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SURFICIAL GEOLOGY OF SUMAS MAP-AREA, BRITISH COLUMBIA

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J. E. Armstrong

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By

J. E. Armstrong

DEPARTMENT OF

MINES AND TECHNICAL SURVEYS

CANADA

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SURFICIAL GEOLOGY OF SUMAS MAP-AREA, BRITISH COLUMBIA

INTRODUCTION

This report deals mainly with the geology of the surficial (unconsolidated) deposits of the Sumas area, British Columbia. The primary aim of the report, geological map and table of surficial deposits is to assemble the geological information needed in the industrial, agricultural and, to a lesser extent, forest development of the area. The general stratigraphic succession and geological history of the Pleistocene and Recent epoch, which are discussed briefly herein, will be dealt with more fully at a later date in a final report on the surficial geology of the lower Fraser Valley.

The field work for this report and map was done intermittently during years 1953, 1954 and 1955. The writer was assisted in the field by F.J. Allan, G.R. Murphy, T.E. Petrie, D.W. Brown, Jr., P.B. Read, R.W. Stuart, and H.G. Young. Pleistocene and Recent marine fossils collected were identified by F.J.E. Wagner. The field work consisted of the examination of all natural and artificial exposures such as stream and river banks, landslides, excavations, gravel and sand pits, drainage ditches, etc. This information was augmented by extensive digging and augering of shallow holes 3 to 20 feet deep. Much information, particularly south of the Fraser River, was also obtained from several thousand holes drilled and dug in search of ground water. The collecting of ground-water information was supervised by E.C. Halstead from 1954 to 1958. Separate ground-water reports have been or will be published. Wherever possible information was obtained from holes drilled for oil and gas exploration, or as foundation tests.

All information was plotted on maps scaled at 1 inch to 1/2 mile with a contour interval of 25 feet; from these the final geological map was constructed. Many of the geological boundaries on the map are gradational and only accurate to within 1/4 mile. Furthermore, map-units are to some extent generalized so that an area representing a certain type of deposit may contain small areas of other related types of deposits shown elsewhere by a different map-unit. No attempt has been made to study in detail the physical and chemical properties of the various materials discussed.

The writer wishes to thank all those persons and organizations who supplied information; without this help, some of the conclusions and correlations would not have been possible.

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PHYSICAL FEATURES

The region under discussion lies within two major physiographic divisions: namely, the Coast Mountain area and the Coastal Trough.

The Coast Mountain area is divided by the Fraser River valley into two unequal parts: Cascade Mountains southeast of the valley, and the Coast Mountains north of the valley. In the Sumas map-area the writer includes all the upland areas north of the Fraser River in the Coast Mountains, although some of them, particularly those with Tertiary bedrock cores should possibly be considered as distinct from the Coast Mountains and as part of the Fraser Lowland (see below). Two such hills in the map-area are Grant Hill, north of Whonock, and the hill northeast of Silverdale. The Coast Mountains consist of rugged mountains rising abruptly 5,000 to 7,000 feet above sea-level, separated by deep U-shaped valleys whose floors range in elevation from near sea-level to a few hundred feet above sea-level. Within the map-area the highest mountains are found in the northeast part, where they reach elevations of about 5,000 feet. However, immediately north of the map-area they are considerably higher. The principal mountain valleys in the area are Hatzic Valley and the valley occupied by Stave River and Lake.

Only a fringe of the Cascade Mountains occurs in the southeast corner of the map-area, where they rise to 3,000 feet, however, east of the map-area they rise to 7,000 feet or more. Mount Vedder on the southeast side of Sumas Valley, and separated from the main ranges by the Columbia Valley, should probably be considered as part of the Cascade Mountains. This mountain consists of an elongated northeast-trending ridge with a maximum elevation of 3,060 feet. Sumas Mountain on the northwest side of Sumas Valley should probably also be included with the Cascade Mountains. This is another elongated ridge with several distinct peaks, the highest more than 3,000 feet in elevation. By definition, Chilliwack Mountain comprises part of the Cascade Mountains. This is a low mountain west of Chilliwack with a maximum elevation of a little more than 1,200 feet.

The Coastal Trough lies between the Coast Mountain area and the Outer Mountain area of Vancouver Island. That part of the Coastal Trough within the map-area is called the Fraser Lowland. It is commonly referred to as the Lower Fraser Valley or the Lower Mainland and is considered by Bostock to be part of the Georgia Depression.

The Fraser Lowland consists of extensive low hills (in this report called uplands) ranging in elevation from 50 to 1,100 feet, separated by wide flat-bottomed valleys. In the Sumás map-area the Fraser Lowland includes one compound upland, namely the Langley upland, and several wide flat-bottomed valleys. The Langley upland occupies the southwestern part of the map-area, and consists of a core of unconsolidated deposits with rolling, hummocky surfaces of glacial till and glacio-marine deposits. But southwest of Abbotsford, it has a flat, terraced surface of glacial outwash. The maximum elevation in this upland is approximately 500 feet.

The flat-bottomed valleys forming part of the Fraser Lowland are as follows: (1) Glen Valley cut out by the Fraser River; (2) Matsqui Valley formed in part by Matsqui glacial lake and in part by the Fraser River; (3) Sumas Valley formed in part by former Sumas Lake (drained in 1926) and in part by an older channel of the Fraser River; and (4) the Fraser River itself which, in the vicinity of the eastern part of the map-area, joins with the Sumas Valley and has a maximum width of approximately 5 miles.

GENERAL GEOLOGY OF PLEISTOCENE AND RECENT DEPOSITS

In the Fraser Lowland surficial deposits cover the entire area. They are extremely varied and have thicknesses up to at least 1,105 feet. They occur as bodies differing in texture, form, and extent, that for the most part have been deposited by glacial ice or in streams, lakes, swamps and the sea. In Table 1 the deposits are classified according to their mode of deposition and age. This table shows graphically the complex interrelations and age of the surficial deposits; the oldest deposits are shown at the bottom of the table and the youngest at the top. Deposits shown along side one another indicate that they are of the same general age but were laid down in different environments. Note that the graphic representation illustrates, for example, that the Sumas glacial deposits (8-12) were laid down in part of the area at the same time as non-glacial Capilano deposits (5-7) were laid down elsewhere in the area.

