This gives details of the methods of laboratory analyses.

Ogilvie, R.T. and B. Baptie, 1967. A Permafrost Profile in the Rocky Mountains of Alberta. Can. J. Earth Sci. 4, 744-745.

This is a short note describing a colluvial soil profile with a frozen layer at 2350 m in Banff National Park.

Ryswyk, A.L. van., McLean, Alistair, and L.S. Marchand, 1966. The climate, native vegetation and soils of some grasslands at different elevations in British Columbia. Can. J. Soil Sci., 46, 35-50.

An elevational transect through Brown, Dark Brown and Black Chernozemic soils near Kamloops.

Part 3

The Soil Landscapes of British Columbia

3.1 INTRODUCTION

K.W.G. Valentine

The land of British Columbia is almost infinite in its variety. It contains many minerals and fossil fuels. Its vegetation ranges from rain-forest to sagebrush and cactus. Parts of the south are subarid with hot summers and parts of the north have permafrost. So it is with the soils. Those of us who have attempted to map and describe the soils of British Columbia through the years have debated long and hard how best to express this complexity in a simple way in our maps and reports. The problem is compounded when a description of the soils of the whole province is attempted instead of the soils of the map sheet, which covers only a small area.

Actually there are two problems here. Firstly how can the province be divided into sections of manageable size within which the soil forming factors produce a particular and unique pattern of soils? Secondly what soil unit should be described? The problems were solved in this publication - if the reader agrees that they have indeed been solved! - partly by borrowing from previous work (to delineate physiographic regions) and partly by developing a concept of a large soil area (the "soil landscape").

Physiography in British Columbia influences climate, hydrology, vegetation and thereby soils. Five large physiographic regions were therefore defined as described in the Introduction to Part 1 and shown in Figure 1.1.1. They have been used periodically throughout this publication, but it is within Part 3 that they will be used most extensively as the initial divisions within which the soil landscapes are described.

A soil landscape is thought of as the total ecosystem with which a particular soil is associated, with emphasis placed on the soil itself. It could be used at any level of the soil classification, but here it is used as a great group. For instance the morphology and chemistry of the Ferro-Humic Podzol soils on the west coast are described within the context of coarse textured acid parent materials, high rainfall, a dense coniferous forest and rugged topography.

There may appear to be some duplication. Many soil landscapes occur in more than one physiographic region, but they usually have a different combination of the soil forming factors in the two regions. For instance Gray Luvisols in the Interior Plateau have developed on calcareous till and lacustrine deposits derived from basic lavas under a forest cover of Douglas-fir. In the Great Plains similar soils have developed from acid, calcareous or saline sandstones and shales under a forest of trembling aspen and white spruce.

The province-wide distribution of the soil great groups is shown initially by the soil map of British Columbia derived from the Atlas of British Columbia (Part 3.2). The soil landscapes of the five physiographic regions are then described by pedologists or geologists who have worked in those areas. In most cases it was possible to describe a single soil landscape that occupies the major portion of a large area. However, in other cases individual soil landscapes were so intimately mixed within an area (as in floodplains) or combinations of soils formed such a distinctive type of country (as in the grasslands or the alpine tundra) that it was more convenient or logical to discuss them together. The pattern of soil landscapes in each region is illustrated by cross sections and oblique air photographs. The vegetation associated with each soil landscape is also described using Krajina's biogeoclimatic zones and Rowe's forest regions (see Further Reading in Part 1.4 for references).

3.2 THE SOIL MAP OF BRITISH COLUMBIA

T.M. Lord and K.W.G. Valentine

The soil map of British Columbia (Figure 3.2.1) incorporates information collected over a long period of time by many people. Very few attempts have been made to produce such a map, probably because pedologists in British Columbia have always been conscious of the vast expanses of soil about which they know very little. An early map appeared in the 1956 British Columbia Atlas of Resources. The next published soil map of British Columbia appeared as part of the Soils of Canada map in 1972. Much of the present map is derived from that 1972 map, but changes were made based on information supplied by pedologists throughout British Columbia.

Many changes have been made. Ferro-Humic Podzols and Folisols have been mapped on the west coast, and Cryosolic soils have been mapped in the north and northeast using recent survey information. Field work in alpine areas has enabled us to identify specific soils there. There is no longer the alpine "Rockland" map unit which pedologists used in the same way that Medieval cartographers used "Here be Dragons" for areas they knew nothing about.

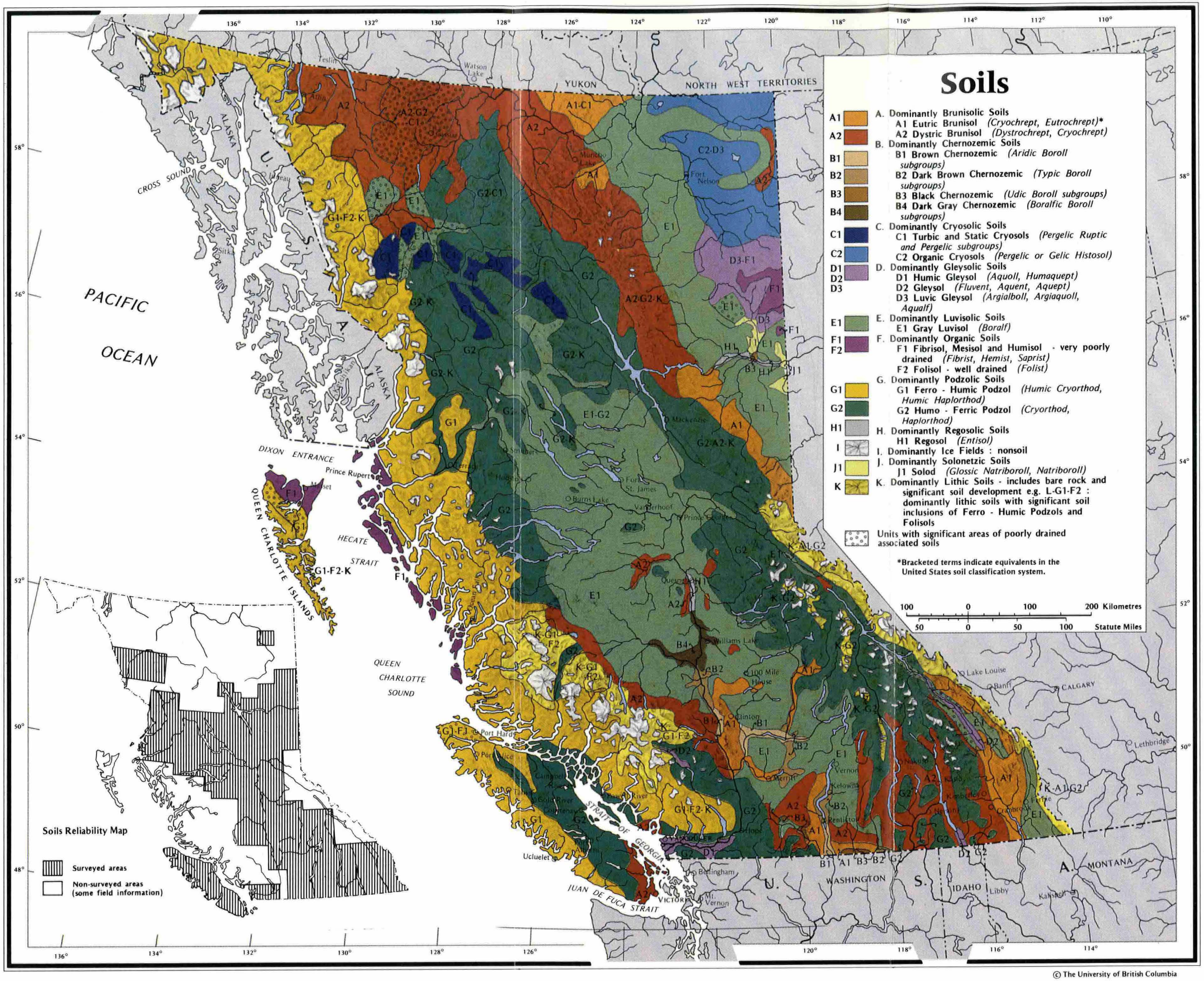
Not all of the map is equally reliable so a small inset map was added showing areas that had been surveyed. These areas contain the most accurate information. Elsewhere the soil units have been mapped from field information derived from special projects.

The map legend includes correlations with the United States Department of Agriculture soil classification following "Soil Taxonomy" (U.S.D.A., Agriculture Handbook 436, 1975). This allows correlation of the soils of British Columbia with the rest of North America.

The map will change again. It represents the present state of our imperfect knowledge of the distribution of soils in British Columbia.

This map is from *Atlas of British Columbia: People, Environment, and Resource Use* by A. L. Farley (Vancouver: University of British Columbia Press, 1979)

FIGURE 3.2.1



3.3 THE COAST MOUNTAINS AND ISLANDS

J.R. Jungen and T. Lewis

The Coast Mountains and Islands occupy an area along the extreme western part of British Columbia stretching from the 49th parallel to the borders of Alaska and the Yukon. The area is large, about 1200 km in length, and is relatively narrow but variable in width. It is dominated by two parallel mountain ranges - the Coast Mountains and the St. Elias-Insular Mountains. These ranges are separated by a largely submerged lowland. Numerous major rivers from the interior flow across the Coast Mountains on their way to the Pacific Ocean. Notable features include, large mountain snowfields and glaciers, and well developed fjords.

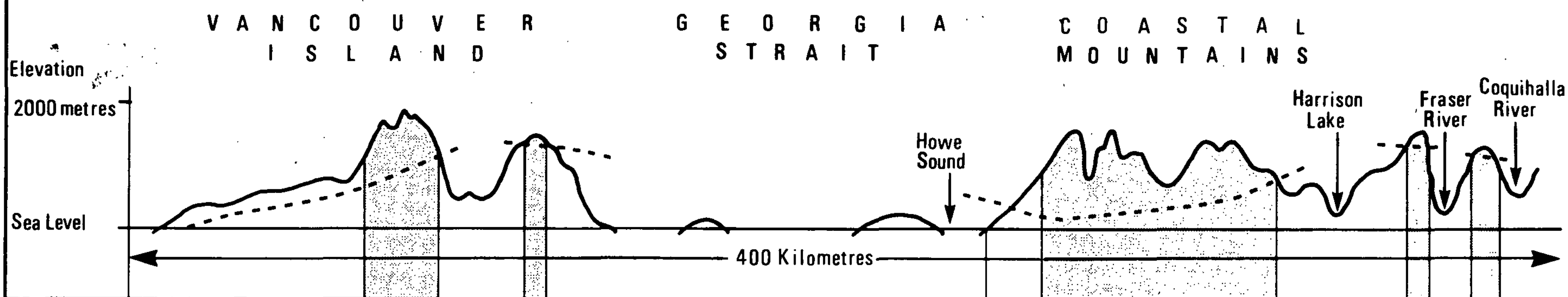
The features of climate, geology and vegetation have been described in Parts 1.2, 1.3 and 1.4. These soil forming factors in combination with topography and surficial material give rise to the distinctive soil landscapes found in the region.

THE FACTORS OF SOIL FORMATION

The region has high precipitation and generally moderate to cool temperatures, including, particularly in the south, a short dry period in summer. In winter, the moisture-laden air of a succession of low pressure systems rises in contact with the coastal slopes, to produce very cloudy and wet conditions. The soils are generally very wet. The upper elevations receive vast quantities of snow which protects the ground from freezing. In the summer there are frequent spells of fine sunny weather as the North Pacific high-pressure cells extend over the coast. The resultant dry period influences the type of soils found over the wide range of landforms in the region, particularly in the south at low elevations.

The terrain is underlain mainly by intrusive igneous rock with minor but significant areas, mainly on Vancouver Island and the Queen Charlotte Islands, of folded and faulted volcanic and sedimentary rocks, flat lying lavas, folded metamorphic rocks, and flat or gently dipping sedimentary rocks. The intrusive rocks are relatively resistant to weathering. The residue from prolonged physical and chemical weathering provides a coarse textured, acid parent material.

In general the vegetation is a coniferous forest blanket. The forest regions (see Rowe in Further Reading of Part 1.4) which occur are "Coastal", and "Subalpine". The biogeoclimatic zones include Coastal Western Hemlock,



	Vancouver Island				Georgia Strait	Coastal Mountains						
Soil Landscape	Ferro-Humic Podzol	Ferro-Humic Podzol	Humo-Ferric Podzol	FHP	Humo-Ferric Podzol Dystric Brunisol	HFP FHP	Ferro-Humic Podzol	Humo-Ferric Podzol, FHP	FHP	HFP	FHP,HFP	HFP, FHP
Biogeo-climatic Zone	Coastal Western Hemlock	AT	CWH, CDF	MH,AT	Coastal Western Hemlock Coastal Douglas-fir	CWH	Mountain Hemlock, Alpine Tundra	Coastal Western Hemlock	MH,AT	CWH	MH	Coastal Western Hemlock
Forest Region (Rowe)	Coastal	Sub-alpine	Coastal	Subalpine	Coastal	Coastal	Subalpine	Coastal	Subalpine	Coastal	Subalpine	Coastal
Precipit-ation (mm/yr)	2500-5000	5000+	1250-2500	1500-2500	1000-1500	1700-3500	2500-5000	1250-2500	900-1700	800-1200	900-1700	

LEGEND

Boundary between Ferro-Humic Podzol Landscape (above) and Humo-Ferric Podzol (below) .... - - - -

Ferro-Humic Podzol ..... FHP
Humo-Ferric Podzol ..... HFP

Coastal Douglas-fir .... CDF
Coastal Western Hemlock .... CWH
Mountain Hemlock .... MH
Alpine Tundra .... AT

FIGURE 3.3.1 The soil landscapes across the southern coast along latitude 49°30′ N.

Coastal Douglas-fir, Mountain Hemlock, Engelmann Spruce - Subalpine Fir, and Alpine Tundra (see Figure 3.3.1 and Figure 3.3.2).

Glaciation has contributed a wide range of surficial materials in which the majority of the soils have formed. The coastal areas were depressed by the weight of ice during, and immediately after glaciation. They later rose by isostatic rebound, leaving behind a complex marine-influenced zone along much of the coast of British Columbia. Glaciation resulted in the typically rounded ridges and summits of all but the highest mountains, and the widespread morainal deposits found in the lower parts of the valleys.

The rugged, very steep terrain results in unstable areas where soil development is hindered by the slow creep of surficial materials. Vegetation holds this process in check until a major disturbance such as logging or fire takes place. Steep topography, therefore, has considerable influence on soil development through colluviation, erosion, talus slopes, and general soil disturbance. Other soil disturbance is caused by windthrow of very large trees which mixes upper soil horizons (turbic).

The main features distinguishing the soils of the coastal area are the prevalence of deep reddish to yellowish brown B horizons rich in iron and aluminum oxides, the thick surface organic horizons derived from forest litter, and the development of extremely compact cemented horizons or pans in the B and C horizons.

THE SOIL LANDSCAPES

The soil map of British Columbia (Part 3.2) indicates the general distribution of soil great groups in the coastal region. It must be clearly understood that this generalized map cannot indicate all the small but nevertheless important soil landscapes which may occur in a particular area.

THE FERRO-HUMIC PODZOL SOIL LANDSCAPE

The lower part of this landscape occurs within the Coastal Western Hemlock biogeoclimatic zone, on the windward side of the mountains. It ranges in elevation from sea level to 900 m in the south, decreasing to 450 m in the north. A cross section of this landscape with its associated soils is shown in Figure 3.3.3. Plate 3.3.1 is an aerial view of part of it near Tofino on Vancouver Island.

The area has a moist, cool climate with abundant rainfall, low snowfall except in the north, and mild winter temperatures. The summers are cool and relatively much drier than are the winters. High humidity tends to

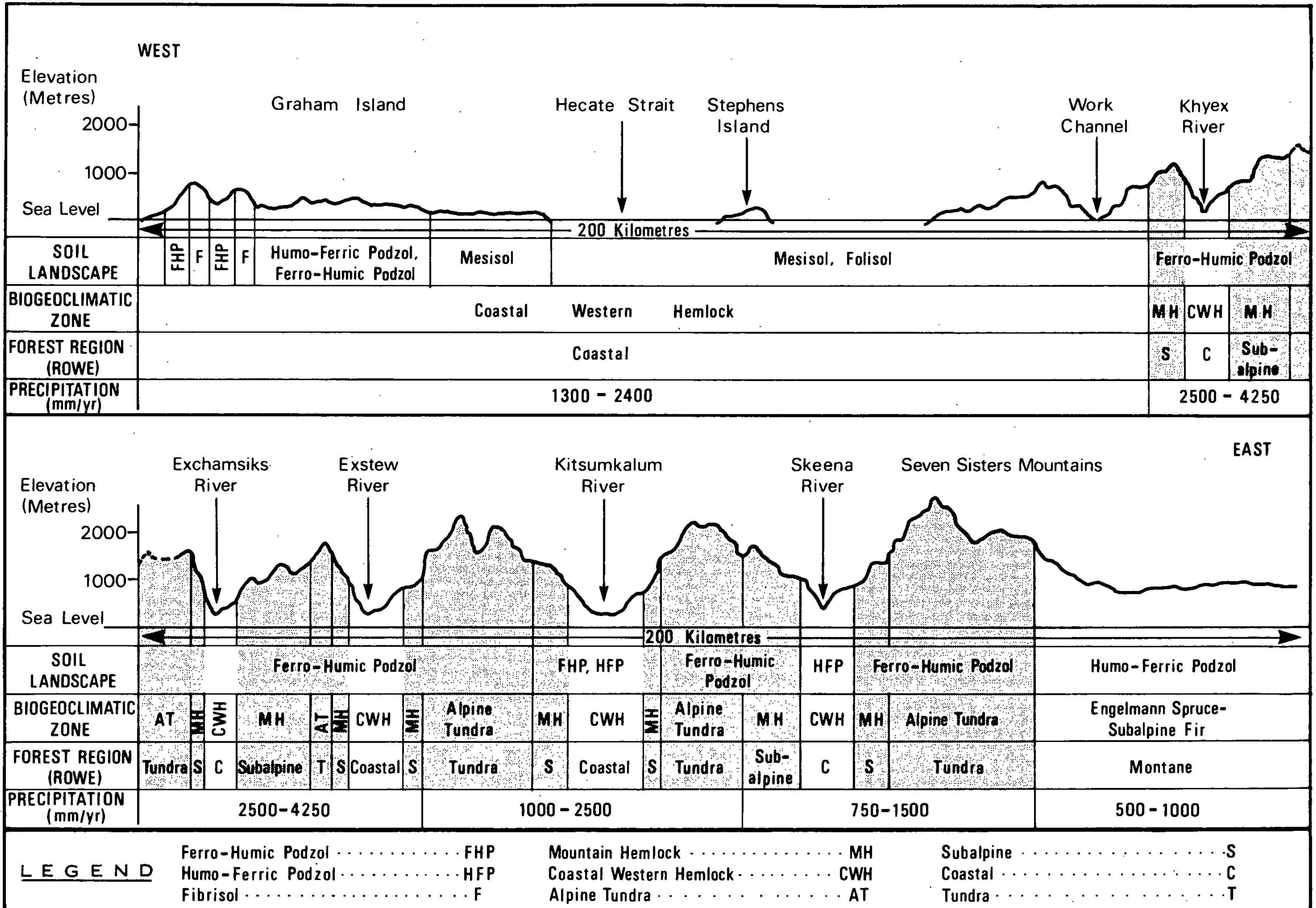


FIGURE 3.3.2 The soil landscapes across the northern coast.

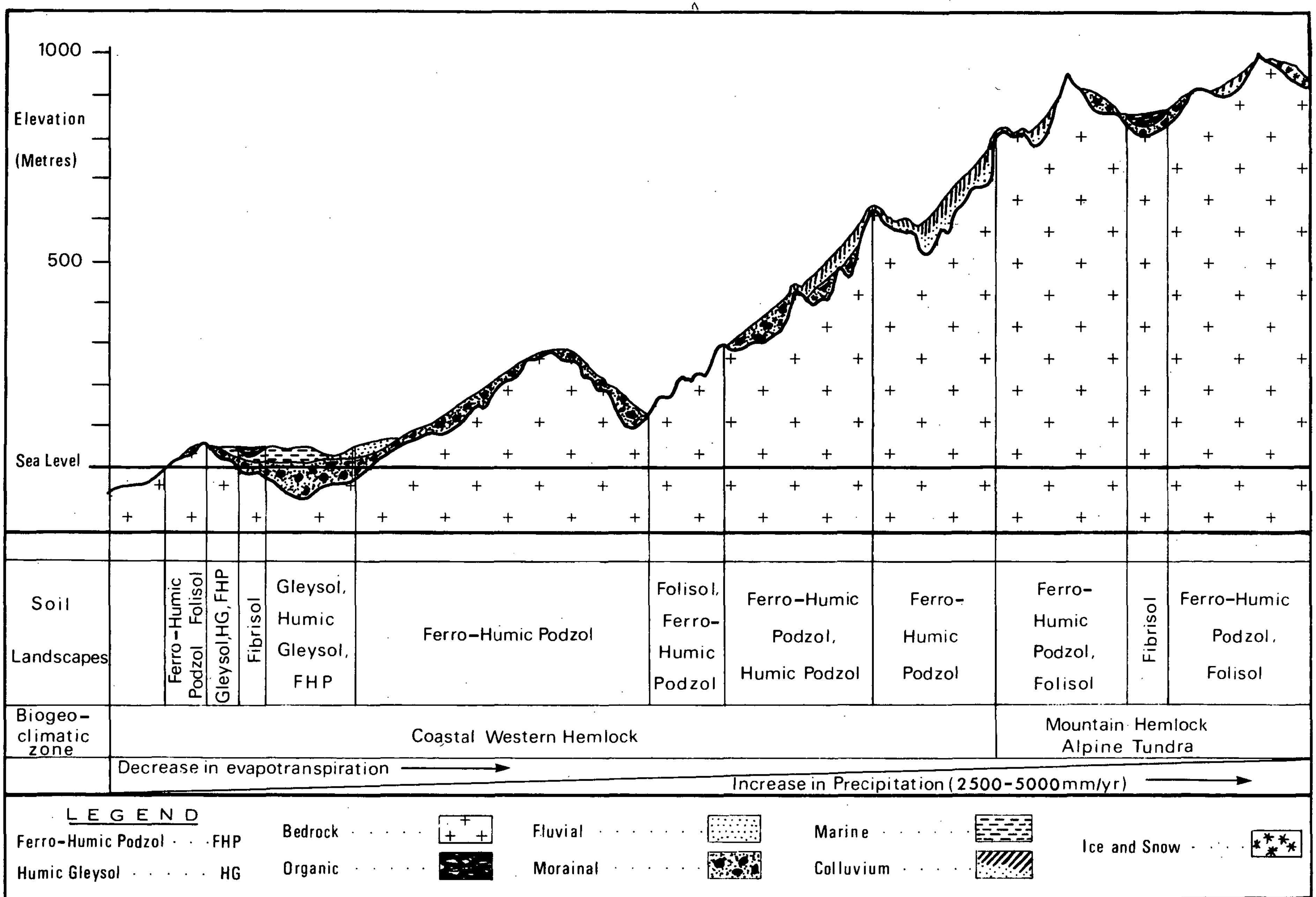


FIGURE 3.3.3 The Ferro-Humic Podzol soil landscape showing associated soils.

PLATE 3.3.1 Soil landscapes on the west coast of Vancouver Island. (photo BC-666-7)

PLATE 3.3.1

SOIL LANDSCAPES ON THE WEST COAST OF VANCOUVER ISLAND

1. Ferro-Humic Podzol, Humic Gleysol and Fibrisol landscapes on the marine and fluvioglacial sediments of the coastal plain. The Ferro-Humic Podzols will occur only on the coarse textured materials or on the better drained sites. There are Humic Gleysols and organic Fibrisols on the level to depressional topography of the marine clays.

2. Ferro-Humic Podzol soil landscape on the morainal deposits that blanket the lower mountain slopes in the Coastal Western Hemlock biogeoclimatic zone.

3. Ferro-Humic Podzol soil landscape on the colluvial materials of the upper mountain slopes in the Coastal Western Hemlock biogeoclimatic zone. There are also exposures of organic Folisol landscapes over bedrock.

4. Ferro-Humic Podzol soil landscape on thin colluvial materials in the Mountain Hemlock biogeoclimatic zone. Organic Folisols and Fibrisols also occur.

5. Alpine soil landscapes with shallow rubbly Regosols, exposed bedrock, snow and ice.

restrict evapotranspiration rates. The soils are moist to wet over most of the year and rarely freeze to any significant depth. The soil temperature regime is mainly cold to moderately cold cryoboreal and the moisture regimes are dominantly perhumid. Excess moisture and a high incidence of associated poorly drained soils typify this landscape.

The upper part of this landscape occurs at elevations ranging between 900 to 1400 m in the Mountain Hemlock biogeoclimatic zone. This area is cooler, and receives more total precipitation than the lower part, much of it as snow. The soils rarely freeze due to the insulating effect of the deep snow. The soil temperature class is predominantly cold cryoboreal and the soil moisture regime is perhumid.

The main soil processes are the accumulation of complexes of amorphous organic matter, iron and aluminum producing soils with exceptionally strong podzol B horizons. In fact, most pedologists would agree that podzols have reached their maximum development in British Columbia within this landscape zone. The soils may or may not have thin eluvial (Ae) horizons; are dominated by thick dark reddish B horizons of ±1 m rich in iron, aluminum and organic matter; have strong indications of turbic activity; are medium to coarse textured, and generally lack horizons in which clay has accumulated (Bt). Leaching is intense in these soils.

Much of the Ferro-Humic Podzol soil landscape is subject to continuous seepage. This excess moisture is not apparent in the soil in the usual form of gleying and mottling but rather is shown by a higher organic matter content and generally duller profile colours. The distribution of organic matter is typically uneven, and often reaches a maximum near the lower part of the solum. The organic matter content may reach or even exceed 30 percent.

This landscape supports some of the most productive forest land in British Columbia. Mean annual increments exceeding 20 m^3/ha/yr are common on the best sites. Coastal western hemlock and Pacific silver fir (amabilis fir) are the dominant species. Sitka spruce occurs on coastal sites.

Forest production in the Mountain Hemlock biogeoclimatic zone is much lower. Extremely heavy snowfall and a short growing season limit forest growth.

