



## QUATERNARY GEOLOGY OF THE ATLIN AREA (104N/11W, 12E)

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**KEYWORDS:** Economic geology, surficial geology, Atlin, placer gold, stratigraphy, auriferous gravels, exploration.

### INTRODUCTION

This paper reports on the preliminary results of an investigation of the Quaternary and placer geology of the Atlin mining district in northwest British Columbia. The area was selected for study because it supports the second largest placer mining industry in the province and has a long history of placer gold production. In addition, dwindling reserves in recent years have resulted in the shutdown of major mining operations such as the Queenstake mines on Spruce and Pine creeks. The Atlin area also offers good exposure of Pleistocene gold-bearing strata as well as dating control provided by interbedded basalts. Gold production from the district, recorded for the 50 year period after discovery in 1897, was approximately 20 000 kilograms (Holland, 1950). The locations of active mechanized mining and exploration projects are shown in Figure 3-9-1.

### PREVIOUS WORK

Early reports on the geology of the Atlin area were provided by Gwillim (1901, 1902). The placer geology of the region was investigated by Black (1953) and Proudlock and Proudlock (1976). Debicki (1984) provided an overview of the placer mining industry in the region. The Quaternary history of the Fourth of July Creek valley just north of the map area was investigated by Tallman (1975). Anderson (1970) constructed a geobotanical chronology of the Atlin area covering the last 11 000 years. Lacelle (1985) investigated the surficial geology of the shoreline region of Atlin Lake in the vicinity of Atlin townsite and produced a terrain materials map of the Atlin 1:250 000 NTS mapsheet (Lacelle, 1989). The bedrock geology was initially mapped by Aitken (1959) and Monger (1975). Regional bedrock maps were compiled by Lefebvre and Gunning (1989), Bloodgood *et al.* (1989a and 1990) and Ash and Arksey (1990a) and discussed by Ash and Arksey (1990 b, c), Bloodgood and Bellefontaine (1990) and Bloodgood *et al.* (1989b). MacKinnon (1986) completed a mineralogical study of placer concentrates from four mines in the area.

### METHODS

Preliminary airphoto interpretation of the surficial geology of NTS mapsheets 104N/11W and 104N/12E was conducted and field checked at 180 sites in conjunction with stratigraphic and sedimentologic studies of gold-bearing Cenozoic deposits in the region. Property visits and geologic descriptions of 16 active and recently active mines offering good section exposure were completed. Sections in the active mines were mapped and lithologic, pebble-fabric and sedimentological studies were conducted. Samples were collected for textural, mineralogical and geochemical

analysis. Pollen, basalt and wood samples were also collected at several sites for stratigraphic control. Gold production in each stratigraphic unit was determined, where possible, by discussions with miners. Heavy mineral concentrates were collected from gold-bearing lithofacies within a number of stratigraphic units in the Spruce Creek area, using a small test sluice, and from commercial operations at several other sites.

