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TERRAIN INVENTORY AND QUATERNARY GEOLOGY, LYTTON, BRITISH COLUMBIA

J.M. RYDER

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Frontispiece *View southwestwards down Fraser Valley from vantage point on Botanie Mountain. The confluence of Fraser and Thompson rivers is at Lytton, slightly left of centre. River terraces bordering the Fraser and adjacent relatively gentle slopes are underlain by thick Quaternary sediments. Steep slopes bounding the valley are fault controlled. (GSC 202992-C)*

TERRAIN INVENTORY AND QUATERNARY GEOLOGY
LYTTON, BRITISH COLUMBIA

Abstract

The Lytton map area includes parts of the Coast and Cascade mountains and the Interior Plateau. The terrain ranges from rugged glaciated mountains to undulating plateaus, and from narrow rocky canyons to broad terraced valleys. The valleys contain thick successions of Quaternary sediments that have resulted from glacial, lacustrine, fluvial and colluvial deposition. A till mantle of variable thickness and composition covers much of the uplands, but merges into colluvium and rock on higher and steeper slopes.

Terrain units are defined according to surficial material characteristics, landforms, and present day geomorphic processes. A concise description of each terrain type is presented.

Most present day landforms and surficial materials are the result of the last (Fraser) glaciation and postglacial processes. The earlier Quaternary history tentatively can be reconstructed from the structure and stratigraphy of valley fill materials.

Résumé

La région cartographiée de Lytton comprend des portions de la chaîne Côtière, de la chaîne des Cascades et du plateau Intérieur. Le terrain comprend des montagnes glaciées aux formes acérées et des plateaux onduleux, des canyons rocheux étroits et de vastes vallées à terrasses. Les vallées contiennent d'épaisses successions de sédiments quaternaires, formées par sédimentation glaciaire, lacustre, fluviatile et colluviale. Un manteau de till de composition et d'épaisseur variables couvre une grande partie des hautes-terres, mais se confond avec les colluvions et rochers sur les pentes les plus hautes et les plus raides.

Les unités topographiques sont définies suivant le caractère des dépôts de surface, les formes du relief, et les processus géomorphologiques qui agissent actuellement. On donne une description concise de chaque type de terrain.

La plupart des formes du relief et des dépôts de surface actuels ont été créés par la dernière glaciation (glaciation de Fraser) et les processus d'érosion post-glaciaires. On peut en partie reconstruire les premières phases de l'histoire quaternaire, à partir de la structure et de la stratigraphie des matériaux de remblaiement des vallées.

INTRODUCTION

Lytton map area spans the transition between the Coast Mountains and the Interior Plateau of British Columbia. Rugged glaciated mountains gradually give way eastwards to rolling plateau country interrupted by the narrow, deeply incised valleys of Fraser, Thompson, and Nicola rivers. The semi-arid environment of these valley floors contrasts strongly with the nival conditions of the high mountains and plateaus. Thick Quaternary sediments are present within major valleys. A drift mantle of variable thickness covers level to moderately sloping upland areas. Mountain peaks, ridge crests, and steep slopes consist of rock and colluvium.

The map area extends 71 km east-west between 121° and 122°W, and 56 km north-south between 50° and 50°30'N. It is crossed by the Trans-Canada Highway and the Canadian National and Canadian Pacific railways, all of which follow Fraser Canyon and Thompson River. Other paved roads follow Fraser Valley north of Lytton, and Nicola and Highland valleys (Fig. 1).

The area was mapped during the summer of 1974. Information that I had acquired during previous work, including helicopter reconnaissance, also was utilized. To the east of Fraser River, logging roads provide ground access to most large tributary valleys and to some parts of the uplands. Access west of Fraser River is limited to roads along the valleys of Nahatlatch River and Kwoiek Creek, and consequently much of this region was mapped solely by airphoto interpretation.

The bedrock geology of Lytton map area was mapped by Duffell and McTaggart (1952); descriptions of bedrock geology that follow are based largely upon their work. Surficial geology has been mapped in adjoining areas to the east (Fulton, 1975) and north (Ryder, 1976). Quaternary geology of lower Thompson Valley has been investigated by Anderton (1970).

Acknowledgments

I would like to thank Don Howes, Willa Tanner, and Janice Aylsworth for their assistance in the field during summer 1974. The support and discussion provided by Lesley Anderton during the course of several field seasons in Fraser and Thompson valleys is also gratefully acknowledged. Thanks are also due to Dr. R.J. Fulton for his advice and patient supervision of this project.

PHYSIOGRAPHIC REGIONS

The map area includes parts of four major physiographic regions – Coast Mountains, Fraser Plateau, Cascade Mountains, and Thompson Plateau (Fig. 1; Holland, 1964).

Coast Mountains

The Coast Mountains constitute the western part of the area and are bounded on the east by the fault-controlled Fraser Valley. The mountains contain the highest peaks of the area. Ten summits rise to elevations of between 2600 and 3000 m, and most summits and ridge crests lie above 2000 m. A general accordance of summit levels is apparent from a distant view of these mountains. Despite this, the terrain is extremely rugged, with elevation differences of as much as 2300 m occurring over horizontal distances of 5 to 7 km. Local relief is greatest along the eastern edge of the mountains where peaks rise 2150 to 2450 m above adjacent Fraser Valley. Within the mountains, local relief is typically

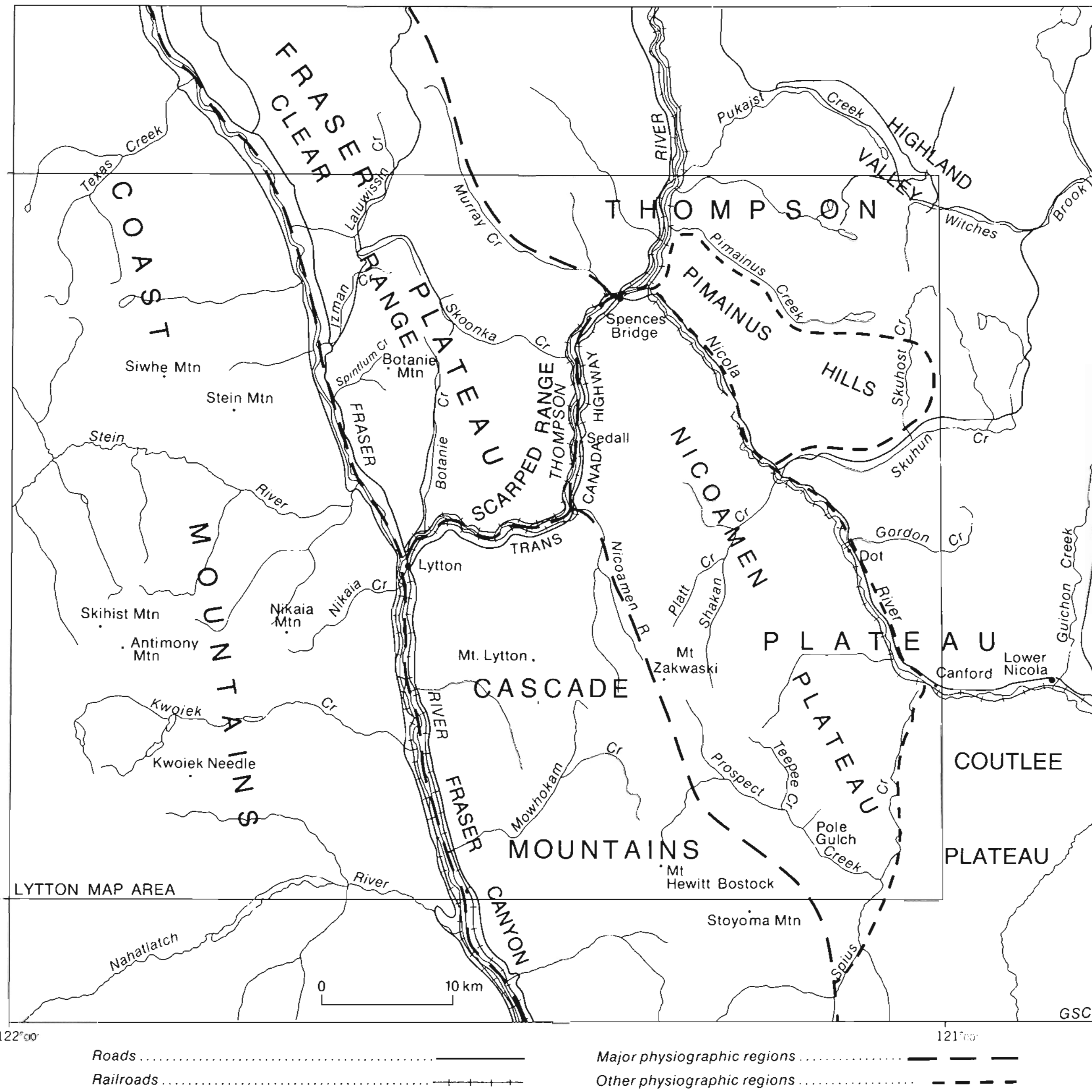

Figure 1. *Location map and physiographic regions.*

900 to 1500 m. Average gradients of valleysides are up to 750 m/km, although gradients may be much steeper over short distances, and vertical rock faces are common. Slopes are consistently steep along the sides of major eastward draining valleys such as Stein and Nahatlach rivers and Kwoiek Creek.

The topography of the Coast Mountains is dominated by landforms of glacial erosion (Fig. 2). Most valleys are typical glacial troughs. Cirques and other landforms of alpine glaciation occur above 1800 m, and thus are relatively restricted in their altitudinal and areal extent; most land surface in the mountains consists of long, steep, valleyside slopes. Cirque glaciers are present today on the flanks of peaks that rise above 2600 m and are most numerous on the Siwhe-Stein Mountain massif and on Skihist and Nikaia mountains. In the southwestern corner of the map area at the head of Kwoiek Creek, a relatively large névé with several glacier tongues occupies an area of 26 km^2 (Fig. 3). Glaciers are restricted to relatively high elevations in the Lytton area; in the Coast Mountains farther west and south, glaciers occur at lower elevations and are more extensive.

Figure 2
View southwestwards to the Coast Mountains from Mount Lytton. Kwoiek icefield is visible on the skyline; the prominent central peak is Kwoiek Needle. Alpine glacial topography in the Coast Mountains is confined to elevations above 1800 m. The ridge with shallow cirques in the middle distance was overridden by ice at the height of Fraser Glaciation. The undulating surface in the foreground consists of rock and till veneer and is typical of the upland surface of the Cascade Mountains. (GSC 202992-D)

Figure 3

Coast Mountains near Kwoiek Peak illustrate rugged topography developed upon granodiorite of the Coast Intrusives. Note joint control on rock face morphology and coarse texture of morainal and frost shattered debris. A double-ridged recent (Neoglacial) moraine is visible in the middle foreground. (GSC 202992-E)

Most of the Coast Mountains area is underlain by coarse grained granodiorite of the Coast Intrusives. The granodiorite is not homogeneous, but varies with regard to mineralogy, content and lithology of inclusions (granite, schist, and others), and degree of foliation. It is typically massive with widely spaced joints. Mechanical weathering produces large, blocky fragments and extremely coarse debris accumulations. Glacial features such as arêtes and steep slopes are well preserved, since the granodiorite has great strength and is relatively resistant to weathering and erosion (Fig. 3). In some places sheeting structures resulting from unloading (probably during deglaciation) are well developed and give rise to smooth, slightly convex rock faces upon which exfoliation is occurring. An example of this is located on the northern valleyside of Kwoiek Creek about 5 km upstream from Fraser River. The roughly rectangular drainage pattern of the Coast Mountains area suggests that major joints or other structural lineations may be a controlling factor.