Because the terrain is rugged and steep, the most common parent material in this landscape is colluvium, deposits of which are often shallow veneers overlying bedrock. These soils are deep (often between 1 and 2 m), well to moderately well drained, loose to friable, and do not contain any sign of cemented horizons.

Morainal deposits also mantle significant areas. These deposits typically flank the lower valley walls as a blanket or veneer. Thick organic mats of 20-50 cm which overlie the mineral soils are common, with Bf (Fe plus Al accumulation), and Bhf (Fe plus Al plus organic matter accumulation) horizons immediately underneath. The Bhf horizon is frequently most pronounced just above an indurated pan that occurs in the uppermost till. The Bhf and Bf horizons are together usually less than 1 m thick; the boundary between them varies from smooth to very irregular with tongues indicating turbic activity. The main distinction between morainal and colluvial soils is the presence of a tough, indurated pan (Bc horizon) in most morainal soils. Cementation is strongest near the upper boundary of the pan. Penetration is nearly impossible with normal hand tools. The average thickness is 20-50 cm; structure is coarse platy or massive; and texture is medium to coarse. Air-dry clods do not slake when immersed in water, and the porosity is low.

Gravelly fluvial materials have soil profiles similar to those on morainal deposits with respect to colour and cementation. These soils are mostly imperfectly to poorly drained.

Chemically the soils of the Ferro-Humic Podzol soil landscape have very low base saturation; low pH values (less than 5.0 is common); high organic carbon; and high Fe and Al contents. The upper part of the landscape is chemically and morphologically similar to the lower areas, except that the horizons contain somewhat greater amounts of Fe, Al, and organic matter.

THE FOLISOL LANDSCAPE

Folisols are organic soils that consist of shallow organic material overlying bedrock. Folisols require a relatively high precipitation and low evapotranspiration in order to develop over otherwise dry, sterile bedrock. They are, however, not continuously saturated. Folisol landscapes are forested and the organic mat is derived from leaves, twigs, roots, branches, and mosses that accumulate over the bedrock. Folisols rarely occur as large, continuous units except in the north, but rather, as minor associates within the Ferro-Humic Podzol soil landscape (see Figure 3.3.3). They are most widespread at high elevations and on the windward outer coast. Without the wet, cool, perhumid moisture regime, the organic matter would not accumulate rapidly enough and outcrops would remain as bare bedrock. Unlike wet, organic soils, Folisols occur on a variety of slopes - crests of ridges, steep well drained positions, gently rolling to undulating bedrock areas.

This landscape is treed, and includes species such as western hemlock, western red cedar, and yellow cedar. Forest productivity is relatively low. Folisols are much more restricted along the east coast of Vancouver Island where the climate is warmer and drier.

THE HUMO-FERRIC PODZOL SOIL LANDSCAPE

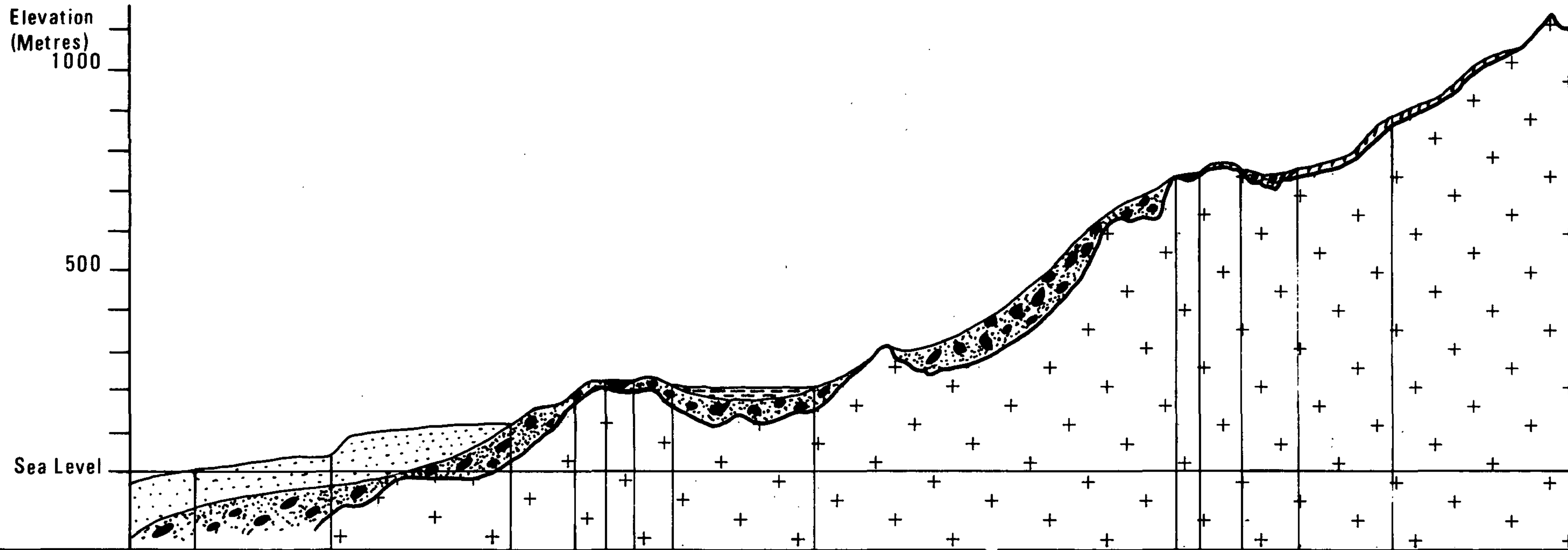
The Humo-Ferric Podzol soil landscape occurs predominantly within the Coastal Western Hemlock and Coastal Douglas-fir biogeoclimatic zones, on the eastern side of Vancouver Island, and in all low valleys away from the outer coast. The vegetation usually consists of a moderately dense Douglas-fir and western hemlock forest with a moderately dense understory layer. Upper elevation limits range from above 900 m on the east coast of Vancouver Island to below 450 m in the lower Fraser Valley (see Figure 3.3.4). In the north this landscape can be found only in the lower parts of valleys such as the Skeena and the Nass. Rapid gradation to the Ferro-Humic Podzol soil landscape takes place with increasing effective moisture.

The principal climatic features are relatively mild winters, cool to warm summers, and moderate to high precipitation. Summers are somewhat warmer and drier than in the Ferro-Humic Podzol soil landscape and evapotranspiration is correspondingly higher. Abundant precipitation occurs during the winter. The soil temperature classes include mild mesic, cool boreal, anc cold cryoboreal while the soil moisture regime is dominantly humid. The snowfall is low to moderate, depending on elevation and latitude.

The major lowlands, including the Fraser and Nanaimo lowlands, the Alberni Basin, the Nass River and numerous low valley systems have Humo-Ferric Podzols. These areas are predominantly gently sloping to moderately rolling, but include areas of steeply sloping, rugged terrain along the mountain sides. The whole landscape has been glaciated resulting in a wide variety of glacial deposits. Morainal, colluvial, fluvial, and marine materials comprise the main surficial deposits in this landscape. Morainal deposits are probably the most extensive parent material.

The above combination of climatic, topographic, and landform factors has resulted in well to moderately well drained podzolic soils with dark reddish colours, low pH values of 4.0 to 5.0, moderate to high Fe + Al content, with low base saturations. Textures are predominantly coarse to medium. Where long term seepage occurs, levels of organic matter are sufficiently high to classify the soil as a Ferro-Humic Podzol. The interplay among the various environmental factors produces a boundary zone of considerable interfingering of the Humo-Ferric and Ferro-Humic Podzol soil landscapes.

The soil profiles have a sequence of organic surface horizons (L-F-H), possibly an incipient eluvial horizon (Ae), and a thick Bf horizon. An indurated pan (Bc and BCc horizons) is found in gravelly fluvial and morainal material wherever suitable textures and stable conditions exist. The degree of cementation of these pans varies from weak to strong; usually it is



Soil Land-scape		Dystric Brunisol, Regosol	Humo-Ferric Podzol	FHP, Dystric Brunisol	HFP	Organic	HFP	Gleysol, Humic Gleysol, Dystric Brunisol	Humo-Ferric Podzol	Organic	HFP	HFP, HG, G	Humo-Ferric Podzol, FHP	Ferro-Humic Podzol, Folisol
Biogeo-climatic Zone	Coastal Douglas-fir					Coastal Western Hemlock								MH, Alpine Tundra

Decrease in evapotranspiration →

Increase in precipitation (900–2500 mm/yr) →

LEGEND

Ferro-Humic Podzol . . . FHP
Humo-Ferric Podzol . . . HFP
Mountain Hemlock . . . . . MH
Humic Gleysol . . . . . HG
Gleysol . . . . G
Bedrock . . . . . .
Organic . . . . . .
Fluvial . . . .
Morainal . . . . . .
Marine . . . .
Colluvium . . . . .

FIGURE 3.3.4 The Humo-Ferric Podzol soil landscape showing associated soils.

strongest near the top of the horizon. These horizons are massive; they do not soften or slake in water, and can be chipped only with difficulty using a geology hammer. Sometimes it is difficult to distinguish the pan from the original parent material because the underlying unweathered morainal material is also compact. Bulk densities are high, greater than 1.8. The pan is streaked with reddish brown colours and often contains mottles and black manganese oxide coatings, in contrast to the more uniform olive greyish colour of the C horizon. Moderate to fine textured soils generally contain concretions in the illuvial Bf horizon.

Colluvial deposits within this landscape are deep to shallow veneers overlying bedrock. The B horizons are deeply weathered, usually extending down from 1 to 2 m to the bedrock contact. Colluvial soils are loose to friable, well to rapidly drained, and contain no indurated pans.

This landscape has been the basis of the forest industry of the southern coastal area over the past century. It contained in vast quantities some of the most magnificent mature stands of Douglas-fir in British Columbia. Today these stands are mostly logged. Forest productivity is lower than in the Ferro-Humic Podzol soil landscape, but is reasonably high in receiving seepage sites where mean annual increments exceed 12 m^3/ha/yr.

THE DYSTRIC BRUNISOL AND SOMBRIC BRUNISOL LANDSCAPES

These landscapes occupy a minor part of the region; since they occur only in southeastern Vancouver Island and the adjacent Gulf Islands, with a minor pocket on the Skagit River next to the international border.

The climate approaches the Mediterranean type having dry warm summers with high moisture deficits and relatively low rainfall. Precipitation ranges from about 650 mm to about 1250 mm. Water deficits during the growing season are considerable, ranging from 140 to 270 mm. The soil temperature class is mild mesic and the moisture regime is semiarid.

The landscapes occur within the Coastal Douglas-fir biogeoclimatic zone. Major tree species include Douglas-fir, Garry oak, Pacific madrone (arbutus), and grand fir, which prefers the sites with impeded drainage.

Major parent materials include medium to coarse textured compact glacial till or colluvium and fine textured marine. The soils are Dystric and Sombric Brunisols. Of the two, the Sombric Brunisol occurs in the driest sites and is associated with an open Garry oak-grass community. It is usually found below elevations of 50 m where effective moisture is lower than it is in the Dystric Brunisol landscape. The soils of both landscapes are moderately to slightly acidic in reaction, and have low to moderate base saturations.

SOIL LANDSCAPES OF FLOODPLAIN AND MARINE DEPOSITS

The soil landscapes in these areas include Eutric Brunisol, Melanic Brunisol, Gray Luvisol, Regosol, Gleysol, and Humic Gleysol. The complexity of soil landscapes occurring on floodplains is readily apparent when one considers the variability which occurs. Textures range from extremely coarse to fine, soil drainage ranges from rapid to very poor, and soil reaction from slightly acid to slightly alkaline. Important industries related to agriculture, forestry and recreation occur, and many towns and cities have been built, causing much conflict at present between urban and agricultural land use. Plate 3.3.2 illustrates some of these floodplain landscapes in the Fraser Valley.

The Eutric Brunisol, Melanic Brunisol and Gray Luvisol landscapes are restricted to large floodplains such as that of the Fraser River. These soils are often neutral to alkaline, and are imperfectly to moderately well drained.

The vegetation cover is largely deciduous, consisting of red alder, broad leaf maple and cottonwood, with grasses, shrubs, and sedges, whose decomposition products contribute to the dark Ah horizons. The parent materials are youthful and fine textured. Many soil characteristics depend on sedimentation, and flooding rather than soil processes. The slightly acid to neutral reaction and moderate to high base saturation of the soil reflects the underlying water table and little-weathered nature of the alluvium. Illuviation of clay is weak to moderate, illuviation of Fe and Al is weak, and organic matter content is variable. Significant areas of poorly drained Gleysolic and Organic soil landscapes also occur.

The Regosol landscape occurs on the most recent fluvial deposits. It is commonly found on all river floodplains including those of the Fraser, Skeena, and Nass, as well as along most smaller streams and rivers. The vegetation is normally deciduous including such species as black cottonwood, red alder, and willow or the landscape may be devoid of vegetation.

Regosols are dependent on the fluvial process of continual lateral stream migration. This process is clearly evident on all major streams and rivers in the coastal areas. New areas are continually being eroded and deposited, changing soils from possibly an older more strongly developed soil back to a young Regosol. This cycle repeats itself over and over again

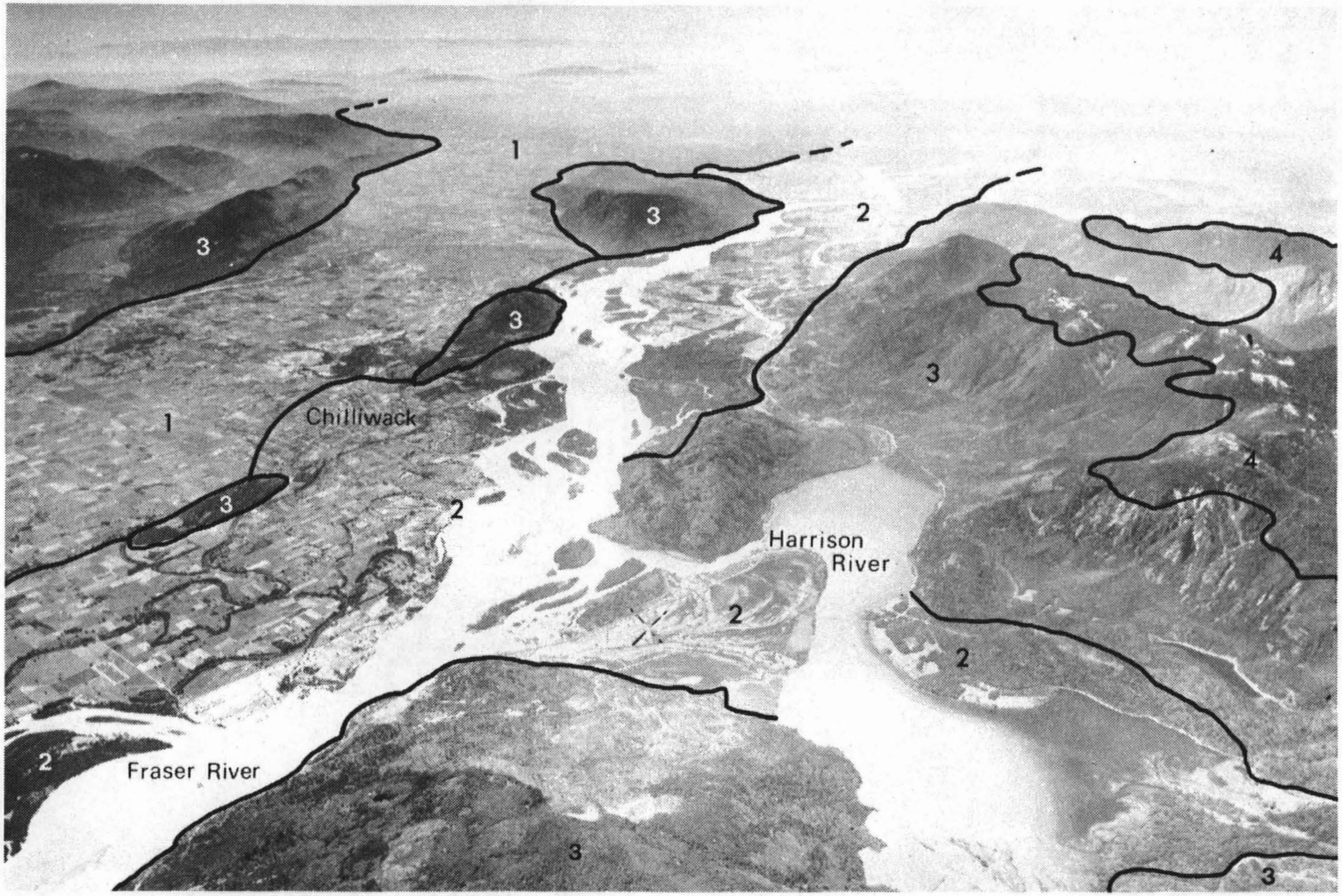


PLATE 3.3.2 Soil landscapes in and adjacent to the Fraser River Lowland looking southwest to Sumas Mountain. (photo BC·498·114)

PLATE 3.3.2
SOIL LANDSCAPES IN AND ADJACENT TO THE FRASER RIVER LOWLAND

1. Floodplain soil landscapes including Humic Gleysols, Gray Luvisols and scattered Mesisols and Humisols on fine to medium textured vertically accreting sediments. The complex pattern of these individual soil landscapes depends on soil drainage on the flat to gently sloping topography. The main tree species are Douglas-fir, Sitka spruce, red alder and black cottonwood.

2. Floodplain soil landscapes including Eutric Brunisols, Melanic Brunisols, and Regosols on medium to coarse textured laterally accreting sediments. The topography is undulating and the trees are mainly black cottonwood and red alder with some Douglas-fir and Sitka spruce.

3. Humo-Ferric Podzol soil landscapes on shallow and deep colluvial and morainal deposits. The main trees are Douglas-fir and western hemlock.

4. Upper mountain slopes and peaks with Ferro-Humic Podzol and Folisol landscapes and bedrock. Mountain hemlock and Pacific silver fir (amabilis fir) are the main trees.

as the streams and rivers meander back and forth across their valley floors. Climate over the whole watershed controls the amount of stream flow and the frequency and severity of flooding, both factors which produce constructive fluvial landforms on which Regosols are found. Low gradient streams common to most large rivers in this area have natural levees which usually occur close to the stream and somewhat higher than the surrounding terrain. During flood periods considerable erosion takes place and when the floodwaters overtop riverbanks and spread across the floodplain quantities of sediments are dropped on the levees and on the surrounding plain producing a Regosolic or Gleysolic soil.

Regosols, Gleysols and Organic soil landscapes occur side by side depending on the soil drainage with the Regosols on the better drained sites, the Gleysols in the poorly drained sites and Organic soils in very poorly drained sites.

The Gleysol and Humic Gleysol landscapes occur on very gently sloping to flat terrain which is often associated with marine and fluvial deposits (see Plate 3.3.2). The main locations of Gleysolic landscapes are the Estevan Coastal Plain, the Nahwitti Lowland, Suquash Basin, the Milbanke Strandflat and the Hecate Lowland.

Poor soil drainage is largely responsible for Gleysolic soil formation. The fine textured marine lowlands are particularly suited for the development of Gleysolic soils. Humic Gleysols have an Ah horizon and underlying horizons that are strongly gleyed and mottled. Weakly developed eluvial and illuvial horizons may be present. Typical vegetation includes red alder, black cottonwood, willows, skunk cabbage and sedges. The wet coastal climate with its predominantly perhumid soil moisture regime leads to Gleysolic soils on low lying receiving areas. The wet conditions of a high or fluctuating water table result in rapid chemical reduction and the production of typical bluish or grayish coloured horizons. Gleysolic soils are less dependent on climate than other soils. For example, much of the Nanaimo Lowland receives considerable water from the mountains to the west. This source of groundwater helps to sustain the water table throughout the lowland and, as a result, contributes to the formation of Gleysols in depressions surrounded by the much drier Brunisolic landscapes.

SOIL LANDSCAPES OF THE ALPINE TUNDRA

These landscapes occur at high elevations (generally over 1500 m on windward slopes, and over 1800 m on leeward slopes) where environmental conditions are severe, with rock, ice, snow and minimal soil development on shallow colluvium. High ridges and mountain peaks where cirques, tarns, horns, arêtes, rock bars, and intervening basins with glaciers and snowfields abound represent a significant part of the coastal region. The landscape includes such notable areas as Mt. Waddington, Silverthrone Mountain and the Homathko Icefield. The terrain is extremely rough and the vegetation and micro-climate changes rapidly over short distances. The soil temperature classes range from cold cryoboreal to subarctic. The area is nearly treeless except for scattered dwarf clumps of Pacific silver fir (amabilis fir), subalpine fir, and yellow cedar. Plate 3.3.3 illustrates some typical alpine tundra soil landscapes in the coast mountains just west of Tatlayoko Lake.

The high elevations make the climate colder, increase the amount of snowfall, and drastically shorten the growing season. Soil development is often absent or weak, occurring only in stable pockets where stunted trees, shrubs and heather, in combination with the harsh climate, have managed to develop a soil.

The processes of solifluction, nivation, and cryoturbation are all active. These processes have a strong effect on any soil development by disrupting and dislocating horizons, displacing and incorporating materials from other horizons, and mechanically sorting soil particles. Such effects in combination with the cold climate, which slows weathering, greatly retard soil development.

Alpine meadows are relatively small and are usually found in gently sloping to flat moisture receiving sites. This type of terrain in combination with large winter snow accumulations support nivation hollows which may or may not be permanently frozen depending on aspect and altitude. Shallow to deep Humic Gleysols and Organic soils are common in the alpine zone due to cold soil temperatures with low microbial activity. Organic matter accumulates. In the northern section of this region and on exposed north aspects Turbic Cryosols and Organic Cryosols are expected to occur. Regosols and Humic Regosols occur in relative abundance. Large areas of stones and boulders exist where cryoturbation and colluviation are common processes. In other well drained areas where tree islands and heather vegetation are found Ferro-Humic Podzols develop.

Because of its scenic beauty this landscape has tremendous potential for recreational activities such as hiking, rock climbing, and skiing.

THE SATURATED ORGANIC SOIL LANDSCAPES

Organic soils occur where the decay of organic residues is inhibited by a lack of oxygen caused by submersion or saturation. Fibrisols, Mesisols and Humisols all occur in the coastal region. Fibrisols are the most common,

PLATE 3.3.3 Soil landscapes of the alpine tundra in the Coast Mountains west of Tatlayoko Lake. (photo BC:1412:82)

PLATE 3.3.3
ALPINE TUNDRA SOIL LANDSCAPES
IN THE COAST MOUNTAINS WEST OF TATLAYOKO LAKE

1. Ferro-Humic Podzol soil landscape on shallow colluvial deposits over bedrock on steep upper valley slopes.

2. Upper mountain slopes and alpine meadows with a very complicated pattern of soil landscapes. They include rubbly Regosols, Humic Gleysols, Organic soils and possibly Organic Cryosols.

3. High ridges and mountain peaks with snow patches and glaciers. Soils are rocky, weakly developed and subject to frost action giving Regosols and probably Turbic Cryosols. Bedrock exposures are common with classic features of mountain glaciation such as cirques, horns and arêtes.

and occur in the wet outer coast region, on some floodplains, and at upper elevations where undecomposed sphagnum and forest peat are the dominant organic source. The main trees are yellow cedar and shore pine with Labrador tea as the common shrub. The soils are extremely acid (pH values less than 4.0). Mesisols have a vegetation cover composed of sedges, hardhack, mosses, willows, grasses, and reeds. Numerous bogs of this type occur on the drier east coastal plain of Vancouver Island. The water comes from seepage inflow from adjacent mineral soils rather than from precipitation only, as is the case with Fibrisols, and is thus richer in nutrients. Humisols occur only rarely and appear to be restricted to the southernmost part of the region.

Organic soils occur as small pockets in the southern coastal region, ranging up to fairly widespread areas on the flat to concave lands of the outer coast and Queen Charlotte Islands. Many in the south are found surrounding small lakes and were originated by the continuous encroachment of vegetation around the margins of what were once much larger lakes. Humisols and Mesisols are widely used for agriculture in the south.

3.4. THE INTERIOR PLATEAU

K.W.G. Valentine and A.B. Dawson

The interior plateau occupies the whole of the southern and central part of the province lying between the coast mountains to the west and the Columbia and Rocky Mountains to the east. It is a very large area approximately 900 km in length and 376 km at its maximum width. Almost all of it is drained by the Fraser River or its tributaries.

The features of the climate, geology and vegetation have been described in Parts 1.2, 1.3 and 1.4. These "factors of soil formation" have combined to give a number of highly distinctive soil landscapes, whose principal features are well known. The terms Okanagan, Cariboo, Chilcotin or Blackwater evoke an immediate picture of distinctive types of country. The main aspects of the environment that have produced the soils of these landscapes are discussed in the next few paragraphs.

THE FACTORS OF SOIL FORMATION

The interior plateau lies in the rain shadow of the coast mountains. Precipitation is therefore low in the west and south and increases eastward towards the Quesnel, Shushwap and Okanagan highlands and northward to Prince George. Effective precipitation is influenced by temperature through evaporation rates. Mean annual temperature decreases from south to north and with any increase in elevation. Most of the soils are frozen in the winter so it is the temperature and precipitation regimes through the spring, summer and fall that influence soil development. Soil temperature classes vary a great deal. Southern valleys around Osoyoos or Ashcroft are classed as moderately cool boreal with hot summers, whereas the plateau northwest of Prince George falls in the cold cryoboreal class. The same areas have soil moisture regimes that range from subarid with a severe moisture deficit to humid with only a slight moisture deficit, respectively.

Most of the plateau lies between 1200 and 1500 m above sea level. The topography is rolling with few high peaks. The main types of soil are homogeneous over large areas. The rugged topography in the east and the steep sides of some large valleys produce colluvial soil parent materials and sharp changes in soil types due either to the influence of elevation or aspect.

The basic basalt lavas of the centre and north contribute to the high base status of many soils. In the south and east the rocks are much more varied. The volcanics and limestones provide base-rich parent materials in parts of the Quesnel Highlands, while metamorphic rocks such as quartzites and gneiss give more acidic parent materials in the Shuswap Highlands.

