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SILT DEPOSITION IN LATE-GLACIAL LAKES OF SOUTHERN BRITISH COLUMBIA

R. J. FULTON

Geological Survey of Canada, Ottawa, Ontario, Canada

ABSTRACT. The extensive late-glacial silt deposits of the major valleys of the Interior System of the Canadian Cordillera hold an important position in the deglaciation of the area. This study is limited to the silt of the South Thompson Valley. If all major silt deposits accumulated under roughly similar conditions as suggested, generalizations of this study may be applied to silt deposition in other valleys.

The South Thompson Valley is a steep-walled valley flanked by rolling uplands. During deglaciation the ice downwasted leaving ice tongues in the main valleys. Silt was deposited in Lake Thompson, an eastward draining glacial lake formed in the South Thompson Valley between an ice tongue retreating to the west and one receding to the east.

Silt up to 500 feet thick is exposed along the 36-mile length of the South Thompson Valley. Lower portions of the silt are marked by varves as much as 250 inches thick, which grade upward into varves about one inch thick. In places the stratification has been modified by slumping due to collapse during the melting of buried ice, drag of floating ice, and simple gravity movements.

The main generalizations of this study which may apply to similar silt deposits are: (1) silt was deposited in glacial lakes; (2) varves are thick in lower parts of the deposit, grading thinner upward; (3) much of the silt was derived from meltwater erosion of till; (4) maximum deposition occurred as the ice receded from adjacent uplands.

INTRODUCTION

Extensive late-glacial silt deposits occupy many of the major valleys of the Interior System (Bostock, 1948, p. 4) of the Canadian Cordilleran Region. Dawson (1879) noted the occurrence of silt in the vicinity of Prince George. and since then many other occurrences have been recorded in the geologic literature [Yukon River valley (Kindle, 1953; Wheeler, 1961), Nechako River valley (Armstrong and Tipper, 1948), Okanagan Valley (Flint. 1935; Nasmith, 1962), and the South Thompson River valley (Dawson, 1895; Mathews. 1944; Fulton, 1963)]. The silt holds an important position in the deglaciation of the Interior System. An understanding of the origin and depositional environment of this deposit is important to any study of ice retreat in this area.

Regional Setting

The Interior System of the Cordilleran Region is divided into a series of upland- and mountain blocks by a reticulate system of major valleys. Stagnation of the Cordilleran ice sheet in this area of variable relief and topography resulted in a complex history of deglaciation. Downwasting freed the uplands

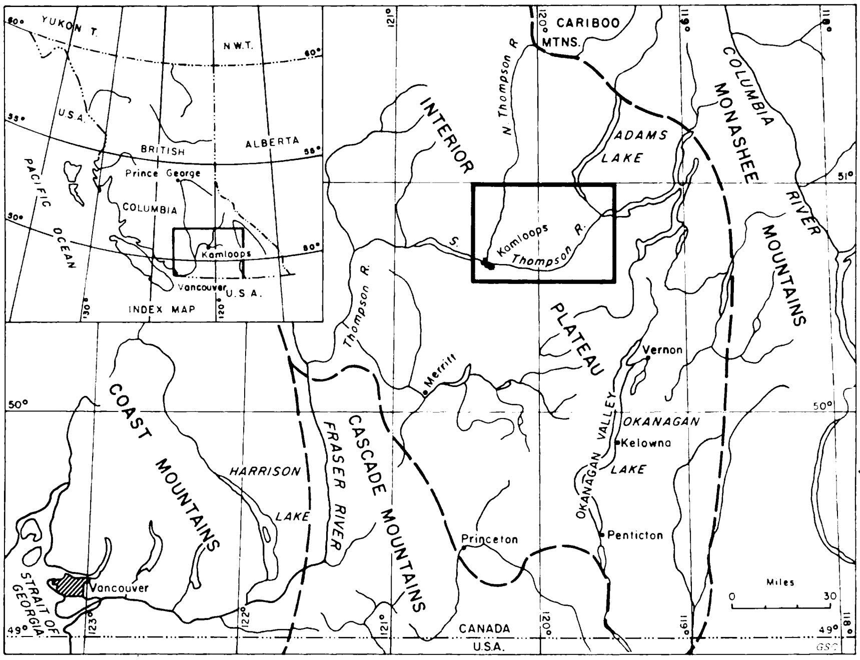


Fig. 1. Physiographic subdivisions of southwestern British Columbia (area of figs. 2 and 5 contained within rectangle).

while stagnant ice tongues remained in the valleys. obstructing the flow of meltwater and producing glacial lakes in which extensive silt deposits were laid down. Sedimentation in the lakes was affected by stage of deglaciation at the time of lake formation, proximity to the receding ice-margin, and the influx of meltwater.

This study deals with the silt in the South Thompson Valley. As all major silt deposits in the Interior System accumulated under roughly similar circumstances, the generalizations concerning silt deposition in the South Thompson Valley can be applied to silt deposition in other valleys.

Local Setting

The South Thompson Valley lies in the Interior Plateau of the Interior System of the Cordilleran Region (Bostock, 1948) (fig. 1). The valley is occupied by the South Thompson River and extends 36 miles from Little Shuswap Lake to the junction with the North Thompson River at Kamloops (fig. 2).