In the Coast and Cascade Mountains the surficial deposits are much thinner and bedrock is intermittently exposed over widespread areas. However, even in areas of bedrock a thin mantle of glacial drift is the rule rather than the exception. The valleys in these mountains may and do contain glacial deposits up to several hundred feet thick in places. The map accompanying this report shows the generalized distribution of the deposits at and near the ground surface.

The term Pleistocene as used in this report refers to that epoch in the earth's geological history when large areas of the earth's surface were covered more than once by great glaciers, many thousands of feet thick. The epoch is estimated to have started sometime less than a million years ago. The last glacial age continued in the Sumas area to within about five to ten thousand years of the present. The term recent is used in this report to refer to post-Wisconsin time or present non-glacial time.

NATURE OF DEPOSITS

Pleistocene and recent deposits of the area consist of sand, gravel, varved clay and silt, stony silty clay and related till-like mixtures, till, and peat. (The terms clay, silt, and sand as used in this report are based on the diameter of the constituent particles and are used as follows: clay, less than 0.002 mm; silt, 0.002 to 0.05 mm; and sand, 0.05 to 2 mm.) The clays and silts of the Sumas area contain only a small proportion of clay minerals. They consist largely of fine particles of feldspar, quartz, and other common rock minerals. The sands consist largely of quartz and feldspar with lesser amounts of ferromagnesian and opaque minerals and rock fragments, the proportions varying from place to place. Varved silt and clay are glacial-lake deposits consisting of alternating light- and dark-coloured layers from a fraction of an inch to several inches thick. Glacio-marine deposits containing isolated sea shells are abundantly represented in the Sumas area. They are massive to stratified, soft plastic materials, ranging in size composition from silty clay to a clayey silt. Many contain no stones and very little sand and are normal sea-bottom muds; others (here called stony clay, clayey silt, and related till-like mixtures) contain a small percentage of sand, pebbles and boulders. Some of these appear to have been formed by submarine slumping or by reworking of glacial till by tides and waves. Most of the stony clays, however, are believed to be of glacio-marine origin and to have resulted from the mixing of debris, carried by floating glacial ice, with sea-bottom mud. Mechanical analyses of stony silty clays show that, exclusive of stones, they comprise on the average about 50 per cent silt, 40 per cent sand, and 10 per cent clay. However, in places this clay content might run as high as 50 per cent and the sand content less than 10 per cent. Many of these deposits are similar in appearance to glacial till.

The glacial tills in the area are compact, unsorted mixtures of sand, silt, clay, pebbles, and boulders which were deposited directly beneath glacial ice. Mechanical analyses of the fine fraction of representative samples of tills from the Fraser

Lowland within and adjoining the map-area yielded the following average results: Surrey till — 57 per cent sand, 41 per cent silt and 2 per cent clay; and Sumas till — 63 per cent sand, 33 per cent silt, and 4 per cent clay. The tills in the mountain valleys have a greater proportion of sand than tills of the same age in the Fraser Lowland.

Outwash (sediment deposited by streams issuing from glaciers) in this area consists mainly of interbedded sand and gravel deposited in deltas, flood plains and meltwater channels.

STRATIGRAPHY AND DISTRIBUTION OF DEPOSITS

The table of surficial deposits that accompanies this report is an attempt to show graphically the complex stratigraphic relations of deposits comprising the Vashon and post-Vashon groups. No attempt has been made to subdivide pre-Vashon deposits as they are exposed in one locality only. In the New Westminster map-area that adjoins the Sumas map-area on the west, pre-Vashon deposits are better exposed and their stratigraphic relations have been in part unravelled (Armstrong, 1957).

Drill-holes indicate that pre-Vashon deposits underlie much of the map-area and form part of the core of the uplands in the Fraser Lowland. The geological logs of four representative deep water-wells listed below illustrate the stratigraphic sequence in these uplands. These wells are shown on the accompanying map with the symbols W_1, W_2, etc.

W_1 — Log of well at Aldergrove Naval Base

(Elevation 358 ft.)

Depth (feet)		
0 - 46	Whatcom glacio-marine deposits (8)	
46 - 65	Huntingdon gravel deposits (5)	
65 - 251	Newton stony clay deposits (3)	
251 - 329	Surrey till (2)	
329 - 336	Sand and gravel	pre-Vashon (1)
336 - 356	Glacial till	pre-Vashon (1)
356 - 415	Sand	pre-Vashon (1)
415 - 465	Sandy clay	pre-Vashon (1)
465 - 484	Clay	pre-Vashon (1)

W_2 — Log of well at Kreiger's Hatchery, Trans-Canada Highway, 1 mile west of Aldergrove

(Elevation 390 ft.)

Depth (feet)		
0 - 110	Whatcom glacio-marine deposits (8)	
110 - 120	Huntingdon sand (5)	
120 - 260	Newton stony clay deposits (3)	
260 - 340	Surrey till (2)	
340 - 359	Gravel and sand	pre-Vashon (1)
359 - 371	Glacial till	pre-Vashon (1)

W_3 — Log of well at Clearbrook Village

(Elevation 220 ft.)

Depth (feet)		
0 - 23	Abbotsford outwash deposits (11)	
23 - 63	Whatcom glacio-marine deposits (8)	
63 - 65	Huntingdon sand? (5)	
65 - 80	Newton stony clay deposits? (3)	
80 - 97	Sand and gravel	probably pre-Vashon (1)
97 - 114	Clay with scattered boulders, possibly till	probably pre-Vashon (1)
114 - 210	Interbedded sand, silt, clay and minor gravel	pre-Vashon (1)
210 - 220	Gravel	pre-Vashon (1)
220 - 307	Clay and silt with scattered stones	pre-Vashon (1)
307 - 339	Semi-consolidated carbonaceous clay, probably Tertiary (R)	
339 - 475	Tertiary sandstone (R)	

W_4 — Log of well drilled for British Columbia Department of Agriculture, Emerson and Marshall Roads

(Elevation 222 ft.)

Depth (feet)		
0 - 17	Windblown sand (119)	
17 - 70	Sumas till (9)	
70 - 74	Huntingdon gravel deposits (5)	
74 - 88	Newton stony clay deposits (3)	
88 - 130	Sand, gravel, minor silt	probably pre-Vashon (1)
130 - 132	Glacial till	probably pre-Vashon (1)

The stratigraphy of the deposits underlying the major valleys is best illustrated by the four logs listed below.