Most of the parent materials are unconsolidated materials which were deposited during the last phase of glaciation and the subsequent wasting of the ice, or during post glacial time. Most of the plateau surface and the mountain slopes are covered with glacial till which usually bears a close association mineralogically with the underlying bedrock. Drumlins and glacial grooves are common and there are large areas of hummocky till where the ice stagnated and melted. The plateau surface therefore is rolling with many enclosed depressions. These depressions contain organic soils in the cooler and wetter north and often saline soils in the hotter and drier south. As the ice melted a large amount of water was released and often accumulated as huge lakes impounded by temporary ice dams. Throughout the interior plateau there are the remnants of lacustrine basins with stratified silty and clayey soils. The largest are around Fort St. James, Vanderhoof, Prince George, Kamloops and in the Okanagan valley. Very coarse materials were deposited by the meltwaters before they reached the lakes. So in many valleys or on the lower parts of the plateau there are gravelly and sandy terraces, plains, esker complexes and occasionally large deltas. All these deposits have thin droughty soils. Lastly, over much of the land, the wind deposited a thin layer of silt and fine sand. This material probably originated from the exposed shores of lakes or river floodplains, but some is volcanic in origin being derived from the Mazama, St. Helens Y and Bridge River ash falls. This volcanic ash can become quite thick close to the source (i.e. Bridge River).

There are a number of quite different biogeoclimatic zones in this large and varied plateau country. At the lowest elevations of the southern valleys are the open grasslands and sparse trees of the Ponderosa Pine - Bunchgrass zone. At higher elevations and further north is the Interior Douglas-fir zone. The parkland of the Cariboo Aspen - Lodgepole Pine zone is found from Clinton to the Bulkley River, and north of this is the Sub-Boreal Spruce zone. Throughout the region the Engelmann Spruce - Subalpine Fir zone occurs above about 1200 m and on the high mountain tops is the Alpine Tundra zone.

THE SOIL LANDSCAPES

The soil map of British Columbia (Part 3.2) shows the distribution of the main soil great groups in the interior plateau. The features of each great group landscape are described on the following pages. The map is very general and cannot show some of the soil landscapes which may cover small areas in total but are nonetheless important members of the whole soil picture. The organic, saline and alpine soils are examples. The geographical

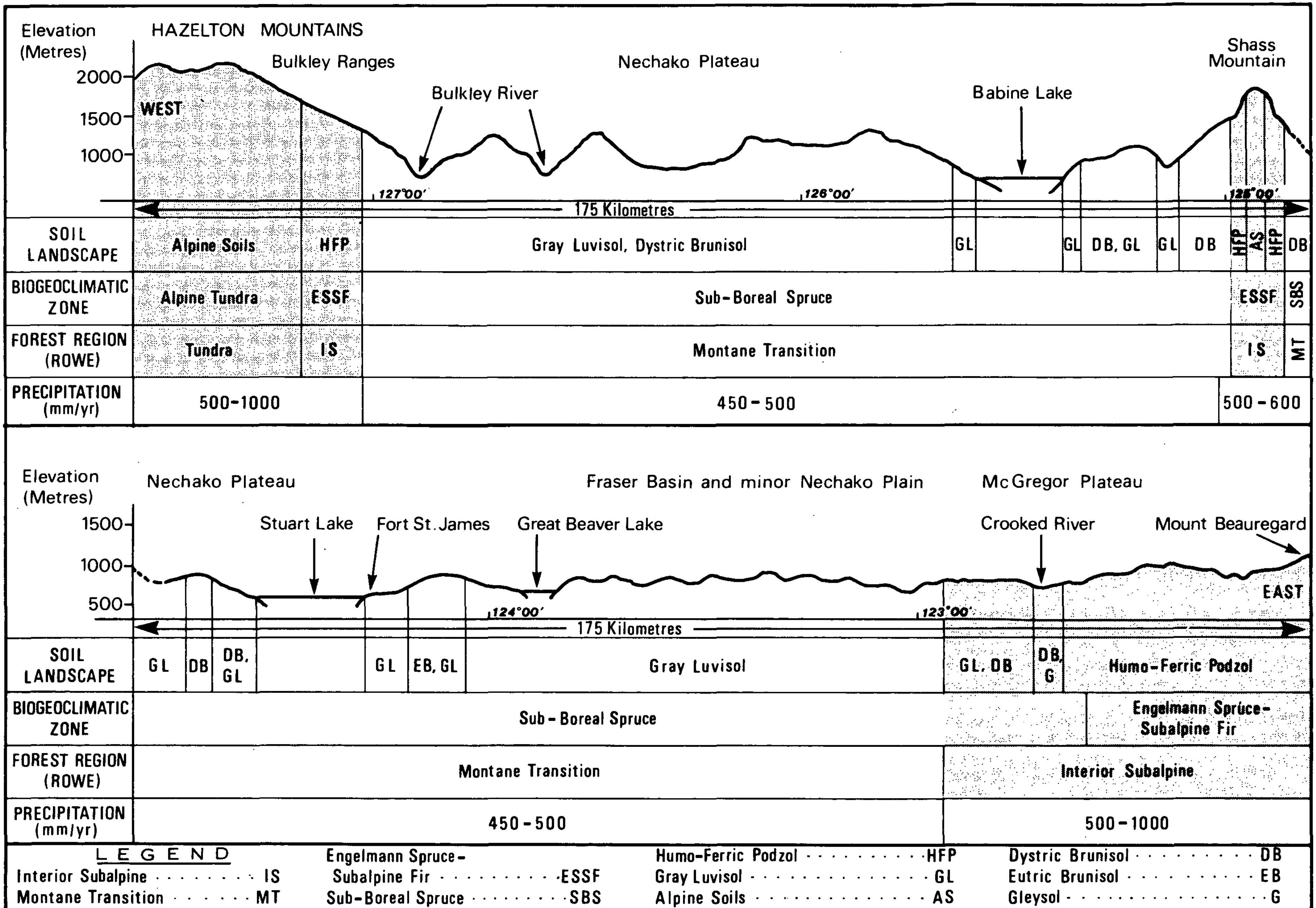


FIGURE 3.4.1 The soil landscapes of the northern Interior Plateau along latitude 54°27′

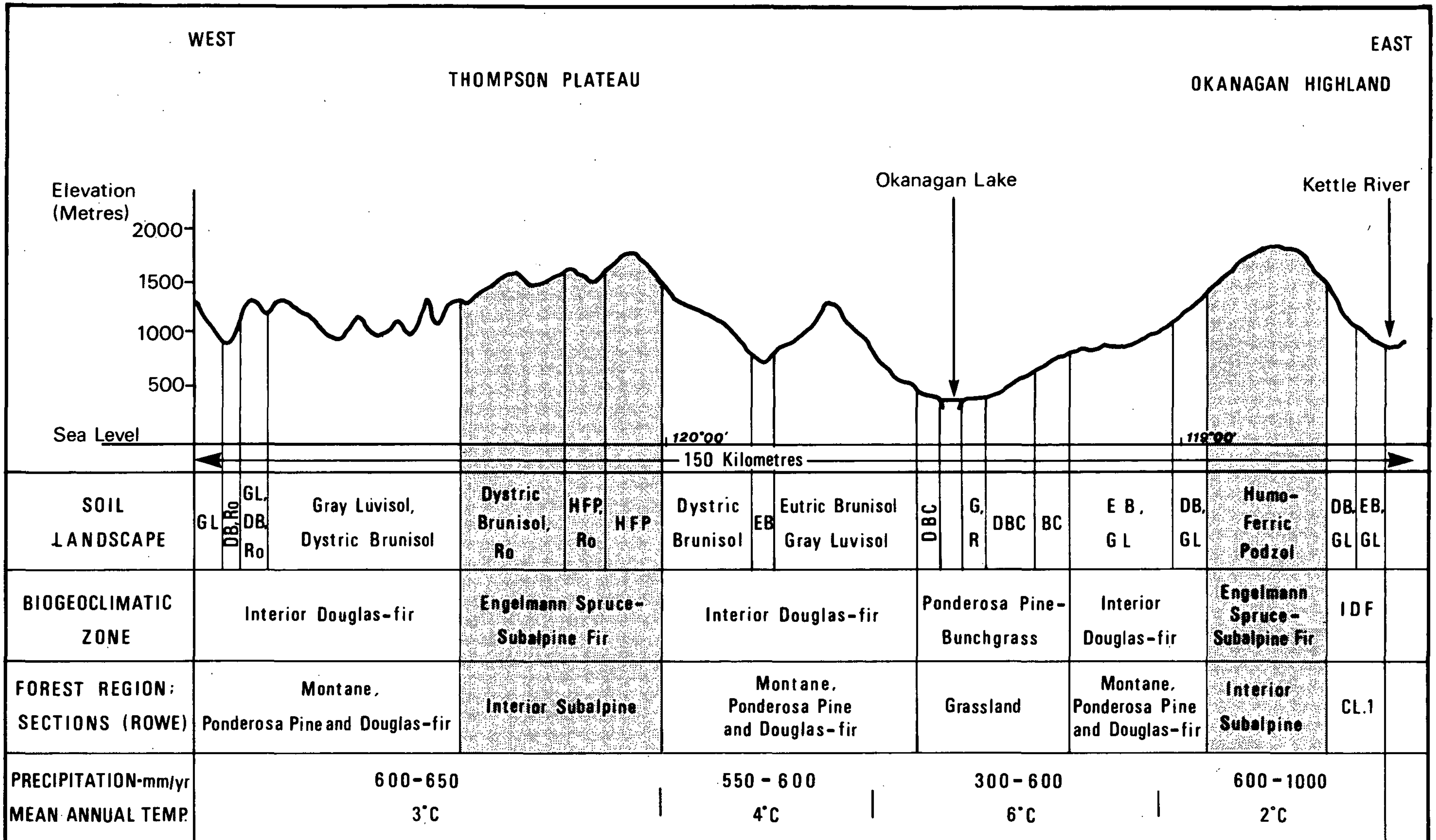
relationships of all the soil landscapes are shown by two east-west cross sections; one across the humid northern portion of the plateau (Figure 3.4.1) and one across the south (Figure 3.4.2).

THE GRAY LUVISOL LANDSCAPE

This is by far the most extensive of all the soil landscapes. In the south Gray Luvisols occur on the medium to moderately fine textured glacial till of the plateau slopes. Most of the till is calcareous being derived from base rich volcanics or limestone, but some in the east is more acid. The vegetation is a moderately dense Rocky Mountain Douglas-fir forest with bluebunch wheat grass and pine grass. The elevation range of these soils in the south can extend from about 1000 m to over 1800 m above sea level. Further north the elevation range becomes lower because the cooler temperatures and higher precipitation result in greater moisture effectiveness at lower elevations. Thus in the Williams Lake area Gray Luvisols are found on the calcareous till of the plateau and on the calcareous lacustrine silts in the valleys down to 800 m above sea level. In the Fort St. James and Vanderhoof area Gray Luvisols occur down to about 600 m on the lacustrine silts and do not extend much above 1100 m on the till of the plateau. Here the trees are mainly white spruce and lodgepole pine. Gray Luvisols rarely occur on colluvium, possibly because the material is too unstable for a definite horizon of clay accumulation to be formed.

The vegetation cover does not add a very large amount of organic matter to the soil so that the surface litter layer of needles and grass (L, F horizons) is thin and poorly decomposed. The uppermost mineral horizon is typically 10-25 cm of grayish brown silt and fine sand (Ae horizon), much of which is wind blown loess and volcanic ash. Below this there is a much finer textured layer 15-30 cm thick (Bt horizon) which has strong angular blocky structure. This horizon, in which clay has accumulated, tends to restrict water percolation, so that these soils can become extremely wet in the spring. The carbonates of the original parent material have been washed out of the A and B horizons, but the intensity of leaching is not great enough to wash them through the C horizon and away via the groundwater. Therefore, there is often a white powdery layer of carbonate accumulation at depth to give a Cca horizon. In the semiarid south this accumulation will be less than one metre below the surface. In the humid north it may be as deep as two metres.

These are the soil landscapes that support much of the extensive logging industry of the interior plateau. Timber productivity is especially high in humid areas bordering the Humo-Ferric Podzol landscapes. In the subhumid and semiarid areas associated with the Brunisolic landscapes the forest is more open and provides important summer grazing for the interior cattle ranching industry.



LEGEND

Shallow soils and rocks	Ro	Black Chernozemic	BC	Gleysol	G
Humo-Ferric Podzol	HFP	Gray Luvisol	GL	Regosol	R
Dark Brown Chernozemic	DBC	Dystric Brunisol	DB	Interior Douglas-fir	IDF
		Eutric Brunisol	EB	Southern Columbia	CL.1

FIGURE 3.4.2 The soil landscapes of the southern Interior Plateau along latitude 50°00'

THE HUMO-FERRIC PODZOL SOIL LANDSCAPES

In broad terms this soil landscape borders the Gray Luvisols on the higher elevations of the Nechako, McGregor, Fraser and Thompson plateaus and the Quesnel, Shushwap and Okanagan highlands. The soil temperature class is mainly cold cryoboreal and the moisture regimes are humid to subhumid. The soil parent materials are usually coarse to moderately coarse textured very permeable glacial till or colluvium derived mainly from igneous and metamorphic rocks such as granodiorites, gneisses and schists. In the more humid northern portion similar soils also occur at much lower elevations on very coarse textured fluvioglacial materials. The vegetation is usually a dense subalpine fir and Engelmann spruce forest with moderately dense shrub, forb and moss layers. It is the basis for the logging industry of the central interior. In the south this soil landscape occurs above about 1200 m but lower on northerly aspects. In the north its elevation range is approximately from 750 m to 1500 m above sea level. Plate 3.4.1 illustrates the occurrence of this soil landscape in the Quesnel Highlands.

The dense vegetation cover provides a thick organic surface litter of needles, twigs and moss (L-F-H horizons) which is acid and poorly decomposed. Below this usually occurs a bleached sandy Ae horizon and then a reddish brown Bf horizon in which iron, aluminum and some amorphous organic matter has accumulated. Leaching of bases is intense in these soils and there is no trace of carbonates throughout the profile.

On its drier and warmer margins the Humo-Ferric Podzol soil landscape borders the Gray Luvisol and Dystric Brunisol landscapes. At higher elevations it extends into the subalpine from continuous tree line to the limit of tree growth. Here there is an accumulation of amorphous organic matter in the surface mineral horizons, a significant accumulation of volcanic ash in the topsoil and a shrub cover of grouseberry. In the extreme south its upper limit is about 2100 m above sea level.

THE DYSTRIC BRUNISOL AND EUTRIC BRUNISOL LANDSCAPES

These soil landscapes occur in a wide variety of environments. They may be found in areas of low precipitation, high temperatures and coarse textured acidic or calcareous parent materials. Whatever the particular conditions are in one place they lead to soils whose main feature is *in situ* weathering with little translocation of soil materials. Morphologically, Dystric and Eutric Brunisols are quite similar. Their difference lies in precipitation effectiveness. The Eutric Brunisol landscape has the lower effective precipitation; there is less leaching of bases than in the Dystric Brunisol landscape and it has higher pH values and higher base saturation.

The soil map (Part 3.2) shows that the Dystric Brunisol is the most common. It occurs mainly in the southern portion of the interior plateau. The parent materials are acid till and colluvium on the plateau and mountain slopes, with a forest cover of Rocky Mountain Douglas-fir or Engelmann spruce. There are some expanses in the northern portion either because the parent material is not calcareous or fine textured enough for Gray Luvisols to develop, or because leaching is too efficient for Eutric Brunisols to develop. Thus, north and west of Prince George, Dystric Brunisols occur on fluvioglacial gravels or on neutral and shallow glacial till and colluvium over bedrock, and southwest of Prince George they occur in the humid Blackwater River country.

The Eutric Brunisol landscape is mainly in the southern valleys. The most common parent materials are slightly alkaline fluvioglacial sands and gravels. The vegetation is an open forest of ponderosa pine or Rocky Mountain Douglas-fir with bluebunch wheat grass or lodgepole pine and pine grass.

The soils of both landscapes have relatively thin, poorly decomposed organic surface layers, little incorporation of the organic matter in the mineral soil and brown Bm horizons. The Eutric Brunisols have pH values above 5.5, high base saturation and may have white powdery calcium carbonate accumulations less than one metre below the surface. They are associated with Chernozemic and Gray Luvisol landscapes. The Dystric Brunisols have pH values below 5.5 and calcium carbonate accumulations usually do not occur within one metre from the surface. They are associated with Gray Luvisol and Humo-Ferric Podzol soil landscapes.

THE GRASSLAND SOIL LANDSCAPES

The grasslands of the central interior have Brown, Dark Brown, Black and Dark Gray Chernozemic soils and some small exposures of Solonetzic soils. They are a very well known part of the British Columbia scene. The cattle ranching industry depends on them for much of its grazing land. Most of the orchards of the southern valleys have been developed on them under irrigation. They also form an integral part of the parkland scenery with lakes, trembling aspen and coniferous trees that attracts thousands of campers, fishermen and hunters each year.

The Brown, Dark Brown and Black Chernozemic soil landscapes form a sequence from drier to moister grassland environments. The Dark Gray Chernozemic soil landscape is a transition zone between the grassland Dark Brown or Black Chernozemic soils and the forest Luvisolic or Brunisolic soils.

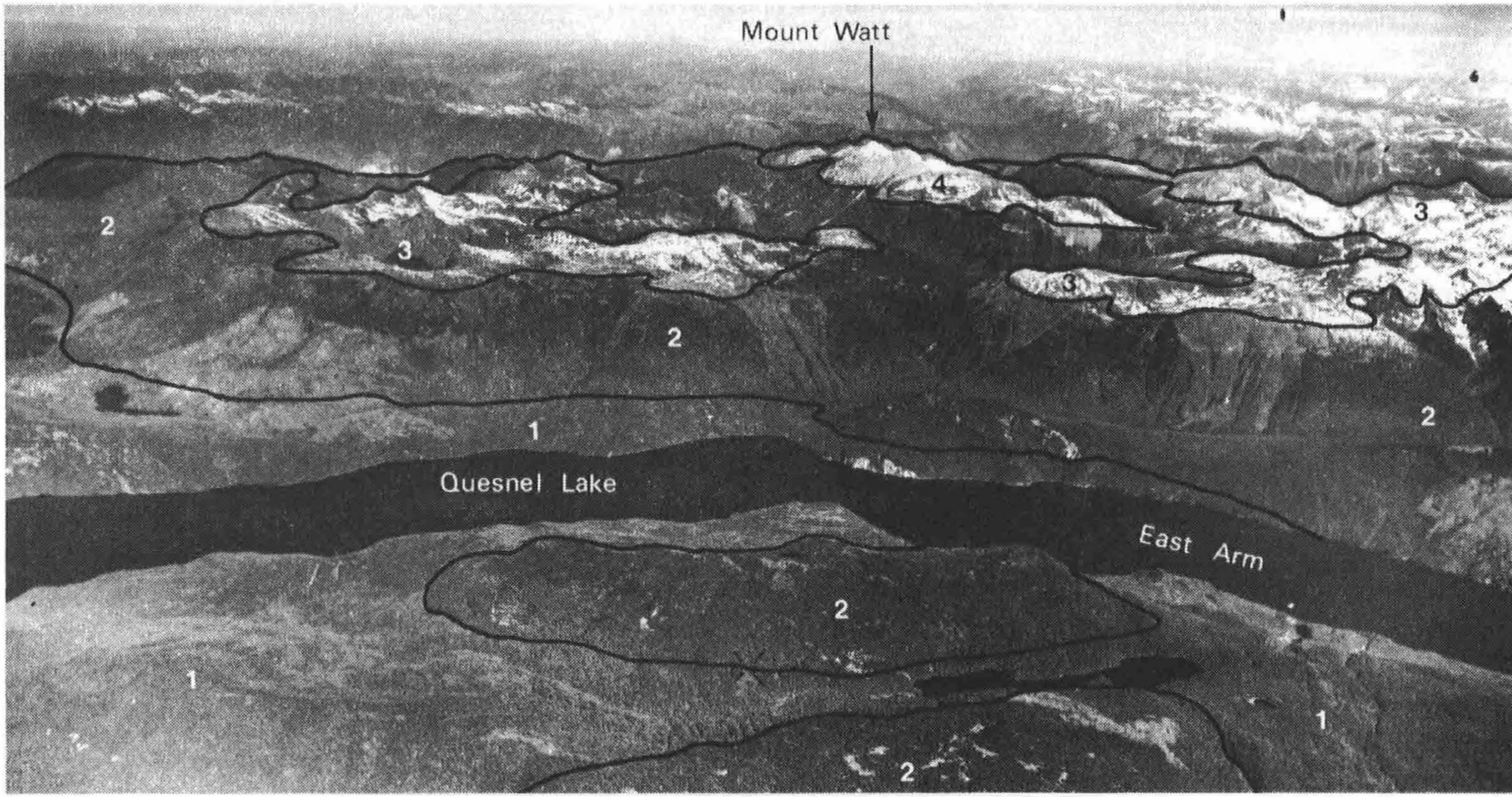


PLATE 3.4.1 Soil landscapes in the Quesnel Highlands. (photo BC:487:45)

PLATE 3.4.1
SOIL LANDSCAPES IN THE QUESNEL HIGHLANDS

1. Humo-Ferric Podzol soil landscape on gravelly moderately coarse glacial till derived from quartz-mica schist and quartzite. Bedrock is close to the surface in some areas. The vegetation is the interior western hemlock forest.

2. Humo-Ferric Podzol soil landscape on gravelly moderately coarse textured colluvium and glacial till derived from quartz-mica schist and quartzite. Bedrock is close to the surface in many areas. The vegetation is the Engelmann spruce - subalpine fir forest.

3. Alpine soil landscapes on acid metamorphic bedrock (quartz-mica schist and quartzite). Mainly Dystric and Sombric Brunisol and cryoturbated Humic Regosol landscapes. Treeless alpine tundra vegetation.

4. Alpine soil landscapes on massive marble bedrock. Mainly Melanic Brunisol and cryoturbated Humic Regosol landscapes. Treeless alpine tundra vegetation.

Solonetzic soils can be associated with any of the Chernozemic soils wherever restricted drainage and high evapotranspiration rates lead to the accumulation of soluble salts.

There are three main areas of the Brown Chernozemic soil landscape: the southern Okanagan valley, the valley of the Thompson near Kamloops and the Fraser valley near Lillooet. All have semiarid to subarid moisture regimes and the soil temperature class is moderately cool boreal. This is the driest and warmest environment occupied by any of the soil landscapes. It occurs at the low elevations of the terraced river valleys (below about 600 m at Kamloops) and especially on south facing aspects where evapotranspiration is highest. The soil parent materials are typically lacustrine silts, fluvial sands and gravels and glacial tills that occupy the valley bottoms. In such a dry environment the vegetation is sparse; mainly big basin sagebrush, brittle prickly pear cactus and bluebunch wheat grass.

There is little or no surface litter layer on these soils. The uppermost horizon is usually a light brown friable sandy loam 15 cm deep with quite a high organic matter content and granular structure (Ah horizon). Below this will be about 25 cm of a brown Bm horizon. Carbonates are precipitated at a shallow depth in such a dry soil to give a Cca horizon. Soil reaction will be alkaline with pH values approaching or exceeding 8. Base saturation will be at or near 100%, and the organic matter is well humified giving C/N ratios of 10 or less.

The Dark Brown soil landscape is found in a slightly cooler and more moist environment than the Brown soil landscape. Hence it is either slightly further north or at a higher elevation. The three areas shown on the soil map are: the central Okanagan valley; Nicola Lake to around Kamloops; and near Clinton. The soil temperature classes are moderately cool to cool boreal and the moisture regime is semiarid. The range of soil parent materials is similar to that on which the Brown soils have formed. However, as the Dark Brown soil landscape occurs at higher elevations (from 600 m to 825 m near Kamloops) a greater proportion of these soils occur on the glacial till of the higher valley and lower plateau slopes. The vegetation is commonly a continuous grass cover dominated by needle-and-thread grass and Sandberg's blue grass.

These soils will have a similar horizon sequence to that of the Brown soils but the Ah horizon is a darker brown and all the horizons tend to be thicker. Their chemical characteristics are similar too, except for a higher organic carbon content in the Ah horizon.

The Black soil landscape lies at the upper elevations of the grasslands (from 825 m to 975 m near Kamloops). At this height on the plateau most of the parent material is glacial till. The soil temperature classes are moderately cool to cool boreal and the moisture regime is subhumid to semiarid. The Black soil landscapes have many more plant species, especially forbs, than the other two lower landscapes. The principal grass is rough fescue and clumps of trembling aspen are common. The horizon sequence is similar to the Brown and Dark Brown soils but the Ah horizon will be thicker with a darker colour and a greater organic carbon content, and carbonates will have been precipitated at a greater depth in the C horizon.

The grassland-forest transition of the Dark Gray soil landscape is the furthest north or highest of all the Chernozemic landscapes. It is found in the cool boreal and subhumid to semiarid zone around the junction of the Chilcotin and Fraser rivers and in the Nicola, Kamloops, Okanagan and Kettle valley areas. Soil parent materials are mainly medium to moderately fine textured glacial till, but they also include sandy and gravelly fluvioglacial deposits on many of the lower valley terraces. The vegetation is typically a continuous grass cover dominated by Kentucky blue grass with many tree islands of trembling aspen, lodgepole pine and Rocky Mountain Douglas-fir.

The morphology of the soils shows the transition to Luvisolic soils, since below the dark gray Ah horizon there is a horizon from which clay and organic matter has been leached (Ahe or Ae). Below this is a brown, blocky, finer textured horizon (Bm or Bt). Greater leaching is also evident in the greater depth to carbonate accumulation which is often more than one metre from the surface. Similarly pH values and base saturation percentages will be lower and C:N ratios higher than in the other Chernozemic soils.

Wherever high rates of evapotranspiration and restricted drainage occur together soluble salts will accumulate to produce a saline Solodized Solonetz or Solodic soil landscape. This can occur in association with any of the described Chernozemic soil landscapes. Sodium and magnesium salts dominate the soil chemistry.

If the soil drainage is restricted by an enclosed depression there may be a muddy saline slough in the centre. Surrounding this there is an area bare of vegetation which usually has a white salt efflorescence on the surface. Towards higher ground salt tolerant vegetation such as desert salt grass, alkali grass, or common silverweed gradually covers the surface, until the normal grass vegetation of the particular Chernozemic soil typical of the area is reached.