### SURFICIAL GEOLOGY

#### BEDROCK AND COLLUVIAL DEPOSITS

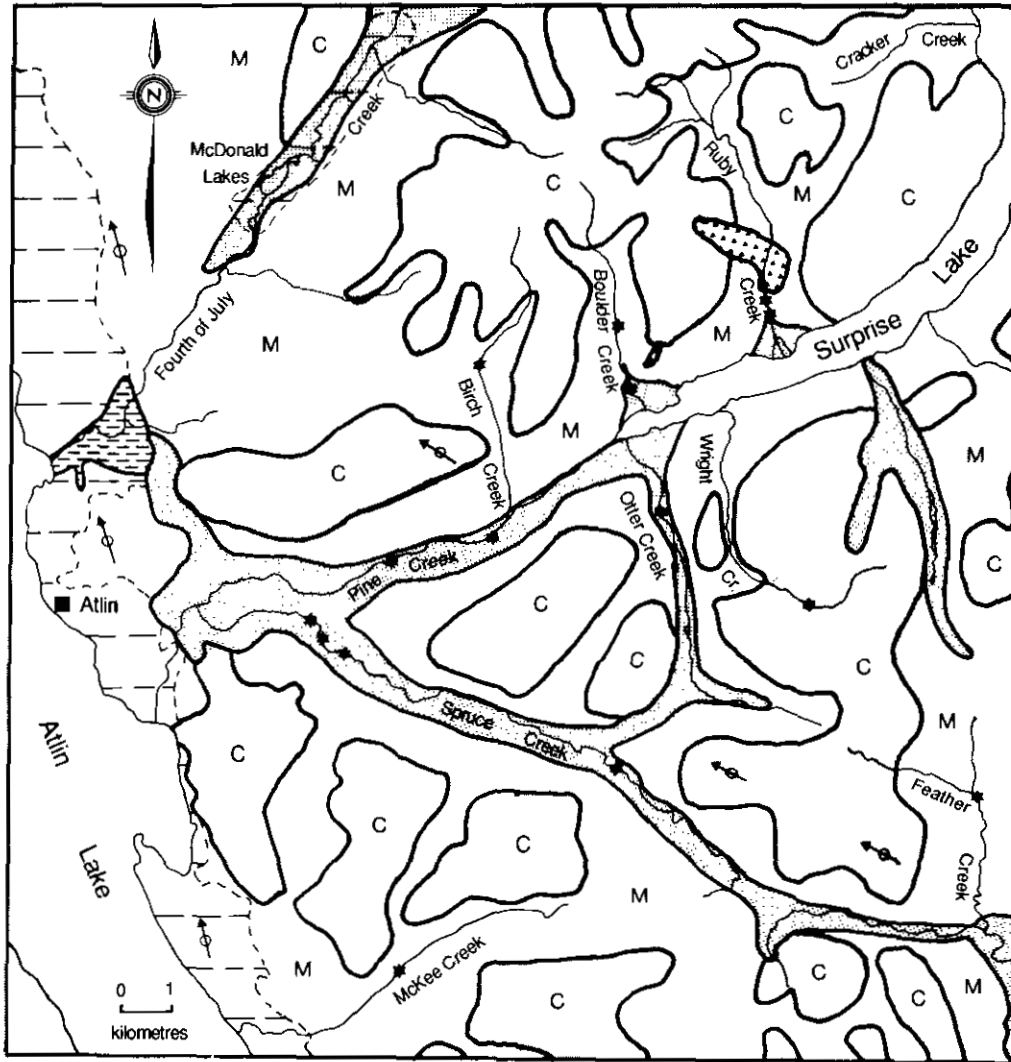
A generalized surficial geology map of the area is given in Figure 3-9-1. Mountain areas, typically but not exclusively above 1500 metres elevation, are characterized by a thin colluvial veneer with about 30 per cent bedrock exposure, mainly on steep slopes. Bedrock outcrops comprise up to 70 per cent of the mountainous areas on the east shore of Atlin Lake and the northeast shore of Surprise Lake, and up to 50 per cent of the uplands immediately north of Atlin townsite. More gentle slopes at high elevations may have a thin blanket of glacially derived diamicton, resedimented by slope processes after initial deposition.

Many high-elevation areas in the region are subject to rapid mass movements (rock falls and debris flows) and snow avalanches. Noteworthy is a large landslide deposit that extends from the east side of Ruby Mountain across the Ruby Creek valley (Plate 3-9-1). Failed materials are mainly Pleistocene vesicular basalts and scoria. Landslide debris typically consists of angular bedrock material ranging in size from sand to large boulders. Some surficial sediments are also incorporated in the slide debris.

Periglacial features such as solifluction lobes, stone stripes (Plate 3-9-2), nivation hollows and cryoturbated soils are common, especially in the northwest part of the map area and to a lesser extent along the high mountains in the south. Talus deposits are common below most bedrock cliffs and rock glaciers occur in some high cirques (Plate 3-9-3).