The generally steep-walled valley varies from 2 to 4 miles in width with an average of 3 miles. The valley is flanked by a strongly rolling upland divided into a series of hilly blocks by shallow, broad valleys. Higher portions of the upland reach altitudes as great as 5000 feet within 10 miles of the valley. The greatest portion of the uplands lie between 2500 and 3500 feet. These altitudes contrast with an elevation of about 1125 feet at river level in the South Thompson Valley.

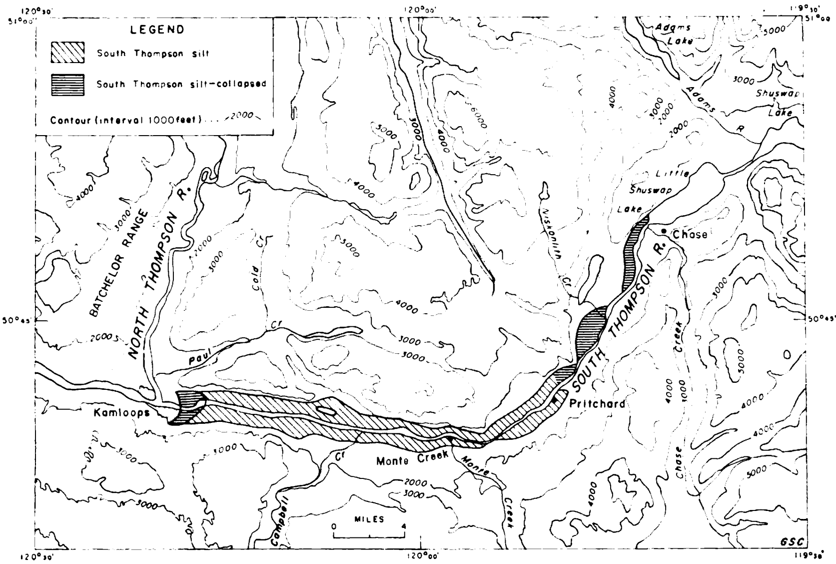


Fig. 2. Distribution of South Thompson silt.

In much of the area bedrock is overlain by a variable mantle of drift with rock outcrops mainly on steep slopes and in deep gullies. Silt and recent alluvium occupy the floor of the South Thompson Valley; gravel and sand overlie till on several less-steep parts of the valley wall. Till and colluvium abound in the upland areas, together with many local pockets of gravel and sand.

The silt of the South Thompson was deposited in a glacial lake referred to as Lake Thompson (Mathews, 1944). During deglaciation the ice receded from the uplands, leaving an ice tongue in the main valley. The tongue separated in the vicinity of Monte Creek (fig. 2), the western lobe retreating toward Kamloops Lake and the eastern one toward Little Shuswap Lake. Lake Thompson, draining east, occupied the valley between the two ice tongues. The various levels of the lake were controlled by retreat of the eastern ice from several drainageways leading into the Okanagan Valley.

Several problems of silt sedimentation, discussed in this report, are:

1. locations of ice tongues at the time of silt deposition;
2. provenance of silt;
3. paucity of coarse sediment associated with the silt;
4. size and level of the lake in which the silt was deposited;
5. origin and significance of the structure and texture of the silt.

Previous Work

Dawson (1878) described the silt bodies in the valleys of north central British Columbia and gave them the name *White Silts.* Dawson (1879) reported silt in the Okanagan and South Thompson Valleys and used the name White Silts to refer to all the silt deposits in British Columbia. A complete statement of his views on the White Silt formation is included in Dawson (1891). Pertinent points are:

1. silt was deposited in deep tranquil water;
2. silt was supplied by melting glaciers;
3. at the time of silt deposition ice occupied those parts of the valleys that are free of silt today;
4. close correspondence of the upper limits of the various silt deposits and lack of morainic material or evidence of other dams indicate silt was deposited in fiords connected with the Pacific Ocean.

Daley (1915) agreed with Dawson on all points except the marine origin of the silt. Instead he proposed that the material was deposited in ice-dammed lakes. Daly gave the composition of the silt in the South Thompson Valley as: 49 percent albite, 15 percent orthoclase, 8.5 percent anorthite, and 18 percent quartz. It would appear, however, that he arrived at this by means of a chemical analysis and analytical methods applicable only to igneous rocks.

Flint (1935) described the silt of the Okanagan Valley as a glacial-lake deposit and presented a reasonable history of late-glacial events in the area studied. He stated that the thickness of the deposit suggests a considerable time interval, and his description of the structure and distribution of the silt imply much of the material to be non-glacial in origin.

Meyer and Yenne (1940) studied the texture and composition of samples of Okanagan silt. They concluded that the size distribution was similar to that of loess and that the composition of the Okanagan silt (about equal parts quartz and feldspar) differed markedly from that of the silt in the South Thompson Valley as given by Daly (1915).

Mathews (1944) concluded that, as silt in the South Thompson Valley did not extend above 1600 feet, it was deposited in a glacial lake that stood at this level.

Nasmith (1962) described the Okanagan silt as glacial-lake sediment and presented a detailed picture of ice recession in the Okanagan Valley.

Acknowledgments

This report is an outgrowth of a section in the writer's doctoral thesis submitted to Northwestern University. Field work was done under the auspices of the Geological Survey of Canada during the summers of 1960 to 1963. L. H. Nobles directed the thesis at Northwestern University; E. Hetherington, G. Antenbring, M. Lambert, and K. Ricker assisted in the field.