W5— Log of well drilled for Department of Transport in Sumas Valley, near Sumas Airstrip

(Elevation approx. 25 ft.)

Depth (feet)		
0 - 3	Sand	Lacustrine deposits
3 - 9	Sand and gravel	
9 - 83	Silt, clayey silt, clay, and minor sand, contains decayed wood	probably Lacustrine deposits (13)
83 - 321	Clayey silt, silty clay, clay and minor silty sand	Probably Cloverdale sediments (see table)

W6— Log of well drilled for D. Brown, Sumas Valley, near Vedder Channel

(Elevation approx. 25 ft.)

Depth (feet)		
0 - 135	Silt and fine sand	Lacustrine and older deposits (13)
135 - 212	Silt, silty sand, and fine sand	
212 - 228	Silt, silty clay, clay, and fine sand	
228 - 410	Silty clay, clayey silt, silt, and fine sand	probably Cloverdale sediments (see table)
410 - 610	Silty clay, clayey silt, and clay	

W7— Log of well drilled for P.J. Cyr, Dewdney

(Elevation approx. 25 ft.)

Depth (feet)		
0 - 28	Clayey silt, and silty clay	Fraser floodplain and older deposits (15, etc.)
28 - 68	Sand, silty sand, and minor silt	
68 - 80	Sand, gravel, and minor clay and silt	
80 - 91	Fine sand	
91 - 98	Sand, siltyclay, and minor gravel	
98 - 125	Silty clay, clayey silt, sand, and gravel	
125 - 130	Sand	
130 - 132	Silty clay with wood	
132 - 141	Fine sand	
141 - 148	Fine sand, and clayey silt	

W8 — Log of well drilled for Catalina Farm, Matsqui Valley

(Elevation approx. 20 ft.)

Depth (feet)		
0 - 197	Clayey silt and silty clay	probably Fraser flood-plain (15), lacustrine (10) and Cloverdale deposits (see table)
197 - 300	Silty clay, clayey silt, and minor beds of sand, and silt	
300 - 328	Clay	
328 - 466	Silty clay, clayey silt, and minor beds of fine sand, and silt	
466 - 470	Sand and gravel	
470 - 480	Sandy clay	
480 - 504	Interbedded silty clay, clayey silt, silt, and sand	
504 - 535	Varve-like silty clay	
535 - 597	Silty clay, clayey silt, and minor fine sand	
597 - 600	Silty clay	
600 - 655	Clayey silt	
655 - 700	Clay and clayey silt	
700 - 750	Clay and clayey silt with marine shells	

The geological map accompanying this report shows the distribution of bedrock (R) at or near the surface. In the Langley upland and the Sumas and Fraser Valleys the depth to bedrock varies from a few hundred to more than 1,100 feet. Of the8 wells tested in the previous section only one reached bedrock. This was at Clearbrook where Tertiary (4) sedimentary rocks were found at a depth of 339 feet. The wildcat oil well west of Abbotsford airport intersected Tertiary (4) bedrock at 1,105 feet. A wildcat well in Sumas Valley was drilled to a depth of 864 feet and did not reach the bedrock. Apparently the pre-Pleistocene bedrock surface underlying the Langley upland and the major valleys is very irregular.

Pre-Vashon deposits (1) are exposed only on the north-east side of Grant Hill; however, such deposits apparently underlie all the Langley upland, and probably also underlie Sumas and Fraser River valleys.

Surrey till (6) is exposed in the area north of the Fraser and west of the Stave Rivers. Along and north of Dewdney trunk road this till has been shaped into drumlin-like ridges, which indicate movement of the Vashon ice from the north, off the Coast Mountains, south into Fraser Lowland. Drill records indicate that Surrey till underlies much of the Langley upland.

Newton stony clay deposits (3) are exposed at only two localities in the map-area; one is northeast of Mission City, near the Benedictine Monastery, and the other is northwest of Mission City, in the valley of a small creek. Newton stony clay deposits are widespread in the core of Langley upland. Possibly some of the deposits mapped as Whatcom glacio-marine deposits (8) are in fact Newton deposits, but in many places the writer has found it necessary to make rather arbitrary correlations based primarily on distribution and lithology and not on stratigraphy.

Haney outwash (4) is exposed only in the northwest corner of the map-area above an elevation of 500 feet.

Huntingdon gravel deposits (5) underlie most of Langley upland, but are exposed in only a few localities. A good section may be seen between Abbotsford and the United States border, along the western wall of the Sumas Valley. Another good area of exposures is found along the sides of Glen Valley. In the front slopes of the Coast Mountains, Huntingdon gravel is exposed in a number of places west of Hatzic Valley and north of Fraser River.

Sunnyside sand (6) and Bose gravel deposits (7) which are widespread in the New Westminster and Vancouver map-areas have very limited distribution in this area. Sunnyside sand is exposed only on the south slope of Grant Hill in the northwestern part of the map-area. Bose gravel deposits overlie part of Grant Hill as a very thin mantle. In the area east of the Stave River and south of Dewdney trunk road the materials mapped as Bose gravel and slopewash deposits are believed to have been laid down in the sea during retreat of Surrey ice and before the advance of the Sumas ice.

The deposits (12) outcropping along Norrish Creek east of Dewdney are extremely complex and no attempt has been made to separate those belonging to different groups.

Whatcom glacio-marine deposits (8) appear at the surface throughout a large part of the Langley upland and on the southern slopes of the Coast Mountains where they are exposed at elevations up to 500 feet. In much of the Sumas map-area they are overlain by Abbotsford outwash (11).

No identifiable deposits of Cloverdale sediments (see Table of Surficial Deposits, in pocket) were observed at the surface in the map-area but drilling indicates that these sediments underlie much of Sumas, Matsqui, and probably Fraser Valley.

Sumas till (9) is widespread in Langley upland and east of the Stave River in the Coast Mountains, and it normally underlies the adjacent areas of Abbotsford outwash (see map).

An area of Abbotsford ice-contact deposits (11d) extends from the International Boundary south of Aldergrove northeast and then north to the Fraser River near Mount Lehman station. This area marks a terminal advance of the Sumas ice-sheet. Ice-contact deposits are also exposed in the northeast part of the map-area, north of the Fraser River between Deroche and Harrison Mills.