#### GLACIAL DEPOSITS

Lower slopes and valley bottoms throughout the area are blanketed by morainal deposits consisting of unsorted, massive diamicton. These glacial diamictons are typically matrix supported with clasts occurring in a mixture of sand, silt and clay. Clasts up to large boulders occur but the modal clast size is in the small to large pebble range. Clasts are of widely varied lithologies and commonly are striated and occasionally faceted. The presence of these glacial abrasion features and erratic lithologies indicates glacial transport. The diamictons are inferred to be tills deposited at the base of over-riding glaciers. They typically have planar erosional lower contacts (Plate 3-9-4) and are very dense. Where



**LEGEND**

**SURFICIAL MATERIALS:**

- M MORAINAL (GLACIAL) DEPOSITS
- ▨ GLACIOLACUSTRINE SEDIMENTS
- ▩ GLACIOFLUVIAL AND FLUVIAL DEPOSITS
- C COLLUVIUM AND BEDROCK
- ▩ LANDSLIDE DEPOSITS

**TEXTURE:**

- mainly diamicton; some sand and gravel; minor exposed bedrock
- silt and clay; overlying diamicton and bedrock
- gravel and sand; minor fines; some diamicton in alluvial fans
- diamicton and rubble; bedrock exposed mainly on upper slopes
- rubble and blocks (angular fragments); minor diamicton

REGIONAL ICE FLOW DIRECTION

ACTIVE PLACER MINE

APPROXIMATE UPPER LIMIT OF GLACIAL LAKE

Figure 3-9-1. Generalized surficial geology of the Atlin area (modified from Lacelle, 1989).



Plate 3-9-1. Airphoto of landslide deposits (L), moraines (dashed lines) and other landforms in the Ruby Creek valley. Note the area of intense mining activity (M) between the landslide and the alluvial fan (F) built into Surprise Lake at the mouth of Ruby Creek (British Columbia airphoto BC 5686 No. 86).



Plate 3-9-2. Cobble to boulder stone stripes (S) separated by finer grained colluvium (F) (with vegetation cover). Stone stripes and other periglacial features are common in high mountain areas throughout the region.

studied, these tills have a well-developed pebble fabric indicated by a strong preferred orientation of elongated clasts. Subglacial tills are typically compact, impermeable and poorly drained.

Tills are often overlain by 1 or 2 metres of poorly consolidated, sandy diamictons. These deposits occur mainly on slopes and probably are produced by colluviation of primary tills. They are comprised of glacially transported debris mixed with angular local materials and are commonly interbedded with thin lenses of sorted gravel, sand and silt. Debris-flow diamictons, comprised of similar materials and occurring on slopes from the surface to a depth of a few to several metres, were probably deposited in paraglacial environments shortly after deglaciation.

### GLACIOFLUVIAL DEPOSITS

Morainal deposits are locally incised by meltwater channels and commonly overlain by one to a few metres of glaciofluvial gravels and sands particularly in the Fourth of July Creek valley, along the southwest end of Surprise Lake and in the Boulder Creek, upper Spruce Creek and Feather Creek drainages.

Glaciofluvial deposits are most concentrated along the valley bottoms of Spruce, Pine, Otter and Fourth of July creeks. Well-developed glaciofluvial terraces occur in the lower Spruce Creek and Pine Creek valleys and merge with

raised glaciofluvial delta complexes east and northeast of Atlin townsite. A large kettled delta complex also occurs in the Fourth of July Creek valley at the northern edge of the map area. An ice-contact kame complex occurs at the mouth of Otter Creek (Plate 3-9-5) and there are esker complexes in the lower and uppermost reaches of Spruce Creek. Glaciofluvial deposits consist mainly of moderately to well-sorted, well-stratified, non-cohesive gravels and sands. They typically have a high porosity and permeability and are well drained. Clasts are well rounded and generally in the pebble to cobble size range.

### GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine sediments are uncommon surficial deposits in the map area but occur along the shore of Atlin Lake. The thickest sequence is at the mouth of Fourth of July Creek (Figure 3-9-1). Elsewhere they form a thin discontinuous veneer over morainal materials and bedrock. They are typically comprised of cohesive, impermeable silts and clays that are horizontally laminated to massive.