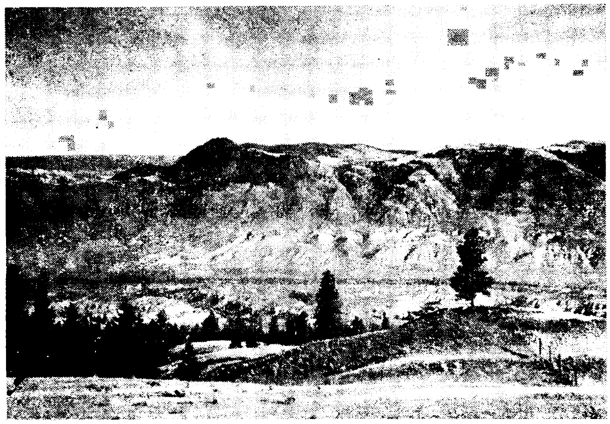
SILT DESCRIPTION

Nomenclature

Dawson (1891) considered all silt deposits in the Interior System to have been laid down at one time in a continuous body of water and so did not apply a different name to each deposit. Because each deposit was laid down separately under its own peculiar depositional environment, some means of designating each one is required. It is suggested here that the silts of the South Thompson River valley, described in this paper and forming a lithologically consanguineous, mappable unit, be referred to as the South Thompson silt.

The South Thompson silt refers to stratified silt occupying the bottom of the valley of the South Thompson River. The deposit is dominantly medium- to coarse-grained silt, light blue-gray in unoxidized exposures and white in dry exposures. Thin, well-marked, clay-rich bands, spaced at from 2 to 20 foot intervals in the lower part of the deposit and one to 6 inches near the top, accentuate the horizontal stratification. The formation overlies till and glacio-

PLATE 1

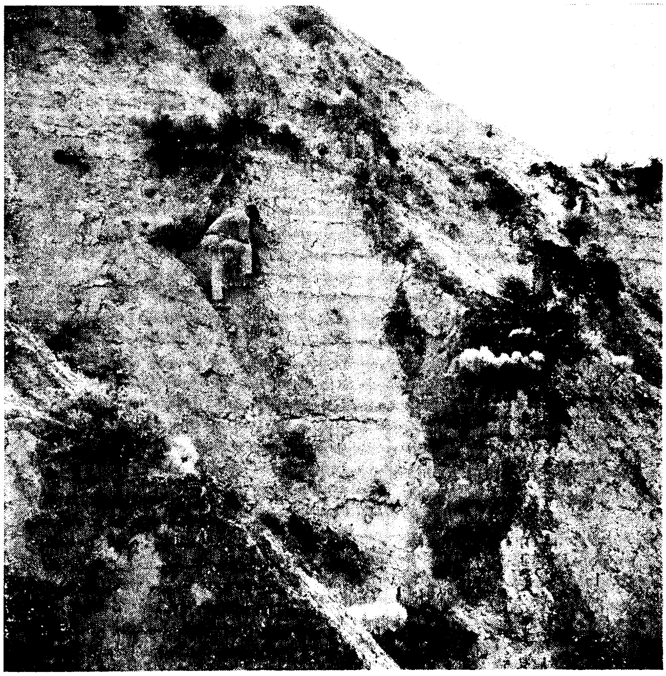


A. Gullies cut in South Thompson silt east of Kamloops.

B. Thin varves near top of South Thompson silt.

fluvial sand and gravel and is capped by wind blown sand and silt up to 10 feet thick. The silt is of late-glacial age and was deposited in a glacial lake. In the western part of the valley the silt underlies well-developed benches on both sides of the river; in the eastern part it does not form a well-defined geomorphic unit, but the distinctive lithology is readily recognized.

PLATE 2



A. Thick varves in middle part of the South Thompson silt.

B. Current structures in South Thompson silt.

Should formational status be subsequently given to the silt a south-facing exposure on the north side of the South Thompson River 5.2 miles east of the junction of the North and South Thompson Rivers would make a good type section (see 9E-9B of fig. 4 for varve thickness of this section; also pl. 1B and 2A). The north side of the South Thompson Valley, from the gully cut by the small creek draining Scheidam Lake to the gully entering the South Thompson River 4.0 miles east of the junction of the North and South Thompson Rivers, could be designated as the type area.

Geometry

Near Kamloops the silt occurs in benches on both sides of the South Thompson River (pl. 1A). The upper surface of the silt fill slopes toward the center of the valley, with altitudes near the valley wall ranging from 1650 to 1550 feet and elevations near the river ranging from 1400 to 1500 feet. This inclination toward the axis of the valley is probably a result of erosion and differential compaction and not a primary depositional phenomenon.

At Monte Creek the silt reaches 1500 feet, but at the south end of Little Shuswap Lake, the eastern limit of the silt, it occurs below 1400 feet. East of Monte Creek, silt exposures are obvious only on the north side of the river; on the south side silt occurs as subdued, partially forested, benches. East of Pritchard the well defined bench form of the silt is marked by shallow depressions, and east of Niskonlith Creek the bench gives way to subdued ridges and closed depressions.