Glacio-lacustrine deposits (10) are found exposed on the slopes of Matsqui Valley and on the lower slopes of the hill northwest of Mission. These lake deposits are believed also to underlie Matsqui Valley.

The distribution of the Salish deposits (13-20) is fairly obvious from the geological map accompanying this paper. Lacustrine deposits (13) are confined to Sumas Valley. Sumas Lake, drained in 1926, occupied part of the area underlain by lake deposits (see map). As the basin in which lake sediments were deposited was filled, Sumas Lake became progressively smaller and beaches or spits (13c) were left in the southwestern part of Sumas Valley as elongated sand ridges.

Fraser flood-plain deposits (15) are confined to the valley of the Fraser River and parts of the Matsqui, Hatzic and Glen Valleys. The distribution of the other deposits belonging to the Salish group is obvious from the map, but particular attention is drawn to the complexity of the deposits in the Yarrow-Vedder area.

HISTORICAL GEOLOGY

This report deals only with the surficial (unconsolidated) deposits; however, the accompanying map shows the distribution of the bedrock deposits and further information is available on GSC Map 8-1956. Final reports on bedrock geology are presently being compiled. As stated in the preceding section deep drill-holes indicate that in the Fraser Lowland the relief on the underlying bedrock probably exceeds 1,100 feet.

The pre-Vashon surficial deposits (see Table of Surficial Deposits) are not exposed at the surface. They have been intersected, however, in a few deep water-wells and in several wildcat oil wells. The sediments penetrated in these deep holes show that the area was subjected to at least one major glaciation prior to Vashon time. Interglacial and possibly preglacial unconsolidated deposits are also indicated.

An ice-sheet probably of continental size, here referred to as the Vashon ice-sheet, is known to have covered the whole area more than twelve and probably less than twenty-five thousand years ago. Prior to the advance of this ice-sheet many of the hills and uplands had much the same shape and size as now. During the advance of the ice-sheet the land was depressed relative to the sea, possibly as much as 1,000 feet. At the maximum of Vashon glaciation the ice rested on the sea floor. Maryhill outwash, which is not exposed in the map-area, was deposited in advance of the ice-sheet and Surrey till beneath the ice. Very little Surrey till is exposed in the map-area, however, a study of the area to the west shows that this till is plastered on the hills, mantling the slopes, indicating that the general shaping of the hills was in pre-Surrey time. In the northeast corner of the Sumas map-area, north-trending drumlin-shaped ridges composed of Surrey till are found above an elevation of 500 feet, indicating that in this area the Vashon ice moved southward. During the retreat of the Vashon ice, largely by wasting, the ice thinned and floated, and glacio-marine Newton stony clay deposits were laid down below elevations of approximately 500 feet. Above elevations of 500 feet Haney outwash was deposited during this recessional stage, largely in the form of eskers. After the Vashon ice melted and as the land rose above the sea, offshore Cloverdale sediments and shoreline Sunnyside sand and Bose gravel were laid down. Some Capilano gravel deposits were also laid down in the form of marine deltas during this stage. The Vashon ice advanced mainly from the north across the Fraser Lowland. Evidence shows, however, that there were local advances from the east down the Fraser Valley.

Huntingdon gravel deposits overlie Newton stony clay deposits. They appear to be stream or outwash deposits that were laid down following the retreat of Vashon ice but before the advance of Sumas Valley ice. They are probably equivalent in part to Capilano gravel, as in places they were deposited in marine deltas. In other places they may represent stream-channel gravels. The writer has no firm evidence as to how high the land rose during the retreat of the Vashon ice and before the advance of Sumas ice. The Huntingdon gravels are found within a few feet of present day sea-level and if they are stream deposits and marine deltas, as suggested by the writer, then sea-level must have stood at relatively the same position, or possibly lower, than at present. However, before the Sumas ice advanced, the relative position of sea-level rose again as suggested below.

During post-Vashon time the Sumas valley ice advanced westward into the Fraser Lowland. In its initial-advance stages this ice-sheet terminated in the sea and deposited glacio-marine Whatcom deposits in front of and beneath the ice, and at the same time normal marine deposits (Cloverdale sediments) were laid down

in the sea west of the Sumas ice-sheet. As these Whatcom glacio-marine deposits are found up to elevations of 500 feet this suggests that at some stage during the advance of the Sumas ice the land was more than 500 feet lower than at the present time. Radiocarbon datings of wood collected from Sumas till in one locality, and from Whatcom glacio-marine deposits below till in three localities, indicate that the Sumas ice-advance took place about 11,000 years ago. During the retreat or wastage of Sumas ice the land rose and the glacier was grounded. At this stage sea-level was about 125 feet lower than at present. At one stage it butted up against the higher part of the Langley upland and deposited along this contact a great variety of materials mapped as Abbotsford outwash and ice-contact deposits. These consist of gravel, sand, and lenses of till, all transected by many meltwater channels. Outwash deposits were laid down to the west. In places outwash river channels were cut in Whatcom glacio-marine deposits and terminated in the sea where deltaic outwash was deposited.

At a later stage in the wasting of the Sumas ice, some areas in the Fraser Lowland became ice-free while others remained covered. At one stage Sumas Valley appears to have been occupied by ice while the area to the west was ice-free, and during this stage recessional outwash deposits were laid down in the vicinity of Abbotsford. In this area are such physiographic features as kettles, outwash plains, pitted outwash, and meltwater channels. Immediately north of this area a glacial lake was formed in Matsqui Valley.

The writer believes that Sumas Valley was the main drainage channel of the Fraser River prior to the advance of the Sumas ice. The Fraser was probably diverted into its present channel because of an ice block in the 'Sumas channel'. Meltwaters escaped mainly westward around Sumas Mountain and thence into the lake referred to above, in the Matsqui Valley. The outlet of this lake was at its northwestern end, near Silverdale. The Sumas channel must have remained ice-blocked and downcutting continued in the westward escape route until the relative position of the land and sea was about the same as at present. Therefore by the time the Sumas ice block finally melted, the present course of the Fraser had been established.

The Salish deposits are still in the process of formation and consist of deltaic, channel, and flood-plain deposits of the Fraser River and smaller streams, and peat bogs and lake deposits. As indicated on the map a shallow lake existed in Sumas Valley until drained in 1926.