### FLUVIAL AND OTHER DEPOSITS

Fluvial deposits are confined mainly to alluvial fans at the mouths of creeks entering the Surprise Lake valley, the Pine Creek fan-delta at Atlin Lake and narrow floodplains of streams throughout the area (Figure 3-9-1). They are similar

to glaciofluvial deposits but tend to be finer grained and often are water saturated.

Bog and marsh deposits occur locally, particularly in the Atlin townsite area. Ephemeral salt-marsh deposits around the townsite contain as much as 43 per cent magnesium oxide (MgO) probably in the form of hydromagnesite (Young, 1915; Cummings, 1940). It is presumed that the hydromagnesite deposits formed as evaporite precipitates from saline pond waters fed by groundwaters rich in magnesium and other dissolved salts. Hydromagnesite with iron oxide cement and interbedded calcareous tufa occurs at a small spring on the north side of Atlin, near the lakeshore.

## QUATERNARY AND ECONOMIC GEOLOGY OF PRODUCING PLACER DEPOSITS

### BIRCH CREEK

The North Rim Resources mine on Birch Creek is currently exploiting gravels in the upper part of the creek where the flow changes from southwesterly to southerly (Figure 3-9-1). The auriferous gravels overlie waterworn bedrock and consist of clast-supported, pebble to cobble gravels.



Plate 3-9-3. Rock glacier in a high cirque on the north side of Ruby Mountain.

They are crudely imbricated, indicating a paleo flow towards 210°. Crude subhorizontal stratification is indicated by the presence of small to medium pebble lenses commonly 5 to 10 centimetres thick and approximately 25 centimetres wide. Up to 50 per cent of the beds have iron oxide staining, particularly small pebble lenses and open-work beds. Approximately 75 per cent of the clasts are subrounded to rounded, with the remainder consisting of angular rocks of local derivation. Four to five metres of overburden are exposed at the mine and consist of poorly sorted, massive to crudely stratified, sandy, cobble gravels interbedded with matrix-supported diamicton and lenses of horizontally laminated sand. Glacially abraded clasts are common, especially in diamicton beds.

Stratification, imbrication, clast rounding and the incorporation of local bedrock in the pay gravels all indicate fluvial transport and deposition in a high-energy erosive system. Gold nuggets vary from rounded to angular, also suggesting both local derivation and fluvial transport. Nuggets up to 155 grams (about 5 ounces) occur but approximately 60 to 70 per cent of the gold is finer than 1 millimetre in diameter. Irregularities in the bedrock surface, defined by near-vertical joints, act as natural riffles and are particularly rich in gold. Overburden sediments are interpreted as glacial debris flows and proximal outwash deposits.

The main paleochannel of Birch Creek was mined hydraulically in the past with some underground mining. For example, pay gravels under one extremely large boulder, excavated by recent mining, had been entirely removed by underground workings and the boulder was left supported only by timbers. Currently, the lower metre of the gravels and upper metre of the bedrock are being mined with a production cut-off of approximately 1 gram per cubic metre. Particularly large machinery and a specially engineered processing plant are currently utilized to mine and process the gravels due to the high silt and clay content and consolidation of the overburden. A possible buried channel on the east side of the creek was being investigated at the time of the property visit. The east side of the creek, throughout most of its length, has produced more gold than the west side (Gerry Schmidt, personal communication, 1991). Mining of unexploited gravels downstream from the current operation is planned.

### BOULDER CREEK

Two small-scale operations are currently active on Boulder Creek. One is working alluvial-fan sediments at the downstream end of the creek. Exposures in test pits indicate that the fan sediments increase in thickness from 1.5 metres near the valley side to more than 8 metres nearer the fan centre. They consist of interbedded pebble, cobble and boulder gravels with crude horizontal bedding and weak imbrication. The gravels are clast supported and are locally open-work. They are characterized by numerous trough-shaped cobble and boulder concentrations a few to several metres wide. Clasts with evidence of glacial abrasion occur mainly in the lower 5 metres. The upper few metres exhibit trough-crossbedding with beds generally more than



Plate 3-9-4. Till (T) overlying glaciolacustrine (L) sediments on lower Otter Creek.