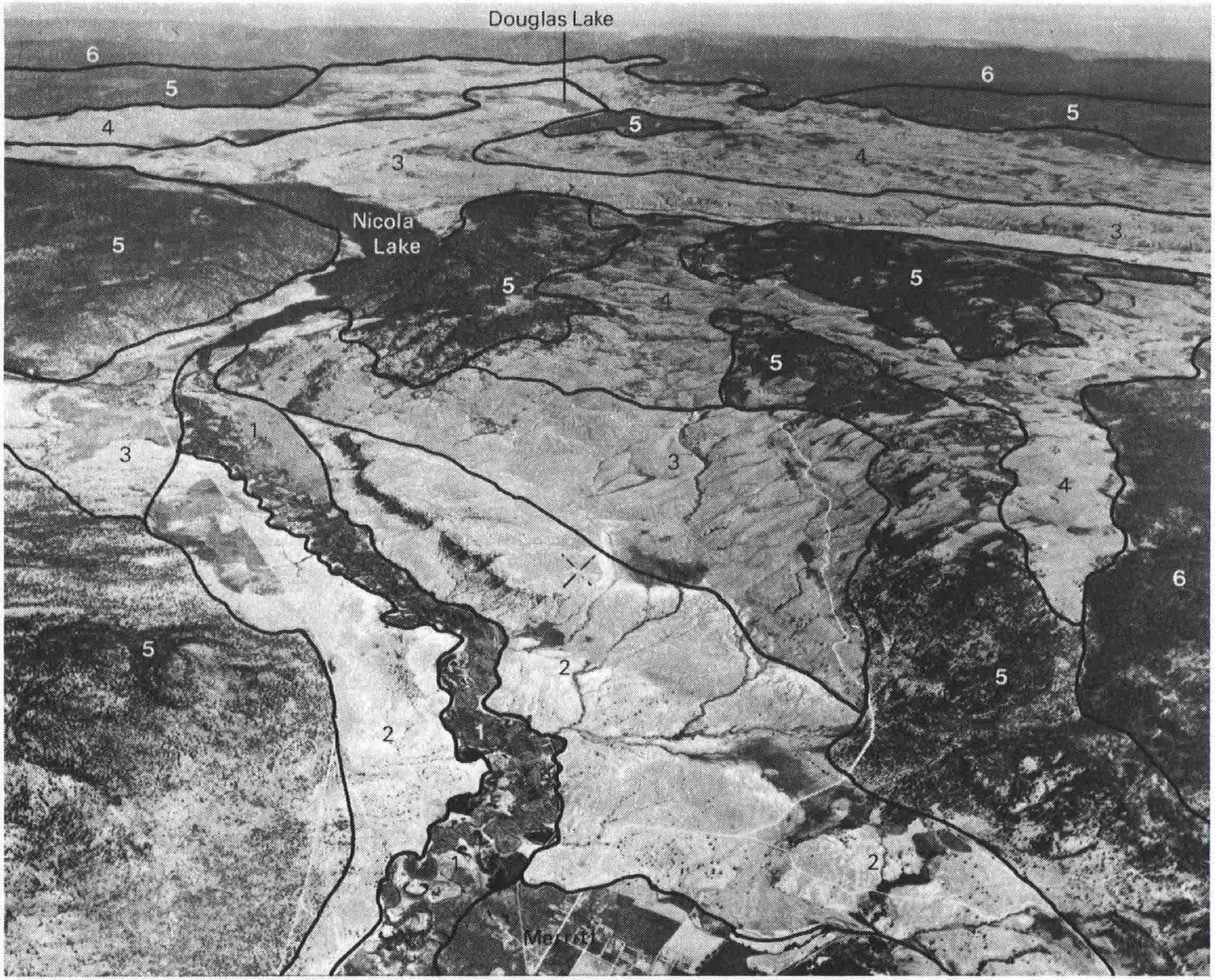


PLATE 3.4.2 Soil landscapes on the southern Interior Plateau near Merritt. (photo BC:651:33)

PLATE 3.4.2

SOIL LANDSCAPES ON THE SOUTHERN PLATEAU NEAR MERRITT

1. Humic Regosol and Humic Gleysol landscapes on the present river floodplain, with medium textured parent materials. The vegetation consists of sedges, and willows.

2. Dark Brown soil landscape on lacustrine silts with grassland vegetation. There are some pockets of the Solodized Solonetz soil landscape with salt tolerant vegetation.

3. Dark Brown soil landscape on gravelly medium textured glacial till with grassland vegetation.

4. Black soil landscape on gravelly medium textured glacial till. The vegetation is mainly grassland with tree islands of trembling aspen and Rocky Mountain Douglas-fir.

5. Eutric Brunisol landscape on gravelly medium textured glacial till and colluvium with an open Rocky Mountain Douglas-fir - pinegrass vegetation cover.

6. Gray Luvisol landscape on gravelly medium textured glacial till. There is a relatively dense Rocky Mountain Douglas-fir - pinegrass vegetation cover.

The sequence of all these grassland soil landscapes and their bordering forest soils is shown in Plate 3.4.2 which illustrates the country around Merritt.

THE ORGANIC MESISOL AND FIBRISOL LANDSCAPES

Organic soils occur wherever soil drainage is very restricted in depressions or on floodplains throughout the humid to subhumid and cold to moderately cold cryoboreal portions of the interior plateau. In the south they are limited to the higher elevations of the plateau and to the low floodplains. They are not found in intermediate positions. Towards the north they are found at progressively lower elevations on the plateau. Thus they can be associated with all types of terrain and have been mapped on floodplains, on terraces, in lacustrine basins, on the plateau and into the alpine country.

The nature of these organic soils depends to a large extent on the quality of the water draining into them. On the calcareous till plateau the water is neutral to slightly alkaline and rich in nutrients. Sedges, bog glandular birch, willows and sometimes black spruce and lodgepole pine grow on them. The organic material is relatively well decomposed. The soil is a Mesisol. In some of the southeastern highlands and on the plateau northwest of Prince George the surrounding mineral landscape is more acid. There the organic soils have a lower pH, a lower nutrient status, support more mosses and fewer shrubs and trees and the organic materials are poorly decomposed. They are Fibrisols.

THE ALPINE SOIL LANDSCAPES

The alpine soil landscapes cover only a minor portion of the central interior. They often have large amounts of volcanic ash in their surface horizons and in this respect they are quite different from most of the other alpine soil landscapes of the province. The pattern of individual soils is exceedingly complicated. The topography, vegetation and meso- and macroclimates change drastically over short distances. In addition the geomorphological processes typical of cold environments often disrupt the soil forming processes. Only a few studies of these soils have been carried out but there seem to be two main soil landscapes depending primarily upon elevation and aspect. Above the limit of tree growth to about 2400 m in the south, acid Dystric and Sombric Brunisol landscapes are found with deep turfy topsoils which contain much volcanic ash. The vegetation is an alpine tundra plant community of grasses, sedges, willows and lupins. Between here and the highest rock peaks are the poorly developed stony soils that show extreme disruption due to cryoturbation and solifluction. They have patchy alpine tundra vegetation communities and are mainly Regosol and Humic Regosol landscapes.

3.5 THE COLUMBIA MOUNTAINS AND THE SOUTHERN ROCKIES

U. Wittneben and L. Lacelle

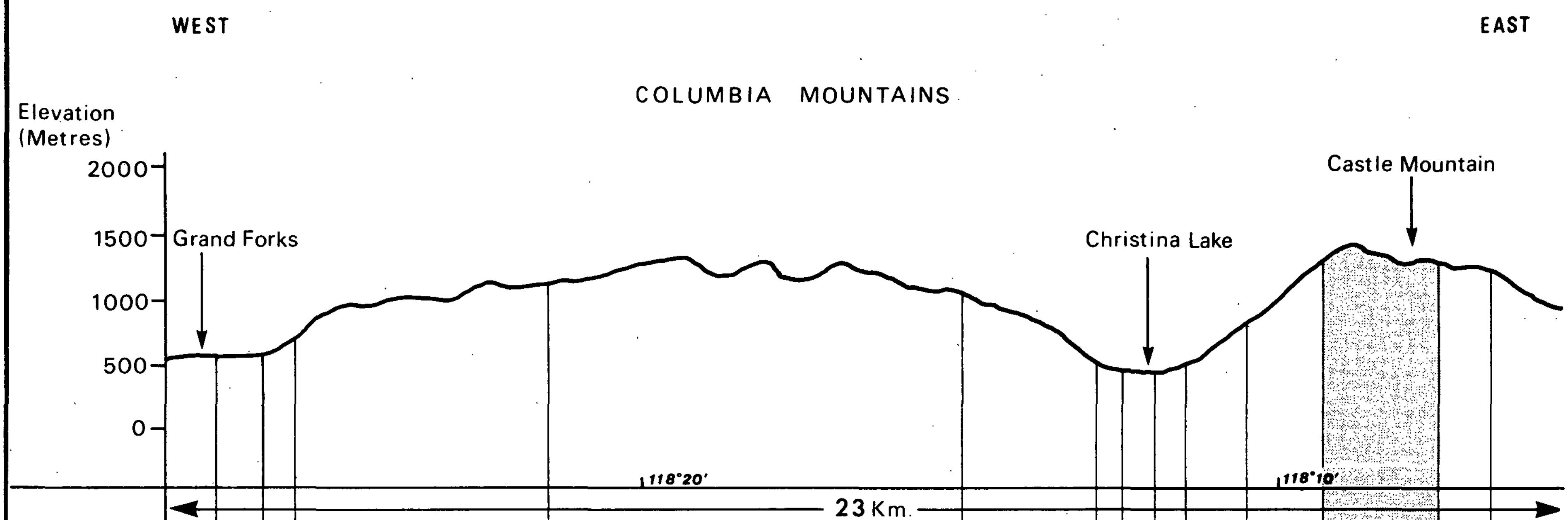
The Columbia and Southern Rocky mountains are in southeastern British Columbia, separated by the Rocky Mountain Trench. These highly faulted, folded and glaciated mountain ranges lie between the Interior Plateau to the west and the Great Plains to the east. The Columbia and Rocky Mountains trend in a northwest to southeast direction and have high relief, with rugged mountainous ranges separated by narrow valleys. The Columbia, Kootenay and Fraser Rivers and their tributaries, as well as several long, narrow lakes, occupy the floors of these valleys.

THE FACTORS OF SOIL FORMATION

Since many of these mountain ranges rise to heights above 3000 m, they form barriers across the eastward movement of moist Pacific air masses. The forced rising of the air results in increased precipitation on western slopes and drier climates in the rainshadow of the mountains. Thus, major valleys such as the Rocky Mountain Trench are relatively dry, especially on their east-facing slopes. Abrupt changes in climate and relief mean that soil temperature and moisture regimes vary a great deal in this area. The drier main valleys have moderately cool boreal soil temperature classes while higher elevation valleys and mountain slopes have cold to very cold cryoboreal classes. Similarly, the dry main valleys have semiarid soil moisture regimes but higher elevation areas have humid to subhumid regimes. A variety of soil landscapes has developed in response to local climate effects.

The high relief, rugged topography and complex geology affects soil formation through the soil parent material found in differing topographic situations. Common parent materials include: rubbly deep and shallow colluvium, fine and coarse textured morainal materials (glacial till), and fine and coarse textured fluvial terraces, fans and floodplains. Remnants of silty lacustrine terraces occur in mountain valleys. Organic soil parent materials occur sparsely in localized depressional areas. In the higher mountain areas volcanic ash is an important component of the soil parent material. In the dry valleys thin cappings of wind-blown sands and silts are common on morainal and fluvial parent materials.

Soil and soil parent material textures bear a strong relationship to the types of bedrock from which they were derived. The common occurrence, especially in the Southern Rocky Mountains, of sedimentary limestones and dolomites results in the presence of large areas of soils developed on



SOIL LANDSCAPE	DBC	EB	DGC	Eutric Brunisol	Dystric Brunisol	Eutric Brunisol	EB	DBC	DGC	EB	DB	HFP	HFP	DB
BIOGEO-CLIMATIC ZONE	Ponderosa Pine-Bunchgrass			Interior Douglas-fir			PPBG			IDF	IWH	ESSF	Interior Western Hemlock	
FOREST REGION (ROWE)	Montane										Columbia	Subalpine	Columbia	
PRECIPITATION (mm/yr)	435-470			500-600			435-470			500-600	700-1000	800-1200	750-1200	

LEGEND

Dark Brown Chernozemic . . . . DBC
Dark Gray Chernozemic . . . . DGC
Dystric Brunisol . . . . DB
Humo-Ferric Podzol . . . . HFP
Eutric Brunisol . . . . EB
Engelmann Spruce-Subalpine Fir . . . . . . ESSF
Interior Western Hemlock . . . . IWH
Interior Douglas-fir . . . . IDF
Ponderosa Pine-Bunchgrass . . . . PPBG

FIGURE 3.5.1 The soil landscapes in the Columbia Mountains.

calcareous parent materials. Soft, readily weathered sedimentary and metamorphic rocks such as shales, siltstones and argillites result in the formation of fine textured soil parent materials, that are prone to mass wasting. Coarse textured, and more stable soils are derived from sandstone, quartzite and conglomerate bedrocks.

The variety in relief and climate in the Columbia and Southern Rocky Mountains results in the existence of a number of biogeoclimatic zones. The Interior Western Hemlock zone occurs on the mountain slopes receiving the heaviest precipitation. Acidic Dystric Brunisols and Podzolic soils develop in this zone. In the rainshadow of the mountains the semiarid Ponderosa Pine - Bunchgrass zone occurs. Grassland Chernozemic soils and Eutric and Dystric Brunisols commonly develop. At higher elevations the colder and wetter climate results in the occurrence of the Subalpine Engelmann spruce - Subalpine fir zone. Humo-Ferric Podzols develop under the dense forest canopy and the humid to subhumid soil moisture regimes in this zone. The highest mountain peaks reach the Alpine Tundra zone where severe climate plus variable relief result in the development of Regosols, Melanic and Sombric Brunisols, and Gleysols.

THE SOIL LANDSCAPES

The soil map of British Columbia shows the distribution of many of the soil great groups in the area. Because the map is very general, some soil landscapes found in this region are not specifically identified, but are grouped with other soil great groups.

THE GRASSLAND SOIL LANDSCAPES

The Chernozemic soils of these landscapes occur in the dry valleys of the Grand Forks area, Creston Flats and the southern Rocky Mountain Trench (Figures 3.51, 3.52 and Plate 3.5.1). Because of their relatively gentle topography and surface horizons enriched with dark organic matter, these soils are often farmed. In addition, because they are open with grass cover, they are an important range area for cattle and big game animals.

Soil moisture classes are generally semiarid and the soil temperature regimes moderately cool boreal. The vegetation is an open grassland with scattered ponderosa pines.

The Dark Brown Chernozemic soil landscape is most common at lower valley elevations, on west and south aspects and on coarse textured fluvial and morainal deposits. Soil parent materials are often highly calcareous. The moderately high temperatures and low precipitation results in incomplete

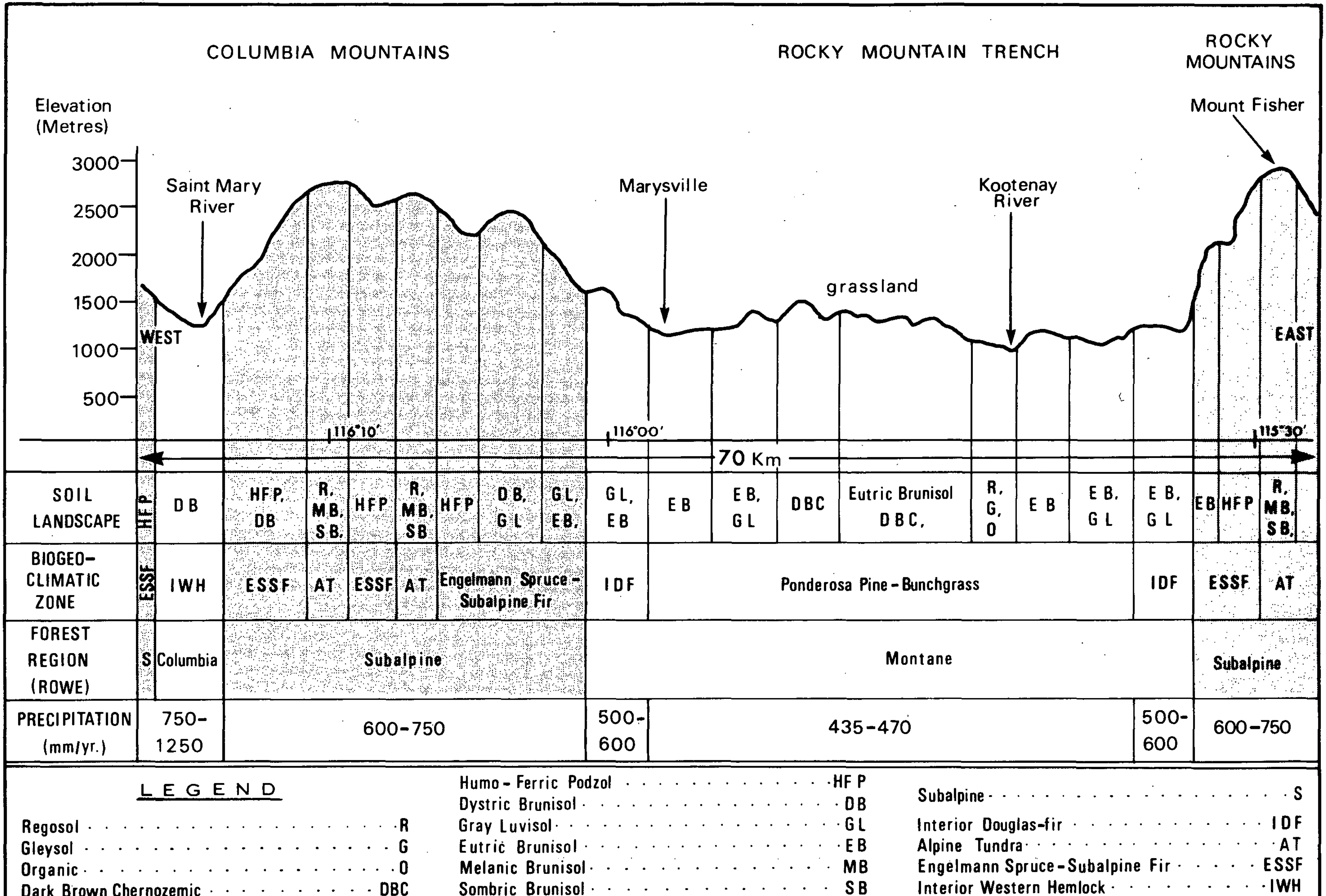


FIGURE 3.5.2 The soil landscapes in southeastern British Columbia along latitude 49°38′N.

soil leaching and a somewhat hardened carbonate layer develops at a shallow depth. The pH of the soil is mostly alkaline and base saturation is high. The Ah horizon capping these soils is enriched with organic matter and well humified.

Dark Gray Chernozemic soil landscapes occur in the grassland - forest transition area and often grade into the Eutric Brunisol soil landscape. Black Chernozemic soil landscapes occur sporadically at higher elevations wherever soil moisture effectiveness is greater and the thick black Ah horizons characteristic of this landscape can develop.

THE EUTRIC BRUNISOL LANDSCAPE

Eutric Brunisols are usually found in areas of greater precipitation and cooler temperatures than those of the grassland soil landscapes. Soil moisture classes are generally semiarid to subhumid and the soil temperature regime varies from moderately cool boreal to cold cryoboreal. In this soil climate Eutric Brunisols develop under fairly open stands of Rocky Mountain Douglas-fir and ponderosa pine. At higher elevations they are also found under more dense stands that include lodgepole pine and Engelmann spruce. Thus they occur within three biogeoclimatic zones; the Ponderosa Pine - Bunchgrass, the Interior Douglas-fir and the lower part of the Subalpine Engelmann Spruce - Subalpine Fir.

The Eutric Brunisol landscape is common in the relatively dry rainshadow valleys such as the Rocky Mountain Trench. It occurs in the valley bottoms and on lower mountain slopes in areas with calcareous parent materials (Figures 3.5.1, 3.5.2 and Plate 3.5.1). It is common on coarse textured parent materials and may grade into the Gray Luvisol landscape in areas where fine textured materials occur. Coarse textured fluvial, morainal and colluvial deposits derived from limestones and dolomites commonly have Eutric Brunisol soil developments. Sandy or silty eolian cappings are frequent on morainal and fluvial materials. Volcanic ash may make up part of the solum.

Eutric Brunisols in the region are shallow with a hardened carbonate layer, having developed from calcareous parent materials. Surface organic layers (L-F) are thin and poorly incorporated with the mineral soil. Leached Ae horizons or organic Ah horizons are usually thin or absent and the Bm horizons are pale brown and usually very shallow. The pH of the soil is generally above 6.0, and that of the parent material is usually greater than 7.0. These soils are either too coarse, or the soil moisture regime is too dry, for significant leaching of clays to have taken place.

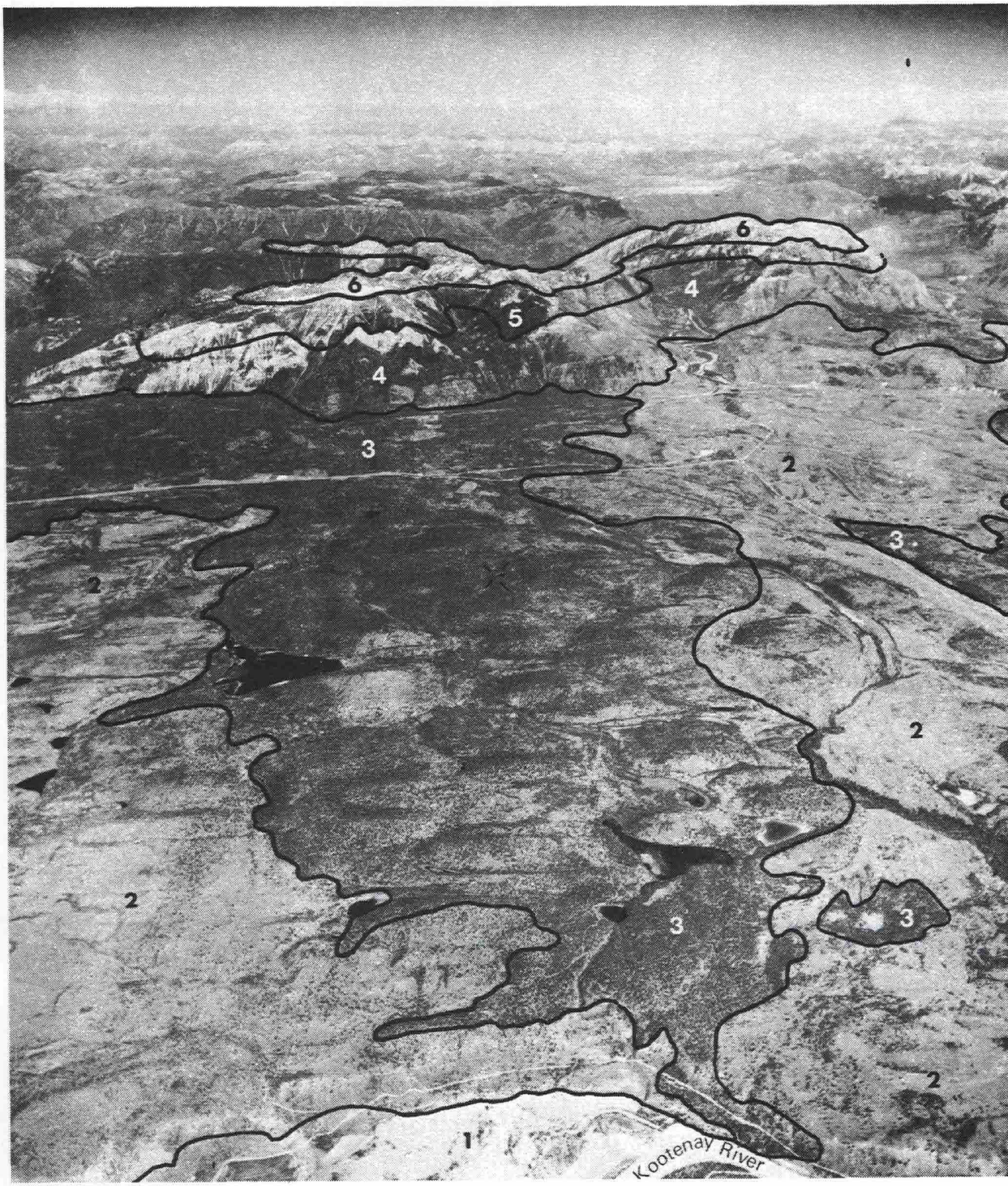


PLATE 3.5.1 Soil landscapes in the southern Rocky Mountain Trench looking east towards Elko. (photo BC: 577:46)

PLATE 3.5.1

Soil Landscapes in the Southern Rocky Mountain Trench

1. Floodplain soil landscapes with Regosols and Gleysols on active silty to gravelly floodplain areas. Vegetation varies from aspen groves to grassland.

2. Grassland soil landscapes with Dark Brown Chernozemic soils on open grassy areas and Eutric Brunisols in areas with open forests of ponderosa pine and Rocky Mountain Douglas-fir. Parent materials are mostly fluvioglacial gravels and morainal deposits.

3. Eutric Brunisol landscape with an open canopy stand of ponderosa pine and Rocky Mountain Douglas-fir. Dark Brown Chernozemic soils may occur on shallow coarse textured deposits or on south and west aspects. Parent materials include morainal, fluvioglacial and colluvial deposits.

4. Eutric Brunisol landscape on the lower mountain slopes with a Rocky Mountain Douglas-fir forest and colluvial parent materials.

5. Humo-Ferric Podzol soil landscape with closed canopy stands of Engelmann spruce and subalpine fir. Shallow and deep colluvium are the most common parent materials.

6. Alpine soil landscapes with steep bedrock and Regosolic soils on shallow colluvial materials. These mountain peaks have little or no vegetation cover.

THE DYSTRIC BRUNISOL LANDSCAPE

Dystric Brunisols may be found in the same topographic position as Eutric Brunisols but where the parent materials are non-calcareous. More commonly, however, they occur in an elevational sequence between the Eutric Brunisol landscape in dry valley bottoms and the Humo-Ferric Podzol soil landscape at higher elevations (Figure 3.5.2). Dystric Brunisols are better for forestry than are Eutric Brunisols because of their non-calcareous parent materials and greater soil moisture. Being at middle elevations and on steep terrains, they are not often used for agriculture. They are common in the Columbia Mountains in areas with acidic parent materials or where precipitation is sufficient to leach carbonates out of the soil.