One major area and several smaller areas in the Coast Mountains are underlain by metamorphosed stratified rocks. The major area is a belt of northwest-southeast striking rocks that extends from Antimony and Akasik mountains to Nahatlatch and Fraser rivers. It consists chiefly of phyllite, argillite, conglomerate, and greywacke, which are thinly bedded or laminated and steeply dipping. In most places, rounded ridges and summits have developed upon these rocks, but some fresh glacial forms persist, as at Kwoiek Needle. On ridge crests and summits, linear groove-like features, which resemble glacial lineations, have developed parallel to the bedding or foliation.

Cascade Mountains

The Cascade Mountains lie east of Fraser River and south of Thompson River and are delimited along their eastern margin by a geological contact that roughly is followed by Nicoamen River and Prospect Creek (Fig. 1). Within these mountains, topography is less rugged and slopes are less steep than in the Coast Mountains. Summit elevations lie between 1700 and 2100 m, and relief varies locally by approximately 750 m; mean valleyside gradients vary from 375 to 525 m/km.

The topography of the mountains is that of a dissected plateau. Mountaintops and ridge crests are undulating or gently sloping (although irregular in detail) and are separated from valleysides by a prominent break of slope. The upland consists of remnants of a Late Miocene erosion surface that has been recognized in many parts of British Columbia. It forms the present surface of the Interior Plateau but persists only as accordant summit levels across the Coast Mountains. It was formed by subaerial erosion and then elevated and warped during the Early Pliocene (Mathews, 1968, 1976).

Glacial troughs and cirques are incised below the upland surface, but are shallower and not as well developed as features in the Coast Mountains. Arêtes are poorly formed, and horns are absent. Cirques are restricted to the northerly and easterly facing rims of higher plateau remnants such as Mount Lytton, Jackass-Kanaka Mountain and Mount Hewitt Bostock. Glacial troughs occur only in the central part of the mountains (Fig. 4).

Within Lytton map area, the Cascade Mountains consist mainly of coarse textured granodiorite and quartz diorite of the Mount Lytton Batholith. These plutonic rocks exhibit conspicuous joints, particularly at the northern end of the range on Mount Lytton where they have been emphasized by glacial erosion (Fig. 5).

Fraser Valley

Throughout its length in the study area, Fraser Valley lies along a major linear structure, the "Fraser River fault zone" (Duffell and McTaggart, 1952). Overall movement along several subparallel faults has elevated the Coast Mountains relative to the plateau and mountain areas that lie to the east. The fault zone itself consists of a graben that is floored by Cretaceous rocks. The steeply dipping bounding faults are reflected in the long, steep mountain slopes that confine Fraser Valley (Frontispiece). There is geological evidence for post-Eocene movement along the faults, and movement probably also occurred during Late Miocene to Early Pliocene time in conjunction with differential uplift of the Miocene erosion surface. There is no evidence of movement along these faults during the Quaternary Period.

Figure 4
View towards Mount Hewitt Bostock illustrates terrain typical of the central Cascade Mountains. Cirques and glacial troughs are incised below remnants of an upland surface (skyline). The area is underlain by granodiorite of Mount Lytton Batholith which gives rise to joint-controlled topography and to coarse frost-shattered debris. (GSC 202992-F)

Figure 5
End-on view of roches moutonnées and ice abraided ridges on the summit plateau of Mount Lytton, Cascade Mountains. Ice flowed towards this viewpoint. Glacial lineations parallel a series of major joints in granodiorite and diorite of Mount Lytton Batholith. (GSC 202992-G)

Clear Range

The Clear Range of the Fraser Plateau occupies the north-central part of Lytton map area (Fig. 1). Its topography is that of a severely dissected plateau, with summit elevations of 1500 to 1800 m. Remnants of the erosion surface form undulating uplands in the central parts of the range, but around the margins these have been consumed and replaced by narrow interfluves as the result of headward erosion by the short, steep tributaries of Fraser and Thompson rivers. The Scarped Range is one of these rugged marginal areas (Fig. 6). No alpine glacial landforms are present in the Clear Range within Lytton map area.

Local relief is greatest alongside major valleys where elevation differences of 1200 to 1500 m occur over horizontal distances of 5 to 6 km, and slopes with mean gradients of 475 m/km are typical. Valleysides are comparatively gentle within the central part of the range (285 to 375 m/km), and local relief is about 600 m (Fig. 7).

The western part of the range is underlain by the northern tip of the Mount Lytton Batholith. The plutonic rocks consist chiefly of granodiorite and quartz diorite but contain localized areas of gabbro and related basic rocks and abundant inclusions. A zone of albite granite, attributed to hydrothermal alteration, extends along the western side of Botanie Mountain and contains numerous zone of brecciation (Duffell and McTaggart, 1952, p. 90). These appear to be susceptible to weathering since a deep surface mantle of rotten granite (grus) is present on the south side of the southern peak of the Botanie massif. Active gullying of this material is progressing in the headwaters of Seven Mile Creek on the western side of the Botanie ridge.

Most of the remainder of the Clear Range is underlain by Lower Cretaceous volcanic rocks of the Spences Bridge Group. These are lavas and pyroclastic rocks that are lithologically variable, but consist predominantly of andesite, dacite, and breccia. Dips are generally low, and in many places stratification is close to horizontal. Structural scarps are present along the steeper parts of some valleysides. At the southern end of the Scarped Range a steep, actively mass-wasting slope overlooking Thompson River is cut in schist and gneiss.

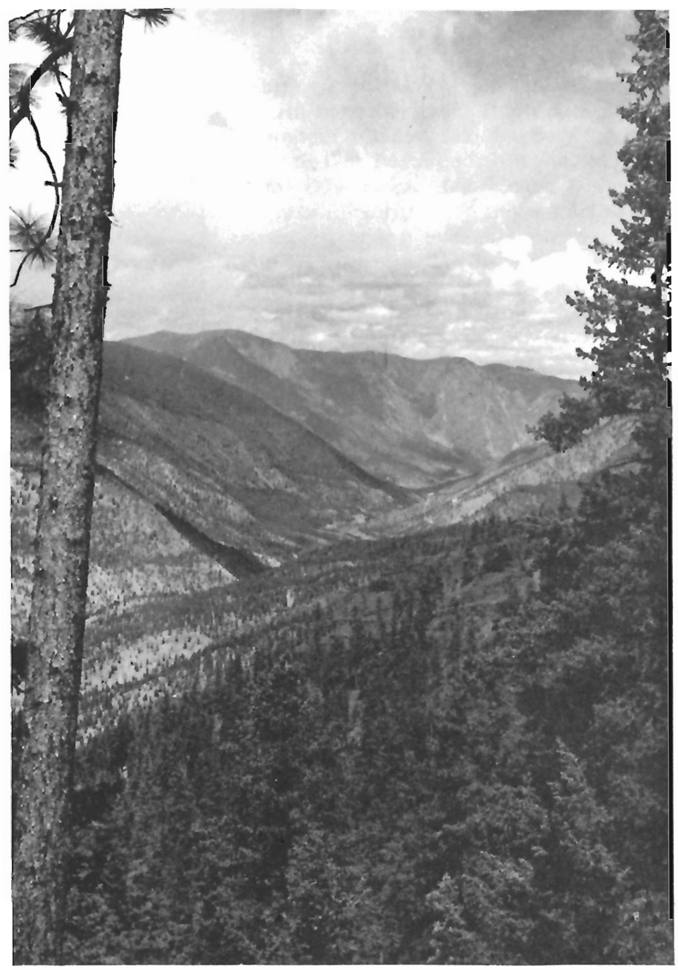

Figure 6. *View northwards along Thompson Valley between Nicoamen River and Skoonka Creek. The far (western) valleyside is the steep eastern edge of the Scarped Range, the dissected rim of Fraser Plateau. Steep slopes consist of rock or colluvial blanket. In the centre of the valley, the level or gently sloping surface of valley fill materials and alluvial fans is visible. (GSC 202992-H)*

Figure 7
View southwards through the Izman-Laluwissin col in the central Clear Range. The valley floor consists of till plain and undulating till (Mp, Mm) bordered in places by alluvial fans (dAf). Valleysides are relatively gently sloping and consist chiefly of till blanket (Mb). (GSC 202992-I)

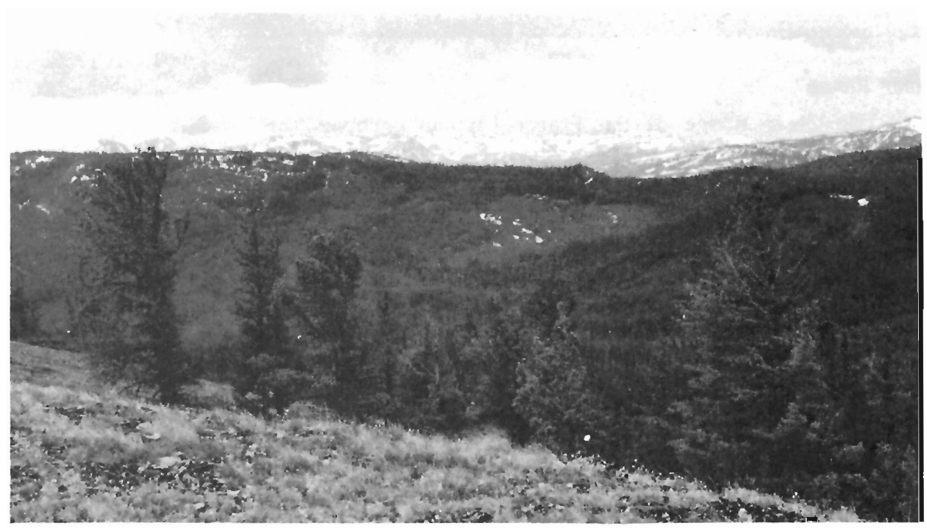

Figure 8
View to Cascade Mountains from Mimenuh Mountain. Tree-covered areas in the foreground and middle distance are parts of the dissected Nicoamen Plateau. Scarps and valleysides are partially controlled by structure. Snow-covered terrain is the central part of the Cascade Mountains. This view illustrates the contrasting types of dissected plateau that constitute these two physiographic regions. (GSC 202992-J)

Thompson Plateau

Thompson Plateau, in the eastern part of the map area, (Fig. 1), is physiographically similar to the dissected plateaus of the Cascade Mountains and Clear Range. Eastward from those areas, however, the upland surface gradually decreases in elevation and incised valleys become shallower. Thompson Plateau is thus relatively low and of relatively slight local relief (Fig. 8). The undulating plateau surface ranges between 1200 and 1675 m elevation with higher eminences here and there rising to more than 1825 m. The surface is undissected between Pimainus Hills and Highland Valley and constitutes a distinctive physiographic subunit which will be referred to as "Pimainus plateau". Major lines of drainage (Thompson, Nicola, and Nicoamen rivers and Spius Creek) are incised 900 to 1200 m below the surface of Thompson Plateau, and their valleysides meet the upland surface along a prominent break of slope. Valleyside gradients are typically about 375 m/km. There are no alpine glacial landforms.