As much as 350 feet of silt is exposed in single vertical exposures east of Kamloops. A hole near Campbell Creek shows the silt extends at least 130 feet below the valley floor. This measurement suggests silt thicknesses in excess of 500 feet. Unfortunately little is known of the profile or depth of the South Thompson Valley. The shape of the valley above the silt fill and the absence of rock in the river channel suggest a regular U-shape. Kamloops Lake is as much as 500 feet deep, Shuswap Lake is as much as 555 feet deep, and the Okanagan Valley (part of the same physiographic system) has been shown, at one place, to contain 1300 feet of unconsolidated material. These facts suggest that the 500 foot thickness of the silt is only a minimum.

Relationship to Other Units

The silt is the youngest traceable unit of glacial material in the Kamloops area. Gravel, sand, and till lie below the silt at several places along the edge of the South Thompson Valley, and though the base of the silt is not exposed, similar material is thought to underlie the silt in the center. To the west the silt appears to grade into sand and sandy gravel, but slumped and grassed-over exposures obscure this relationship. Over most of the valley the silt is overlain by modern alluvial and wind deposits.

Gravel is exposed below silt in a pit, on a side road south of the river, 4.0 miles west of the mouth of Campbell Creek (fig. 2). The exact relationship of the silt to the sand and gravel is obscured by slumping but the silt appears to overlie unconformably the coarser materials (pl. 3B). East of the exposure several "ice-contact" hummocks composed of a similar gravel rise above the

PLATE 3

A. Tilted varves in area of collapsed South Thompson silt.

B. South Thompson silt overlying outwash gravel.

general level of the silt. The gravel underlying the silt was probably deposited in the same phase of ice-contact deposition as the hummocks to the east, with the silt laid down during a later phase of lake deposition.

Silt is exposed above gravel in several gullies 1.7 miles west-southwest of the mouth of Campbell Creek (fig. 2). South of the silt stands a steep slope of coarse unstratified gravel; small tongues of gravel enter the silt from the south, and gravel is exposed beneath the silt. The upper surface of the gravel is contiinous with a large kettled terrace which was built at the mouth of Campbell Creek while the South Thompson Valley was occupied by ice. The gravel cannot be genetically related to the silt, as the silt was deposited in a glacial lake that occupied the Thompson Valley *after* it was free of ice. Interfingering of the two deposits resulted from gravel slumping into the lake during deposition.

On the north side of the valley well sorted, stratified coarse sand occurs below the silt in a gully 3.3 miles west of the mouth of Campbell Creek. About 100 feet of cover intervenes between the sand and the silt exposed above; hence the relationship of the two is not known.

In the vicinity of Kamloops, west and south of the main body of silt, fine-grained sand, pebbly sand, and sandy gravel occur as the only unit above the till (the stratigraphic position occupied by the silt to the east). As the stratification of the material near Kamloops is contorted and there is much slumping, a transition from silt to sand can not be proved. However, as the silt becomes coarser as the area of sand and pebbly sand is approached, it seems likely that the collapsed, coarse material in the vicinity of Kamloops is a facies equivalent of at least the upper portion of the South Thompson silt.

Throughout much of the valley the silt is overlain by from 6 inches to 10 feet of massive, silty fine-grained sand. As the stratification of the silt is destroyed from 1 foot to 3 feet below the massive sand, the silt must have been exposed and weathered before being covered by the sand. The massive sand is thought to be eolian.

Other deposits on top of the silt are alluvial fans built along the valley-wall edge of the silt benches by ephemeral streams and terraces developed by the entrenching river. In the case of the terraces it is difficult to distinguish between cut- and depositional, as both consist almost entirely of silt.

Lithology

Composition.—Little consideration was given the composition of the silt, as it has no bearing on the main problem of sedimentation. The fine grain size of the silt makes compositional analysis utilizing common optical procedures exceedingly difficult. As a consequence the study was restricted to fine sand-sized grains taken from the silt. Quartz was seen to be the main constituent, with mica and feldspar major constituents, and rock fragments, ferromagnesian minerals, and garnet most common of the minor constituents. X-ray determination of the clay mineralogy of 5 samples indicated 28 to 35 percent illite, 27 to 36 percent chlorite, and 35 to 40 percent montmorillonite.

A complete study of the composition of the South Thompson silt might aid in locating the source of the deposit. However, before such a study could have any significance a complete composition- and variability analysis would have to be made on the till and bedrock of the area (Cockfield, 1948).

Texture.—Each section consists of thin clay-rich bands alternating with thicker silt bands. Silt is the dominant grain size, with 19 of 24 samples analyzed containing less than 20 percent clay, and 4 of 9 samples sieved containing between 6 and 10 percent sand-sized material, and the rest containing 5 percent or less.

Silt bands near the top of the deposit are considerably finer grained than those near the base (fig. 3A). However, the variation in grain size is not uniform, as any single band may be either coarser- or finer grained than the bands immediately above and below. The grain size of an individual silt band studied at several localities varies slightly (fig. 3B). As this variation was nonsystematic, on the scale of study employed, it is considered a reflection of locally anomalous conditions in a uniform regional depositional pattern.

Small wedges of sliderock and gravel are interbedded with the silt at several positions along the valley wall. As these tongues are volumetrically insignificant, and there is no gradation from this material to silt, the wedges are considered to be the result of local freshets of no regional importance.