APPLICATION OF GEOLOGICAL STUDIES

The geological study and mapping of the Pleistocene and recent unconsolidated deposits of the Sumas map-area was undertaken to afford information essential to the orderly development of the area.

A proper appreciation of the influence of geological conditions is essential to the planned development of industry and agriculture and may result in saving considerable sums of money, and in avoiding floods, slides and other disasters. In order to explain the geological conditions it is necessary to unravel the stratigraphy and geological history of the area. To do this, all available information on the physical nature, origin and extent of surficial deposits was obtained, even from areas where it has no immediate practical application. Some of the present and future applications of this basic geological knowledge are discussed in the following.

ENGINEERING GEOLOGY

Adequate data on the kind and distribution of geological materials aid the engineer, regional and town planner, and contractor in solving many problems pertaining to foundation materials, sewage disposal, flood control, slides and washouts, drainage, and construction materials.

FOUNDATION MATERIALS

A knowledge of the properties of foundation materials is particularly desirable wherever the stability and durability of structures may be affected by the nature of the underlying material. The more important properties are permeability, which controls drainage, stability and shearing strength, and workability. Information on these properties is valuable in the design and location of buildings, roadways, airport runways, bridges, dams, and playing fields.

In areas of clay, silty clay, clayey silt, silt, stony silty clay, glacio-marine till-like mixtures, till, and bedrock, most of the drainage is by surface runoff, as these materials are nearly impervious and permit very little downward percolation of water. Areas of sand and gravel are, as a rule, pervious and allow much downward drainage except where the water-table is at or near the surface as is the case in much of the Fraser River, Matsqui, and

Sumas Valleys. Although the tills contain relatively little clay and a high percentage of sand their coherent nature tends to make them nearly impervious. The dense coherent nature is partly a result of the weight of glacial ice beneath which they were deposited, and partly a result of their mechanical composition; that is, fine particles fill voids between coarse particles and bind them together to form a natural physical concrete. This is the reason the tills reconsolidate themselves after sliding or after excavation when used as fill.

Of particular interest is the fact that the Surrey till (1) and older deposits have been pre-loaded by up to 7,500 feet of ice whereas the post-Surrey deposits west of the maximum advance of the Sumas ice have only been pre-loaded by the weight of the sediments above them. During the greater part of its life the Sumas ice-sheet was apparently floating in the sea and only in its final stages was it resting on land; consequently, sediments underlying this ice were probably subject to a load consisting of only a few hundred feet of ice. The maximum advance of Sumas ice is difficult to establish, however, remnants of Sumas till (9) found along the western border of the map-area south of the Fraser River would definitely indicate that a tongue of Sumas ice advanced to this area. The writer believes that probably most of the area south of the Fraser River was covered by Sumas ice. Included are large areas of Whatcom glacio-marine deposits (8) in which no overlying till was observed. This coverage by Sumas ice is in part substantiated by recent soil-testing that shows that some of the Whatcom glacio-marine deposits, where not overlain by recognizable till, have been pre-loaded. The writer believes that the only possible pre-loading must have been by Sumas ice. Until the present, not enough testing has been carried out on pre-loaded Whatcom glacio-marine deposits to accurately compare their relative foundation values with similar materials that have not been pre-loaded, or with tills that have been pre-loaded. However, it is safe to conclude that they have lower bearing-values than the tills and higher values than similar material that has not been pre-loaded.

Surrey till (1) and Sumas till (9) should remain undeformed under heavy loads whereas superficially till-like Whatcom glacio-marine deposits (8) that have not been pre-loaded by ice may fail when subjected to relatively light loads. The difference in the reaction of similar-appearing materials to loads is readily explainable when the origins of the two are considered. The tills were deposited under a great weight of ice, whereas the glacio-marine deposits were dropped from floating ice. In the Fraser Lowland the glacio-marine deposits attain great thicknesses and when major industrial expansion is undertaken in areas underlain by them they will certainly present bearing problems quite dissimilar to those of the tills that they resemble superficially.

Fraser flood-plain and lacustrine deposits (13a, 15a), consisting of silt and clay, cover large lowland areas and have only been naturally loaded by the weight of the overlying sediment. They will support only light loads without some deformation. As these sediments are commonly not too thick and normally overlie sand, pile foundations will take care of this condition in most places. In part of the Sumas Valley the lacustrine sands (13b) overlying silt and clay are only a few feet thick and consequently should be dealt with in the same manner as the areas in which silt and clay are exposed at the surface.

Peat bogs wherever found present greater foundation problems than any of the other deposits mapped. Peat undergoes extreme deformation when loaded and it is very difficult to drain. Hard-surface roads laid across bogs tend to develop alternating swells and depressions and deteriorate rapidly. To correct this the peat should be excavated and, where necessary, replaced by fill before building the road.

Throughout the Fraser, Matsqui, and Sumas Valleys drainage problems are encountered; in all these areas the ground-water table is either at or within a few feet of the surface, consequently nearly all drainage is by surface runoff.

The following table summarizes the characteristics pertinent to foundations of the various materials found in the area.

Type of Deposit	Value for Foundations	Drainage
If foundations penetrate surface deposits, underlying deposits must be considered. (See Table of Surficial Deposits)		
Bedrock (R)	Excellent bearing-value	Surface drainage only

Type of Deposit	Value for Foundations	Drainage
Surrey till (1)	Excellent bearing-value; pre-loaded by several thousand feet of glacier ice	Surface drainage only
Sumas till (9a)	Good to excellent bearing-value; pre-loaded by at least several hundred feet of glacier ice	Mainly surface drainage, but also limited downward drainage
Pre-Surrey (5) sand and gravel (1)	Good to excellent bearing-value; pre-loaded by glacier ice	Excellent downward drainage
Haney outwash (4) sand and gravel Bose gravel and slopewash deposits (7) of sand and gravel Abbotsford outwash (11a, b, d, e, f, g) sand and gravel Fan gravel and sand (19c)	Good bearing-value	Excellent downward drainage
Mountain-stream deposits (14) of sand and gravel	Good bearing-value	Excellent downward drainage in places, other places poor as ground-water table within few feet of surface
Newton stony clay deposits (3) Whatcom glacio-marine stony clayey silt and silty clay, silt, and clay (8)	Areas where these deposits have been pre-loaded by glacier ice have fair to good bearing-value. Areas where they have not been pre-loaded by glacier ice have poor to fair bearing-value, and may have excessive settlements	Surface drainage only