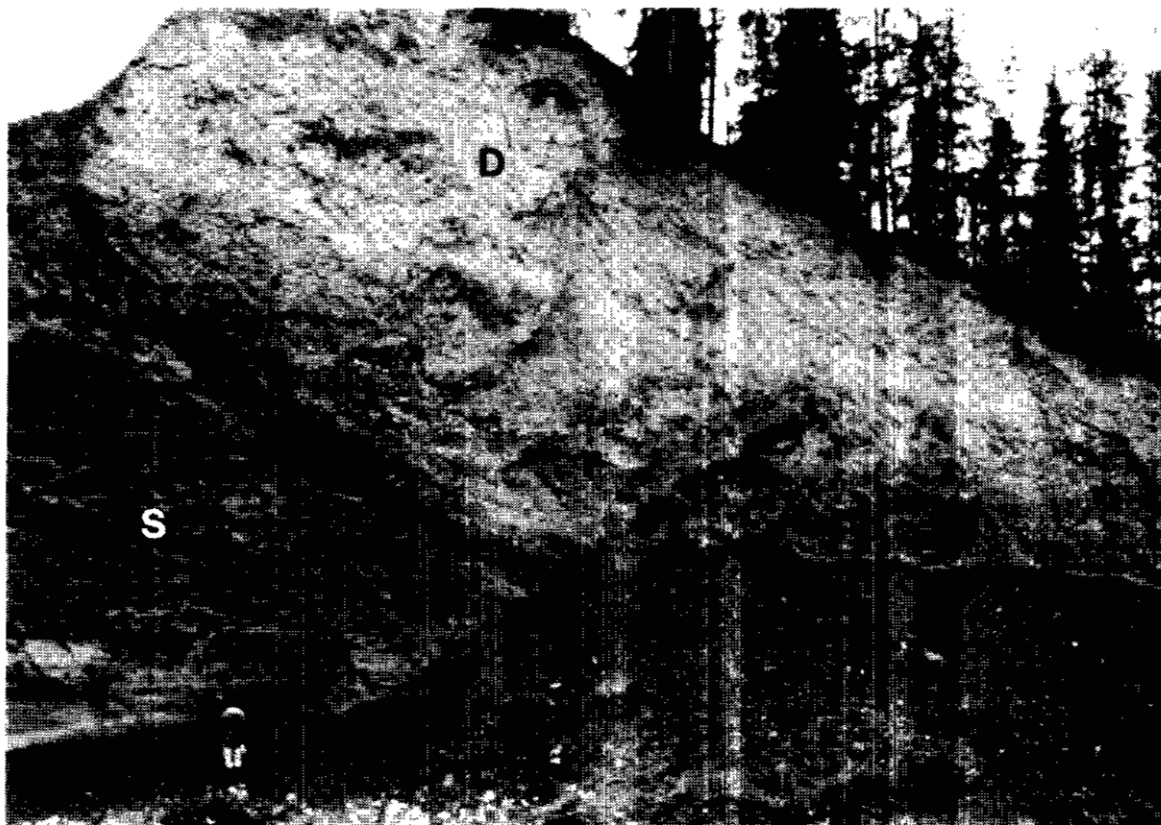


Plate 3-9-5. Exposure in part of a large ice-contact kame complex at the southwest end of Surprise Lake. Debris-flow deposits (D) unconformably overlie a faulted sand sequence (S).

5 metres wide and less than 0.5 metre thick. Exposed bedrock consists of oxidized basalt with numerous joints and small faults.

The bulk of sediments in the fan was probably deposited under paraglacial conditions and derived dominantly from glacial debris. The presence of crude imbrication, open-work beds, clast-supported strata and crossbedding suggests deposition by relatively fluid flows. Numerous trough-shaped, coarse-clast concentrations, interpreted as channel lags, and scour-and-fill structures indicate deposition in braided channels. Gold distribution is probably strongly facies-controlled with coarse gold concentrated along channel lags and finer gold more evenly distributed throughout the fan sequence. The gravels in the upper few metres show evidence of more fluvial reworking and probably have higher gold contents than the underlying deposits. Gold concentrations are expected to be highest in channels cut into bedrock near the fan apex. Buried fan-head channels associated with preglacial or interglacial stream courses of Boulder Creek are the best targets.