The Nicoamen* Plateau subunit of Thompson Plateau is underlain by the Lower Cretaceous Kingsvale Group, which consists of a succession of basaltic and andesitic lavas with agglomerates, tuffs, and breccias of various textures. The flows are generally close to horizontal and outcrop as structural scarps along the upper part of valleysides, thereby emphasizing the plateau surface-valleyside break of slope. Good examples of structural scarps are present on a prominent ridge that lies north of Pole Gulch and east of Teepee Creek, and along the western side of Platt Creek. The Kingsvale volcanics overlie a sedimentary sequence which outcrops as a belt 1 to 2 km wide along the southwest side of Nicola Valley.

An 8 km wide zone of Spences Bridge Group volcanic rocks lies along the northeastern side of Nicola Valley. Adjacent, to the northeast, the Pimainus plateau is cut in granodiorite, quartz diorite, and quartz monzonite of the Guichon Creek Batholith (Northcote, 1969). Structural lineations such as joints (and probably also faults) are marked by long, narrow depressions and stream gulleys on the exposed surface of the batholith. Many of these are several kilometres long and transect prominent ridges. Their orientations are widely divergent, but one set of features is aligned parallel to ice flow direction (azimuth 135° to 145°) and has given rise to the development of roches moutonnées and other streamlined rock knobs.

* Map 1511A shows the spelling as Nicomen Plateau

CLASSIFICATION OF SURFICIAL MATERIALS AND LANDFORMS

Terrain units are delimited according to the character of the surficial material. Materials are divided initially according to their mode of origin (genesis), and then further subdivided on the basis of texture and surface expression (landform). Surface expression is classified by a simple morphological system which employs descriptive terms such as "plain" and "fan". Some landforms and surficial materials are undergoing (or have undergone) modification by geomorphic processes other than those by which they were originally formed. These are indicated by the use of a modifier term such as "gullied" or "avalanched" where appropriate.

Compositional Categories - Genetic

Morainal, Till (M)

Morainal deposits are the most widespread surficial material within Lytton map area. Most areas mapped as "drift" (see below) are chiefly till. In general, till covers gently to moderately sloping surfaces except those at low elevations within major valleys (where till has been eroded by rivers or buried by deposition of postglacial sediments). Recent (Neoglacial) moraines occur in some Coast Mountains cirques, but all other morainal deposits shown on Map 1511A date from the final Pleistocene glaciation the Fraser Glaciation (Armstrong et al., 1965).

Within the steep terrain of the Coast Mountains, till is restricted to valleysides of relatively low elevation and gradient. On many slopes of intermediate elevation and steepness, till underlies avalanche deposits and rubbly postglacial colluvium. On the higher parts of the upland surface in the Cascade Mountains, small shallow patches of till occur within rocky areas. Till is thicker and more continuous on lower spurs, rounded ridge crests, and along some moderately steep valleysides such as the western side of the northern branch of Mowhokam Creek (6.5 km east of Kanaka Mountain). Till covers most gently sloping uplands in the Clear Range, although it is patchy or absent from higher summits such as Botanie Mountain. It also remains on some steep slopes within this range and occurs as plains, mounds, and ridges on valley floors. On Thompson Plateau the till mantle is extensive and continuous.

On the upland surface in general, till thickness is variable. It generally is thin or absent on crests and convex slopes and thickens in depressions and on concave slopes. Typical thicknesses range from less than 1 m to about 6 m, although greater thicknesses probably occur locally. Where till is present within major valleys, its thickness is extremely variable. Lens-like masses of till that are as much as 30 to 60 m thick lie along the eastern side of Thompson Valley near Pimainus and Inkikuh creeks. These "lenses" pinch out abruptly against bedrock valley walls to the east and terminate to the west as outcrops on the steep banks of Thompson River.

Texture of till varies with texture of the bedrock or older unconsolidated deposits from which it was derived. The granitic rocks of the Coast and Cascade mountains and Pimainus plateau have given rise to coarse tills that are pale grey to white. They consist of subrounded boulders and cobbles, set in a matrix of gritty sand and minor silt. Bouldery till is especially prevalent on Pimainus plateau. Volcanic rocks of the Clear Range, Nicoamen Plateau, and the northeastern side of Nicola Valley have produced fine textured tills with silt and clay matrix and chiefly pebble-sized clasts of a variety of lithologies; these tills are typically dull reddish-brown to pale red. In places, tills with bedrock-derived characteristics are found within the main valleys, as for example near Spintlum Creek and at Kanaka Bar in Fraser Valley where till is of Coast Mountain provenance. More typically, however, the valley till of the last glaciation appears to be a mixture of interglacial valley sediments such as lacustrine silts and fluvial gravels. Its matrix is a poorly sorted sandy silt that constitutes 20 to 75% of the till by volume. Most clasts are rounded pebbles or small cobbles. The till ranges from white to light brownish grey.

Recent moraines in Coast Mountains cirques consist of angular fragments that vary in size dependent upon the character of the local bedrock. Blocks up to 1 m across or larger comprise moraines in granitic terrain at the head of Kwoiek Creek.

Drift (D)

This is a general term that may include any type of unconsolidated material. It is used in areas of no ground access where airphoto interpretation alone provides insufficient information for more specific identification of materials. It is also used where many different materials outcrop in close proximity and cannot be separated due to limitations imposed by map scale; examples are found along high river banks in Fraser Valley where a layered sequence of several different materials is exposed.

Most upland and valleyside areas mapped as drift are, in fact, probably till; (this was assumed in the foregoing description of till distribution). Small areas of fluvioglacial materials, recent alluvium, and lacustrine sediments also are present within drift areas.

Alluvial, Fluvial (A)

This category includes both postglacial fluvial deposits and lateglacial outwash. These materials are restricted to linear zones along valleys and include floodplains, terraces, and alluvial fans. Terraces and fans ocur up to 60 to 90 m more above present river levels. Fluvial materials are moderately to well sorted and consist chiefly of bedded gravel with interstitial sand. Clasts are rounded or subrounded and vary in size from pebbles to boulders. Sand (and minor silt) commonly is interbedded with the gravel.

Fluvial gravels that predate the last glaciation outcrop in river banks and roadcuts along Fraser Valley and in Thompson Valley between Lytton and Spences Bridge; these gravels are more than 100 m thick. In Thompson Valley they are visually impressive and form a prominent feature of the valley landscape. However, because their areal extent is small and because they are overlain by younger materials, they do not appear as a map unit.

Fluvioglacial (A^G)

Materials mapped as fluvioglacial are gravels and sands that were deposited in contact with glacier ice by meltwater. They include the materials of kames, kame terraces, eskers, and crevasse fillings. Sections in fluvioglacial gravel generally display features such as faults, slump structures, and otherwise irregular bedding resulting from collapse and settling as retaining ice melted. The gravel may be bedded or massive, sorted or nonsorted. Clasts are generally rounded or subrounded, but the larger clasts in particular are not as rounded as those in fluvial gravel.

Fluvioglacial materials are extensive in Highland Valley and occur in cols of Thompson Plateau and Clear Range. Small patches of late glacial ice-contact gravel occur here and there within Fraser, Thompson, and Nicola valleys but generally are too small to appear as map units.

Lacustrine (L)

This term is applied to sediments that accumulated in lakes by settling from suspension. Gravelly deltaic sediments are classed with fluvial deposits which they resemble texturally and topographically, since their mode of deposition was most strongly influenced by fluvial processes. Lacustrine materials were deposited in proglacial lakes during final deglaciation. Late glacial lake history for the Thompson and Okanagan basins has been outlined by Fulton (1969). During deglaciation, proglacial lakes within the map area occupied large parts of Nicola, Fraser, and Thompson valleys. Lakes also were ponded in some tributary valleys, such as those of Botanie Creek and Nahatlatch River. Older lacustrine materials that underlie till of the last glaciation are also present but do not constitute mappable units.

Lacustrine sediments are mostly silts and fine sands that consist chiefly of fragments of quartz and feldspar. They are typically laminated or thinly bedded, although zones of massive silt occur in some locations. Ice-rafted clasts commonly are present. Bedding is close to horizontal but is locally disturbed by slump structures.

Lacustrine silt is best exposed in Thompson Valley in the general vicinity of Spences Bridge and in Nicola Valley near Dot. At the latter site, varved silt occurs that resembles the South Thompson silts described by Fulton (1965). Lacustrine sand occurs in Fraser Valley south of Lytton. At many locations the silt and sand are overlain by fluvial terrace gravels and alluvial fans. Consequently, lacustrine silt appears much more limited in extent on Map 1511A than it actually is on the ground.

Lacustrine materials vary in thickness, generally being thickest in mid-valley locations and pinching out laterally against valleysides. At Spintlum Creek in Fraser Valley, lacustrine silts are 120 m thick, but elsewhere, thicknesses of up to 30 to 60 m are typical.

Colluvium (C)

This category includes most postglacial accumulations of mass wasted materials. Not included are thin coverings of slopewash or materials undergoing soil creep such as occur on most slopes on unconsolidated materials.

Colluvial deposits include a variety of materials and landforms ranging from mudflows and talus to major landslides. These are dealt with individually in the descriptions of terrain units that follow.

Organic (O)

Numerous depressions that are sites of organic sediment accumulation occur within the map area. They are typically less than 0.5 km in diameter, and thus most are too small to be mapped. Many depressions also contain lakes.

Ice-scoured rock basins constitute the most common type of enclosed depression and are scattered throughout the area. They are common within valleys of the Coast Mountains and on the upland surface in the Cascade Mountains and Thompson Plateau, particularly the Pimainus plateau. Kettles and other depressions where drainage is impeded by morainal or fluvioglacial deposits are common close to drainage divides in cols; the area around Quiltanton Lake in Highland Valley and the Turnip Lake Pasulko Lake region in the Clear Range are examples of this type.

Organic sediments consist of peat, commonly interlayered with thin beds of sand or silt. The surface of organic areas is flat or slightly domed and seasonally flooded.

Eolian (E)

Eolian deposits mantle many terraces and fans along Fraser, Thompson and Nicola valleys. The material is coarse silt or fine sand that is typically well sorted and massive.

Eolian materials were derived by winnowing from floodplains at times of low river discharge and from unconsolidated sandy or silty sediments exposed in river cutbanks. It is likely that eolian processes were most effective during the Hypsithermal (Alley, 1976) when warmer and dryer conditions may have caused reduction in vegetation cover. Yet some eolian activity continues at present and may be observed on windy days, particularly in the area around Lytton.