Type of Deposit	Value for Foundations	Drainage
Lacustrine (17b, 17c) sand (13a, 13c) Fraser flood-plain sand (15b)	Fair to good bearing-value depending on density	Drainage poor as ground-water table is within a few feet of surface
Glacio-lacustrine silt, clayey silt, and silty clay (10)	Poor to good bearing-value, may have excessive settlements	Surface drainage only
Lacustrine silt, clayey silt, and silty clay (13a) Fraser flood-plain silty clay, clayey silt, clay, silt, and fine sand (15a, 15c)	Very poor to fair bearing-value; areas where clayey silt, silty clay, and clay predominate, may have excessive settlements; areas where silt and fine sand predominate are susceptible to liquefaction	Surface drainage only as ground-water table is either at or within a few feet of the surface
Swamp deposits (20) consisting of peat, clayey peat, and peaty clay	Remove from foundations	Very difficult to drain as peat will hold up to 26 times its own weight of water

In the areas of mixed or complex deposits (12, 16, 17 and 18) detailed studies to determine the character and properties of the sediments are recommended.

With exception of the tills and, to a much lesser extent, the glacio-marine sediments, all the unconsolidated deposits found in the area are easy to excavate. In the tills, cohesion is so high in places that they may have to be blasted before excavation. In places large stones in both tills and glacio-marine sediments may have to be broken to be removed.

SEWAGE DISPOSAL

As sewage disposal is dependent on septic tanks throughout the area, a knowledge of the drainage and subsoil conditions is desirable. Drainage conditions may have been summarized in the preceding table on foundations. Many of the uplands are covered by impervious or nearly impervious Surrey till (1), Whatcom glacio-marine deposits (8), Sumas till (9), glacio-lacustrine deposits (10), and bedrock (R) at or within a few feet of the surface. For all practical purposes these materials permit no downward drainage. It is, therefore, evident that much of the overflow from septic-tank absorption fields in many of the higher areas must eventually drain down slopes by surface or near-surface run-off. If septic tanks must be used under the unfavourable conditions outlined they should be placed sufficiently far apart so that the development of adjacent lots will not be affected.

Many of the highland areas not already discussed are underlain by deposits of Abbotsford outwash (11) and, to a much lesser extent, by Huntingdon gravel (5). These consist of thick deposits of permeable gravel and sand permitting easy downward circulation of septic-tank effluent. However, throughout the map-area these deposits are a source of domestic ground-water supply and contain abundant ground-water reservoirs, the water table in many places rising to 10 or 15 feet from the surface. Consequently great care should be taken in the construction and spacing of septic tanks and the local ground-water supply should be checked periodically for contamination.

Septic-tank sewage disposal systems will not operate satisfactorily in areas where the ground-water level is up to, or nearly up to the absorption tile, or in areas that are periodically flooded. These conditions exist in much of the Fraser, Matsqui, and Sumas Valleys, especially during the rainy winter and spring flood seasons.

FLOOD CONTROL

To effectively combat flooding along rivers by means of dyking and dredging, the nature of the river-bank and bottom deposits must be known. Most of the dyking problems along the Fraser River are caused by dykes having been built on permeable sand. This sand is either at the surface or it lies beneath a few feet of silt and clayey silt. Consequently when the river is in flood, the water level is higher than the land behind the dyke, and the hydrostatic pressure forces some of the water through the sand beneath the dyke. This seepage may result in saturation or flooding of the dyked land and occasionally in the failure of the dykes. A contributing factor to the unstable condition of the dykes is the fact that the ground-water table in these areas is at or near the surface during the rainy season and floodwater therefore cannot be dissipated into the ground.

The Mission-Matsqui area is probably subject to the most frequent flooding of any part of the Fraser River. This is partly due to the permeable sands underlying the top silt and partly to the course of the river at this point. The river makes a large sweep to the southwest and then turns at Matsqui and flows northwest, resulting in the main current striking the dykes in the Matsqui-Mission area. The floodwater normally rises 20 to 25 feet and dykes are built to take care of this. The worst flood condition in recent years was in 1948. However, in July, 1955 part of the Mission-Matsqui bridge was washed out by floodwater.

The Vedder River which enters the Sumas Valley near Yarrow, drains a very rugged section of the Cascade Mountains to the east. This area is subjected to very high precipitation and the rise and fall of water in the Vedder River varies greatly. The Vedder Canal takes care of a great deal of the high water, but occasionally the Vedder River floods the immediate area adjoining its banks.

Flooding along the lower reaches of the Stave River is effectively controlled by dams maintained by the B.C. Electric Power Company. However, in the spring the stretch between the Fraser River and the lower dam is flooded by high waters of the Fraser. This is considered a natural condition and no home-building has been allowed in the area.

SLIDES AND WASHOUTS

Over the years large slides and washouts have occurred in much of the Lower Mainland area. Many of these occur in unconsolidated deposits on steep slopes where the soil conditions are rendered unstable by heavy rainfall and, in some places, excessive clearing of the land. Most of the spectacular slides have been to the west of the Sumas map-area, although in recent years the glaciolacustrine deposits (10) exposed near Mount Lehman station, have slid onto the Canadian National Railways mainline track. These interbedded clays and silts, when wet, have a tendency to slide along bedding planes, especially where they stand on steep faces and have very little vegetative cover.

CONSTRUCTION MATERIALS

Construction materials produced from surficial deposits found in the map-area consist of gravel, sand, and clay.

Tertiary shale is mined at several places on Sumas Mountain and is processed in two plants at Kilgard and Abbotsford.

Granite is produced from exposures along the Canadian National Railways line on the northwest slope of Sumas Mountain.

The production of gravel and sand is an important industry in the Sumas map-area. At present at least 47 pits are operated intermittently or year around. No accurate figure on total production is available; however, it undoubtedly exceeds a million yards a year. The operations range from small pits removing several thousand yards a year to plants that produce in excess of 50,000 yards a year. In most of the smaller pits, particularly those operated by the municipalities, only pit-run gravel and sand is produced. Several of the privately-owned pits crush, wash and size the gravels and also maintain ready-mix plants for concrete sales. The value of production before treatment probably exceeds several hundred thousand dollars a year and after treatment would be at least twice as high. The bulk of these materials is used for concrete aggregates, for fill, and for base cores or surfacing roads.