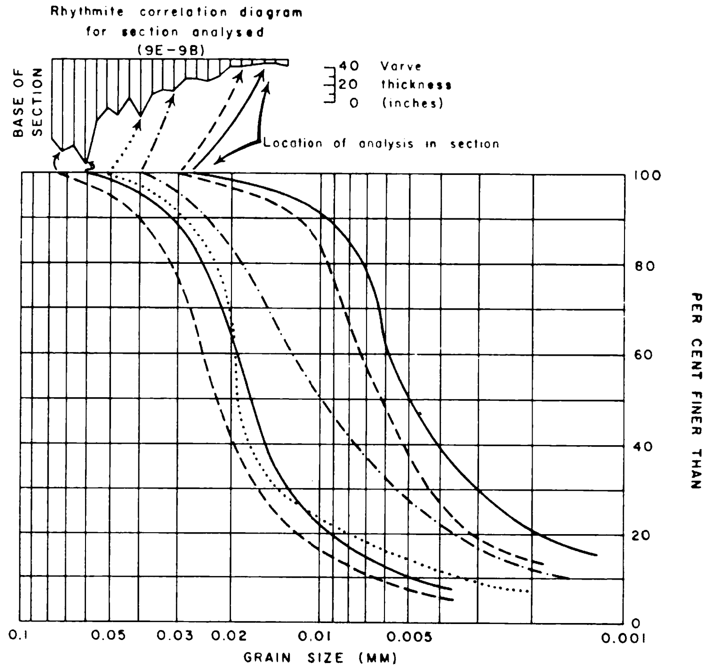
Structure.—As noted, the South Thompson silt is marked by bands rich in clay alternating with bands composed mainly of silt-sized material (pls. 1B and 2A). Each couplet of such a succession has been referred to as a rhythmite (Flint, 1957, p. 293). The term, as used here, refers to a unit made up of a silt band on top of a clay band. Each clay band is thin, with those occurring near the top of the section one inch or less thick; those lower in the section half an inch to four inches. The silt band of the rhythmical succession ranges from one inch to 250 inches with the thinnest bands at the top of the section, the thickest at the base, and a relatively uniform gradation between (fig. 4; pls. 1B and 2A).

Most of the silt bands consist of several sub-units and as a general rule, the thicker the main band the greater the number of sub-units. Each sub-unit is a single discrete unit of deposition and is characterized by a single sedimentary structure. Graded beds or reverse graded beds are the most common structures, but in the lower portions of the sections some of the sub-units are marked by small-scale cross-lamination and by other current-made structures (pl. 2B). Sub-units marked by current structures generally occur in the middle or lower portions of the major silt bands. However, sub-units marked by graded or reverse graded beds do not appear to occupy any preferred positions within the bands.

Each clay band is also composed of several sub-units, with reverse graded beds (variation of grain size gauged by color change) the most common sedimentary structure. In many places the sub-units of the clay bands are set off by thin, light-colored streaks of silt-sized material (see the second lowest clay band in pl. 1B). In the lower parts of the sections, that is, the parts characterized by thick silt bands, silt streaks within the clay may be from half an inch to four inches thick.

The base of each clay band is generally well defined; the dark-colored clay contrasts sharply with the lighter-colored silt below. The upper contact is

A.



B.

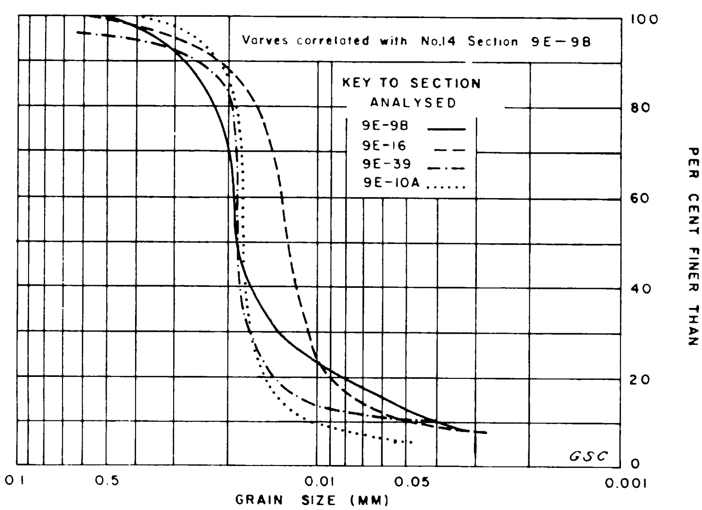


Fig. 3. (A) Grain-size analysis of individual varve in a single section (lowest varve on left); (B) grain-size analysis of a single silt varve sampled in correlated sections (see fig. 4).