Bedrock (R)

This category applies to bedrock outcrops or sites where rock is covered by only a thin mantle of drift or colluvium.

Compositional Categories - Texture

The texture of surficial materials is defined according to Wentworth size classes:

		Size (mm)
b - bouldery:	abundance of boulders in a matrix of gravel and coarse sand	>256
g - gravelly:	cobble and pebble gravel, commonly with sand matrix	4 - 256
s - sandy:	granules and sand	0.0625 - 4
f - fines:	silt and clay	<0.0625
d - diamiction:	a heterogeneous mixture of all sizes ranging from clay to gravel or boulders	
r - rock fragments: (rubble)	angular fragments derived by mechanical weathering of bedrock and ranging in size from gravel to large boulders (blocks)	

Texture of surficial materials is not shown for every terrain unit. It is omitted where texture could not be reliably determined either on the ground or from airphoto interpretation and where a certain texture is invariably associated with a specific terrain unit or landform. In either case, the reader is referred to material descriptions in the map legend for textural information.

Landform Categories – Morphologic Expression

Plain (p)

This term describes flat surfaces that are either horizontal, such as a lacustrine plain, or have an imperceptible (less than 3°) uniform inclination in a constant direction, such as a floodplain.

Undulating (m)

This term is used to describe gently undulating terrain with variable slope directions and gradients of up to approximately 10°. This category is intermediate between "plain" and "hummocky". Undulating terrain that consists of parallel low ridges and depressions of glacial origin is indicated by the use of appropriate symbols (e.g. drumlins, glacial lineations).

Hummocky (h)

Terrain of this type consists of small but steep-sided hillocks and hollows. Local relief may be the same as in "undulating" terrain, but locally slopes are steeper and reach up to about 30° on unconsolidated materials and up to 90° on bedrock.

Ridged (r)

Small, steep-sided, markedly linear features such as eskers and moraines are included within this category. These features are shown by on-site symbols on the map if they are sufficiently large to be mapped individually.

Terraced (t)

This term is used to describe terrain that consists of flat (0-3°) elements that are bounded abruptly by scarps. It is used to refer to both single and groups of features.

Fan (f)

This is a sector of a cone with gradient generally less than 15° (but in places as high as 25°) at the apex and decreasing towards the toe. This category also includes bajada-like areas of coalescing fans that form a continuous piedmont at the foot of a scarp slope.

Apron (a)

This term is used to describe talus and similar forms that constitute relatively gentle slopes at the foot of steeper slopes and have surface gradients within the range of 25 to 35°.

Veneer (v)

This is a thin mantle (less than 2 m thick) of surficial material with topographic expression directly controlled by the shape of the upper surface of the underlying unit. A veneer may be of variable thickness and may include pockets of deeper material and outcrops of the underlying unit.

Blanket (b)

This is a cover of surficial material that is thicker than a veneer but otherwise similar. It is thick enough to mask minor irregularities on the surface of the underlying unit, but generally conforms to the underlying topography. Outcrops of the underlying unit may be present, but will be less extensive than outcrops within a veneer.

Steep Slopes, Scarps (s)

This term is applied to steep (more than 30°) erosional slopes of bedrock or drift.

Complex (x)

This term is used to denote terrain consisting of several distinct and recurring landform units that are too small to map separately. A descriptive explanation of each complex is given in the section dealing with the description of map units and features.

Modifying Process Terms

Gullied (V)

This term is applied to terrain units that have been modified by gully development to the extent that approximately one-third or more of the original land surface has been removed. On hillsides and on scarp slopes in unconsolidated materials, the term is applied where many parallel or subparallel gullies have developed. These are typically V-shaped in cross-section and may be as much as 15 m deep. Some horizontal or near horizontal surfaces, such as fluvial and lacustrine terraces and alluvial fans, have also been dissected by gully development. These gullies formed along small watercourses that have become incised in conjunction with postglacial downcutting by major rivers. Such gullies are more widely spaced that hillside gullies and are considerable deeper (up to 100 m). Gullies are rarely formed on bedrock. Small alluvial fans or cones consisting of slopewash and mudflow deposits are found where gullies debouch onto comparatively level ground.

The process of gullying probably is continuing sporadically at present. Most gullies contain flowing water only during heavy rainstorms. Severe rains may produce mudflows if materials suitable for saturated flow are available. During spring 1974 many freshly deepened gullies and small mudflows were found in Thompson Valley near Spences Bridge. Meteorological records show that 25 mm of rain was recorded at Lytton on March 16, 1974 (mean total precipitation for March is 28 mm). This rainstorm probably caused the observed effects and thus gives a rough indication of the magnitude of event needed to produce gullying and mudflows in the present environment.

Soliflucted (S)

This modifier is applied where surficial material has undergone (and is probably still undergoing) downslope movement due to solifluction. Other periglacial processes, such as frost creep, and areas of patterned ground probably also occur within these units. Solifluction (as mapped) is restricted to alpine zones above timberline where morainal and colluvial materials are affected. Various types of solifluction lobes and terraces occur in these areas in accord with variations in slope gradients, amount and type of vegetation, and texture of surficial material.

Nivated (N)

This term is applied to terrain units that contain many hollows and depressions that are occupied by (and owe their existence to) semi-permanent snowbanks. It normally modifies bedrock, colluvial, and morainal units. Some units containing several small cirques that are too small to show individually are also mapped as "nivated".

Failing (F)

This term is applied to zones in bedrock or unconsolidated materials that are currently undergoing failure and display tension cracks, pressure ridges, or other evidence of instability or movement.

DESCRIPTION OF MAP UNITS AND FEATURES

Till Plain (Mp, Dp, bMp)

Small areas of till plain (drift plain) are located along the floors of valleys within the Clear Range (in the headwaters of Botanie, Skoonka, Laluwissin and Izman creeks) and on Pimainus plateau (Fig. 7). These areas are underlain by till that in places may be as thick as 15 to 30 m and masks any irregularities in the surface of underlying bedrock or unconsolidated material. The water table commonly is close to the surface in these areas in the Clear Range, and they are poorly drained, particularly in the spring.

Undulating Ground Moraine (Mm, Dm, bMm)

Undulating areas of till occur in several parts of the map area. Within the central Clear Range undulating ground moraine occupies linear zones within valleys. These are mapped either as parts of compounds units or as homogeneous units which cover areas as large as 5 to 8 km^2. An example is located in Botanie Creek valley around Botanie Lake. Depressions in These areas are poorly drained and may contain lakes or organic sediments.

Parts of the upland surface in the Clear Range and Nicoamen Plateau, and some open, gently sloping valley heads in the Cascade Mountains are covered by undulating till. On Pimainus plateau there are large areas of undulating, bouldery till interrupted by ice-abraided, streamlined rock hillocks. This area includes linear depressions which are poorly drained and which contain standing water where bedrock lies close to the surface.

Hummocky Ground Moraine (Mh, Dh, bMh)

This type of terrain is restricted to a few small areas. For example, it occurs in association with fluvioglacial deposits near cols and valley junctions in the central Clear Range. This till is gravelly and constitutes hillocks which rise abruptly to heights of 3 to 15 m. They are irregular or arcuate in plan and from 45 to 90 m across. The arcuate moraines have steeper north-facing slopes and may be small end moraines.

Terrain with Linear Glacial Features

Various linear glacial forms are indicated by on-site symbols on the map. Many occur on Pimainus plateau; they range from erosional features consisting entirely of bedrock (such as rock drumlins, roches moutonnées, and discontinuous grooves and ridges) through mixed rock and till forms (crag and tail, rock-cored drumlinoid ridges) to a few true (till) drumlins. The abundance of rock-controlled features here is due to the parallelism of one set of bedrock structural lineaments with glacier flow direction.

Elsewhere on Thompson Plateau linear glacial features are uncommon. There are a few examples of roches moutonnées near Soap Lake south of Spences Bridge. Roches moutonnées and short glacially scoured ridges and grooves occur on the Mount Lytton massif in the Cascade Mountains (Fig. 5). Glacial lineations are rare in the remainder of the map area.

Till Veneers and Blankets (Mv, Dv, Mb, Db, bMv, Mb-V, Db-V)

Till veneers and blankets are widespread east of Fraser River and on relatively gentle slopes in the Coast Mountains. Till generally rests directly upon bedrock, except on lower slopes along major valleys where till blankets may overlie older Quaternary sediments. Small areas of this latter type occur along the eastern side of Thompson Valley north of Nicola River and along the eastern side of Fraser Valley near Laluwissin and Izman creeks. Till veneers typically contain many rock outcrops and pockets of deeper till. On airphotos, bedrock structural features are visible in areas where rock is overlain by a veneer of till, but generally they are masked by till blanket.

Till blankets on valleysides are commonly gullied and flanked by small alluvial fans (Fig. 9). An example of terrain of this type is located along the northern branch of Izman Creek. Some gullies have downcut through the till blanket, exposing bedrock on gully floors. As gullies enlarge, more bedrock is exposed and the till interfluves shrink. It appears that till cover has been completely removed from some hillsides in this way. The north side of Skuhun Creek valley is one such area; the valleyside consists of rubbly colluvium and bedrock and overlooks a piedmont of alluvial fans.

Alpine Moraines and Other Moraine Ridges (rMv, rMb, Mr)

In high cirques of the Coast Mountains there are morainal ridges and ground moraine that are products of recent glacial activity. Most of these features are mapped as part of a cirque complex (R:Cx, described below). Some relatively large features are indicated as distinct units or by on-site symbols.

Figure 9
View in Nicoamen-Mowhokam col, Cascade Mountains. The hillside that is largely tree covered consists of gullied till blanket (Mb-V). Alluvial fans (dAf) emerging from the gullies have covered late glacial kame and outwash terraces. In postglacial time, streams have cut down 3 to 6 m into the older materials (foreground). (Photo D. Howes) (GSC 202992-K)

These moraines characteristically occur close to modern glaciers: moraines seldom are present in empty cirques. They mark the maximum extent of the most recent Neoglacial phase and probably date from the last one or two centuries. The moraines are most common around Kwoiek icefield and in Skihist, Nikaia, Stein, and Siwhe mountain areas. Both lateral and end moraines occur, and several large one consist of two or three (or more) ridges. The ridges are fresh, shar crested, and up to 60 m high (Fig. 3).

Ablation moraine (veneers and blankets) mantles the lower part of some glaciers. There is a gradation from features of this type to rock glaciers (described below). In some cirques, the former extent of a glacier is indicated by a smooth blanket of ground moraine which may have a fluted surface. Elsewhere, discontinuous rubbly veneers and scattered glacier-transported blocks occur within a recent trimline.

Several small moraine ridges are present on till-covered areas along the east side of Thompson Valley between Inkikuh and Pimainus creeks. The ridges are 1.5 to 3 m high, 50 to 150 m long, and asymmetric, with steeper sides facing north.