Soil moisture classes are subhumid to humid and soil temperature regimes are moderately cold to cold cryoboreal. Characteristic tree species in this environment include: Rocky Mountain Douglas-fir, western red cedar, western hemlock and Engelmann spruce. Dystric Brunisols occur in the Interior Douglas-fir, the Interior Western Hemlock and the Subalpine Engelmann Spruce - Subalpine Fir biogeoclimatic zones.

Soil parent materials are medium to coarse colluvial and fluvial deposits derived from non-calcareous sandstones, quartzites and argillites. Volcanic ash is often a component of the topsoil. In areas of fine textured materials the Dystric Brunisol landscape grades into the Gray Luvisol landscape. At high elevations or in wet areas, it is associated with the Humo-Ferric Podzol soil landscape.

These soils have brown Bm horizons that are more reddish than the Bm horizons of Eutric Brunisols. The whole soil is much deeper and the carbonate layer is absent. Surface litter layers (L-F-H) are shallow and poorly incorporated in the mineral soil. An eluviated Ae horizon may or may not be present. The pH of the soil is acidic (4.5-5.5) and compared with Eutric Brunisols and Chernozemic soils, the base status is low.

THE GRAY LUVISOL LANDSCAPE

This soil landscape frequently occurs on finer textured parent materials than the Eutric or Dystric Brunisol landscapes. In this region it is found in a broad elevational range from valley bottoms to high on the mountain slopes (see Figure 3.5.1). It is one of the most common soil landscapes in the region. The fine texture of the parent materials and their instability when wet must be considered when planning logging, road construction, agricultural or urban land uses.

Soil moisture conditions vary from subhumid to humid and soil temperature regimes from moderately cool boreal to very cold cryoboreal. At low elevations this soil landscape is associated with the Eutric Brunisol landscape and at high elevations with the Dystric Brunisol or the Humo-Ferric Podzol soil landscape. Because it occurs over a broad elevational range, its vegetation is variable. Tree species range from ponderosa pine at low elevations, through Rocky Mountain Douglas-fir, western red cedar, western hemlock and Engelmann spruce at middle elevations, to subalpine fir at high elevations. Therefore, this soil landscape can occur in the Interior Douglas-fir, the Interior Western Hemlock and the Subalpine Engelmann Spruce - Subalpine Fir biogeoclimatic zones (Figure 3.5.1).

The soil parent materials are fine textured morainal, fluvial and lacustrine deposits, generally derived from readily weathered siltstones, shales and argillites.

In the Southern Rocky Mountains Gray Luvisols develop on calcareous parent materials. They have a relatively shallow clay-enriched Bt horizon, in which carbonates are often still present. The blocky structure and clay skins that are characteristic of Bt horizons are not always strongly developed. In fact, the structure of the parent Ck horizon often closely resembles that of the Bt horizon.

In the Columbia Mountains Gray Luvisols develop on non-calcareous parent materials which often contain wind blown silt or volcanic ash. They have deeper profiles than those developed from calcareous parent material. However, even these non-calcareous soils often do not have strongly structured Bt horizons with prominent clay skins. Base saturation, pH and cation exchange capacity are lower in the Columbia Mountain Gray Luvisols.

THE HUMO-FERRIC PODZOL SOIL LANDSCAPE

This soil landscape is found at high elevations (1000-2300 m). In an elevational sequence, they are found above the Dystric Brunisol landscape and below the alpine soil landscapes (Figure 3.5.1 and Plate 3.5.2). They occupy large areas in the Columbia Mountains, especially in the "interior wet belt". With their increased moisture and cooler climate these soils are among the most productive in the whole region for tree growth.

Soil moisture classes are humid to subhumid while soil temperature regimes range from cold to very cold cryoboreal. In general, the climate of this soil landscape is much colder and wetter than that of the Eutric Brunisol landscapes.

PLATE 3.5.2 Soil landscapes in the Columbia Mountains from Goldstream River looking up McCulloch Creek.(photo BC-489-92)

PLATE 3.5.2

Soil Landscapes in the Columbia Mountains

1. Floodplain soil landscapes with Regosols and Gleysols on active, gravelly floodplain and fan materials. The vegetation cover includes western red cedar, western hemlock and white spruce.

2. Humo-Ferric Podzol is the dominant soil landscape from valley bottom to alpine in this part of the "interior wet belt" in the Columbia Mountains. Dense stands of western hemlock, western red cedar, Engelmann spruce and subalpine fir on colluvial, morainal and fluvial parent materials are characteristic.

3. Alpine soil landscapes with steep bedrock, shallow Regosols, Brunisols, Gleysols, and Podzolic soils on colluvial materials. Vegetation cover is limited to grasses, sedges, forbs and dwarf shrubs.

Humo-Ferric Podzols develop under dense tree stands that include Engelmann spruce, subalpine fir, western red cedar and western hemlock in the Interior Western Hemlock and Subalpine Engelmann Spruce - Subalpine Fir biogeoclimatic zones (Figure 3.5.1 and Plate 3.5.2).

They develop on medium to coarse textured morainal, colluvial and fluvial parent materials derived from non-calcareous bedrock such as quartzite, sandstone and argillite. Even on calcareous parent materials, the soil leaching in this environment is sufficient to allow shallow podzols to develop. The topsoil often contains considerable volcanic ash.

The dense coniferous forest cover, plus the colder climate at this elevation result in the build-up of thick organic surface horizons. This material is acidic, relatively undecomposed and poorly incorporated with the mineral soil. Eluviated Ae horizons are present and podzolic Bf horizons are readily evident, but these are not so red as those on the coast. Heavy leaching ensures that the soils are carbonate free even on calcareous parent materials. By comparison with the lower elevation Eutric Brunisols, the pH, base status and cation exchange capacities are low.

At higher elevations, or in wetter areas, considerable amounts of organic matter can accumulate in the B horizon of podzols, giving the horizon a darker colour (Bhf). These soils are called Ferro-Humic Podzols and are found in the transitional krummholz area between the Humo-Ferric Podzol soil landscape and the alpine soil landscapes.

THE ALPINE SOIL LANDSCAPE

Found at the highest elevations (2300-3600 m) in the Columbia and Southern Rocky Mountains (Figure 3.5.1 and Plates 3.5.1 and 3.5.2), these soil landscapes are portrayed on the soil map of British Columbia as containing dominantly lithic soils. Since they are rugged and have panoramic scenic views, the alpine soil landscapes have important potential for recreational uses.

Soil moisture classes at alpine elevations are generally humid while soil temperature regimes are very cold cryoboreal. In general the climate at these elevations is very severe and growing seasons very short. The harsh climate limits vegetation cover to non-forest species including alpine grasses, sedges, lupine and willows. Trees do not occur in the Alpine Tundra biogeoclimatic zone.

A variety of soils occur as a result of variations in topography, local climate, parent materials and drainage. Because of active processes such as colluviation, cryoturbation and solifluction, Regosols with disrupted horizons are common. Areas with impeded drainage have Gleysolic soils while under alpine grass vegetation Melanic and Sombric Brunisols with turfy Ah horizons develop. Because of the steepness of the topography, exposed bedrock or unconsolidated rock slopes make up much of the land surface.

Soil parent materials are rubbly colluvium of varying depth, and youthful morainal deposits associated with recent deglaciation. Volcanic ash is commonly found in the alpine soils surface horizons. Soil developments in the alpine soil landscape are often obscured because of the activity of geological processes in the landscape. Surface and subsurface soil horizons are often churned and intermixed due to cryoturbation and solifluction.

THE FLOODPLAIN SOIL LANDSCAPES

The largest areas of floodplain soil landscapes occurs in the major intermountain valley bottoms such as the upper Columbia River and the Creston flats (Figure 3.5.1 and Plates 3.5.1 and 3.5.2). Regosolic, Gleysolic and Organic soils are common. These floodplain soils are often used for agriculture because they are flat and accessible. Marshy areas on the floodplains are important habitat for waterfowl.

Soil moisture classes are generally subaquic to peraquic on floodplains while soil temperature regimes resemble those of other soil landscapes in the valley. On these wet soils the vegetation consists primarily of water tolerant species such as grasses, sedges, trembling aspen, black cottonwood and Engelmann spruce.

Because of regular flooding, floodplain soils are commonly Regosols with some mottling in lower horizons. Gleysols, Humic Gleysols and Organics are common in areas that are more or less continuously wet. In the major valleys floodplain soil textures are silty. In the narrow, steep, high elevation valleys, floodplain soil textures are often gravelly and sandy. The texture of floodplain soils depends on the velocity of the river and the type of bedrock in the upper drainage basin.

In the Rocky Mountains and in major valleys floodplain soils are generally calcareous. Soil development is often limited to surface organic matter accumulation, gleying and mottling.

3.6 THE NORTHERN AND CENTRAL PLATEAUS AND MOUNTAINS

G.K. Young and N.F. Alley

The Northern and Central Plateaus and Mountains region occupies the north half of the province and is bounded by the Coast Mountains on the west, and the Rocky Mountains on the east. The centre of this vast area comprises the westernmost portion of the continental divide, and the Omineca and Cassiar Mountains. Here the tributaries of the MacKenzie River rise, including the Dease, Liard, Finlay and Parsnip Rivers. To the west numerous large streams wind their way across the Yukon and Stikine Plateaus to the Pacific Ocean. Some of these include the Taku, Stikine, Iskut, Bell-Irving, Nass and Skeena Rivers, most of which have their headwaters in the Skeena Mountains.

Although the factors which generally affect soil formation anywhere in the province have been described in Part 1, some of these in the study area operate to produce a distinctive set of soil landscapes. These factors include the geology and climate which together produce a predominance of periglacial, geomorphic processes not found in other parts of British Columbia.

THE FACTORS OF SOIL FORMATION

This region lies in the rain shadow of the Coast Mountains. As a consequence, precipitation is low, especially in the area adjacent to the mountains such as the Tagish and Tahltan highlands. Precipitation increases eastward across the Yukon-Stikine Plateaus towards the Cassiar and Omineca Mountains.

In the southern portion of the region, the large valley of the Nass River permits westerly winds to penetrate the Coast Mountain barrier, resulting in increased precipitation locally in the Skeena Mountains. Similar moderation of climate occurs along the Stikine River in the vicinity of Telegraph Creek although, in contrast to the Nass River area, the climate is warmer and drier. These two micro-environments are discussed later. With the exception of micro-climates and edaphic situations, moisture deficiencies during the short growing season are rare in these dominantly humid to subhumid soil moisture regimes.

Generally, the northern plateau has a very cold, subarctic climate resulting from its elevation and the southward penetration of arctic air masses into the area. The west, south and east facing slopes of the NNW-SSE trending valleys of highlands and mountains peripheral to the plateaus range from cold cryoboreal to very cold subarctic. Thus, on the plateaus and adjacent uplands climate produces an environment in which frost plays an important part in geomorphic processes and soil formation.

Perhaps the most important factors influenced by the cold climate are the rate and operation of geomorphic processes. The periglacial processes which contribute most to the distribution and character of the soils in the area include frost shattering, cryoturbation, solifluction (and related processes), nivation, permafrost development and snow avalanches. Together these processes have produced large masses of colluvium which mantle the plateaus and mountain slopes, and an environment in which the materials are constantly in motion either downslope or by churning. Consequently, the dominant soil landscapes in the area are pedogenically youthful and have evidence of cryoturbation such as broken or buried horizons, and displaced materials.

The periglacial activity and turbic soils extend virtually from ridge and plateau tops to valley bottoms. Probably cold air, draining from the plateaus down into lower elevations, contributes strongly to periglacial activity in valley bottoms at an altitude where frost action is normally insignificant (see "Cold valley floors" in "Other soil landscapes").

The north-northwest orientation of major valleys and their asymmetry in transverse profile also influence the distribution and operation of periglacial processes in the plateau area. Gentler west-southwest-facing valley-sides are dominated by deep blankets of colluvium produced mainly by nivation and solifluction. In contrast, east-northeast-facing slopes are steeper and have snow avalanches and rockfalls. These slopes often consist of bare rock or thin colluvium in their upper reaches, where mass-wasting predominates, whereas blankets, fans and aprons of colluvium occur on the lower levels where deposition predominates.

Geology influences the soil landscapes of the region in a variety of ways. First, the geological materials affect the texture and chemistry of soils. Intrusive plutonic and low grade metamorphic rocks in the Omineca and Cassiar Mountains weather to produce generally medium to coarse grained acidic soils whereas the volcanic rocks in the western part of the region weather to fine and medium textured soils of higher base status. Sedimentary rocks in the Skeena Mountains and Stikine Plateau are variable, although the predominance of fine grained strata commonly produces fine textured soils which are normally acidic except in the vicinity of calcareous rocks.

Second, the western portion of the area is composed of flat-lying or gently folded rocks which form broad plateaus high enough to be in the alpine-subalpine zone. This has created extensive areas in which periglacial processes dominate, producing thick mantles of colluvial debris which form solifluction terraces and lobes, that often lead up to nivation hollows, patterned ground, block-fields, stone streams and rock glaciers in the valleys. The soils are obviously youthful and dominantly of the Cryosolic order or have been influenced by cryoturbation.

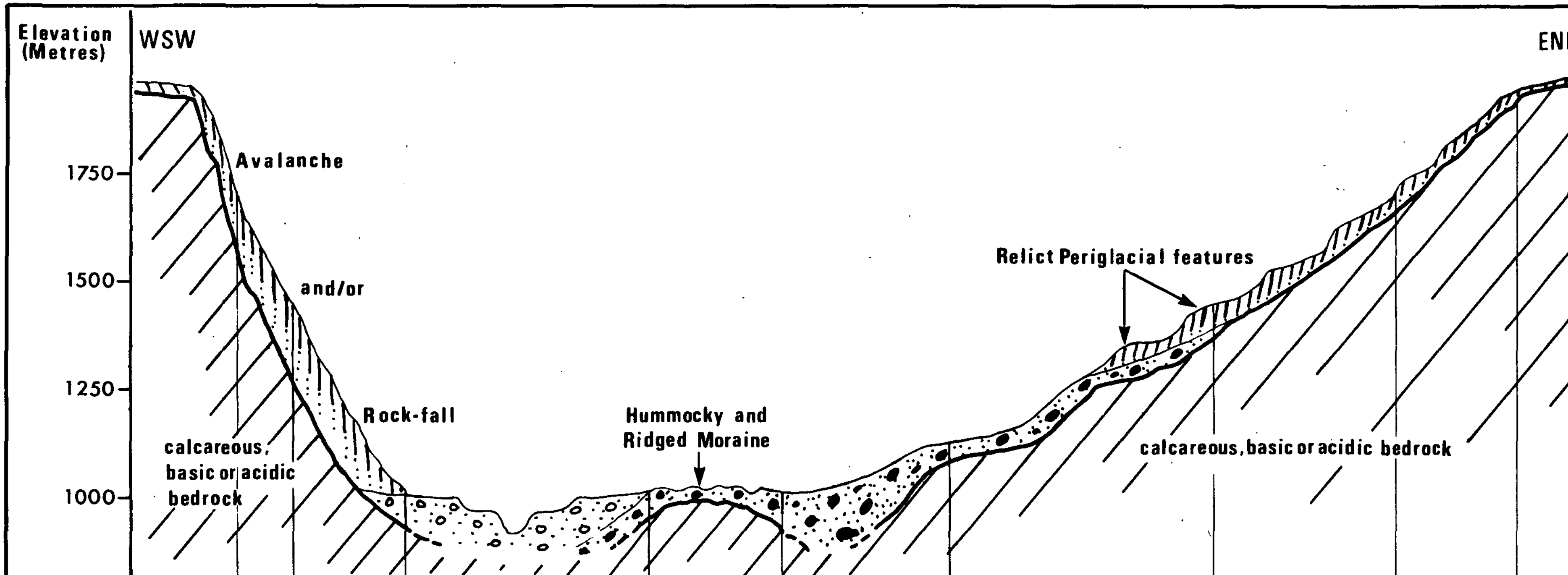
Third, glacial deposits exposed at the surface were formed largely during the Fraser Glaciation; only small remnants of ice now remain either as cirque or short valley glaciers. Advances of these glaciers during the Neoglaciation formed the moraines now found in close proximity to the ice. Regosols or Cryosols have formed on these moraines. More important, however, is that the colder climatic conditions which produced the Neoglacial advances also led to an expansion of the periglacial zone well into what is now the subalpine. The features, such as talus, patterned ground, solifluction lobes, nivation hollows, block streams and even rock glaciers, which formed as a consequence of the colder climate are now relict.

THE SOIL LANDSCAPES

The soil map of British Columbia (Part 3.2) shows the distribution of the main soil great groups in region. However, the map is very general and does not show some of the soil landscapes which may cover only small areas. An idealized diagram illustrating the vertical sequence of soil landscapes is presented in Figure 3.6.1 and the main features of each soil landscape are described in the following pages.

GRAY LUVISOL LANDSCAPE

This soil landscape occurs on well drained morainal deposits below 1200 m in broad valleys of the Sub-Boreal Spruce and Boreal White and Black Spruce zones. Parent material texture, colour and mineralogy are closely related to bedrock. Texture varies from medium to coarse and colours vary from dark brown to dark gray on moraine derived from basalt and sedimentary rocks, to gray or light gray on moraine derived from granitic and plutonic rocks. Parent materials formed from limestones are calcareous. Basalts and other sedimentary rocks produce mildly calcareous or neutral materials, and granitic materials are acidic. The soil solum, however, is affected by leaching resulting from the humid and subhumid soil moisture regime and organic acids formed by decomposition of vegetation. Consequently the soils are neutral to slightly acid on limestones, basalts and sedimentary rocks, and acidic on granites and plutonic rocks.



Soil Land-scape	Regosols (disrupted) Turbic Cryosols	HFP, FHP, TC	HFP, FHP, Humic Gleysol,	Humo-Ferric Podzol, Dystric Brunisol, Eutric Brunisol	Gray Luvisol, Humic Gleysol	Gray Luvisol	Humo-Ferric Podzol	HFP, Melanic Brunisol, Regosol (disrupted)	EB, DB and MB (disrupted), TC	R (dst), TC
Biogeo-climatic Zone	Alpine Tundra	SWB or ESSF	Boreal White and Black Spruce or Sub-Boreal Spruce					SWB or ESSF	Alpine Tundra	
Active Peri-glacial Processes	Congeliturbation Congelifraction Solifluction Nivation							Congeliturbation Congelifraction Solifluction Nivation		

LEGEND

Spruce-Willow-Birch . . . . SWB
Engelmann Spruce-Subalpine Fir . . . . ESSF
Fluvio-Glacial . . . . [symbol]
Humo-Ferric Podzol . . . . HFP
Ferro-Humic Podzol . . . . FHP
Turbic Cryosol . . . . TC
Eutric Brunisol . . . . EB
Morainal . . . . [symbol]
Dystric Brunisol . . . . DB
Melanic Brunisol . . . . MB
Regosol . . . . R
disrupted . . . . dst
Colluvium . . . . [symbol]

FIGURE 3.6.1 The soil landscapes across an asymmetrical valley in northern British Columbia.

The moraine has a rolling, ridged or hummocky topography with a repetitive pattern of soil drainage conditions. Slope position, gradient, and slow permeability of morainal parent materials result in a range from well drained to very poorly drained soils. Organic soils occupy enclosed depressions, whereas Humic Gleysols occur where seepage accumulates along extensive gentle slopes, or at the base of steep slopes.

DYSTRIC AND EUTRIC BRUNISOL LANDSCAPES

Broad valleys within the Sub-Boreal Spruce and Boreal White and Black Spruce biogeoclimatic zones often contain extensive deposits of fluvioglacial deposits, which range in texture from coarse cobbles and stones to gravels and fine sands. As a result of coarse texture the soils are characterized by rapid percolation and iron accumulation, especially on acidic parent materials. The preponderance of lodgepole pine on these soils, the lack of minor vegetation elements, and the presence of charcoal in the litter and upper mineral soil indicates a relatively high frequency of fires. These edaphically dry acidic landscapes result in Dystric Brunisol soils with highly coloured B horizons.

Brown coloured soils of Eutric Brunisol landscapes also occur here on calcareous, coarse textured parent materials, especially on well drained fluvioglacial and colluvial deposits. In other areas they are commonly restricted to climatically or edaphically drier sites such as southern exposures and along the lower terraces of the Stikine River, in the extreme rain shadow of the Coast Mountains. As a consequence of frequent burning in the rain shadow, vegetation is commonly reduced to trembling aspen, lodgepole pine, shrubs and grasses, representing early stages of secondary plant succession.

HUMO-FERRIC PODZOL SOIL LANDSCAPE

This landscape is common between elevations of 1200 to 1500 m on steep, moist slopes in the Boreal White and Black Spruce biogeoclimatic zone. Surficial deposits are mainly colluvium and moraine covered by a veneer of coarse colluvial debris. Humo-Ferric Podzols are the main soils on these sites, but Dystric Brunisols are associated with them due to locally dry environments produced by the combined influence of aspect and shallow colluvium. Other associated soils receiving considerable seepage water along the base of slopes are Humic Gleysols.

Since the vegetation consists primarily of white spruce the resulting litter is acidic and tends to accumulate as thin, distinct L and F horizons but thicker H horizons, as a result of the cold climate and slow rates of decomposition. With the exception of some soil creep and avalanche tracks on steep slopes, periglacial processes are virtually absent. However, relict periglacial features are common but have been covered by vegetation and are not readily visible.

THE SUBALPINE SOIL LANDSCAPES

Subalpine vegetation occurs between elevations of 1350 m and 1800 m. There are extensive areas of subalpine fir in mountain valleys (notably on northern exposures) and willow and glandular birch on plateaus. The Humo-Ferric Podzol soil landscape is the most common throughout this subalpine area. Relict periglacial materials, including solifluction lobes, and other well to moderately well drained sites on colluvial and morainal parent materials, allow subalpine fir to grow in pure stands. Here, the brightly reddish brown podzolic B horizons occur under thin litter layers.

At higher elevations in the krummholz subzone, solifluction and nivation become active in the moist openings between the clumps of trees. On gentle slopes shallow nivation hollows have permanently frozen subsoils and shallow organic surfaces. Thus, in the upper subalpine area Turbic Cryosol landscapes occur with the Humo-Ferric Podzols.

Drier, more exposed plateau areas, such as the Spatsizi, are dominated by subalpine willow and glandular birch with occasional white spruce trees, and small openings occupied by alpine vegetation. Fire appears to be frequent here, and in combination with a cold relatively dry climate, it retards plant succession. The most common soil landscape is again that of the Humo-Ferric Podzol. However, as a result of slow decomposition and humification of litter from the deciduous shrub vegetation, a significant depth of organic matter accumulates at the soil surface. The Podzolic soils are best developed along well drained portions of glacial and relict periglacial features where shrub vegetation is present. In open depressions along gentle slopes, on the leeward sides of ridges, the vegetation ranges from stable alpine plants to an increasingly sparse cover as periglacial activity increases. Soil development is determined by the severity of the dominant geomorphic processes and other soil landscapes include Humic Regosols and Melanic Brunisols.

THE ALPINE SOIL LANDSCAPES

The alpine tundra occurs above 1500-1800 m. It has a very cold subarctic soil climate with a subhumid moisture regime. Within this environment windswept ridge-tops are often desiccated, because there is a lack of snow cover in winter and relatively dry conditions during the short growing season.

Cryoturbation is very active, churning the soil materials and developing patterned ground features including block fields, sorted and unsorted circles, and stone stripes. Regosol landscapes are the most common with disrupted horizons resulting from this strong periglacial activity. Constant churning of surface and subsoil particles results in poor horizon differentiation and the prevalence of buried and fractured bands of organic-rich materials resembling former A horizons. Parent material, commonly derived from local bedrock, is mixed directly with the A horizon resulting in an AC horizon sequence.

Turbic Cryosol landscapes with permanently frozen horizons are found on fine textured materials, such as thin moraine, where subsurface drainage is impeded by topographic location. Patterned ground features associated with these soils are prevalent but not as conspicuous as they are with adjacent shallow colluvial soils. However, on sloping landscapes, features associated with solifluction and nivational activity are enhanced by the better water holding capacity of the fine textured parent materials. Such sites form a Melanic Brunisol landscape marked by disrupted and buried horizons. Ah horizons attain greatest thicknesses along the downslope edges of solifluction lobes with buried organic horizons often occurring under the solifluction material. The surface horizon thins from the front of one lobe to the leading edge of the next lobe upslope. Permanent and intermittent snow patches occupying nivation hollows provide a continuous supply of melt-water to solifluction lobes lying immediately downslope. Sometimes melting snow patches reveal that the bottom of nivation hollows are bare of vegetation, creating an environment in which patterned ground is readily formed. Regosols with disrupted horizons predominate in these hollows. Gleying is usually absent since aerated seepage water percolates through soil parent materials throughout all or most of the growing season. The topographic position of these alpine soil landscapes in addition to some of the others is shown in Plate 3.6.1.

In addition to the generalized vertical zonation of soil landscapes described in the previous paragraphs there are numerous other variations. A few of the more important are described here.