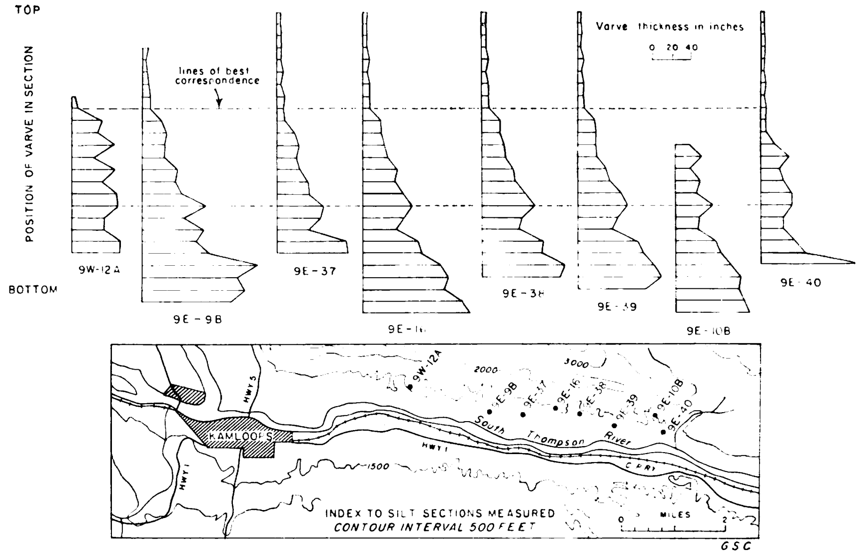


Fig. 4. Rhythmic correlation diagrams and location of South Thompson silt sections measured.

generally indefinite, the upper portion of the clay band grading upward into silt. Other clay band-silt band relationships observed are: gradational lower contact (clay over silt), sharp upper contact (silt over clay), both contacts sharp, both contacts gradational.

In several areas the primary structure has been modified by post-depositional deformation. Gravity sliding appears to have been the most common mechanism of deformation, but in a number of places disruption resulted from the drag of partially grounded, floating ice or slumping as buried ice melted.

Gravity-slide features are commonly seen in parts of the silt deposit marked by clay bands containing thick (2 to 4 inches) silt streaks. Where this type of disruption has occurred the lower part of the clay band remains undisturbed, the upper clay is repeated by a series of low-angle thrusts, and the silt between is disrupted, contorted, and in part mixed, in a series of flame structures, with the clay above. Possibly, during compaction, the pressure of silt pore-water, trapped between the two impervious clay bands, reduced the friction so that slight down-slope movement was possible. The flame structure could have resulted from upward movement of the confined silt and fluid.

Certain of the secondary structures appear due to movement of grounded icebergs because: (1) disruption decreases downward and is not limited to a single plane of dislocation; (2) there is no set pattern of deformation; (3) lenses of sand, gravel, and till occur in the upper portion of the disturbed material along with scattered pebbles and boulders; (4) disruption occurs only near the top of the section;[1] and (5) thin undisturbed strata overlie the disturbed section.

[1] During early stages of deposition the lake was too deep for floating ice to affect the sediment, but later in the history, when the basin was nearly filled, it was possible for floating ice to become grounded.

It appears that the highly contorted and steeply tilted silt east of Kamloops (fig. 2) was deposited over an actively melting tongue of ice. The disruption increases downward and the silt grades into sand containing lenses of sandy gravel. There is a similar increase in degree of disruption toward the west. where the silt grades into sand and gravel. To the east the disturbed silt underlies undisturbed silt. Unfortunately the poor exposure and the disrupted nature of the stratification make it impossible to trace out the true relations.

Silt with stratification disruption of a different nature is prominent west of Little Shuswap Lake (fig. 2; pl. 3A). In this area the stratification is similar to that of the undisturbed areas (compare pls. 3A and 1B) except that the stratification dips at various angles. The silt apparently was deposited on blocks of ice, with the stratification being rotated from its original horizontal position as the silt slumped into the holes left by the melting ice. This simple disruption of primary stratification contrasts with that near Kamloops, where the ice on which the silt was deposited was actively melting at the time of deposition.

INTERPRETATION

Correlation of Sections

If the South Thompson silt was deposited in a single body of water, each rhythmite should be continuous through the length of the deposit. If one could trace a single unit throughout the basin it would be possible to map the pattern of sedimentation by studying the areal variation of thickness, structure, and texture. Because exposure is not continuous, a technique similar to that used in varve chronology (Antevs, 1925, p. 9) was used to correlate the rhythmites of the various exposures. The thickness of each rhythmite was measured, and a curve or graph (rhythmite correlation diagram) drawn for each section (fig. 4). In comparing the diagrams to find the best correlation, it was assumed a single rhythmite might vary in thickness from one section to the next, but that the relative thickness would remain the same.

As a pilot study a deeply gullied area was selected and rhythmite correlation diagrams were made for a number of closely spaced sections. The similarity of the diagrams left little doubt that the rhythmites are continuous over the area studied. After the feasibility of this approach was established for a small area, a series of more widely spaced sections was measured and correlation between sections made by this method.

The broad study was conducted on the north side of the valley, as it contains the best exposures. In selecting sections an attempt was made to maintain an equal spacing, to choose sections as near the center of the basin as possible, and to select sites where there was little or no slumping. Compromise was necessary because the sections near the center of the valley showed the greatest evidence of slumping. Section locations and the correlation of rhythmites are shown on figure 4.

Correlation of rhythmites was made for a 5-mile portion of the valley (fig. 4). The study proved the units are continuous through at least a 5-mile section of the valley and suggests that there is a slight thinning, at least in the upper units, to the east. Grain-size analysis of one rhythmite sampled in several sections showed no systematic change (fig. 3).

A complete history of the sedimentation of the South Thompson silt could be written if the entire deposit could have been studied in this manner. Unfortunately, tracing of the individual units requires excellent exposures, close spacing of sections, and detailed study.

Origin of Stratification

The annual climatic cycle is invoked as the probable periodic change in environment to explain the rhythmites. The thicker or silt portion of the rhythmite would correspond to the deposition of one summer while the thin, clay-rich portion would be laid down in winter, when inflow and sedimentation were at a minimum. By definition rhythmites with an annual period are varves.