Drift Terraces (Dt, gDt)

Drift terraces are mapped along Fraser, Thompson, and Nicola valleys where they underlie alluvial fans and other postglacial materials. These terraces are the remaining parts of the upper surface of a thick valley fill of Pleistocene sediments. The valley fill is structurally and sedimentologically complex, because it represents several erosional and depositional episodes and includes a variety of materials. These are discussed in the section dealing with Quaternary history.

Steep Slopes in Unconsolidated Materials (Ms, Ds, $A^{G}s$)

Steep erosional slopes are mapped as terrain units if they are sufficiently extensive; alternatively, they are indicated by the use of the scarp symbol. These slopes are usually river banks or terrace scarps that have been formed as rivers and streams degraded into valley fill sediments (Fig. 10). Scarp slopes 90 to 120 m high are present along Fraser and Thompson rivers and lower scarps occur along Nicola River and smaller streams. The steepest parts of these slopes provide many excellent exposures of valley fill materials (Fig. 11). Commonly, however, slopes are slightly less steep than the angle of the repose and are covered by colluvial veneers. Many scarps are gullied. They may include rock outcrops and terrace remnants.

Kames ($A^{G}hm$), Kame Terraces ($A^{G}mht$), Eskers ($A^{G}r$, Dr), and Fluvioglacial Complex ($A^{G}x$)

Ice-contact fluvioglacial deposits were not specifically identified within the Coast Mountains. Throughout the remainder of the map area these features occupy scattered areas, but also occur in fairly distinctive locations. Chief amongst these are low cols where valleys are continuous across drainage divides (Fig. 12). The association of eskers, meltwater channels, and kames with such sites suggests that before deglaciation, hydrostatically controlled subglacial and englacial drainage went through these passes from one topographic drainage basin to the next. Subsequently, unequal ice levels on either side of the pass (and possibly a local ponding of meltwater on the upstream side) promoted subaerial drainage across it.

Figure 10
Thompson Valley at the mouth of Nicoamen River, view downstream. Nicoamen gravels are exposed in the foreground and in the bluffs (Ds) traversed by the railroad. The bench above consists of fluvioglacial gravels and alluvial fans; the house in the background (above train engine) is on a dissected fan. Thompson River is incised into bedrock here and farther downstream. During high discharge, river level is close to road level. (GSC 202992-L)

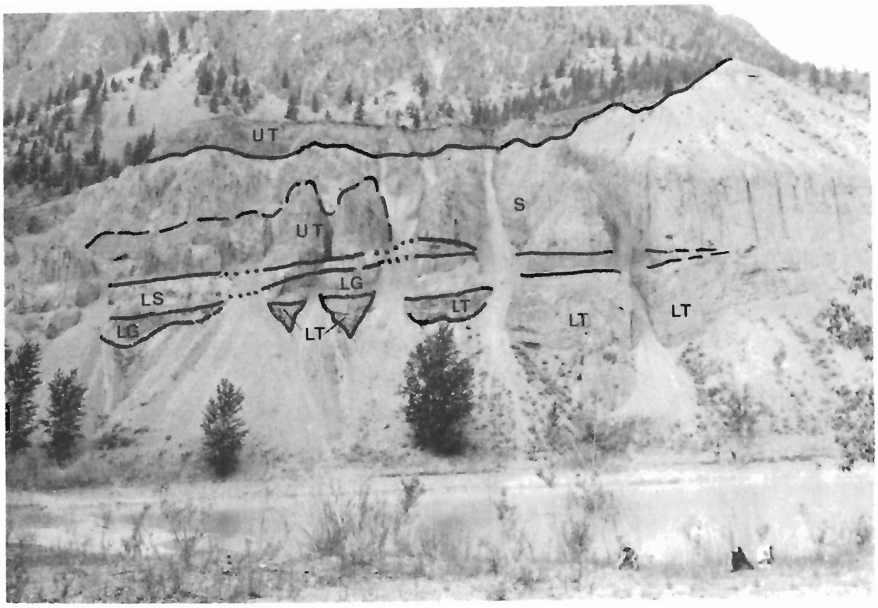

Figure 11

Quaternary sequence at Mud Lake near Spences Bridge:

UT = upper (Fraser) till;
S = silt of Lake Deadman Durand;
LS = lower silt;
LG & LT = lower till and associated gravels.

The upper outcrop of unit UT is topographically higher but stratigraphically lower than unit S. The lower outcrop of upper till is a slump block. Contacts are irregular but generally slope outwards at various angles, accounting for the apparent pinching out of some units in the sequence. Thin gravels which occur between lower silt and upper till are not shown.

The most extensive area of fluvioglacial materials occurs in Highland Valley, where the broad valley contains the headwaters of eastward draining (Witches Brook) and westward draining (Pukaist Creek) streams. Eskers, kames, kame terraces, and numerous meltwater channels are included within a "fluvioglacial complex" unit; materials here consist of gravel and sand. Kame gravels and small gravel eskers occur in and close to cols in the Clear Range. Kame terraces are mapped in the Nicoamen-Mowhokam (Fig. 9) col and in the upper part of Mowhokam Creek valley in the Cascade Mountains. Kames, eskers, kame terraces, and associated meltwater channels are widespread near Skuhost Creek in the eastern part of Pimainus plateau. Many other areas of fluvioglacial gravels occur, but are too small to show as map units.

Meltwater Channels

Meltwater channels are numerous on Pimainus plateau where three types may be distinguished: (1) Ice-marginal channels have gentle gradients and run across hillsides roughly parallel to contour lines. They commonly occur as a series of subparallel features that mark successively lower positions of the edge of downwasting ice. (2) Proglacial channels carried drainage away from the ice margin; they follow valley floors and generally contain small creeks. The largest meltwater channels are of this type, some being more than 30 m deep. (3) Subglacial channels are short and steep and plunge directly downslope or obliquely across slopes at a large angle. They are located on steep slopes around plateau margins overlooking the main valleys. Examples are present in the northern headwaters of Kloklowuck Creek, tributary to Nicola River.

Meltwater channels are steep-sided with flat floors and commonly are underlain by gravel. They may contain small lakes and pockets of organic sediments.

Isolated examples of proglacial and ice marginal channels occur in the Clear Range and Nicoamen Plateau. With the single exception of the Nicoamen-Mowhokam col, none are mapped in the Coast and Cascade mountains.

Eolian Veneers and Dunes (Ev)

A mantle of wind-deposited fine sand and coarse silt covers many terraces, fans, and other gently sloping surfaces along Fraser, Thompson and Nicola valleys. Eolian veneers are mapped, however, only where they were actually observed in the field, since it was not possible to identify them on aerial photographs. Consequently, the true extent of eolian veneers is probably much greater than that represented by the map.

Eolian veneers vary in thickness from 0.1 to 2 m. They are generally thickest close to the outer edge of terraces and fans and gradually become thinner towards the valleysides. Cliff top dunes occur on the edges of terraces where sandy Quaternary materials exposed in the terrace scarp are undergoing deflation. Eolian sands are thickest, and many dunes are present within 5 or 6 km of Lytton.

Floodplains (Ap, sAp, bAp)

Floodplains are not extensive in Lytton map area because downcutting has predominated along most rivers and creeks thoughout postglacial time. The Nicola is the only major river with a distinct floodplain. It is very narrow between the northern end of the valley and Gordon Creek, where it is mapped as part of the "Nicola Valley Complex" (A:Dx, described below). Between Gordon Creek and the eastern edge of the map area the floodplain broadens to its maximum width of 0.5 km and is flanked by low terraces. The floodplain is underlain by gravel which is partially covered by a sand veneer. Scroll patterns and abandoned channels mark the floodplain surface. Much of it is flooded regularly during the spring freshet.

The only floodplain that exists along Thompson and Fraser rivers is that composed of their cobble-gravel bars. These are of very limited extent, except along Thompson River upstream from Skoonka Creek where well developed alternating channel-side bars and some mid-channel bars are present.

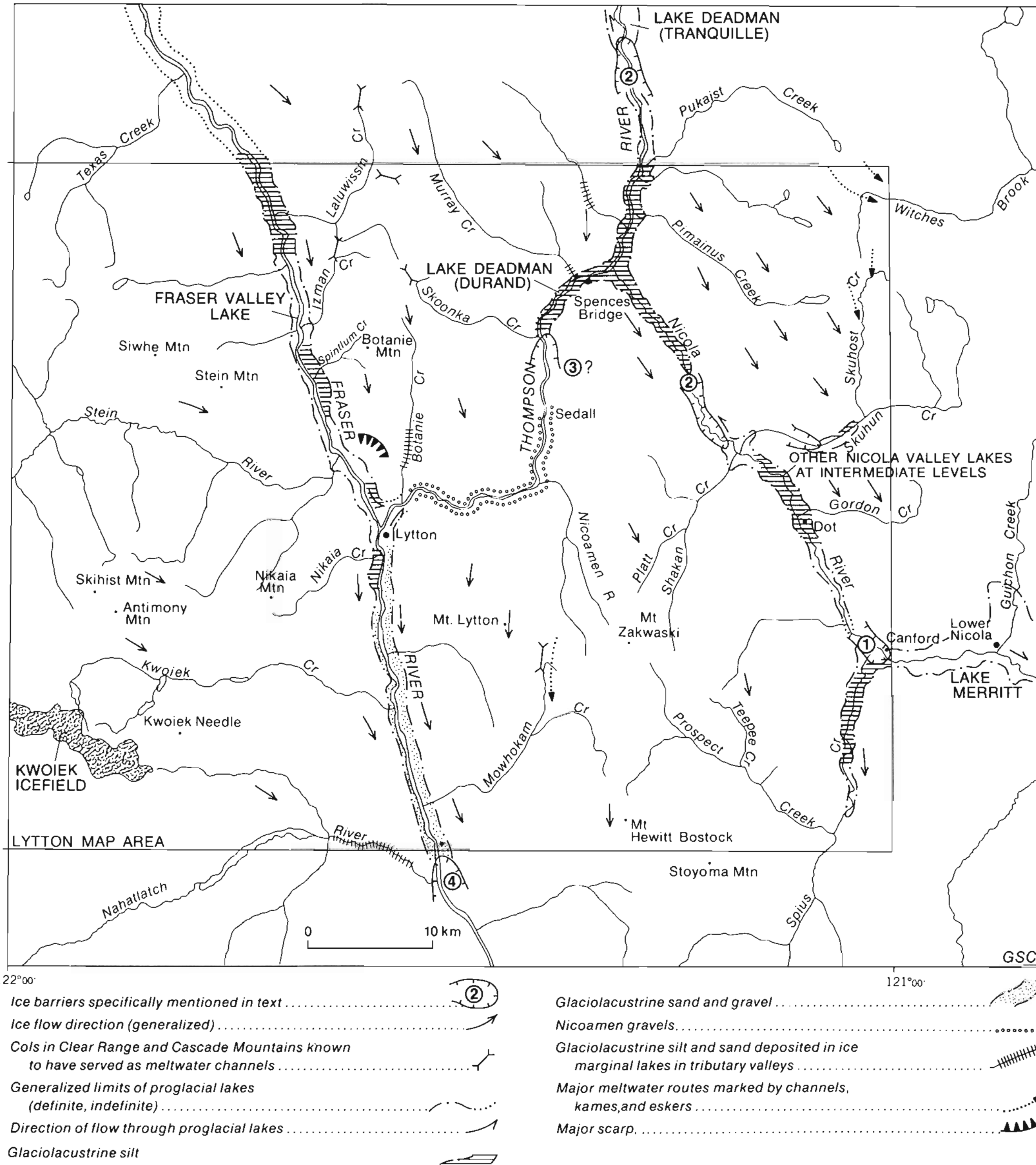

Figure 12. *Some features of Fraser Glaciation and deglaciation in Lytton and adjacent areas.*

Many large streams within the mountains and plateaus have reaches with narrow floodplains of cobble and boulder gravel. The relatively wide floodplain of Stein River, however, is the only one large enough to be shown as a map unit.