COLD VALLEY FLOORS

The most extensive of the variations that occur throughout the region is the phenomenon that can best be described as "the inverted alpine-subalpine valley". Narrow and broad upland valleys with limited air drainage form collecting basins for extremely cold air flowing southward across the plateaus and mountains from the arctic or merely flowing down from the cold adjacent uplands. The cold air trapped in the lowlands forms a strong atmos-

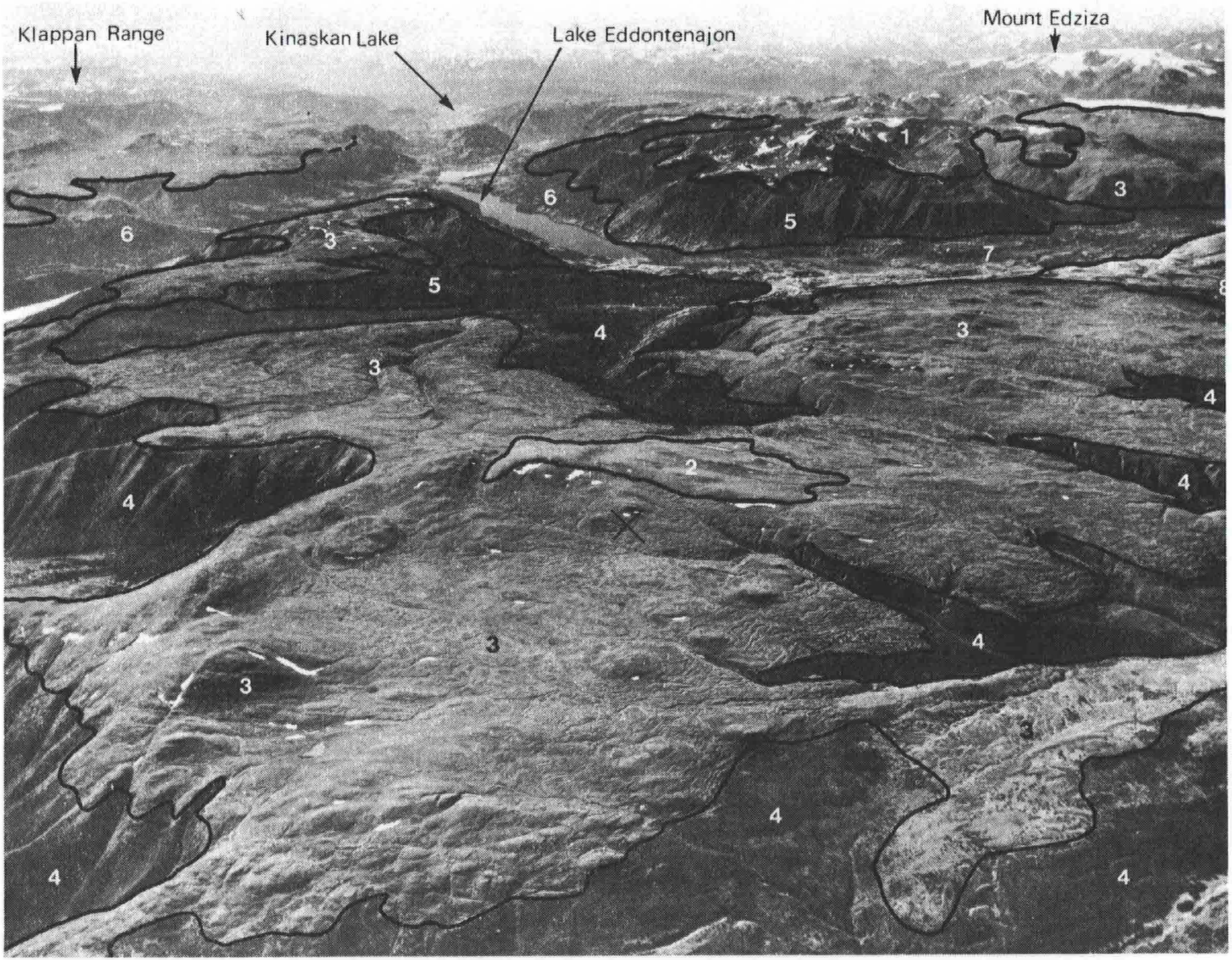


PLATE 3.6.1 Soil landscapes on the Klastline Plateau looking southwest from the Stikine River. (photo BC·538·20)

PLATE 3.6.1
SOIL LANDSCAPES ON THE KLASTLINE PLATEAU
LOOKING SOUTHWEST FROM THE STIKINE RIVER

1. Alpine Tundra soil landscape. Regosols with disrupted horizons. Unit comprised of cirques with active alpine glaciation and nivation patches. A large percentage of this mountainous upland unit is dominated by bare rock, talus and other products of active periglacial processes.

2. Alpine Tundra soil landscape. Melanic Brunisol forms the most common landscape on morainal blankets or morainal veneer. Cryosols may occur in depressions.

3. Subalpine soil landscapes (willow and glandular birch). Humo-Ferric Podzol is most common soil landscape. Moist depressions are either Humic Gleysol or Cryosols.

4. Humo-Ferric Podzol soil landscape on coarse textured colluvial (steep slopes) and fluvial materials. Humic Gleysols occur in depressions.

5. Aspect as factor of soil formation. Shallow colluvial materials accentuate the effects of aspect. Soils range from dry Dystric Brunisol to moister Humo-Ferric Podzol.

6. Humo-Ferric Podzol and Gray Luvisol Landscapes. Deep post-Pleistocene colluvial fan material overlying and dissecting the morainal blanket. Within the Boreal White and Black Spruce biogeoclimatic zone Humo-Ferric Podzols occur on coarse parent materials and Gray Luvisols on fine textured substrate.

7. Humo-Ferric Podzol soil landscape occurring within the Boreal White and Black Spruce biogeoclimatic zone on fluvial and fluvioglacial deposits.

8. Subalpine soil landscape. Gently sloping areas of moraine extend from subalpine conditions to lower elevations. Soil landscapes are a complex of Humo-Ferric Podzols, Humic Gleysols and Organic Fibrisols. Sporadic permafrost probably occurs.

pheric inversion and thus induces periglacial activity, growth of permafrost and delays snowmelt along the valley bottoms. The floors of the valleys are occupied by vegetation that is normally considered alpine or subalpine, although the normal vertical zonation from subalpine fir to willow and glandular birch to alpine tundra occurs on the slopes above.

Soil landscapes are varied and reflect the harsh characteristics of the alpine micro-environment. On well to rapidly drained coarse textured fluvioglacial deposits, deep Ah horizons develop under a dominantly grass vegetation comprised of alpine fescue producing Black Chernozemic soil landscapes. On finer textured colluvial and fluvial parent materials, Melanic and Sombric Brunisol landscapes predominate but on well drained medium textured moraine deposits under the subalpine vegetation in the broader upland valleys, Humo-Ferric Podzol soil landscapes occur.

VALLEY ASYMMETRY

As discussed above, the north-northwest orientation of many major valleys and their asymmetrical transverse profiles profoundly influence the distribution and operation of the geomorphic processes. The asymmetry and the strong orientation of the valleys is a result of glacially modified bedrock structure. The gentler west-southwest-facing valleysides are commonly dip-slopes and, since the slopes are gentle, nivation, solifluction and deep-seated rockslides are dominant subaerial processes. The steeper east-northeast-facing slopes are escarpments eroded through the bedding planes; on these slopes snow-avalanches and rock-falls are common.

Vegetation is also affected by the orientation of the valleysides. The vertical zonation from subalpine fir through willow and glandular birch to alpine tundra is most common on north-facing slopes. These zones are often dissected by avalanche tracks. However, south-facing slopes may have only a sparsely treed subalpine fir zone, or the subalpine and alpine vegetation of the cold valley bottoms may continue up the valleyside to the mountain tops.

Soil landscapes follow the pattern described earlier for these environments with the addition of soils characteristic of the snow and debris avalanche tracks. The latter are most commonly Melanic Brunisols with deep Ah horizons developed under lush vegetation. These landscapes are associated with the Humo-Ferric Podzol soil landscapes where they extend in forested areas.

WARM COAST VALLEYS

In the western part of the region where major river systems breach the Coast Mountain barrier, a small but significant micro-environment exists. Warm, moist air from the Pacific Ocean fingers up the Stikine and Nass Rivers moderating the predominantly continental climate of the region. The extent of this influence diminishes rapidly eastwards and with increasing elevation.

At Telegraph Creek (300 m a.s.l.) on the Stikine River, other factors such as steep south-facing slopes, coarse textured, basic colluvial and fluvial soil parent materials, and copious amounts of coarse grained volcanic ash deposits from Mt. Edziza combine with the warmer climate to produce a Eutric Brunisol landscape with minor inclusions of Dark Gray Chernozemic soil landscapes. As a result of the microclimate and the soils a variety of agricultural crops can be grown.

Further south, the Nass River and its major tributary, the Bell-Irving River provide a similar opportunity for warm, moisture-laden air flow to penetrate the Coast Mountains. Here, however, the Skeena Mountains form a northern and eastern barrier to the air-flow thus intensifying the orographic effect and resulting in heavy annual precipitation including deep snow accumulations. The mountain systems also block out arctic air from the north, to produce a markedly different environment from that along the Stikine River. Indeed, vegetation is lush and dominated by conifers, including western hemlock, Sitka spruce and balsam fir in the lower zone with subalpine fir in the upper zone, giving way to extensive alpine tundra on the mountain tops. Ferro-Humic Podzol and Humo-Ferric Podzol soil landscapes dominate the lower forest zones with the varied soils common to the alpine occurring above tree-line.

THE SOIL LANDSCAPES OF VOLCANIC TERRAIN

Volcanic features ranging in age from 15 million years right up to 180 years dot the landscape in an area extending from the Mt. Edziza - Spectrum Range uplands to the western Spatsizi Plateau. Although most of the volcanic deposits have been modified by glaciation, some post Pleistocene volcanic activity has added volcanic ash and cinders, and subaerial lava flows to the original surface.

The Mt. Edziza plateau is flanked by recent volcanic ash deposits, fluvio-aeolian material, recent moraine, lava flows and cinder cones. Soil landscapes on these youthful materials are disrupted Regosols and Turbic Cryosols. In contrast, Level Mountain to the north of Mt. Edziza, takes the form of a large inverted saucer. A series of shallow ridges across the slope of the mountain obstructs lateral surface and subsurface drainage. This, along with the cold environment, results in poorly drained soil landscapes, mainly Organic and Humic Gleysols. At higher elevations where periglacial conditions prevail, soil landscapes include Organic Cryosols and Fibrisols. Turfy, moderately well drained solifluction lobes and hummocks permit development of Humo-Ferric Podzol soil landscapes within the unusually extensive subalpine area.

LAND USE

Traditional resource activities such as hunter and guide outfitting and fur trapping are the most common. This pattern of use extends over the broad upland subalpine and alpine terrain where many species of wildlife, including caribou, mountain sheep, mountain goat, moose, grizzly and black bear and many smaller fur bearers, abound. Because of the remoteness of much of this region and because there are no alternative land uses over large areas, the importance of the wildlife resource cannot be overstated. However, regardless of the vastness of the area involved, the sensitivity of the terrain and its inherently low productivity of food and cover impose constraints on animal populations not encountered in southern regions thus demanding careful management.

Within the Gray Luvisol and Humo-Ferric Podzol soil landscapes there is a limited potential for forest harvesting. It is estimated that forest capabilities range from classes 4 to 7. The Nass River Basin, in the extreme southwestern corner of the region, is an exception and contains moderate and high capability forests especially at lower elevations in the Ferro-Humic Podzol soil landscape of the coastal environment.

Mineral potential in the region remains relatively unexploited with some notable exceptions such as the asbestos at Cassiar. Exploration activity is flourishing in areas of mineralization. Within the Skeena Mountains in the Ground Hog Range an extensive area of coal has been found but as yet has not been developed.

Transportation is provided by air, and by road. The Stewart-Cassiar Highway is currently being upgraded as an alternative route to the Yukon. It leaves Highway 16 at New Hazelton in the south and joins the Alaska Highway just west of Watson Lake in the Yukon Territory.

3.7 THE GREAT PLAINS

A.J. Green and T.M. Lord

In British Columbia somewhat more than 10 percent of the province lies east of the Rocky Mountain Foothills and within the high plains division of the Great Plains of North America.

The term "Great Plains" brings to mind that part of Canada lying between the Rocky Mountain Foothills and the Canadian Shield, known as "the Prairies". However, no part of the British Columbia Great Plains is semiarid grassland, and only a relatively small portion can be described as subhumid aspen parkland. Most of the area is forested.

The region is drained by two major rivers and their tributaries, the Peace and the Liard. The Peace River is formed at the confluence of the Findlay and Parsnip Rivers which is now part of Lake Williston Reservoir. The Peace River leaves the lake near Hudson Hope, flowing to the east onto the plains, where it is joined by its tributaries the Halfway, Moberly, Pine, Beatton and Kiskatinaw Rivers. The Liard drains northwest with its major tributaries the Fort Nelson and Prophet Rivers. Most of these rivers originate in the Rocky Mountains and have cut deep postglacial valleys through the plains. Rivers such as the Chinchaga and Fontas which originate on the plains are not deeply entrenched and have meandering stream courses. There are very few large lakes in the region. The two largest are Moberly Lake in the south and Kotcho Lake in the north.

THE FACTORS OF SOIL FORMATION

The geology, vegetation and climate combine to produce a soil forming environment that is different from the rest of the province in several ways.

The Cretaceous sedimentary bedrock has a great influence on the landscape. It is composed of sandstones and shales which are horizontally bedded or dip gently to give low asymmetrical ridges. The sandstone tends to form low rolling uplands. The more easily erodible shales usually underlie the flat lowlands. The sediments can be acid, neutral or alkaline and calcareous. Some marine shales of the Peace River Lowland are saline, others in the Fort Nelson Lowland are not.

The surficial deposits are closely related mineralogically to the bedrock, and this is reflected in the soils. The area was glaciated by Cordilleran ice from the west and Keewatin ice from the north east. The Cordilleran till is medium textured, stony, calcareous and often less than

3 m thick. The Keewatin till is fine to medium textured, has few stones and can be saline, slightly calcareous or acid. In the north around Fort Nelson it is quite thin and difficult to distinguish from the underlying bedrock. Lacustrine materials border many of the large river valleys. They are fine textured, have few stones and are generally saline and somewhat calcareous. The upper limit of these deposits in the Peace River lowland is at about 810 m, but they do occur in areas of local ponding up to 850 m. The large rivers flowing from the Rocky Mountains have carried coarse textured sediments out onto the plains. Sandy and gravelly fluvioglacial and fluvial deposits are found in and adjacent to the valleys in a broad zone bordering the Rocky Mountain Foothills. They have often been reworked by the wind into dunes and ridges. A rather different but important surficial material is the organic "muskeg" that blankets much of the plains in the northeast forming organic soils.

The important features of the climate that influence soil formation are the long cold winters that severely restrict many soil forming processes, the short warm summers and the moderate precipitation with a summer maximum, including many thunderstorms. Winter frost penetrates deeply into many soils and some organic bogs in the north have permafrost. Paradoxically, high rates of evapotranspiration lead to water deficits and very dry soils in late summer, especially in the lowlands.

The whole of this area lies within the Boreal White and Black Spruce biogeoclimatic zone. The lowlands have a mixedwood forest of trembling aspen, white spruce and black poplar. This adds a less acid litter to the soil surface than the coniferous forests of white spruce, lodgepole pine and subalpine fir of the uplands and the north. In the driest parts of the south there is an attractive open parkland of trembling aspen and grass much of which was probably burnt periodically. The very wet parts of the north have stunted black spruce, tamarack, willows, Labrador tea and mosses.

The shape or form of the land in the great plains is also important in determining soil quality. The influence of aspect is seen in many large river valleys. Dry, south facing slopes in the Peace River lowlands have dry soils with trembling aspen, open grassland and even plains prickly-pear. Cool, moist north facing slopes have white spruce. The combination of steep slopes and fine textured materials along many of the entrenched river valleys leads to very unstable soils and in extreme cases huge landslides, such as the Halfway slide that completely blocked the Peace River for 12 hours in May 1973. On the flatter plains and uplands the long smooth slopes of this plateau country are susceptible to sheet erosion and gullying. The combination of soft materials, slow percolation, long slopes and summer thundershowers makes any slope over 5% susceptible. Finally, there are peculiar topographic features, known as "humpies", bordering the main rivers and their tributaries in the Peace River lowlands (see Plate 3.7.1). They are earth mounds of variable composition and orientation up to 12 m high. They change rapidly in soil profile characteristics from their crest to their base.

THE SOIL LANDSCAPES

The arrangement and distribution of the main soil great groups in the great plains is shown in the soil map of British Columbia (Part 3.2). A single soil great group landscape may predominate in one area as does for example the Gray Luvisol. However, combinations of soil landscapes are common in areas where slopes, vegetation and parent materials change within short distances. This sort of situation can be seen in Plate 3.7.1 around Fort St. John, and it is also typical of the large area mapped as Organic Cryosol-Luvic Gleysol in the northeast. Other soil landscapes are quite limited in extent, as is for instance the Solod soil landscape within the trembling aspen parkland of the Peace River lowland. The general pattern of soil landscapes is shown as a diagrammatic cross section in Figure 3.7.1, which runs from Fort Nelson to Dawson Creek.

THE GRAY LUVISOL LANDSCAPE

The Gray Luvisol landscape occupies about 40 percent of the Great Plains and extends in a broad zone east of the Rocky Mountain Foothills from the southern Peace River lowlands to the Yukon border. It occurs under pure or mixed stands of coniferous and deciduous trees with a humid to subhumid cryoboreal soil climate. It has gently to strongly rolling topography on the till uplands and long, smooth, gentle slopes on the lacustrine plains. The soils on the till are well to moderately well drained but on the lacustrine plains, with subdued topography and fine textured layered sediments, they are wet for part of the year. This is shown by mottling and dull soil colours in the upper horizons. Typically, the Gray Luvisols have a thin layer of decaying leaves, needles and grasses accumulated on the soil surface; a gray or grayish brown, distinctly platy Ae horizon, 10-30 cm thick; and light brownish gray or dark grayish brown B horizons, 50-100 cm thick. The C horizon is often similar in texture and colour to the B horizons but lacks a well developed structure. The peds in the B horizons frequently have strong subangular blocky structure and clay films can be detected on the surface of the peds. The Bt horizon of the Gray Luvisols in the Great Plains is often much more difficult to detect visually and texturally than the Bt horizon of the Gray Luvisols in the Interior Plateau. The latter are markedly different in texture and colour from the horizons above and below them, whereas in the Great Plains the difference is one of soil structure.

PLATE 3.7.1 Soil landscapes in the Peace River lowlands around Fort St. John. (photo BC:1952:60)

PLATE 3.7.1

SOIL LANDSCAPES IN THE PEACE RIVER LOWLAND AROUND FORT ST. JOHN

1. Steep sides of river valleys entrenched into the plateau. Disrupted Regosols on the slumping fine textured shales and lacustrine sediments. The Peace River is 240 m below the plateau rim.

2. Solod soil landscape on the lacustrine clay plain, with "humpy" topography near the breaks to the river valleys.

3. Solod soil landscape on the gently undulating lacustrine clay plain. The Solods are on the well drained sites with Gray Luvisols in lower positions and organic Mesisols in the depressions - 3(0).

4. Solod soil landscape on the gently to moderately sloping ridges of clay till over sandstone with trembling aspen and grass vegetation.

5. Gray Luvisol landscape on clay till over sandstone under a mixed forest of trembling aspen and white spruce. It is about 90 m higher than the Solod soil landscape on similar till (4).

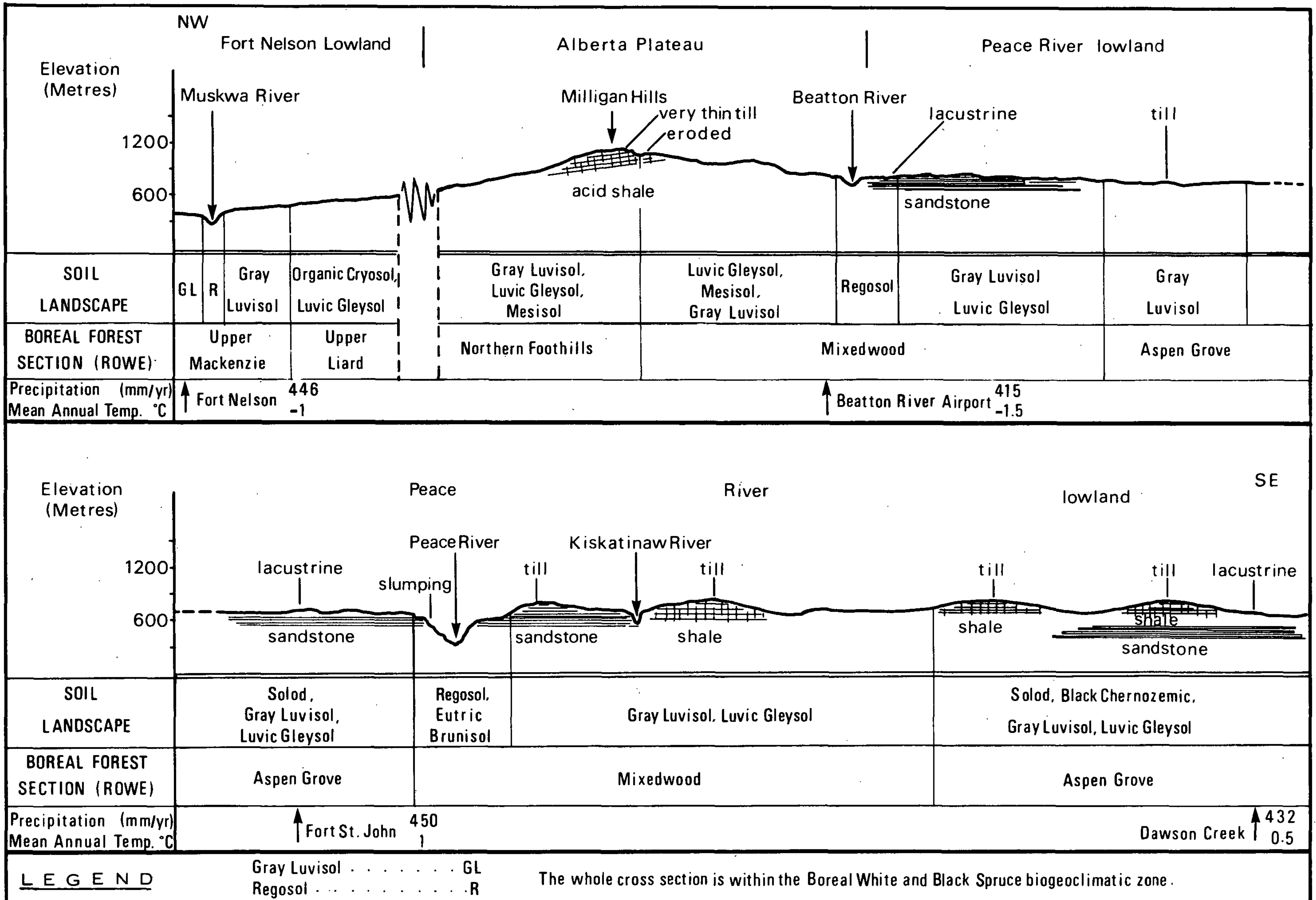


FIGURE 3.7.1 The soil landscapes from Fort Nelson to Dawson Creek

Although the Gray Luvisols of the Great Plains have developed under much the same forest cover and climate (see Figure 3.7.1), they do vary structurally and chemically because of the nature of their parent materials. Those soils that have developed on till, lacustrine or fluvial deposits derived from slightly calcareous, somewhat saline sandstones and shales usually have strongly developed columnar and subangular blocky structure in the B horizons. Those soils developed on deposits derived from acid or calcareous materials usually lack this strongly developed soil structure.

Where climate and topography are suitable, Gray Luvisols have been used for agriculture, particularly forages and seed production. They require the addition of nitrogen and organic matter. They also have an inherently weak structure in the upper horizons that makes them susceptible to puddling and crusting and to wind and water erosion. About 25 percent of them are moderately to strongly acid in reaction and they may need liming to counteract aluminum and manganese toxicity, particularly for such crops as alfalfa and barley.

THE LUVIC GLEYSOL LANDSCAPE

This soil landscape occurs on the wetter margins of the Gray Luvisol landscape. The moisture regime is humid for most of the year, but there are short periods of complete saturation (subaquic regime). The landscape is found most commonly on the northern border of the lowlands where fine textured, nearly impervious materials occupy poorly drained level to depressional areas with sedge, willow and other moisture loving forms of vegetation.

A typical Luvic Gleysol has a thin layer of raw organic litter on the soil surface; a bleached, gray, mottled, platy Aeg horizon, 5 to 10 cm thick; a dark gray, mottled Btg horizon with rounded or subangular blocky structure (when dry), 10 to 15 cm thick; and a mottled light olive brown C horizon.

Although saturated for short periods they are well enough aerated for clay translocation to have occurred. Since they occupy areas that receive runoff from surrounding higher areas, they usually have more bases than the Gray Luvisols. However, like the Gray Luvisols they need the addition of nitrogen and organic matter for crop production. Poor natural drainage and the promotion of poor physical condition if worked when too wet are also important factors limiting the agricultural productivity of Luvic Gleysols.

THE ORGANIC SOIL LANDSCAPES

The Fibrisols and Mesisols that make up these landscapes occupy extensive tracts of level or depressional ground in the Peace River and Fort Nelson lowlands as wetter associates of the Luvic Gleysols. A typical portion is illustrated in Plate 3.7.2. They are saturated for moderately long periods of time (aquic regime), and organic matter accumulates on the surface of the mineral soil. These landscapes (with the Organic Cryosol discussed below) are the "muskeg" that is such a fascinating but perplexing part of northern Canada. It has been perplexing mainly to engineers who have had to build roads, railways or pipelines through this very wet, very cold and often very unstable land. The organic surface is usually quite thin, commonly less than 1 m. But it acts as a huge sponge that regulates stream flow by holding and slowly transmitting vast quantities of water. If the sponge is disturbed by route construction the water may be released quickly to cause extensive erosion.

The peat is moderately (Mesisol) or poorly (Fibrisol) decomposed plant residues, mainly mosses and sedges. It is usually reddish to yellowish brown in colour and below it there will be strongly gleyed sands, silts or clays. It is moderately to very strongly acid and very low in nutrients. This is because most of the soil water is derived from precipitation; it has not accumulated as runoff from surrounding uplands from which it would have carried dissolved nutrients, as is the case with the organic soils of the Interior Plateau. Mesisols have a vegetation cover of sedges, hypnum mosses, blueberries and bog glandular birch. Fibrisols have sphagnum mosses, common Labrador tea and stunted black spruce and tamarack.

THE ORGANIC CRYOSOL LANDSCAPE

This soil landscape which occurs in the Fort Nelson Lowland consists of organic soils that have permafrost within 1 m of the surface. The southern limit of discontinuous permafrost is just south of the -1°C mean annual isotherm which crosses the region at about 58°N latitude. From here to the 60th parallel parts of the organic terrain will have layers that do not thaw in the summer, because they are effectively insulated by the surface peat. Not all the peatland will be frozen, neither will all of it have a thick organic cover. Therefore, there is a very complicated pattern of Organic Cryosol, Organic and Luvic Gleysol landscapes in the Fort Nelson lowland.