Geologically the deposits in which the pits are located include the following:

1. Pre-Surrey gravel (1), (1 pit)
2. Huntingdon gravel (5a, 5b), (6 pits)
3. Abbotsford ice-contact deposits (11d), (10 pits)
4. Abbotsford recessional outwash (11a, b, e, f, g), (22 pits)
5. Non-marine mountain-stream deposits (14), (3 pits)
6. Slopewash fan deposits (19c), (5 pits)

The only pit developed in pre-Surrey gravel (1) is on the north side of Grant Hill, and here gravel and sand is overlain by Surrey till (2) about 10 feet thick. Probably 95 per cent or more of the stones are pebble size, the remainder are cobble size. Granitic rocks comprise 50 to 80 per cent of the stones.

Huntingdon gravel deposits (5a, b) underlie Whatcom glacio-marine deposits (8) and Sumas till (9) and as a result may be buried beneath great thicknesses of these materials. However, they are developed only in areas where the overlying deposits are less than 15 feet thick. They consist of well-sorted pebble gravel with a few cobbles. The stones in them consist of 40 to 70 per cent granitic and associated rocks and the remainder of volcanic and sedimentary rocks. Cherts are a characteristic of these gravels although in only a few places do they make up more than 15 per cent of the stones.

Abbotsford ice-contact deposits (11d) are fairly widespread in the Sumas area and as they were deposited by Sumas ice, the last ice advance, they are exposed at the surface in the uplands and are very economical to develop. The ice-contact deposits consist of gravel and sand containing lenses of till and glacio-marine stony clayey silt, all cut by deep meltwater channels. The deposits probably range in thickness from 25 to 50 feet and overlie older gravel deposits. Ten gravel pits are developed in these deposits and most of these use not only the ice-contact materials but the underlying gravels. Stones range in size from pebbles to boulders. They consist of 60 to 70 per cent granitic rocks, with the remainder being of sedimentary and volcanic rocks, in which cherts, porphyries, and argillites predominate. The writer believes that these ice-contact deposits should form a large gravel reserve for future use. The areas in which they occur have very poor agricultural soils and it appears that development of a sand and gravel industry in these areas would be most logical as well as the best use for the land. The deposits underlie an area of at least 10 square miles and, including in part, the underlying gravels, they have an average thickness of 50 feet or more, forming a reserve in excess of 350 million yards.

The Abbotsford (11a, b, e, f, g) recessional outwash deposits are very widespread in the map-area, both north and south of the Fraser River. They are believed to be at least 125 feet thick in places, and probably average a minimum of 50 feet throughout the area. They cover an area of at least 40 square miles, and provide an abundant supply of ground water. The water-table normally lies within 50 feet of the surface. Most of the area underlain by Abbotsford recessional outwash forms relatively good agricultural land especially for growth of small fruits, vegetables and bulbs. Because of the agricultural value of much of the area the writer suggests that in planning for its development, zoning for gravel-pit operations be established. The gravel reserve in this area is in excess of 1.5 billion yards. These gravels in most places consist of well-sorted pebble and cobble gravel interbedded with medium to coarse sand. The stones consist of about 40 to 60 per cent granitic and associated rocks with the remainder of volcanic and sedimentary rocks, in which cherts, argillites and porphyries are characteristic. The two largest privately operated pits occur in Abbotsford recessional outwash. They are the Abbotsford Gravel Sales Ltd. and Duecks Gravel Pit.

Stream deposits (14) on the lower Stave River supply the materials for three gravel-pit operations. These deposits are at least 25 feet thick in the Silverdale area. They consist of well-sorted pebble and cobble gravel, largely composed of granitic and associated rock types. Beds of sand comprise only a small part of the deposits.

Slopewash deposits (19c) of the Salish group provide a source of gravel in parts of the area. Five gravel pits have been developed in these deposits, all in fan gravels. Two are in the large fan in upper Hatzic Valley, one in a small fan in lower Hatzic Valley, and two are found in fans on the southeastern side of Sumas Mountain. These fan deposits are generally poorly sorted and reflect the bedrock geology of the nearby areas. They contain considerable quantities of subangular stones and are relatively low in sand. However, they do provide a convenient source of local gravel.

In the operation of gravel and sand pits some of the difficulties that may be attributed to geological conditions are as follows:

(1) Excessive overburden of glacial till or stony clay, both of which are difficult to handle with a shovel and hard to dispose of. This problem is encountered only in some of the pits in Huntingdon gravel (5a, b) and the pre-Surrey deposits (1).

(2) The 'lensy' nature of many of the gravel beds; as a result the pit-run contains much sand for which the market is limited. This is a common fault in all deposits except those in the fans (19c) and stream deposits (14) along the lower Stave River. The proportion of sand to gravel varies greatly, and in many pits the operation has to be moved from one part to another to avoid excessive production of sand.

(3) The large size of some of the boulders, which in places are 4 to 12 feet in diameter, and cannot be handled without blasting. This applies mainly to the deposits found in the Abbotsford ice-contact gravels (11d).

(4) The occurrence of interbedded thin strata of silt or clay materials which cannot be handled satisfactorily in washing and sizing. This condition also is most probable in the Abbotsford ice-contact deposits (11d).

(5) The presence at the base of some deposits of ridges of glacial till or glacio-marine till-like deposits, both of which when wet form mud-holes. Indeed, if these ridges are high, they make the overlapping gravel and sand deposits too thin to remove economically. Some of the Abbotsford recessional outwash deposits (11b) north and northwest of 'Mission City' overlie Whatcom glacio-marine deposits (8) and are of value only for local use. In some of the areas south of Abbotsford, till underlies the top gravels but the till in most places is thin and may be penetrated to the underlying gravels without excessive expense.

(6) The presence of high ground-water tables. This is a particularly troublesome problem to the small operator who uses only shovels and does not wash or crush. This condition is found in the deposits on the lower Stave River and in some of the deposits in the recessional Abbotsford outwash.

Other difficulties might be mentioned but those enumerated above are probably the most significant. The Sumas area is indeed fortunate in having abundant good deposits of gravel and sand; in this area the cost of these materials is very low compared to most places in Canada.