River Terraces (AT)

Terraces occur along major rivers and many of their large tributaries. They are highest along the Fraser where they occur at all elevations up to about 150 m above present river level. Along Nicola River most terraces lie within 30 m of river level. The number of terraces is not constant along a valley, and they are generally not paired. Terraces formed due to slow lateral shifting of rivers during constant degradation. A prominent terrace level occurs 45 m above river level in Thompson Valley. Three broad terraces occur on the west bank of the Fraser between Stein River and Lytton at 30, 52, and 90 m above river level (Frontispiece), in Spius Creek valley near its mouth, ten distinct terrace levels are preserved.

In general, terraces have been cut into valley fill deposits, although a few rockcut terraces were found. Terrace surfaces are level or gently rolling if old channel scars or low eolian dunes are present. Fluvial gravels occur as terrace cappings, unconformably overlying older drift. The cappings are from 1 to 12 m thick and consist of poorly bedded coarse gravel with rounded cobbles and boulders which are commonly imbricated.

Alluvial Fans (bAf, Af, dAf)

Many alluvial fans occur within Fraser, Thompson, Nicola, and Stein valleys. Fans are also common within some major tributary valleys, especially those of Skuhun, Botanie, Mowhokam, and Izman creeks. Large fans typically are perched upon valley-fill terraces (Fig. 10).

Diamicton fans are constructed chiefly of mudflow (debris flow) material and consist of thick beds of diamicton separated by thinner beds or partings of fluvial gravel, sand, and silt. The proportion of fines in both diamictons and fluvial materials increases towards the fan toe, where fan material may consist almost entirely of silt. Mudflow fans typically are located below steep, dry gullies in which debris flows occasionally are generated by heavy rainfall.

Fans described as bouldery or gravelly consist chiefly of fluvial material. Poorly bedded, bouldery gravel commonly occurs near the fan apex, but the material generally becomes finer downslope. Extremely coarse gravels containing boulders up to 2 m in diameter occur within fans along the western side of Fraser Valley near Nikaia Creek. Fluvial fans are associated with perennial streams, such as those draining from the Coast Mountains.

These two types of fans – mudflow and fluvial – constitute end members of a continuous gradational sequence; many fans contain both types of material. Those dominated by mudflows generally are smaller and steeper than those built chiefly of fluvial material.

Most large fans are now relict features with entrenched streams. Deposition still occurs sporadically on small steep fans throughout the area and upon large fluvial fans within the Coast Mountains, such as the fans that impound the lakes in Nahatlatch Valley.

Lacustrine Terraces and Scarps (Lt, Ls)

Sediments of proglacial lakes have been severely eroded by postglacial fluvial action and other processes of denudation. The lacustrine sediments that remain commonly are overlain by fluvial terrace cappings and alluvial fans. Consequently, most outcrops of lacustrine material occur in gullied terrace scarps. These are mapped as Ls, or as Ds if other types of drift are also exposed. Lacustrine terraces occupy small areas, are typically gullied, and are undergoing piping. Few are sufficiently large to comprise individual map units.

Talus Slopes (Ca, dCa)

Talus material (Ca) accumulates as cones, coalescing cones, and sheet talus beneath steep rock faces. These slopes consist chiefly of angular rock fragments (rubble) whose size is controlled by the spacing of joints or bedding planes in the parent rock. Thus talus material derived from plutonic rocks consists of blocks and boulder-sized fragments, whereas that derived from volcanic and metamorphic rocks is typically much finer. A matrix of silt, sand, and small rock fragments occurs below the surface of the talus. On individual slopes, clast size increases downhill, and the toe of the slope may be a zone of huge, scattered blocks. Talus slope gradients are normally close to 33°.

Mechanical weathering and mass wasting processes that produce talus slopes are most active at the present time above timberline in the Coast and Cascade mountains (Fig. 4). Talus slopes are also common along steep valleysides throughout the map area, although rates of accumulation at low elevations are probably much slower than in the alpine zone.

Mass wasted material derived from Quaternary sediments may comprise similar landforms (dCa), but differs in texture since clasts are relatively rounded and more fines are included (Fig. 11).

Colluvial Veneers and Blankets (Cb, Cv, Cv-S, Cb-S)

This is one of the most extensive terrain types. Mantles of colluvial material typically occur on relatively steep (20 to 33°) slopes that are steeper than those covered by morainal blankets and veneers. Colluvium is derived locally from bedrock and consists of a mixture of rubble and fines that is mechanically (and possiblly chemically) weathered (Fig. 6).

Colluvium on hillsides is most commonly mapped as composite units with bedrock or till. Witin such units there tends to be a typical arrangement of materials. In colluvium and rock units, rock generally is present upslope and colluvium downslope, by an irregular boundary zone where tongues of colluvium extend upslope between rock buttresses. In colluvium and morainal units, colluvium generally occupies upper and steeper parts of the slope, although colluvium may have moved downslope to overlie till at lower elevations. In general, both colluvium and till become thicker downslope. If gullies are indicated in either of these composite units, then tongues of colluvium likely occupy gully floors and interfluves consist of rock or till.

Landslides (Ch, Cm, fdCh, dChr-F)

In addition to the colluvial designators shown, R-F and Rs-F, in conjunction with the landslide scar symbol, in places are used to designate slide deposits in rock.

Rockslides in Coast Mountains

Several major rockslides were identified within the Coast Mountains: (1) a slide impounds a small lake 3 km south of Stein River on an unnamed creek that enters the Stein opposite Cottonwood Creek (rCmrb); (2) slide impounds a lake near the head of Siwhe Creek (rCmhv); (3) slide on east side of Texas Creek 5 km from the northern edge of the map area (part of Ca unit); (4) slide northwest of the main forks of Stryen Creek (rCmba); and (5) slide on south valley wall above Stein River 9 km downvalley from Cottonwood Creek (rC:Rs-F). This is very recent failure, and some movement is still occuring.

These slides are all on granodiorite and probably occurred due to failure along joint planes where the slide scars are located, high on the valleysides. Upon release, the slide debris flowed down the hillside until it encountered the opposite valley wall, where it was deflected downvalley. The distance travelled by the debris (mapped length of debris tongues) varies from 0.3 to 3.7 km. The material contains large blocks, and many of these are sufficiently large that they are clearly visible on airphotos.

Drynoch Landslide

A major active landslide - Drynoch slide - is located on the east side of Thompson Valley 8 km south of Spences Bridge. It has been described by Brawner (1960), Armstrong and Fulton (1965), Anderton (1970) and Van Dine (1980). It is a slow-moving earthflow (dChr-F). The toe is crossed by the Trans-Canada Highway and the Canadian Pacific railway, and consequently it has received attention from engineers. Stabilization measures (chiefly drainage) have been undertaken but have succeeded only in slowing the rate of movement. The Drynoch slide contains 1 670 000 m^3 of material and is from 136 to 1100 m wide and 6 km long. Two much smaller, but morphologically similar, slides are located north and south of the major slide.

The main slide is shaped somewhat like a glacier. It has longitudinal ridges and furrows along its margins, and open tension cracks as much as 7.6 m deep have been reported. A cross-profile of the lower part of the slide is convex, whereas the upper part of the slide is concave. It appears to be originating from several large shallow embayments at its head that are separated by promontories of stable rock.

The slide material texturally is a diamicton. It contains fragments of local rocks, including fragments from Tertiary coal measures which now outcrop over a small area high on the north side of the slide. The clay fraction is largely montmorillonite, probably derived from bentonite beds such as are common in Tertiary coal measures. The slide material probably also includes a large volume of till. It has been suggested by engineers of the British Columbia Ministry of Highways that the slide originated by slumping of the coal measures. Movement is maintained as a result of high porewater pressures (Brawner, 1960).

The toe of the slide rests on low fluvial terraces adjacent to Thompson River and overlies the Mazama tephra which was deposited 6600 years ago (Wilcox and Powers, 1964). Fragments of wood from the slide have been dated at 3175 ± 150 years (Fulton and Armstrong, 1965). These dates thus bracket the time when the slide toe reached its present position.

Landslides in Lacustrine Silts

Many landslides have occurred within lacustrine silts. Generally these are slumps and involve cohesive masses becoming detached from the scarps of lacustrine terraces and sliding downslope with backwards rotational movement. The largest of these within the map area is the Spences Bridge slide which occurred in 1905 on the north bank of Thompson River at the mouth of Murray Creek. It consists of an irregular mass of hummocky silt and gravel (fdCh) in front of a steep slide scar. The slide debris occupies an area 1300 m wide by 1000 m long. Deltaic gravels underlie the lacustrine silts and outcrop as a terrace above and behind the slide scar. Thompson River was temporarily dammed by the slide, and its level rose upstream by 20 to 25 m; within a few hours, however, the river had cut a new channel across the slide debris and resumed its former level (Anderton, 1970).

Several mechanisms have been suggested for this slide. It occurred after a period of heavy rainfall when Murray Creek was in flood. Irrigation was practised on the delta-terrace at this time. Undoubtedly it was excess water from one or all of these sources that percolated into the silt and induced high pore-water pressures, resulting in loss of cohesion. Irrigation water was probably a significant factor, since several similar slides near Ashcroft resulted from this cause (Stanton, 1898). Sliding also may have been aided by the outward-sloping basal contact of the silt and by sloping bedding planes within the silt near this boundary.

Similar slumps that have occurred in lacustrine silts and overlying colluvium extend for several kilometres along the north bank of Thompson River to the southwest of the Spences Bridge slide. On Map 1511 A these are represented by the fdCbh component of a composite unit. Several slumps have occurred in lacustrine silts along Nicola River, but these are too small to indicate on the map.

Avalanche Cones and Avalanche Slopes (Ca-A, Cb-A, -AV, -A)

The term "avalanche" as used here refers only to snow avalanches. Avalanche deposits are accumulations of rock debris transported by rapidly moving snow.

Mapped avalanche features are restricted to the Coast Mountains. Avalanches also occur in the Cascade Mountains and in the Clear Range, but they do not have a marked effect on landforms or vegetation patterns.