The forty or so varves, one to two inches thick at the tops of most sections (pl. 1B), compare favorably with the descriptions of varves formed in proglacial lakes in areas of low relief (Deane, 1950, p. 38; Flint, 1957, p. 294). The 15-foot varves below the "normal" glacial-lake stratification (pl. 2A) require special conditions not found in areas of low relief.

The varved sediments were deposited in a trough-shaped basin through which a large area is drained. At certain stages during the deglaciation large quantities of sediment-laden melt water were funnelled into this narrow trench. It appears that under such optimum conditions as much as 20 feet of material could be deposited in a single year. At these times of maximum inflow the current in the narrow glacial lake was strong enough to develop small-scale current structures in the bottom sediment (pl. 2B).

Position and Nature of Ice-Front

The locations of ice-contact portions of the South Thompson silt suggest the deposit was laid down between an ice tongue occupying the Little Shuswap–Shuswap Lakes portion of the valley and ice tongues located in the North Thompson Valley and the Kamloops Lake part of the Thompson Valley (fig. 5). Lack of rafted material throughout the greater part of the silt suggests that calving was not an important form of ablation.

The distribution of ice-contact deposits and the occurrence of collapsed lacustrine material in the vicinity of Kamloops (fig. 2) indicate the terminus of the western ice tongues was convex east and sloped below the level of Lake Thompson. As the thick silt fill of the South Thompson Valley does not extend west of Kamloops, it is assumed that during deposition of the South Thompson silt, the Kamloops Lake portion of the Thompson Valley was occupied by ice. Similarly, as the silt does not extend into the valley of the North Thompson River, this area must also have been occupied by ice at the time of silt deposition.

Kettled and collapsed lacustrine deposits between Pritchard and Little Shuswap Lake indicate that ice blocks were buried by silt in this section of the valley. Termination of the silt at the west end of Little Shuswap Lake suggests that east of this point the valley was occupied by ice that stood above the level of lacustrine deposition.

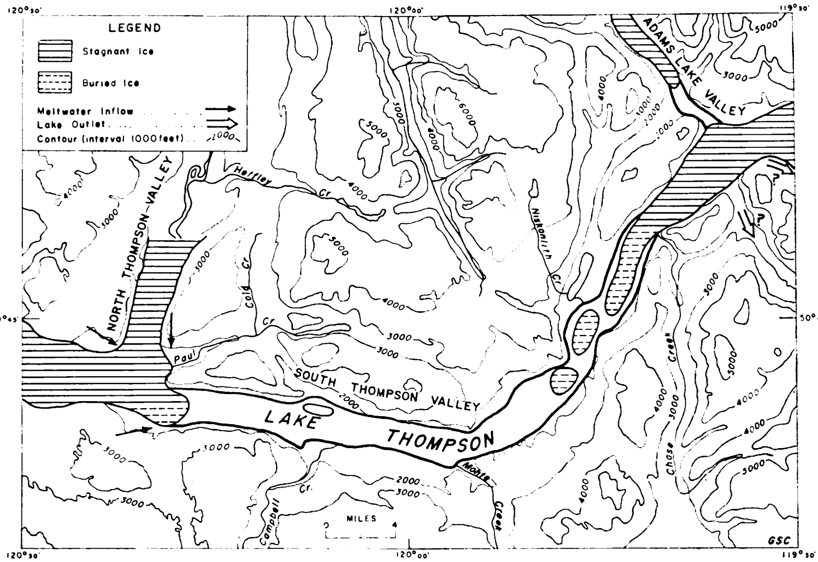


Fig. 5. Approximate positions of receding ice tongues during final stage of deposition of the South Thompson silt.

Levels of Lake

Lake Thompson formed in the valley of the Thompson River between two dams of ice. The dam at the west completely blocked the Thompson-Fraser drainage through the Coast Mountains (fig. 1) ponding water in the Thompson Valley and allowing it to discharge eastward into the Okanagan Valley via a series of outlets. The complex nature of ice retreat in the interconnected series of outlet valleys .and differential isostatic readjustment (measured, for a shoreline at 1400 feet, as 3.6 feet per mile on a line trending northwest) makes it impossible to assign an outlet to each lake stage without a complete study of all valleys in the area.

The exact level of Lake Thompson at the time of silt deposition is not known because: (1) many of the terraced deposits present were formed in contact with ice and so do not necessarily indicate lake level, and (2) definitive shoreline features were not developed on the rock walls of the South Thompson Valley by the narrow lake. However, the lake could have been no lower than 1650 feet, the level of the highest occurrence of silt. The lowest kettled terrace at Kamloops has an altitude of about 1750 feet; so Lake Thompson was at this level or lower when the South Thompson silt was deposited in this part of the valley (that is, ice occupied this part of the valley at least until the lake level dropped below 1750 feet). From this it may be concluded that Lake Thompson stood at between 1650 and 1750 feet during silt deposition.

Source of South Thompson silt

The South Thompson silt is an isolated deposit lying in the bottom of a large deep valley. As it has no obvious single source its provenance is a problem.