A second small operation on upper Boulder Creek is mining mainly old tailings in the channel bottom. Outcrops of original gravels are rare, with most remaining auriferous sediments being buried by thick glacial overburden and colluvium along the valley sides. At one outcrop, however, 2 metres of original pay gravels are exposed. They are heavily oxidized, massive to crudely stratified, cobble to boulder gravels interpreted as fluvial channel-fill gravels. They are overlain by 4 metres of bouldery, massive, matrix-supported diamicton of presumed glacial origin.

### FEATHER CREEK

The lowest exposed sediment observed at the Feather Creek mine is a matrix-supported, compact, oxidized, sandy-silt diamicton up to 8 metres thick, with interbedded lenses of well-sorted pale yellow (unoxidized) silts. Clasts are mostly angular, local rocks and some are striated. The diamicton is unconformably overlain by gold-bearing, unoxidized, clast-supported, cobble to boulder gravels grading locally into sandy gravelly diamicton. The upper part of the gravels has crude horizontal bedding, manganese and iron-stained open-work beds, small lenses of pebble gravel and more rounded to well-rounded clasts. Bedrock in the area is a pyritic basalt with silica and iron oxide filling vugs. It rises to within 3 metres of the surface upstream from the mining area and is exposed along the valley sides. Downstream from the minesite bedrock drops off as much as 20 metres, indicating the possible presence of a deep paleochannel. Buried paleochannel placers in the area have been mined underground in the past.

The gold-bearing unoxidized gravels are interpreted as Holocene stream deposits. Most of the recovered gold is flattened and rounded and predictably comes from the basal portion of these gravels where it has been reconcentrated from the underlying sediments. Glaciers overriding the area probably eroded and incorporated gold from the bedrock and possibly also from pre-existing fluvial placer deposits in the area. During deglaciation, resedimentation of glacial debris occurred to form debris-flow diamicton deposits,

poorly sorted fluvial gravels and local waterlain silts. A dominantly local derivation for the sediments is indicated by the large proportion of angular clasts and by the presence of some fragile gold forms (Plate 3-9-6). Oxidation of fine-grained diamicton and silty sediments is probably a relict feature resulting from the incorporation of oxidized bedrock as the sediments have a low permeability and are now in reducing conditions below the water table. The largest recently recovered nugget weighs approximately 28 grams.

### MCKEE CREEK

Exceptionally coarse gold has been recovered in the McKee Creek placers, mainly from buried paleochannel deposits (Plate 3-9-7). Gold-bearing strata in the area are overlain by a well-exposed Quaternary sequence consisting of over 30 metres of non-auriferous gravel, sand, silt and diamicton. Exposures at the upstream end of the mine area reveal a diamicton complex overlying horizontally stratified gravels and sands. Exposures farther downstream also have thick, horizontally laminated silt and clay units that grade vertically and laterally (to the southwest) into sand and gravel beds that dip consistently up valley (to the northeast) as much as 15° (Plate 3-9-8). They are erosionally truncated