Avalanche features are abundant within the Coast Mountains, particularly on mountain slopes below ridge crests that rise above timberline into the zone where major avalanches are generated. Avalanches descend mountainsides either down gullies (-AV), which probably originate from a combination of erosion by avalanches, fluvial erosion during summer, and nivation, or down open slopes where their effects prevent tree growth and create avalanche tracks (-A). Rock debris transported by the snow is deposited as cones (Ca-A) at the foot of gullies or as a mantle of debris (Cb-A) overlying rock or morainal slopes. Avalanche cones have lower gradients than talus slopes (15 to 30°) and often carry surface water flow in steep channels during summer. Their surfaces consist of unstable rubble let down from melting snow, and little size sorting of clasts is apparent.

Rock Glaciers (Chrm, Cr)

A great variety of proglacial and periglacial features occur above timberline in the Coast Mountains. Most are included in cirque complex (R:Cx) map units (described below), but in places individual features are found which are large enough to map specifically.

Two types of rock glacier occur: (1) Ice-cored rock glaciers are debris-covered remnants of former ice glaciers. These are the "cirque-floor" rock glaciers of Outcalt and Benedict (1965). Several features of this type occur directly east and southeast of the peak of Stein Mountain. A rock glacier may merge upslope into a normal glacier of exposed ice. An example of this is located east of Siwhe Mountain where a rock glacier (too small to be indicated on the map) occurs between a glacier and the adjacent Mbr unit. (2) Rock glaciers occur at the foot of talus slopes. These are the "valley-wall" rock glaciers of Outcalt and Benedict (1965). They are rounded bulges, convex downslope, or low round-topped ridges which develop in front of talus slopes due to slow-flowage of debris. They contain interstitial ice.

Morphologically they can be similar to protalus ramparts. Features of this type are distributed throughout the alpine parts of the Coast Mountains.

Bedrock (R, Rs, Rr, Rh)

Bedrock outcrops are most extensive in the Coast Mountains (Fig. 3). They occur both on slopes that are steeper than the angle of rest of loose debris (rs) and on ridge crests. In the Cascade Mountains some parts of the upland consist of glacially abraided rock surfaces (Fig. 5). Steep rock slopes occur along deeply incised valleys within the Clear Range and Thompson Plateau and along major river valleys. Bedrock-controlled landforms are dependent upon the structure and weathering characteristics of the rock, as has already been described.

Cirque Complex (R:Cx)

This descriptor is applied to cirques in the Coast Mountains where a variety of landforms and genetic materials occur within a small area. Landforms in the complex include cirque headwalls (Rs), rock thresholds and other outcrops (R), colluvial veneers and blankets (Cv, Cb), talus slopes (Ca), cirque glacier moraines (Mr, rMvb), both types of rock glacier and glaciers. These landforms and materials commonly are affected by avalanching, nivation, and solifluction.

Nicola Valley Complex (A:Dx)

Along the floor and lower hillsides of Nicola Valley are numerous small but distinct terrain units which are too small to be mapped separately. A narrow, discontinuous floodplain (Ap) along the river is bounded by low terraces (At) which commonly have a thin covering of eolian sand or coarse silt. Alluvial fans (Af, dAf) have been built onto these terraces by deposition from large tributaries (e.g. Skuhun Creek, Gordon Creek) and from small steep gullies. There are also gullied benches and steep slopes of lacustrine silt (Lt-V, Ls-V). Parts of the lower valleysides are included in the complex and consist of colluvial and morainal blankets (Cb, Mb) and some small, steep rock outcrops (Rs).

QUATERNARY HISTORY

Most surficial deposits and landforms of Lytton map area were formed during and since Fraser Glaciation. They provide evidence for reconstruction of the sequence and pattern of late Quaternary events. Deposits which predate the last glaciation occur within Fraser and Thompson valleys. Together with younger drift, they constitute a valley fill of complex structure and stratigraphy. Abrupt lateral and vertical facies changes, interfingering of sediment from tributary and main valley sources, and many unconformities make correlations difficult, in some cases even between adjacent sections. For this reason, pre-Fraser sediments and chronology for the two main valleys are described separately.

Pre-Fraser Sediments and Chronology for Thompson Valley

Materials underlying Fraser till outcrop at many sites along Thompson Valley. In general, fluvial gravels predominate between Botanie and Skoonka creeks. Lacustrine silts, gravels, and an older till ("lower till") are the most common pre-Fraser sediments farther upstream. The chief sedimentary units and the sequence of events are described below and summarized in Table 1.

1. The oldest exposed material outcrops beneath lower till in a major eastbank section on Nicola River 3.2 km upstream from Thompson River. It consists of approximately 10 m of roughly horizontal, thinly interbedded silt and fine sand that is interpreted as lacustrine (or glaciolacustrine) sediment.
2. Lower till is exposed at the base of several sections near Spences Bridge (e.g. Fig. 11). Typically, it is thicker (12 to 46 m) than the upper (Fraser) till. Its character varies from place to place in accordance with its provenance. North of Spences Bridge it is a pale grey silty diamicton, probably derived from older Quaternary materials. Farther south, the till is extremely hard and compact and has a pale red, silt-clay matrix with clasts of volcanic rocks. Late glacial ice-contact gravels overlie lower till in some places. This till is considered to represent a major glacial episode.
3. In Thompson Valley near Spences Bridge and farther north, up to 90 m of silt and minor sand overlies lower till and associated gravel. This unit will be referred to as "lower silt". In some sections, the base of the silt is a gradational zone where till and silt are interlayered or where lenses of silt occur within the upper part of the till. In sections near Spences Bridge, a massive graded bed which is up to 8 m thick occurs at the base of the silt. The remainder of the unit is stratified, although visually it is dominated by strongly developed vertical joints. The silt is light grey and contains many ice-rafted clasts. It clearly represents late glacial lacustrine conditions. A gravel delta at Twaal Creek may be contemporaneous with the lower silt. Downvalley from Skoonka Creek, isolated pockets of silt and coarser lacustrine materials occupy the same stratigraphic position. Maximum elevations of these lacustrine sediments show that the lake surface was more than 470 m above present sea level.
4. Fluvial gravels that are exposed in roadcuts and riverbanks from Botanie Creek to Seddall lie between lower silt and upper till. They are best exposed in the vicinity of Nicoamen River (Fig. 10) where they are more than 150 m thick and are referred to here as "Nicoamen gravels". They consist chiefly of well stratified and moderately well sorted gravel and sand with both horizontal bedding and crossbedding. Structures indicate that flow direction was the same as that of modern Thompson River. A series of horizontal unconformities within the gravels are marked by landslide deposits (Armstrong and Fulton, 1965; Anderton, 1970) and by cobble and boulder horizons. These occur between 43 and 60 m above present river level and probably constitute a terraced, erosional surface that was formed between two episodes of gravel deposition. Gravels in the same stratigraphic position are exposed north of Spences Bridge near Pimainus and Inkikuh creeks. At Pukaist Creek (1.6 km north of Inkikuh Creek) two thick fluvial gravel units are separated by a wedge of boulder gravel which unconformably overlies the lower unit. The Nicoamen gravels thus represent two phases of fluvial aggradation with an intervening interval of degradation and terracing.
5. Poorly sorted and nonsorted gravels containing till inclusions overlie Nicoamen gravels. They are 30 to 45 m thick near Nicoamen River. This material is interpreted as advance outwash and other drift of Fraser Glaciation. At Spences Bridge and farther north, silt lenses and units of interbedded silt and till-like diamicton underlie and grade up into Fraser till. These probably were laid down in small ice marginal lakes that occupied tributary valleys during the Fraser ice advance.

Table 1. Stratigraphic units and sequence of events in Thompson and Fraser valleys and adjacent areas. Tentative correlations are intended only where indicated by horizontal lines.

Southwestern British Columbia (Armstrong, 1977)	Lytton Area Fraser Valley	Lytton Area Thompson Valley	Southern Interior British Columbia (Fulton and Smith, 1978)
POSTGLACIAL	Degradation and terracing, deposition of alluvial fans, colluvial and eolian material, and Mazama ash.		POSTGLACIAL
	Glaciolacustrine sediments and ice contact gravels	Glaciolacustrine sediments	
FRASER GLACIATION Fraser drift	Till	Till	FRASER GLACIATION Kamloops Lake Drift
		Ice-contact gravels and ice marginal silts (5)*	
OLYMPIA INTERGLACIATION Quadra and Cowichan Head Sediments	Erosional interval (?)	Upper Nicoamen gravel Fluvial degradation and terracing Lower Nicoamen gravel (4)	OLYMPIA INTERGLACIATION Bessette Sediments (depositional-erosional-depositional intervals represented)
	Glaciolacustrine sediments (3)	Lower silt (glaciolacustrine) (3)	
SEMIAHMOO GLACIATION ? Semiahmoo Drift	Glacial erosion ?	Lower till and ice-contact gravel (2)	OKANAGAN CENTRE GLACIATION Okanagan Centre Drift
HIGHBURY NONGLACIAL INTERVAL Highbury Sediments	Inkoiko gravel (2) (fluvioglacial)		WESTWOLD INTERGLACIATION Westwold Sediments
	Ice-contact gravel (1) and till	Lacustrine sediments (1)	

*Numbers refer to sediment descriptions in text

Pre-Fraser Sediments and Chronology for Fraser Valley

Pre-Fraser Glaciation sediments in Fraser Valley consist chiefly of fluvial and fluvioglacial gravels and lacustrine sand and silt. Till is uncommon within the valley fill; probably it was mostly eroded and redeposited as gravel by glacial meltwater and Fraser River. The chief sedimentary units and a tentative sequence of events are described below and summarized in Table 1.

1. The oldest exposed material in Fraser Valley consists of very coarse, nonsorted gravel which is 24 to 30 m thick. The gravel outcrops close to river level in major riverbank sections between Lytton and Intlpam Creek. Bedding within the gravel has been severely distorted by settling and slumping. Zones of compact, gritty diamicton occur within the gravel. These materials are interpreted as till and ice-contact gravel.

2. Finer textured gravel and sand that overlie and grade down into the ice-contact gravel extend throughout Fraser Valley within the map area. This material is well exposed in a large riverbank section at the mouth of Inkoiko Creek and will be referred to as "Inkoiko gravel". At Inkoiko Creek it consists of 30 to 45 m of stratified, poorly sorted gravel containing pockets of ice-contact sand and gravel, overlain by an approximately equal thickness of better sorted material containing thick beds of massive pebble gravel. Inkoiko gravel is interpreted as the result of prolonged outwash aggradation during slow deglaciation of this part of Fraser Valley and later fluvial aggradation. It is possible that more than one phase of aggradation occurred.

3. Lacustrine silt and sand overlie and are inset down into Inkoiko gravel throughout Fraser Valley. This structural relationship, together with the presence of ice contact features in the basal part of the lacustrine sediments, suggests that Inkoiko gravel was partially eroded during a glaciation which terminated in glaciolacustrine conditions.