The surface of these soils is poorly decomposed reddish or yellowish brown fibric peat. Below this the frozen peat looks very similar. It just feels hard. There are no large ice lenses only ice coatings on all the organic fibres that bind them together. The vegetation cover is also similar to the Fibrisol landscape with sphagnum mosses, Labrador tea, stunted black spruce and tamarack.

With the unfrozen Organic soil landscape this forms part of the muskeg terrain of the north. It presents all the same problems of use as the unfrozen soils with the added difficulty of a frozen layer whose upper surface fluctuates in depth throughout the year.

THE EUTRIC AND DYSTRIC BRUNISOL LANDSCAPES

The principal difference between these two landscapes is the nature of the fluvioglacial parent material. The Eutric Brunisol has developed on calcareous materials, the Dystric on acid materials.

The Eutric Brunisol landscape commonly occurs on the coarse textured calcareous fluvioglacial deposits on the terraces of major rivers such as the Peace and the Liard. The vegetation is a mixed forest cover of trembling aspen and white spruce. Because of the coarse texture, low water holding capacity and rapid drainage characteristics of the materials many sites are very dry and subject to forest fires. In these areas the forest trees are lodgepole pine and trembling aspen. The profile characteristics are similar to the typical soils that were described in Part 2.4, apart from very weak structure.

The Dystric Brunisol landscape has developed on fluvioglacial deposits that are acid in reaction and low in bases. Such deposits are found along streams such as the Doig River and Milligan Creek that have their sources in the acid peatlands of the Great Plains, or they are found bordering the sections of the Rocky Mountain Foothills that have less calcareous bedrock. The forest is composed of white spruce and trembling aspen. The soil profile is similar to the Eutric Brunisol except that the horizons are less calcareaus.

Under suitable climatic conditions the soils of these two landscapes can be used to grow forage crops. Moisture deficiencies in the growing season are the main limiting factor.

THE GRASSLAND SOIL LANDSCAPES

The Black Chernozemic, Solodized Solonetz and Solod soil landscapes that form the grasslands of the Peace River lowlands are of limited extent. But they form a part of the larger aspen parkland of the Prairies. It was this landscape that first attracted white settlers to the Peace River lowland and formed the basis of the agricultural economy that sustained them there.

The limited Black Chernozemic soil landscapes occur mainly on the gently to strongly sloping fans along the south facing wall of the Peace River valley between Hudson Hope and the Alberta border. They are young shallow soils (often having only an Ah, C horizon sequence) developed on young geological deposits. Other small patches occur on the lacustrine deposits of the shale lowlands. The vegetation is grasses with occasional clumps of trembling aspen.

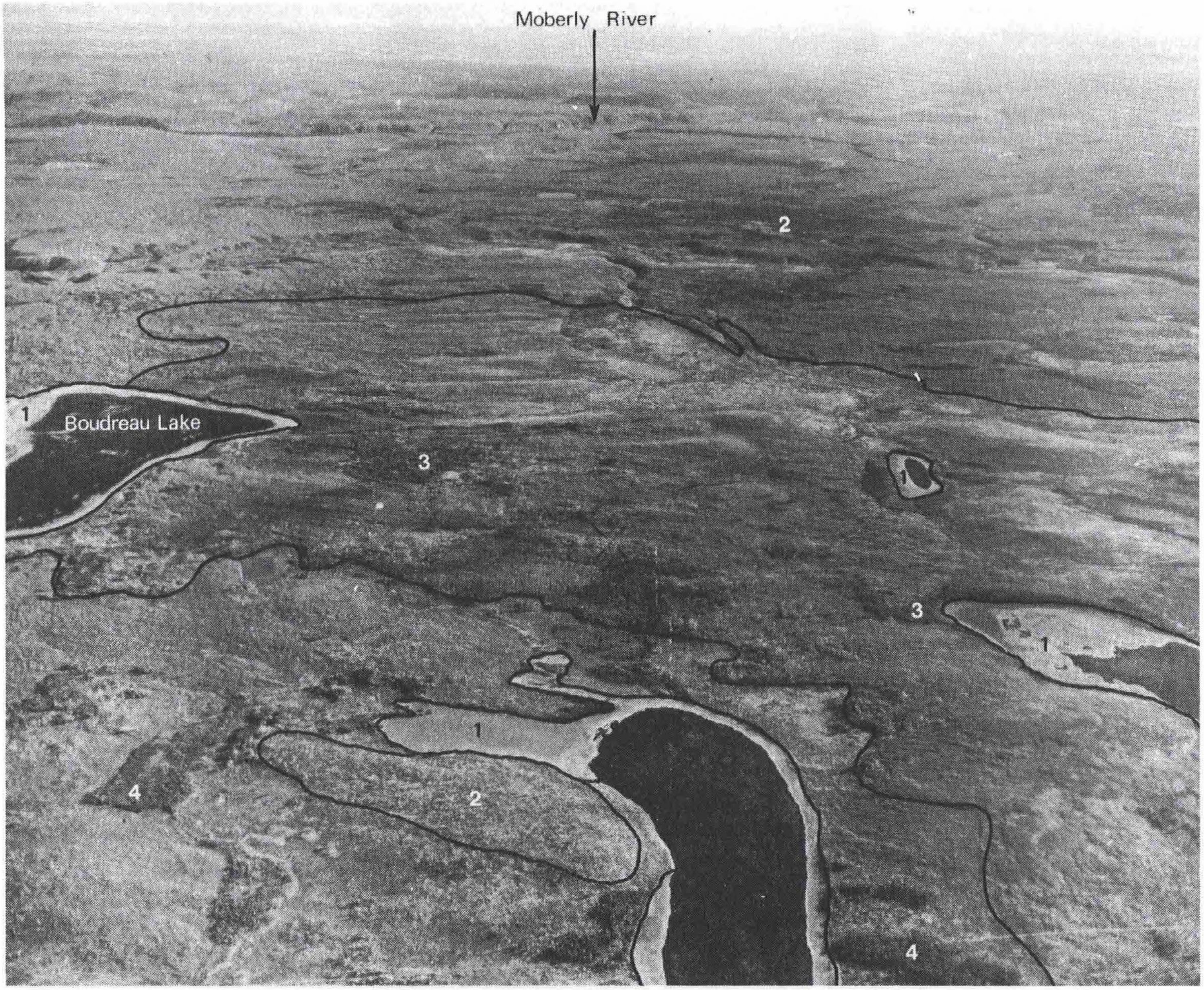


PLATE 3.7.2 Soil landscapes near Boudreau Lake in the Peace River lowlands looking south to Moberly River. (photo BC:1951:34)

PLATE 3.7.2
SOIL LANDSCAPES NEAR BOUDREAU LAKE IN THE PEACE RIVER LOWLANDS LOOKING SOUTH

1. Fibrisol landscape. Deep fibrous spahgnum peat occurring around the periphery of lakes and along drainage ways.

2. Gray Luvisol landscape on the moderately well drained low ridges on the till plain. There are some Luvic Gleysols in depressions.

3. Luvic Gleysol and Gray Luvisol landscapes on the "fluted" till plain. Luvic Gleysols occur in the depressions and nearly level topography. Gray Luvisols are limited to the moderately well drained slopes of the low ridges, which have a forest cover of white spruce, trembling aspen and white birch with a ground cover of reindeer moss.

4. Luvic Gleysol and Mesisol landscapes on nearly level topography. Luvic Gleysols occur in imperfectly and poorly drained sites with Mesisols in the slight depressions that are very poorly drained. The vegetation cover is sphagnum moss, common Labrador tea, willows, tamarack and black spruce.

The saline soil landscapes contain two soil great groups; the Solodized Solonetz and Solod. They are found in the subhumid aspen parkland of the Peace River lowland where the parent materials contain considerable quantities of residual soluble salts. They occur mainly on the lacustrine deposits overlying the marine shales in the lowlands. But they are also found on the adjacent till deposits.

Both types of soil have B horizons that contain relatively large amounts of Na and Mg salts, and a strong columnar structure that breaks to subangular blocks. There are large accumulations of calcium carbonate at depth and below this accumulations of gypsum.

THE REGOSOL LANDSCAPES OF THE FLOODPLAINS

The soils of the recent fluvial deposits on the floodplains and terraces of the Peace River, the Liard and their tributary streams are Regosols. They are formed from sediments deposited with each flood. They do not have distinct horizons, although they may have an organic surface litter or a weakly developed Ah horizon. Distinct layers may be found in Regosolic soils but they are due to variation in sediments rather than to soil horizon development. Sometimes buried Ah or L-F horizons are encountered in the soil profile. They result from repeated burial by flooding.

The frequency of flooding is variable since it is often caused by unpredictable ice jamming in the spring. Depth to water table is also variable both from place to place and through the year. In the spring the soils can be saturated, later in the summer they are liable to moisture deficits. The vegetation cover is a dense forest of black poplar and white spruce with mountain alder, willows and red-osier dogwood forming a dense understory.

Regosols also occur on the steep valleysides above the floodplains. These slopes are extremely unstable. The soft fine textured materials are constantly moving downslope. What soil horizons do occur are disrupted. The soils are well drained but unstable.

These floodplain soils are very productive if not flooded. With the suitable climate of the Peace River valley good crops of potatoes, corn and other vegetables may be grown on many suitable sites in the floodplains. Large populations of deer, moose and domestic cattle graze the vegetation on the terrace and adjacent slope soils.

Part 4

The Development and Use of Soil and Terrain Surveys in British Columbia

4.1 INTRODUCTION

P.N. Sprout

Soils do not uniformly cover the earth's surface. They vary from place to place and can be thick or thin, wet or dry, fertile or infertile. The proper use of soils with such diverse properties calls for prior knowledge of their location and characteristics. Part 4 deals with the survey activities which have taken place over the years to acquire such knowledge. It outlines the methods which have evolved to identify, map, and report on the different soils of British Columbia, and on how they can be used. This procedure of identifying soils in the field was initiated in 1926, but even today not all of the province has been covered; large areas in the northern and coastal sections are still to be done.

The first section of Part 4 describes the pioneering efforts of a few individuals who persisted in spite of difficult conditions and meagre support. The second section deals with the heady days of the Canada Land Inventory programme when support and funding for soil surveys reached unprecedented levels. The final section summarises these accomplishments and gives a glimpse of things to come.

4.2 SOIL AND LAND UTILIZATION SURVEYS PRIOR TO 1965

L. Farstad and N.T. Drewry

THE BEGINNING OF SYSTEMATIC SOIL SURVEYS (1920 TO 1935)

Soil surveys were started in 1926 by the B.C. Forest Service. The first survey was carried out in the central interior along the Canadian National Railway route between Fraser Lake and Smithers. The soils were classified according to surface texture and slope. Foot traverses were made at .8 km intervals to cruise the timber and examine the soil. Slopes were plotted on the base maps from Abney readings. From 1927 to 1929 soil surveys were also carried out in the environs of Prince George, Sicamous and in the North Thompson valley from Kamloops to Barrière. F.D. Mulholland of the British Columbia Forestry Service, directed the study. His assistants were all agricultural graduates. They had no precedents of soil survey techniques, and had to develop their own methods and classification to suit the particular area in which they were working.

The purpose of these early soil surveys was to separate arable land from non-arable land, as part of the program to establish permanent Forest Reserves within which alienation would be denied. The results of these surveys formed the basis for Mulholland's report "The Forest Resources of British Columbia" in which he attempted to determine the 'allowable cut' from area and growth ratios. Later this concept was further developed into the first 'sustained yield' policy in Canada, and for that matter in North America. Lack of financial support in 1929-30 brought these surveys to an abrupt end.

In 1931 soil surveys were revived in response to a recommendation of the W. Sanford Evans Royal Commission of 1930 which was appointed to investigate the problems of the tree fruit industry in the Okanagan Valley. C.C. Kelley, a district agriculturist from Prince George, was appointed to direct the work from headquarters in Kelowna. Like many of the pioneer soil surveyors he had no previous experience in the work. The Experimental Farms Service of the Federal Department of Agriculture agreed to participate in the programme on a 50:50 basis and R.H. Spilsbury who had been one of Mulholland's original assistants joined Kelley as the representative of the federal staff.

The first survey in the Okanagan on a scale of 1:40,800 was a detailed survey of the irrigation districts north of Kelowna. The soils were mapped on the basis of soil series. The survey contributed to the solution of dieback problems in apples and other tree fruits by showing that these and other problems were confined to the poorly and somewhat poorly drained soils.

Later, the plant pathologists found that the corky core disease of apples was due to a boron deficiency in the soil materials. In 1935 the demand for detailed soil surveys diminished and turned to reconnaissance surveys in the Lower Fraser, Okanagan and Similkameen Valleys.

THE CO-OPERATIVE FEDERAL - PROVINCIAL SOIL SURVEY PROGRAM (1935-1965)

This period saw the expansion of soil survey activities from detailed mapping projects for special purposes by a few individuals to more general surveys of the major valleys and lowland areas in central and southern British Columbia by groups of soil surveyors.

During the 1935-36 field seasons reconnaissance soil surveys were carried out by Kelley and Spilsbury in the Okanagan, Similkameen and the Lower Fraser Valleys where intensive agriculture was practised and some high priced crops were grown. The scale of mapping was 1:63,360. The map units consisted of soil zones, series, types and phases (see Soil Survey Reports Nos. 1 and 3 in Further Reading).

During this time some preliminary soil mapping was done on Vancouver Island to assist the Forest Service in their tree planting project by designating the location of arable lands.

In 1939 L. Farstad replaced R.H. Spilsbury as the federal soil surveyor, and started work in the Prince George area. The survey had begun in 1938 in an area where agricultural development was limited and where soil information was needed in connection with land settlement. Traverses were on foot following compass lines at one to two mile intervals. Due to the heavy forest cover, lack of roads and inadequate base maps the amount of detail was much less than that obtained in the open agriculturally developed area in southern British Columbia (Soil Survey Report No. 2).

The purpose of these early surveys was to classify and map soils, examine their physical and chemical nature, and determine as far as possible their agricultural possibilities. The information also provided an inventory of the soil resources and served as a guide to land use for government departments concerned with land and agricultural policies.

In 1941 differences in policies between the federal and provincial governments developed and L. Farstad's headquarters were moved to Vancouver where he established an informal co-operative agreement with the Department of Soil Science at the University of British Columbia. Farstad was placed in charge of surveys in the north, the central interior and the Peace River

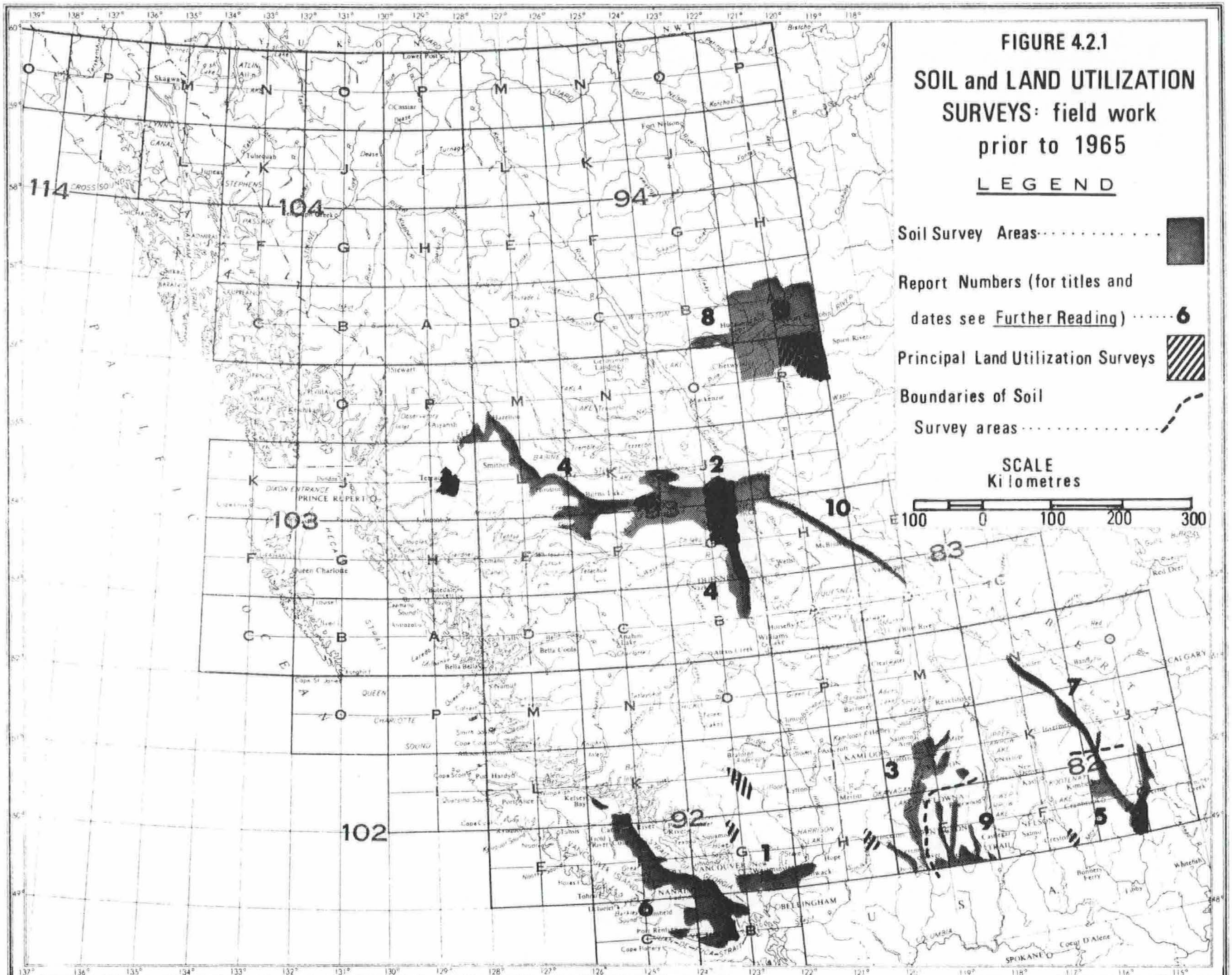
Block. Later, he completed the soil survey of the southeast portion of Vancouver Island. The University of British Columbia provided the Federal group with office space, laboratory facilities, and stenographic services. In addition, Dr. D.G. Laird assisted in the field work in the Central Interior and the Peace River Block.

Soil surveying in the sparsely populated areas of British Columbia in the late 30's and early 40's was not only interesting but difficult and often hazardous. Base maps consisted of information compiled from British Columbia Land Surveys (BCLS) and Dominion Land Surveys (DLS) supposedly locating lands "topographically suitable" for agriculture. The soil surveyors followed survey cut lines, compass lines and game trails. In the spring sow bears with cubs challenged our right to traverse their terrain and in the fall amorous bull moose claimed the right of way. We travelled by team and wagon, horseback, canoe, and on foot and dined on bannock, beans, bacon, grouse, venison and berries.

From the late 40's until the early 60's soil surveys were completed over most of the potentially agricultural land in British Columbia (see Figure 4.2.1). There also developed a gradual distinction between those areas that were to be handled by provincial surveyors and those that the federal unit would survey. However, this distinction should not be overemphasized. There long remained a bewildering interchange of personnel and financing that would turn a modern administrative officer gray.

During the first part of this period Kelley worked alone in Kelowna doing detailed soil surveys of small irrigation projects associated with the Veteran's Land Act. The first expansion of the provincial soil survey unit was associated with the need for soil information by the International Joint Commission Investigation which lead to the Columbia Treaty. The Upper Kootenay and Elk (Report No. 5), the Upper Columbia (Report No. 7) and the Kettle (Report No. 9) river valleys were all surveyed under this programme. In addition there was an irrigation capability survey of the Okanagan valley. The purpose of all these surveys was to gauge the irrigation potential and the total water requirements of the soils. Then an estimate could be made of how much water should be withheld in Canada. The field mapping was carried out at a scale of 1:31,680. Soil zones, series, types and phases were mapped. In addition to soil surveying the provincial group provided an extension service to advise farmers on irrigation, drainage and other soil related problems in southern British Columbia.

Meanwhile the federal unit with the help of provincial personnel undertook the mapping of soils in the north central interior (Reports 4 and 10), on Vancouver Island (Report 6) and in the Peace River area (Report 8).



Produced by Geographic Division, Surveys and Mapping Branch, Dept. of Lands, Forests, and Water Resources, Victoria, B.C.

MAP NO. 15NT

The purpose of these surveys was to determine where the actual or potential agricultural lands were. Soil types, series and complexes were mapped at a scale of 1:63,360 or 1:126,720 and slope classes were usually mapped by superimposed symbols. The area mapped was determined by the road access along the valley bottoms or how far up the valleysides you could walk in a day. Aerial photographs were first used in the Vanderhoof area in 1943. But there were no stereoscopes available, so only every second photograph was supplied (they had 60% overlap) from Ottawa. Stereoscopes and stereo pairs were not used until 1946 in the Peace River survey.

LAND UTILIZATION SURVEY 1942-1953

The British Columbia Department of Lands in 1942 started a programme of systematic land classification surveys under the direction of F.D. Mulholland who had previously been in charge of forest surveys, making inventories of forest resources. The object of the Land Utilization Division was to classify the Crown lands of the Province according to their present land use and, from the available land considered suitable for settlement, to make recommendations regarding the development of economic farm units.

After World War II the programme expanded with the appointment of a new director, D. Sutherland, a conservation officer and a soils specialist. The survey method was broadened to include both land use and soil capability standards. To the present-use classification developed by Mulholland was added an adaptation of the land-use capability system employed by the U.S. Soil Conservation Service. The capability classification system closely resembled the soil capability for agriculture approach subsequently used by the Canada Land Inventory (see section 4.3). Eight land-use capability classifications were recognized. Classes 1 to 3 were arable, class 4 was arable with special practices, classes 5 to 7 were suited to increasingly restricted use of the natural vegetation because of their susceptibility to erosion and ecological damage. Class 8 was land suited only for wildlife production, recreational use or watershed protection.

Field surveys, employing supplementary summer help from the University of British Columbia, were conducted in the principal settlement areas from 1947 to 1953 when the work was suspended due to a change in government priorities. Extensive surveys were carried out in the Peace River, Prince George, Terrace, Creston and East Kootenay areas. The Peace River project was the largest, with over a million acres of land classified and mapped (see Figure 4.2.1).

Numerous special projects were undertaken to meet special government or community needs. The Pemberton Valley was studied to assist in determining the feasibility of dyking the Lillooet River. A detailed study was made of the Doukhobor lands to assist in resolving land use and ownership problems involving the Doukhobor sect and the Province of British Columbia (see Rowles in Further Reading). These projects, and others, demonstrated the applicability of the land capability classification approach to dealing with problems having both social and technical implications. The capability classification has proven to be an effective vehicle of communication between the technician and the general public which makes use of the technical information.

FURTHER READING

Farley, A.L., 1950. Summary and Map of Soil Surveys and Land-Utilization Surveys in British Columbia. Annual Rept. Br. Col. Lands Service, II 49-57, 1 map.

This contains a brief description and a detailed table of many of the early surveys.

Rowles, C.A., 1955. Soil, Agriculture and Rehabilitation. in Hawthorn, Harry B. (editor). The Doukhobors of British Columbia, Univ. British Columbia and J.M. Dent (Canada) Ltd. pps. 221-245.

A study of the soils of Doukhobor lands with recommendations for their future use.

All the following are soil reports for the areas which were surveyed prior to 1965. They are arranged according to report number.

Kelley, C.C. and R.H. Spilsbury, 1939. Soil Survey of the Lower Fraser valley. Br. Col. Dept. Agric. and Exp. Farms Service, Dominion Dept. Agric., Publ. 650.

Kelley, C.C. and L. Farstad, 1946. Soil Survey of the Prince George Area, British Columbia. B.C. Soil Survey Rept. No. 2, Br. Columbia Dept. Agric. and Exp. Farms Service, Dominion Dept. Agric.

Kelley, C.C. and R.H. Spilsbury, 1949. Soil Survey of the Okanagan and Similkameen Valleys, British Columbia. B.C. Soil Survey, Rept. No. 3, B.C. Dept. Agric. and Exp. Farms Service, Dominion Dept. Agric.

Farstad, L. and D.G. Laird, 1954. Soil Survey of the Quesnel, Nechako, Francois Lake and Bulkley-Terrace Areas. B.C. Soil Survey, Rept. No. 4, Exp. Farms Service, Can. Dept. Agric.

Kelley, C.C. and P.N. Sprout, 1956. Soil Survey of the Upper Kootenay and Elk River valleys. B.C. Soil Survey Rept. No. 5, B.C. Dept. Agric. and Exp. Farms Service, Can. Dept. Agric.

Day, J.H., L. Farstad, and D.G. Laird, 1959. Soil Survey of Southeast Vancouver Island and Gulf Islands, British Columbia. B.C. Soil Survey, Rept. No. 6, Can. Dept. Agric.

Kelley, C.C. and W.D. Holland, 1961. Soil Survey of the Upper Columbia River Valley. B.C. Soil Survey, Rept. No. 7, B.C. Dept. Agric. and Can. Dept. Agric.

Farstad, L., T.M. Lord, A.J. Green, and H.J. Hortie, 1965. Soil Survey of the Peace River Area in British Columbia. B.C. Soil Survey, Rept. No. 8, Univ. British Columbia, B.C. Dept. Agric. and Can. Dept. Agric.

Sprout, P.N. and C.C. Kelley, 1964. Soil Survey of the Kettle River Valley, B.C. Soil Survey, Rept. No. 9, B.C. Dept. Agric. and Can. Dept Agric.

Hortie, H.J., A.J. Green, and T.M. Lord, 1970. Soils of the Upper Part of the Fraser Valley in the Rocky Mountain Trench of British Columbia. B.C. Soil Survey, Rept. No. 10, Can. Dept. Agric. and B.C. Forest Service.