Lafarge Cement of North American Limited operates a 'clay' pit near the Canadian National Railways line between Mount Lehman station and Glen Valley station. The deposit consists of more than 400 feet of clayey silt, silty clay, and thin interbeds of silt and sand. Stones are scattered throughout most of the deposit. They are marine in origin, as fossil shells were found in one locality on the road to the west. They are at least in part Whatcom glacio-marine deposits (8) but they may also include the older Newton stony clay deposits (3). The company operates an electrically powered scraper to scrape 'clay' from the deposits to a bin. Water is mixed with the clay in large tanks to form slurry. The slurry is pumped into barges for transportation to the company's cement plant on Lulu Island.

AGRICULTURAL APPLICATIONS

SOILS

Modern soil classification is based upon the nature of the soil profile, which reflects the influence of various factors of soil development including parent material, climate, organisms, topography, time, and geological environment. Parent material and topography are elements in geological environment, but in this report they refer to geological features outside the soil body itself but which may directly or indirectly affect the development of the soil. For example, the stratigraphy and geological structure in and around a particular soil may be an important factor in soil development. This is illustrated by the varieties of soil on the same parent material that have resulted from different kinds of deposits underlying the parent material and thereby setting up different soil-development patterns. Drainage is generally recognized as highly important in soil development, but drainage depends mostly on the permeability of the underlying material, which is in turn dependent on the stratigraphy and the depth to the saturated zone. The latter is commonly a function of regional geomorphology and geologic structure. Each of the soil factors mentioned above is in itself directly or indirectly dependent on the geological history of the area; parent material, topography, and geological environment as used in this

report are directly dependent on the geological history, and climate and organisms are indirectly dependent. Parent material, climate and organisms primarily control differences in kind of weathering and topography, time, and geological environment in degree of weathering.

The geologist is most able to help the soil scientist in his interpretation of soils by indicating the role played by parent materials and geological environment. The soil profiles in the Sumas map-area, for example, are poorly developed, and the texture and composition of the parent material is still dominant. The writer believes that when the agricultural soils of the area are remapped, the broad divisions of the completed soil map will show a marked similarity to the geological map accompanying this paper.

The Sumas map-area has many soil units covering a wide range of characteristics. The soil units developed from different types of unconsolidated materials that outcrop at the surface in areas of agricultural development may be roughly classified as follows:

Parent Material	Main Soil Types
Glacial	
Surrey till (2)	Stony sandy loam and stony silty loam
Sumas till (9a, b)	Stony sandy loam
Glacio-fluvial	
Abbotsford recessional outwash with gravel at surface (11b, e)	Gravelly loam and gravelly sandy loam
Abbotsford recessional outwash with sand at surface (11a, c, f)	Sandy loam
Abbotsford recessional outwash overlain by dune sand (11g)	Sandy loam, loamy sand, silt loam, and sand
Abbotsford outwash, ice-contact deposits (11d)	Gravelly loam, gravelly sandy loam, and sandy loam

Parent Material	Main Soil Types
Glacio-marine	
Whatcom glacio-marine deposits (8)	Silt loam, clayey silt loam, silty clay, and clay, all with scattered stones
Marine-shore and slope-wash deposits (7)	Gravelly sand loam and sandy loam
Marine-shore Sunnyside sand (6)	Sandy loam, loamy sand and sand
Non-marine deltaic, channel and flood-plain deposits	
Mountain-stream deposits (14)	Gravelly sandy loam, loamy sand, and sandy loam, also silty loam, silty clay loam
Fraser flood-plain deposits (15a-d)	Silt loam, silty clay loam, clay loam, loamy sand, sandy loam (possibly these could be broken down on the basis of the sub-divisions on the map)
Huntingdon gravel (5a, b)	Gravelly loam and gravelly sandy loam
Glacio-lacustrine deposits (10)	Silty clay loam, silty clay, and clay loam
Lacustrine deposits (13a-13c)	Silty loam, silty clay loam, silty clay, clay loam, loamy sand, and sandy loam
Non-marine slopewash deposits (19a-c)	Gravelly loam, gravelly sandy loam, sandy loam, and sand
Non-marine swamp deposits Peat and muck (20a, b)	Peat and muck

The areas mapped as deposits of mixed origin (16-18) would have soils similar to those developed on the component deposits (13-15) where mixing has not taken place,, but due to the mixing the soil types would have a much more limited areal extent.

DRAINAGE

Drainage has been discussed briefly in the foregoing as a factor controlled largely by geological environment. A few additional remarks included here enlarge on the previous statements, and show the general relation of drainage and soils.

The moisture content of a soil depends partly on the slope on which it rests, partly on the permeability of the soil profile itself and the underlying parent material, and partly on the presence or absence of a permanent water-table. The soils of the region fall naturally into two classes based on downward drainage (permeability), namely, those with restricted downward drainage and those with good or adequate downward drainage. The soils with restricted downward drainage may be subdivided into those with good surface drainage and those with poor surface drainage.

Restricted downward drainage occurs in soils developed on the following parent materials: till; glacio-marine stony clayey silt, silty clay, and related till-like mixtures; glacio-lacustrine clay and silt; lacustrine clay and silt; alluvial clay and silt; and peat. All are impervious or nearly so. Included in these parent materials are the Surrey till (2), part of the Sumas till (9), all of the glacio-lacustrine deposits (10), all of the Whatcom glacio-marine deposits (8), part of the Fraser flood-plain deposits (15), part of the lacustrine deposits (13) and all of the swamp deposits (20). The surface drainage on these soils is controlled by local topography, therefore if they occur on a slope the surface drainage is good, but if they occupy a hollow or a flat-lying area, the surface drainage is poor. The areas underlain by till are mainly hilly, and except locally in depressions and flat areas, they have excellent surface drainage. The stony glacio-marine deposits normally have a rolling to relatively flat topography and as a result have only limited areas with good surface drainage. The glacio-lacustrine deposits are mainly exposed on steep slopes and have relatively good surface drainage. All the remaining deposits with restricted downward drainage underlie flat-lying areas and have poor surface drainage.

Sand and gravel of all origins normally have good downward drainage. Exceptions are found in low-lying areas where the water-table is near the surface, permitting little downward circulation of water. Most sand and gravel deposits have relatively flat surfaces, such as outwash plains and valley bottoms.