Silt predominates in lacustrine sediments north of Lytton, whereas sand occurs to the south. Some lacustrine materials underlie fluviogracial gravel or a gritty diamicton that is possibly till. At other sites, silt or sand constitute the land surface and probably were deposited during the final (Fraser) deglaciation. South of Lytton there appear to be two lacustrine units separated by an erosional unconformity and pods of till. On the basis of these stratigraphic relationships and other observations, late glacial lacustrine conditions are considered to have occurred in parts of Fraser Valley in conjunction with both the penultimate and Fraser Glaciation. The lower lacustrine unit outcrops extensively in the Lillooet area of Fraser Valley (Ryder, 1976).

Pre-Fraser Chronology for Fraser and Thompson valleys is summarized in Table 1, and tentative correlations between the two valleys and between Lytton map area and adjacent areas also are indicated.

Fraser Glaciation

At the onset of Fraser Glaciation the high peaks of the Coast Mountains, especially the Kwoiek icefield area, functioned as an ice accumulation and dispersal zone. Advancing glaciers from troughs such as Stein, Kwoiek, and Nahatlatch valleys emerged into Fraser Valley and caused ponding and drainage diversions.

A prolonged phase of cirque and valley glaciation may have occurred at this time (Phase 1 of Davis and Mathews, 1944). Well formed troughs and cirques in the Cascade Mountains, cirques on relatively low peaks (e.g. Pyramid Mountain), and troughs in the Coast Mountains did not form during the Fraser Glaciation maximum, since the high ground upon which they are located was overridden by ice, and flow directions bore little relationship to local topography (Fig. 12). Retreat of Fraser ice was relatively rapid (Fulton, 1971), and there is no evidence that glaciers occupied Cascade Mountain cirques at any time after the Fraser maximum. Consequently the glacial landforms in question probably relate to an early phase of Fraser Glaciation.

During the glacial maximum, the Coast Mountains continued to function as an ice accumulation zone, but ice flowing eastwards off the mountains was deflected southwards by a broad southerly and southeasterly flowing ice stream that occupied the Fraser and Thompson plateaus and overrode the Cascade Mountains (Fig. 12). The distribution of erratics and striae show that the surface of the ice sheet stood at about 2400 m over this general area (Duffell and McTaggart, 1952; Wilson et al., 1958).

Ice erosion on the uplands produced rounded peaks and ridge crests, roches moutonnées, and other erosional landforms described earlier. The cirques on the highest peaks of the Coast Mountains, such as those that still retain glaciers, probably were enlarged at this time. At low elevations, erosion appears to have been greatest in broad valleys that trended parallel to ice flow. This is well illustrated in Thompson Valley where pre-Fraser Nicoamen gravels survived in that part of the valley that is constricted and transverse to ice flow (from Seddall to Botanie Creek). Pre-Fraser sediments in Thompson Valley north of Spences Bridge were eroded down to below present river level, unless sheltered in embayments at the mouths of tributary valleys.

A broad embayment in the eastern side of Fraser Valley opposite the mouth of Stein River probably was formed due to erosion of ice moving out of Stein Valley (Fig. 12).

Deglaciation of the study area occurred chiefly by downwasting in the Thompson Plateau, Clear Range, and Cascade Mountains, but probably by recession of glacier tongues in the Coast Mountains. During deglaciation, the ice surface sloped down eastwards from the Coast Mountains. Ice retreated generally from east to west, although the pattern of deglaciation was extremely irregular.

Downwasting of Fraser ice on the southern Interior Plateau has been described by Fulton (1967, 1975). As ice thinned, uplands were exposed whilst slow moving ice tongues remained in deep valleys. Later, stagnant ice and detached masses of inert (dead) ice remained at low elevations. Proglacial lakes were ponded in valleys that drained towards ice.

Features indicative of an early phase of downwasting, such as lateral meltwater channels, are common on Pimainus plateau, which was probably the first ice-free part of Lytton map area. Landforms such as eskers, kames, marginal and subglacial meltwater channels indicate that Highland Valley and the valley of Skuhost Creek contained stagnant ice masses during a slightly later stage of deglaciation. Features of this type, however, are not widely distributed in the Clear Range and are rare in Nicoamen Plateau. It is possible that meltwater drained across the ice surface during deglaciation of these areas.

An ice tongue remained in Nicola Valley as adjacent uplands became ice free. This ice impounded Lake Merritt (Mathews, 1944; Fulton, 1969) in the upper Nicola basin. The lake drained northwards to South Thompson valley near Kamloops. Its water plane has been deformed by isostatic tilting. At the Nicola River-Spius Creek confluence, the lake surface stood at approximately 760 m above present sea level (Fulton and Walcott, 1975). As the Nicola ice tongue receded downvalley, Lake Merritt extended westwards into the southeastern corner of Lytton map area. Lacustrine silt at elevations of up to 730 m in Spius Creek valley and slumped (ice-contact) lacustrine silt near Canford were deposited at this time (1 of Fig. 12).

Lake Merritt existed until melting ice in Nicola Valley no longer formed a water-tight barrier; drainage then escaped down Nicola Valley and into Thompson Valley near Spences Bridge. Ice remaining in these valleys at this time, however, still formed a partial barrier to drainage so that water levels fell slowly. Ice-contact lacustrine sand and silt between Clapperton and Skuhun Creek and lacustrine silts near Dot and in Skuhun Creek valley were deposited during this phase (2 of Fig. 12). Gravel and sand deposited in contact with melting ice underlie the lacustrine materials (Anderton, 1970).

The water level of the glacial lake in the Thompson-Nicola system stabilized next at 375 m a.s.l. (3 of Fig. 12). This has been termed the Durand Stage of glacial Lake Deadman and was the lowest and final phase of the glacial lake sequence in Thompson Valley. The lake occupied lower Nicola Valley and extended through Thompson Valley from Skoonka Creek to Bonaparte River, roughly 25 km beyond the northern edge of Lytton map area. Lake Deadman Durand drained eastwards through Thompson and South Thompson valleys to the Okanagan system. There is no measurable isostatic tilting on the Deadman-Durand shoreline. Lacustrine silts of this stage are prominent near Spences Bridge where they constitute a bench at about 365 m a.s.l. This "Spences Bridge silt" also extends up Nicola Valley as far as Kloklowuck Creek.

Late glacial lacustrine silt and sand in Fraser Valley occur up to 378 m a.s.l. Lake Deadman-Durand may have extended into Fraser Valley, or a Fraser Valley lake may have been connected to Lake Deadman-Durand by a low gradient river through lower Thompson Valley. In either case, Fraser Canyon must have been blocked by ice at this time. Thick deposits of lacustrine silt in lower Nahatlatch Valley (4 of Fig. 12) suggest that a lake was also impounded here by ice in Fraser Canyon. Late glacial sand, gravel, and minor silt have been traced down Fraser Valley as far south as Inkitsaph (Fig. 12). Sand predominates and commonly shows ice-contact features. A spectacular railroad cut exposure, 1.5 km south of Inkitsaph, shows ice-contact deltaic gravel dipping northward (Fig. 13). It is tentatively concluded that the northern edge of the ice barrier was a short distance south of the map area boundary, close to the mouth of Nahatlatch River.

Final drainage of Lake Deadman and the Fraser Valley lake occurred as ice melted from Fraser Canyon, and flow in the present downstream direction was established. This occurred prior to 9000 years ago (Fulton, 1969).

Postglacial Landscape Development

The final drainage of the proglacial lakes brought about the end of general sedimentation in the three major valleys of the Lytton area. In early postglacial time there was some minor aggradation of fluvial gravels in Fraser Valley, but degradation has dominated along the major valleys throughout the Holocene. Valley fill materials have been eroded, terraced, and dissected by the major rivers and their tributaries. Thompson River has cut down through the valley fill and is entrenched about 30 m into bedrock downstream from Nicoamen River. Fraser River similarly is entrenched south of Cisco. Elsewhere, Pleistocene materials appear to underlie the river beds.

Figure 13
Ice-contact delta foreset beds and massive gravels near Inkitsaph in Fraser Valley. Materials were deposited in a lake impounded by ice in Fraser Canyon. (GSC 202992-O)

Most terraces are non-paired and have resulted from lateral migration of river channels during continuous downcutting. Remnants of a persistent terrace level at approximately 42 m above present river levels, however, can be identified in Thompson Valley and in Fraser Valley near Lytton. The development of this feature may be attributed to local base level control by bedrock sills in Fraser River south of Lytton, such as at the canyon cut by the Fraser beside Cisco railroad tunnels.

Alluvial fans were constructed upon valley fill materials and postglacial terraces. Fan aggradation was most rapid shortly after deglaciation because drift of Fraser Glaciation was a readily available source of sediment (Ryder, 1971). Deposition of eolian silt and sand upon fans and terraces has occurred throughout the Holocene but was probably most effective before the establishment of postglacial vegetation and during the Hypsithermal. Processes of mass wastage, such as talus development, landslides, and accumulation of colluvial material on slopes, also may have been more active during early postglacial time than at present.

Mazama ash was deposited 6600 years ago (Wilcox and Powers, 1964). It occurs as a well defined, 15 to 40 mm thick bed in alluvial fans and eolian materials and provides a useful marker horizon. At Drynoch slide Mazama ash occurs within eolian silty sand that overlies fluvial gravel 16 m above river level, suggesting that most fluvial degradation occurred during the first one-third of postglacial time.

ECONOMIC GEOLOGY

Gravel and sand are readily available throughout the main valleys of Lytton map area. Because this area is remote from major settlement, however, granular materials are extracted for local purposes only and are used chiefly for highway maintenance. Pockets of fluvioglacial gravel in the uplands are utilized for forest road construction.

The roads and railroads which pass through this region are continually menaced by geologic hazards. Steep slopes have necessitated much excavation along routeways, and the resulting undercut slopes in both unconsolidated materials and bedrock often are subject to debris slides, rockfalls, and dry ravel. Slumps and flows occur in silty and clayey tills and lacustrine sediments at groundwater seepage sites and under conditions of heavy rainfall. Drynoch earthflow in Thompson Valley is a persistent problem. Rockfalls, debris slides, and snow avalanches commonly block the railroads and highway in Fraser Canyon for intervals ranging from several hours to a few days. Various means of slope stabilization and highway and railroad protection are being attempted. Slope instability is most common during winter and early spring when saturated ground conditions result from melting snow or heavy rainfall and temperatures fluctuate above and below 0°C.

The extent of agricultural land in Lytton map area is limited by topography and summer drought. In some locations, diversion channels have been built to carry water from streams to cultivated areas on terraces and fans. Most perennial streams, however, are deeply incised below the benchlands, and diversions are prohibited by steep terrain or require continual maintenance. The water table is deep beneath terraces and fans, and wells rarely are used for irrigation purposes. Irrigated benchlands are utilized for grazing, forage crops, and vegetable production. Eolian sand and silt have given rise to stone-free soils.

Logging operations are carried out in many parts of the mountains and plateaus. Steep slopes and unstable materials pose local problems.

The scenic route followed by the Trans-Canada Highway generates considerable tourist traffic, but recreational opportunities for highway travellers are limited, and facilities are poorly developed. The Coast and Cascade mountains contain many scenic wilderness areas suitable for hiking, climbing, camping, and related activities.

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