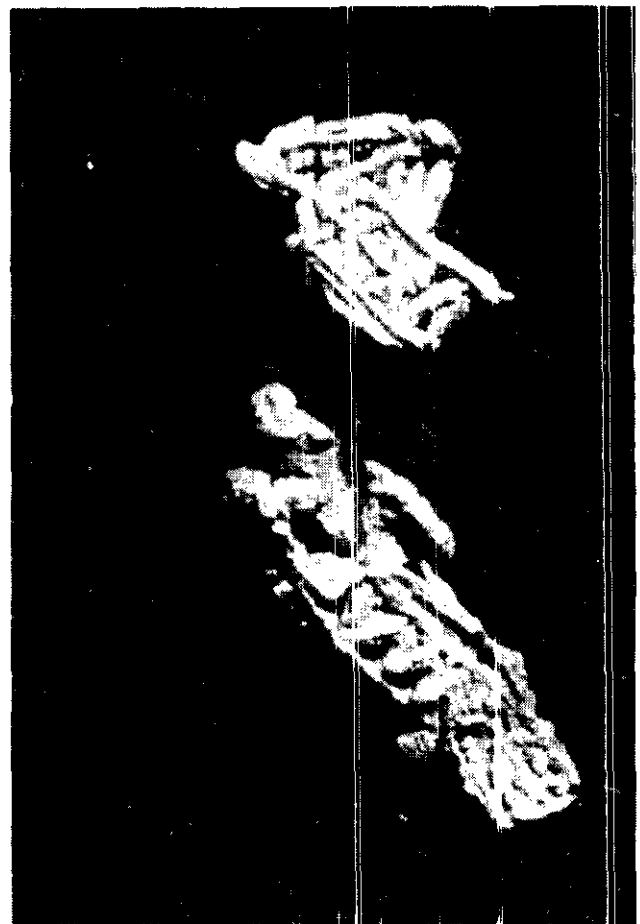


Plate 3-9-6. Locally derived gold nuggets from Feather Creek. (Small nugget is 1 cm long)

at the sharp base of a massive, compact diamicton with an exceptionally strong preferred fabric.

Study of these exposures indicates that gold was deposited in fluvial channel gravels in preglacial or interglacial times. Some of the lower gravels containing large boulders up to 2 metres in diameter have sedimentary characteristics indicative of high-energy hyperconcentrated flows (Plate 3-9-8). The presence of overlying glaciolacustrine silts and clays indicates that drainage in the McKee Creek valley was dammed, presumably by the advancing Atlin Lake valley glacier. Horizontally laminated fines, interpreted as bottom-set beds, grade into dipping sand and gravel strata inferred to be foreset beds in a prograding glaciofluvial delta (Plate 3-9-8). The massive diamicton erosionally overlying the delta sequence is interpreted to be a till deposited at the base of the Atlin valley glacier as it expanded up the McKee Creek valley. Debris-flow and proximal outwash deposits shed off this glacier created the complex sequence of deposits exposed in higher parts of the valley. The uppermost part of the diamicton sequence represents till deposited during full glacial times and resedimented glacial debris deposited during and after deglaciation.

Mining in the area has included early hydraulic mining, open-pit mining and some underground activity. The most recent large operation exploited a buried channel remnant on the northwest side of the valley. There is potential for other channel remnants in the area as the bedrock rim has not yet been exposed along many parts of the valley side. A dry, boulder-gravel stream bed at the upper end of the mine

area, on the southeast side of the valley, is the focus of current interest and has good potential for a shallow mining operation.

### OTTER CREEK

The upper Otter Creek mine is the area's largest, with several large pieces of heavy mining equipment operating continuously. The open pit is nearly 2 kilometres in total length and provides excellent exposure of the Quaternary succession. The active highwall at the south end of the mine (Plate 3-9-9) reveals about 6 metres of gold-bearing sediments consisting of angular pebble to cobble gravel interbedded with poorly sorted, normally graded cobble to pebble gravel and diamicton. The upper part of the pay gravels has relatively high gold contents where large rounded boulders up to a few metres in diameter are concentrated. The bedrock surface under these bouldery gravels is well water-worn, undulatory and generally dips steeply towards the north and east. Overburden consists of 7 metres of crudely stratified large-pebble gravel, 10 metres of compact, massive, matrix-supported diamicton, grading up into 7 metres of very crudely stratified diamicton, capped by 4 metres of horizontally and trough cross-stratified gravels and sands.

The current mine is apparently working channel-margin deposits on the west side of the Otter Creek paleochannel. Poor sorting, numerous angular clasts and normal graded bedding in gravel and diamicton beds indicate a debris origin. The debris flows were locally derived and incorpor-



Plate 3-9-7. Coarse gold nuggets from McKee Creek paleochannel placers.





Plate 3-9-8. Glacigenic debris-flow and till deposits (T) unconformably overlying delta foreset and bottomset beds (D) and fluvial channel deposits (F) along lower McKee Creek. Exposure is 32 metres high. Large boulder at lower left is 2 metres in diameter.