4.3 THE CANADA LAND INVENTORY PERIOD 1965 - 1975

P.N. Sprout

INTRODUCTION

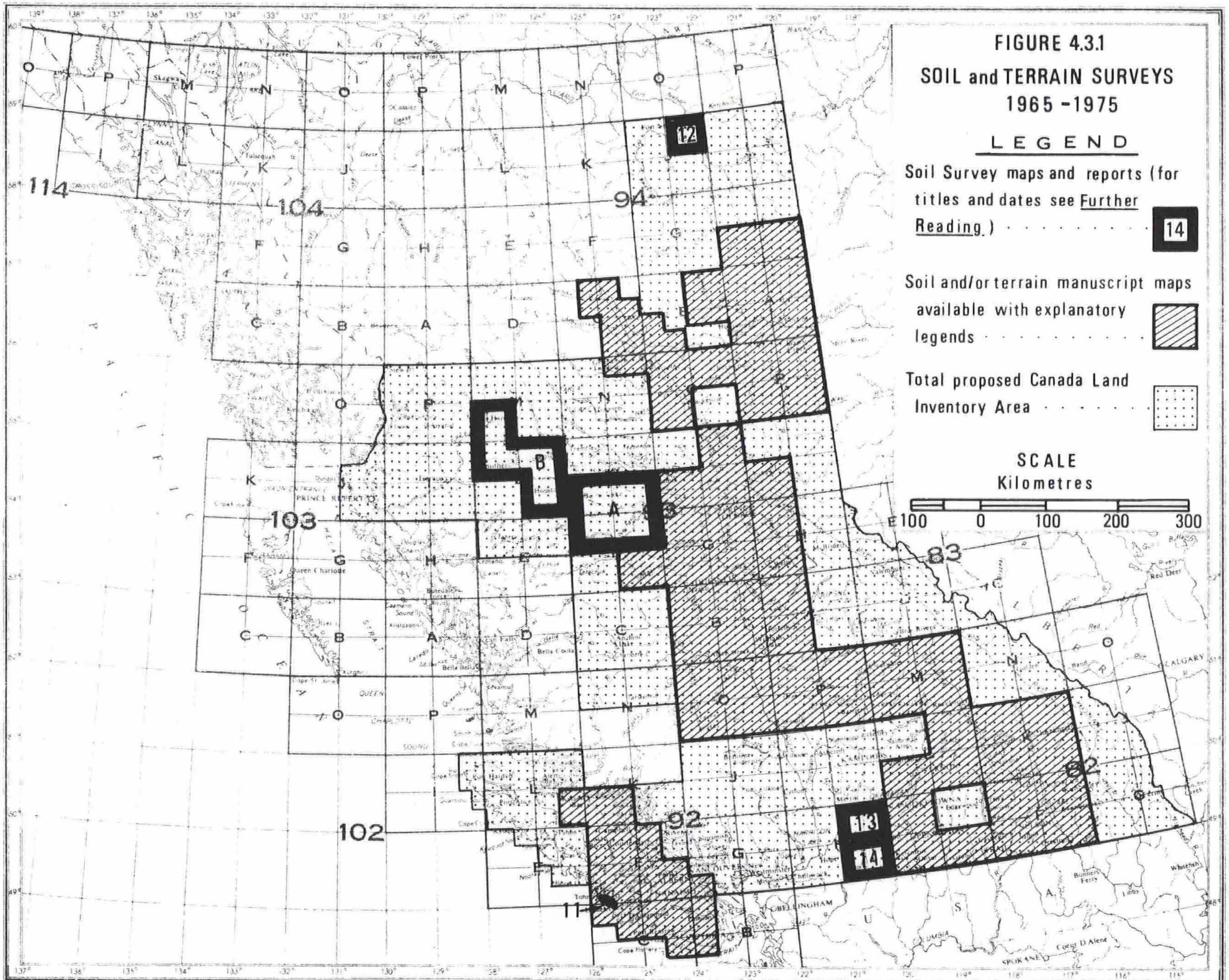
The period 1965 to 1975 was the coming-of-age of soil and terrain surveys in British Columbia. It was the period when soil surveys changed from being mainly agriculturally oriented to providing basic information for a wide variety of resource uses. It was the period of large increases in the resources allocated to soil and terrain inventories and to the area covered annually by such surveys. It was the period when soil survey activities changed from being primarily fact gathering missions to programmes whose objectives were to supply information relevant to land-use planning and management.

The result of these changes was a de-emphasis on classifying soils and an emphasis on developing methods of mapping soils quickly and interpreting the gathered data for a wide range of uses.

The changed emphasis came early in the period and was spurred by the Canada Land Inventory programme (referred to as the CLI programme). This fostered interagency communication and promoted the assessment of the natural capability of land. The activities in British Columbia were part of a Canada-wide inventory of land capability which was designed to provide a basis for resource and land-use planning. They were undertaken as a cooperative federal-provincial programme and initially were administered under A.R.D.A. (Agricultural Rehabilitation and Development Act, later changed to Agricultural and Rural Development Act).

At first the CLI programme was oriented toward multiple-use areas of the province in which agriculture was one of the main users. Later it was expanded to include a much larger part of the province which included considerable multiple-use land and a much higher forestry potential (see Figure 4.3.1).

To meet the administrative and coordinative demands of the programme, a "Soil Capability for Agriculture and Forestry Committee" was formed in 1964. The committee was active until 1972 and administered most of the soil survey activities during the 1965-1972 period. Subsequently this was done through the B.C. Land Inventory Group in cooperation with the Canada Agriculture Soil Survey Unit.



Produced by Geographic Division, Surveys and Mapping Branch, Dept. of Lands, Forests, and Water Resources, Victoria, B.C.

By 1972 there was less emphasis on land capability assessments sponsored by the CLI programme and more on meeting specific requests generated within the province. This general interest in the use of soils information was partly a reflection of the success of the CLI programme, and partly due to an increase in competition for the province's natural resources. Soil survey information was in demand as an aid to making decisions on land-use, in preparing impact assessments prior to development, and in preparing resource folios. Information on other related land-based resources was also being requested, and a more holistic approach to inventorying land was required. This led to the concept of integrated resource or biophysical surveys whereby terrain features, vegetation, aquatic systems and climate were surveyed along with the soils.

Until this time soil surveys in Canada had traditionally been sponsored by Agricultural Departments, and this was also the case in British Columbia. But with integrated resource surveys and the broad application of soils information for other resource uses, a new sponsoring agency was needed with a broader mandate. This resulted in 1974 in the shift of soil survey responsibilities from the B.C. Department of Agriculture to the Resource Analysis Unit of the Environment and Land Use Committee Secretariat, the staff arm of Environment and Land Use Committee. This Committee is a provincial cabinet committee comprised of Ministries whose activities affect the natural resources of British Columbia. The shift encouraged and solidified the concept of integrated resource surveys in British Columbia. It also encouraged the process of using soil and terrain information in the land-use planning process.

SOIL SURVEY TECHNIQUES

In 1965 the sudden widespread demand for information generated by the CLI programme required new survey techniques. Reconnaissance surveys were emphasized having a field scale of 1:50,000 or 1:63,360, and a publication scale of 1:125,000 or 1:126,720. The surveys had to cover terrain which varied in accessibility from good to non-existent. This meant the old approach of going from the specific to the general, that is, the process of digging numerous holes to identify soil series and as a means of establishing mapping boundaries was not practical. Instead an approach was applied which was nearly the reverse. Map boundaries were established first by using stereoscopic pairs of air photos to identify landforms that were distinguished by their surface form and shape. Lines were drawn where distinctive and repeated patterns could be distinguished. Since certain shapes and patterns are characteristic of certain depositional and erosional processes, inferences could be drawn about the materials making up the landform. The landforms and position of the boundaries were then checked in the field and the soil units occurring on the landforms were identified. Where access by road was possible this checking was done by ground transportation; where road access was not possible, spot checks were made by helicopter.

In general, the pattern of soils occurring on the landforms was too complex to permit the identification of all the soil series which occurred (see definition Part 2.2). Such an approach would have retarded the progress of the surveys and would have resulted in the final maps being unduly cluttered and complex. Instead, in 1967 the use of soil associations was instituted. As indicated in Part 2.2, a typical soil association consists of a number of soils, generally soil series, which may vary from well drained to poorly drained. However, not all of the soils making up an association will occur together. So various combinations of them are mapped in different "soil association map units". For example one map unit may contain only the well drained soil, while a second map unit may contain the well drained and the poorly drained soil. Being able to identify the soil in any particular place is important when land-use interpretations and recommendations are being made. This method of mapping proved very successful and was still being applied at the end of the 1975 period.

The soil series has always played a key role in detailed soil mapping at scales larger than 1:30,000. During the period when the CLI programme was demanding most of the resources of soil survey agencies, a number of special projects were conducted at these detailed scales. The largest of these was the survey of the Lower Fraser Valley (scale 1:24,000), but a number of smaller surveys were also completed, some related to irrigation districts, ARDA sponsored community pasture projects and Indian Reserves. Some of these were carried out at scales as large as 1:6,000. In all cases, soil series and complexes of soil series comprised the map units. Their identification required an intensive field examination of the soils and landscape, and this in turn ensured good definition of the various soil properties and an accurate placement of the soil boundaries. The information collected depended upon the objective of the survey, but typically characteristics such as texture, drainage, structure, reaction, salinity and nutrient content were identified in considerable detail. This detailed definition allowed the user to apply the information easily and confidently. However, increased precision is costly and detailed surveys are restricted to situations where the impact and the benefits in relation to the cost are high.

With the expansion of reconnaissance soil surveys into forested and mountainous areas, a number of technical soil classification problems were encountered. Inadequacies were most evident in the Brunisolic, Podzolic and Organic orders (see Part 2.3) and in high elevation or alpine soils.

Increasingly precise morphological and chemical criteria had resolved many of the problems by 1974 and allowed for a better fit between the classification system and the natural environment. More specific but important from the standpoint of soil use and biological productivity was the occurrence of surface churning and the downslope movement of seepage water on the long steep slopes so prevalent in much forested terrain in British Columbia. Similarly, the presence of hard and nearly impenetrable pans was noted in the subsoil of many coastal and some interior soils. The identification and characterization of such features during this period allowed the surveys to proceed in a uniform, precise manner.

When dealing with lands in their natural state, one is mainly concerned with characterizing and manipulating the total ecosystem. It became evident quite early in our attempts to inventory forest lands that the information collected by traditional soil surveys, however important, comprised only one aspect of the total resources. To obtain the complete picture also required inventories of climate, vegetation, aquatic systems and landforms. Thus the concept of biophysical or integrated resource surveys began to take shape in the mid-1960s, to be applied generally from about 1970 onward. The application was in some respects forced by the increased demand for multi-resource information. However, the need was anticipated several years earlier as evidenced by a meeting convened in 1962 by R. Spilsbury (B.C. Forest Service), and the resultant pilot projects at Minnie and McGillivray Lakes. These projects were primarily concerned with developing a method of classifying and mapping soils through the integration of information on soils, landforms and vegetation. Valuable data were gained from these projects; they introduced the principle of airphoto interpretation as a means of pre-mapping forested terrain. The biophysical mapping concepts were finally formalized and documented in 1967 under the auspicies of the National Committee on Forest Land.

CLI PROGRAMME

The impetus for conducting reconnaissance soil surveys over large areas of British Columbia was initially supplied by the CLI programme in 1965. The objectives of the programme were firstly to undertake a country-wide assessment of resource supplies which could be set against a long term assessment of resource needs, and secondly to make possible systematic studies of problems of resource management and development in all fields. The programme sponsored assessments of land capability for agriculture, forestry, recreation, wildlife, waterfowl and present land use. In British Columbia, soil survey information was used as the underpinning for agriculture and forestry capability ratings and subsequent discussion of the programme will be restricted to these aspects.

Both the Agriculture and Forestry Capability Classification systems rated the soils into seven classes. In the Agriculture system the mineral soils were ranked according to their capability for producing a range of common field crops. In the Forestry system, all mineral and organic soils were rated on their inherent capability for growing commercial timber. Capability for Forestry was therefore based on productivity. Agriculture Capability ratings were initially applied only to previously surveyed areas, but the first Forest Capability investigations consisted of pilot projects in the Prince George, Princeton and East Kootenay areas. This initial work resulted in adjustments to both rating systems, the better to depict conditions in British Columbia. Once these problems were solved the work proceeded rapidly with survey activities reaching a high level by 1968 of nearly 3 million ha, increasing gradually to 1975 with 5.9 million ha. The programme ended in 1975. In spite of these efforts, not all of the target area was covered (see Figure 4.3.1). Notable exceptions were the west Chilcotin, the area north of the Peace River block, and the east-central part of the province. For those areas which were surveyed, maps showing capability ratings for agriculture and forestry were published at a scale of 1:126,720. This contrasts with other resource capability maps which were published at 1:250,000 for the total of the Canada Land Inventory area.

One of the earliest uses of the CLI information were broad regional land-use recommendations based on a comparative analysis of the capability ratings for each resource. This procedure was termed a Land Capability Analysis and was undertaken for seven regions in the Central, Southern and Peace Rivers areas. The product was a map at a scale of 1:250,000 showing the land's best use capability following an examination of the individual capabilities for agriculture, big game, forestry, recreation and waterfowl, and for special uses such as native range. The information was used for a short period as a guide in setting land alienation policies.

An example of the use of CLI data for planning was the designation of Agricultural Land Reserves in British Columbia. A Farm Land Preservation Policy was introduced by Order-in-Council in December 1972, followed by the Land Commission Act in April 1973. This policy placed a moratorium on the subdivision of all farmland as defined by the Taxation Act, and on all lands with Agriculture Capability Classes 1 to 4. The moratorium was in effect only until the lands were permanently designated as Agricultural Reserve after a complex review and referral procedure. A basic prerequisite of the review process was the production of maps for all of the province indicating the location of lands which were proposed to be reserved for agricultural use. Compilation of the maps was based on lands with a capability for agriculture rating of Classes 1 to 4. In ranching areas where grazing lands were an integral part of the operation, Class 5 and 6 lands capable of use for spring and fall grazing were also included. More than 300 map sheets at 1:50,000, encompassing more than 4 million ha of land proposed for Agricultural Reserve were prepared within a few months. Without the basic information provided by the CLI programme, the task would have been impossible.

The CLI programme was a success in many ways. Besides the main objective of producing a broad scale assessment of soil and land capability, there were desirable spin-offs: it gave a much needed impetus to the federal and provincial soil survey programmes; it created a large data base on soil and terrain which could be used for other purposes; it fostered communication and cooperation in relation to resource management and planning; and it created an awareness of the value of soil interpretations and of the need to integrate the components of the ecosystem. The capability data produced by the programme are still the main sources of information available for management and planning over large areas of British Columbia. The major drawback is the broad scale on which the surveys were conducted. They were designed to provide an input to regional land-use planning and are well suited for the purpose; but the data are too general for most management activities although many agencies have used them with varying success in the absence of more relevant information.

SPECIAL PURPOSE SURVEYS AND APPLICATIONS

To make soil survey data useful for land-use planning and management, the information must be reliable, readily available, and in an easily understandable form. The capability maps produced by the CLI programme were only the beginning of the kinds of practical applications which could be made. The soil survey reports which were produced from 1965 to 1975 illustrate the gradual transition from very technical reporting on soils to publications which emphasize use and management for multi-resource purposes. The report format was itself simplified and made more appealing by eliminating or appending much of the technical data.

Besides making the report user-oriented, a major effort was made to shorten the period between completing the inventory and reporting the results. One means of accomplishing this was to produce interim copies of both maps and reports. Computer storage of data facilitated the manipulation of the data and its accessibility to other agencies.

Many of the requests received could not be met from the data accumulated in the CLI programme. This generated the need for more specialized surveys, often at detailed scales, and for new ways of applying the information.

Some of the demand could be met by the traditional soil survey organizations of the Federal and Provincial governments. Some could not, and this led to the hiring of pedologists by private companies and other government agencies. Some large forest companies undertook their own soil and terrain surveys and initiated specialized applications for them. The Federal and Provincial soil survey units meanwhile became more specialized. The Federal unit undertook an increased correlation function to ensure standardization and integrity of the information being collected by the various agencies. Its role in research was also strengthened.

The Provincial unit concurrently geared up to conduct more special purpose surveys and to make more sophisticated interpretations. By the end of the 1965 to 1975 period, the interpretations covered not only the traditional resource fields of agriculture, forestry, recreation and wildlife, but also included engineering, urban development and regional planning. Their preparation used not only soils data, but also the related aspects of climate, terrain systems, aquatic systems and vegetation. Truly, soil surveys had come of age and were in a strong position to meet the demands of the next decade.

FURTHER READING

Anonymous, 1970. The Canada Land Inventory: Objectives, Scope and Organization, Report No. 1, second edition, 61 pp.

This report describes the Inventory, with brief summaries of the classifications used.

National Committee on Forest Land, 1969. Guidelines for Bio-Physical Land Classification. Canadian Forestry Service Publication No. 1264.

A description of the methods to be used in the mapping of land using the Bio-Physical Land Classification.

Staff of the Resource Analysis Unit, 1976. Terrain Classification System, E.L.U.C. Secretariat, Victoria.

Descriptions and definitions of a mapping system for terrain.

The following are all soil surveys published during the period, which include technical soil descriptions and chapters on soil capability for various uses.

Valentine, K.W.G., 1971. Soils of the Tofino-Ucluelet Lowland of British Columbia, B.C. Soil Survey Report No. 11, Canada Dept. of Agriculture, Ottawa, 29 pp.

Valentine, K.W.G., 1971. Soils of the Fort Nelson Area of British Columbia, B.C. Soil Survey Report No. 12, Canada Dept. of Agriculture, Ottawa, 60 pp.

Lord, T.M. and A.G. Green, 1974. Soils of the Tulameen Area of British Columbia. B.C. Soil Survey Report No. 13, Canada Dept. of Agriculture, Ottawa, 163 pp.

Cotic, I., 1974. Soils of the Nechako-Francois Lake Area. Interim Report. British Columbia Dept. of Agriculture, Victoria, 218 pp. (A)

Runka, G.G., 1974. Soil Resources of the Smithers-Hazelton area. Interim Report, British Columbia Dept. of Agriculture, Victoria, 234 pp. (B)

Green, A.J. and T.M. Lord. Soils of the Princeton Area. B.C. Soil Survey Report No. 14, Canada Dept. of Agriculture, Ottawa, (in press).

4.4 SOIL AND TERRAIN SURVEYS FROM 1975

T.M. Lord

The preceding sections introduce the reader to the beginnings of soil surveys in the province and carry him through the development and use of soil and terrain surveys as a base for the Canada Land Inventory (CLI) mapping programme, which ended officially in British Columbia in the spring of 1975. Apart from completing the publication of land capability maps and the funding of special projects, the resource analysis was completed of a vast area comprising some 96 million ha. Coincidental with the progress of the land inventory programme was an increased expertise in the mapping of soil and terrain units, refinements in technology, and a sharp rise in the volume of requests by land managers for basic resource information. These "spinoffs" from the CLI program have important ramifications for the present and future direction of soil and landform surveys in British Columbia.

Although the soil surveyor has traditionally made use of other natural sciences, he was sometimes forced, in remote, unclassified areas, to rely entirely on his own judgement in describing terrain units, plant communities and geological structures. Today he is part of a resource team that comprises specialists in hard rock geology, terrain analysis, vegetation, climate, hydrology, etc.

Upon completion of the CLI field programme in 1975, a large amount of survey information was available. This included new knowledge of the soils and landforms of the province, particularly in the northern half and within the mountain ranges. Already the application of this fresh information has altered the soils picture of British Columbia as depicted on the recently published soil map. For example we now recognize a more extensive distribution of Humo-Ferric Podzols within the interior plateau, and have mapped Ferro-Humic Podzols and Folisols within the mild rainforest belt of the outer coast. Recent surveys in the mountains and through the northern plateaus have enabled us to map more accurately areas formerly labelled as "dominantly rockland".

This new information on our soils is closely related to the development of more refined systems for classifying and mapping terrain and vegetation. Although practically all resource mapping under the CLI programme was done at a scale of 1:50,000, the principles involved apply equally to any scale of mapping. That is, the terrain or landform units are first identified by stereoscopic photo interpretation and then delineated on airphotos. The soils and vegetation are next described within this established framework. Reconnaissance soil surveys, covering a range of scale from about

1:30,000 to 1:125,000, differ from detailed surveys (<1:30,000) mainly in degree of intensity. That is, although each map delineation must be identified, the range of soils within a map unit will be wider and more complexes may occur under a reconnaissance survey. The value and practical use of any soil-terrain survey, at any level of intensity, depends on the composition of its mapping units and their relationship to the soil map legend. Soil mapping units must not only accommodate the natural landscape pattern of soils, they must be mappable, and they must meet the objectives of the particular survey. Although mapping units may be described at the level of soil series, complexes or associations they are defined by taxonomic classes.

Only recently have soil surveyors been forced to take a critical look at how they map soils and why they show soils on maps in certain ways. This assessment has resulted largely from a rapidly growing awareness and critical evaluation of soil information by concerned users. In British Columbia, resource managers require a wide range of basic soil and related landscape data. This information includes soil descriptions, soil classification, soil moisture regime, landform types, texture and depth of materials, and vegetation associations. Although most of these data have been included in the traditional soils report and soil map and legend, the mode of presentation has often left something to be desired.

Even though "soil is soil" whether under a wheatfield or supporting a stand of Douglas-fir trees, a mapping system used for agricultural needs would not necessarily be the same as one designed for forestry purposes. Soil surveys of rugged forested terrain, carried out primarily to provide a range of soil interpretations for forestry and engineering, are of recent origin in British Columbia. They grew out of the need for soil and landform information to provide a sound base for making land capability ratings under the CLI programme. Even while the soil maps were in the early stages of drafting, land managers, particularly those in private and government sectors of forest management, requested the use of this provisional soils information. It is now our task in this post-CLI period to explore some of the ways in which present and future surveys may best meet these needs.

Even while there were strong pressures from some resource managers for the basic soil and landform information in CLI maps, there was a growing awareness that these broadly-based maps did not always meet the needs of the user. With the rapid opening up of new areas to the travelling public, the importance of good resource management has become obvious. The effects of poor soil management practices that result in the scarring of a mountain side, the fouling of a stream, the loss of a new generation of trees, or the bulldozing of a grassland range are not readily hidden from view. The managers of our resources are actively trying to prevent such losses in productivity and to avoid confrontation with public pressure groups. Public and private agencies engaged in soil and terrain mapping must provide not only the basic map information but must show how to interpret clearly the survey data for any resource use.

Before getting into the uncertain area of prophecy a brief review of the present relationship of soil and terrain surveys to the natural resources of the province is in order. Soil and terrain mapping is now being done not only by federal and provincial agencies but also, and to an increasing extent, by surveyors in some of the larger forest companies. The current trend in surveys of forest land is to map at a number of levels within the detailed intensity range i.e. at scales of 1:30,000 or larger. But even if a mature forest stand growing on a steep mountain slope were mapped at the same intensity of survey as a cleared tract of level alluvial bottomland, say 1:15,000, the resulting soil and terrain information would be markedly different. Accurate photo interpretation of terrain and surficial materials, viewed through a dense tree cover, is extremely difficult even at high levels of intensity. The validity of many map unit boundaries and the components of each mapping unit must be closely field checked if dependable soil maps are to result. Soil maps produced at reconnaissance scales of 1:30,000, or smaller have limited use for forest land managers at an operational scale. Mapping units must be defined at a more detailed level for interpretive use by foresters and engineers.

The current review of present and projected developments in resource surveys is timely for a number of reasons. An important aspect of the CLI programme was the introduction of new or revised classification systems for three of the basic resources - soils, landforms, and vegetation. The year 1976 saw a major revision in the Canadian System of Soil Classification (to be published 1978) under the Canada Soil Survey Committee aided by pedologists from across Canada. Some of the more important changes were: the addition of a new category - Cryosolic Order, the revision of definitions in the Brunisolic and Podzolic orders, a reduction in the number of subgroups, and the use of a more readable style and format. Included in the revised publication is a chapter on landform classification. This system is closely related to the provincial scheme of terrain classification and was developed jointly by pedologists and surficial geologists. A great deal of progress has been made by plant ecologists and botanists in devising compatible means of mapping plant communities and associations.

There have been advances in the use of Landsat remote sensing imagery and the development of the orthophoto. These and other mapping aids, including the helicopter, are helping to speed up field mapping. Computer technology in the form of data banks for the storage, analysis and display of soils information will permit more uniform classification and correlation of soil units within and between surveys.

Permanent retention and ease of recovering field data for new interpretations will enable response to questions unanswerable at present. Further, the ability to correlate statistically data for soils, terrain, climate, vegetation and water, should enhance and support land management and planning decisions.

The development of autocartography should speed up the production of flexible soil interpretation maps tailored to the specific needs of users.

By 1976 it was clear that the traditional reconnaissance soil survey had evolved into, and become part of a broad land resource programme. Such programmes are drawn up to meet specific objectives within a rigid time frame. The soil surveyor and terrain specialist provide field data at whatever levels of intensity are required to meet the needs of the study.

Detailed mapping of soils and landforms may be required to locate townsites and communication routes through corridors while less intensive surveys may meet the needs in the plateau and mountain sections. The pedologists and surficial geologists will be responsible for interpreting the basic resource data such as airphotos, geological and old soil reports and land surveys. Preliminary field legends will be drawn up. The format of the mapping units will be established prior to field survey. During the preliminary stages and throughout the field programme, the supervisory soil and landform specialists work closely with representatives of other sectors, such as vegetation, climate, wildlife and recreation. The duties of the soil and landform specialists involve correlation of the soil and terrain mapping programme, classification and sampling of soil units, and revisions in the map legend to deal with new information.

Interpretations of soil mapping units for selected uses are an integral and important part of any modern soil survey report. A rating system is generally used expressing relative degrees of risk or limitations for potential uses. A knowledge of soil behavior based on field observations and generally a limited amount of analytical data, form the basis for most suitability ratings. Although interpretations cover a wide range of uses such as recreational parks, or assessment for septic tank fields, interpretations for forestry are of major importance in British Columbia. Foresters in particular are concerned with the stability of forestry roads and how they relate to soil characteristics, bedrock geology, soil water, and forest productivity.

We can expect the new technology that is rapidly developing for computer-assisted resource planning to have far reaching effects on forest management (for example in the folio system of the British Columbia Forest Service and in similar programmes in other agencies). With the development and use of federal (CanSIS) and provincial data banks there will be greater opportunities for exchanging soil information and maintaining standards for surveys by private companies and public agencies. Programmes that deal with materials for highways cut and fill and topsoil criteria, could be adapted for mine reclamation. Much more than in the past, survey data must be linked to fertility and productivity analysis for agriculture and for other resources.

81-2000-19