Origin and transport of the silt.—The thick varves indicate the greater part of the South Thompson silt was laid down under anomalous conditions. Glacial meltwater is thought to have been the main agent of transportation and deposition. Some material was undoubtedly picked up as the water found its way to the ice margin through englacial debris, but the greatest portion of the silt was acquired as the meltwater carved drainage channels along the margins of the receding ice and as it flushed glacial debris from the preglacial drainage system. Additional material was added as the normal processes of mass-wasting, accelerated by the presence of large tracts of saturated, plastic till, brought the recently exposed slopes to equilibrium. During maximum deposition, as much as 20 feet of silt was dumped in the Thompson Valley each year. With retreat of the ice from the area, the supply of meltwater and sediment decreased and varves became thinner (fig. 4).

Problem of associated coarse material.—Assuming an average valley width of 1.2 miles and a silt thickness of 300 feet, a rough estimate places the volume of silt at 2.2 cubic miles. In the foregoing it was suggested the silt was derived by erosion of till. Mechanical analysis of 20 till samples from the vicinity of Kamloops indicates the average till consists of 35 percent silt-sized material and 45 percent material coarser than silt. If the South Thompson silt was derived from the average till, about 2.8 cubic miles of material coarser than silt would have been liberated and should be directly associated with the silt deposit. Before the silt can be said to have originated by erosion of till, the location of this large quantity of coarse material must be found.

A considerable quantity of gravel and sand lies south of Kamloops (fig. 2), but its volume is far short of 2.8 cubic miles. A second large deposit of gravel occurs on lower Campbell Creek. The silt, however, overlies this material (p. 561), and here, as at Kamloops, the deposit does not measure up to the volume required. Many local pockets of coarse material occur on the upland south of Kamloops. They range from small deltas and ice marginal terraces to veneers of lag gravel. Similar features are found in all upland areas and though each individual deposit is small, in one aggregate these features contain a considerable quantity of coarse grained material.

The small upland gravel deposits were formed during deglaciation while ice occupied the valleys and depressions, and most drainage was along the ice margins. Well developed drainageways were not common. In some places water was ponded in small ice-marginal lakes; in other places it moved onto the ice; in other instances the water flowed freely along the ice margin. The many changes in gradient occasioned by the irregular nature of the drainage caused coarse material to be trapped, whereas the general gradient was such that the silt and finer material remained in suspension. These fines were sluiced from the uplands into the lakes which occupied the deglaciated valleys to the south and east. Consequently the upland gravel and valley-bottom silt were derived by erosion of the same till; however, the unusual drainage regimen, resulting from the mode of deglaciation and nature of topography, led to a complete separation of the two sizes of material.

Source of silt.—No single area supplied the material in Lake Thompson, but in outlining possible source *areas* the following should be noted: (1) the source areas underwent deglaciation at the same time as or later than the site of silt deposition; (2) the meltwater flowed from the source area to the depositional area; and (3) overflow channels and associated gravel deposits indicate till was eroded and sorted in the source area.

The variation in varve thickness and the change in texture and structure of the silt near Kamloops suggest that at least the upper portions of the South Thompson silt entered the valley in that vicinity. It is, however, difficult to judge whether most of the silt came from the area to the south, the Thompson Valley to the west, or the North Thompson Valley to the north.

Terraces and abandoned channels afford abundant evidence that silt-laden meltwater flowed into the valley from south of Kamloops. There are no ice-marginal terraces or other evidence of meltwater flow in the Thompson or North Thompson Valleys. Despite the lack of positive evidence silt-laden meltwater may have been funnelled into the Kamloops area by these major valleys. As mentioned on page 190 much of the sand and other coarse materials, the deposits that make up the major portion of the terraces, remained on the uplands. It is possible that once the meltwater was in the main valleys there was no deposition until the deglaciated portion of the South Thompson Valley was reached. Possible proof of this is seen in the abundant gravel deposits with no associated fines that occur west of the Bachelor Range and in the Cold Creek-Paul Creek Valleys (fig. 2). In both areas the meltwater, which deposited the gravel, flowed toward the North Thompson River Valley. The only possible way the water could have escaped is through the South Thompson Valley; however, in neither case is there evidence of flow of this water within the main valleys.

CONCLUSIONS

Conclusions pertinent to deposition of the South Thompson silt are:

1. Deposition took place in a glacial lake formed between ice tongues at either end of the South Thompson Valley.
2. The lake was at a level of between 1650 and 1750 feet during silt deposition.
3. The silt is varved with thick varves grading upward into thin.
4. Portions of the deposit were laid down in contact with ice.
5. Much of the silt entered the South Thompson Valley in the vicinity of Kamloops.
6. Silt was derived largely from the erosion of till on the uplands adjacent to the valley.
7. The drainage regimen was such that the coarse portion of the till was left on the upland while the silt was carried off to the adjacent valley.
8. Maximum erosion, transportation, and deposition (maximum 20 feet per year) took place as the ice was receding from the adjacent uplands.

Generalizations which probably hold true for most of the other silt deposits of the Cordilleran are:

1. Silt was deposited in a glacial lake.
2. Varves, if present, will be very thick in the lower parts of the deposit, becoming thinner upward.

3. The major portion of the silt was probably derived from erosion of till by meltwater.
4. Maximum deposition took place as the ice receded from adjacent uplands.
5. The localities from which the silt was derived and the position at which it entered the basin will not be obvious.
6. It will be difficult to ascertain the level of the lake or the position and nature of the lake outlet at the time of silt deposition.

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