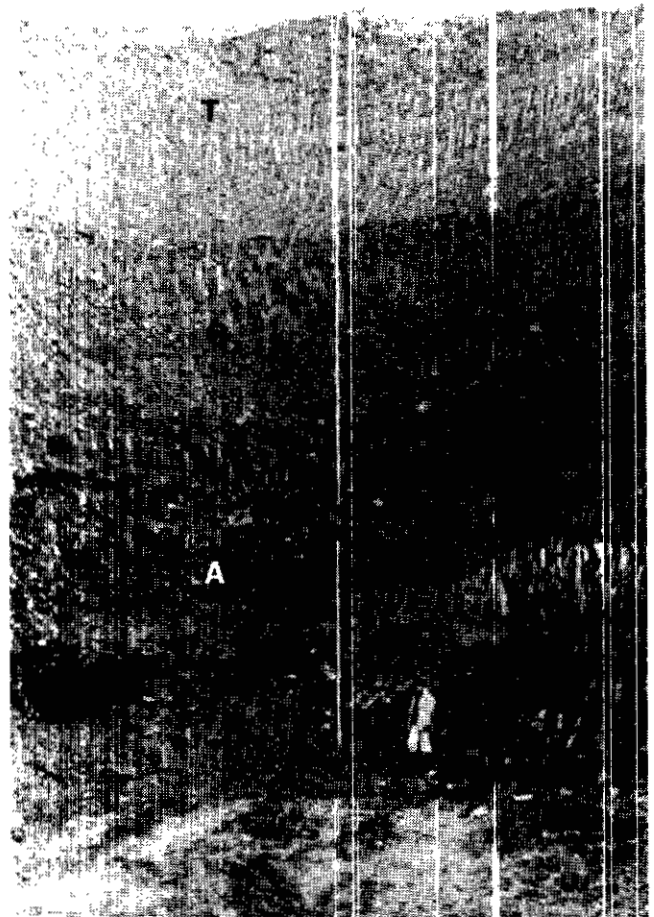


Plate 3-9-9. Gold-bearing gravels (A) overlain by non-auriferous gravels (G) and till (T) in the lower half of the active highwall at the Otter Creek mine.

ated gold from pre-existing auriferous colluvial and alluvial sediments. Boulder-gravel beds represent more typical channel deposits but their occurrence relatively high on a bedrock rim that dips steeply towards the east (paleochannel centre) as well as the north (downstream) indicates that deposition occurred along the channel margin and not in the thalweg (deepest part of the channel). The steep undulatory geometry of the bedrock is suggestive of a paleowaterfall and plunge pool.

Overburden deposits are interpreted as proglacial outwash stream gravels succeeded by till, postglacial debris-flow deposits, and finally Holocene fluvial channel gravels. Down valley, the complexity of the overburden succession increases with the addition of a deltaic gravel sequence (Plate 3-9-10), laminated glaciolacustrine silts and sands (Plate 3-9-4) and up to three auriferous gravel units interbedded with till deposits.

### PINE CREEK

Pine Creek is the second largest placer-producing stream in British Columbia and formerly supported a large mining

community at Discovery, approximately 10 kilometres east of Atlin. Gold-bearing gravels in the area consist of massive to crude horizontally stratified boulder gravels. They are poorly sorted and mainly clast supported and contain discontinuous, poorly defined interbeds of diamicton with abundant silty-clay matrix. Discontinuous silty clay, granular gravel and pebbly sand strata also occur. The auriferous strata are overlain by a diamicton complex a few to several metres thick. The diamicton is locally crudely stratified and contains interbeds of sand and gravel. Elsewhere it is compact, massive, matrix supported and contains numerous striated clasts, sheared sand lenses and slickensided sub-horizontal partings. Up to 5 metres of well-stratified sands and gravels, commonly with convoluted bedding, locally overlie the diamicton sequence.

The gold-bearing gravels are interpreted as fluvial channel and debris-flow deposits, possibly derived in part from the valley side. The overlying diamicton complex is inferred to be till and glacially derived debris-flow deposits. The uppermost sand and gravel sequence is interpreted as ice-contact and proximal outwash deposits. A large mine recently operated by Queenstake Resources Limited

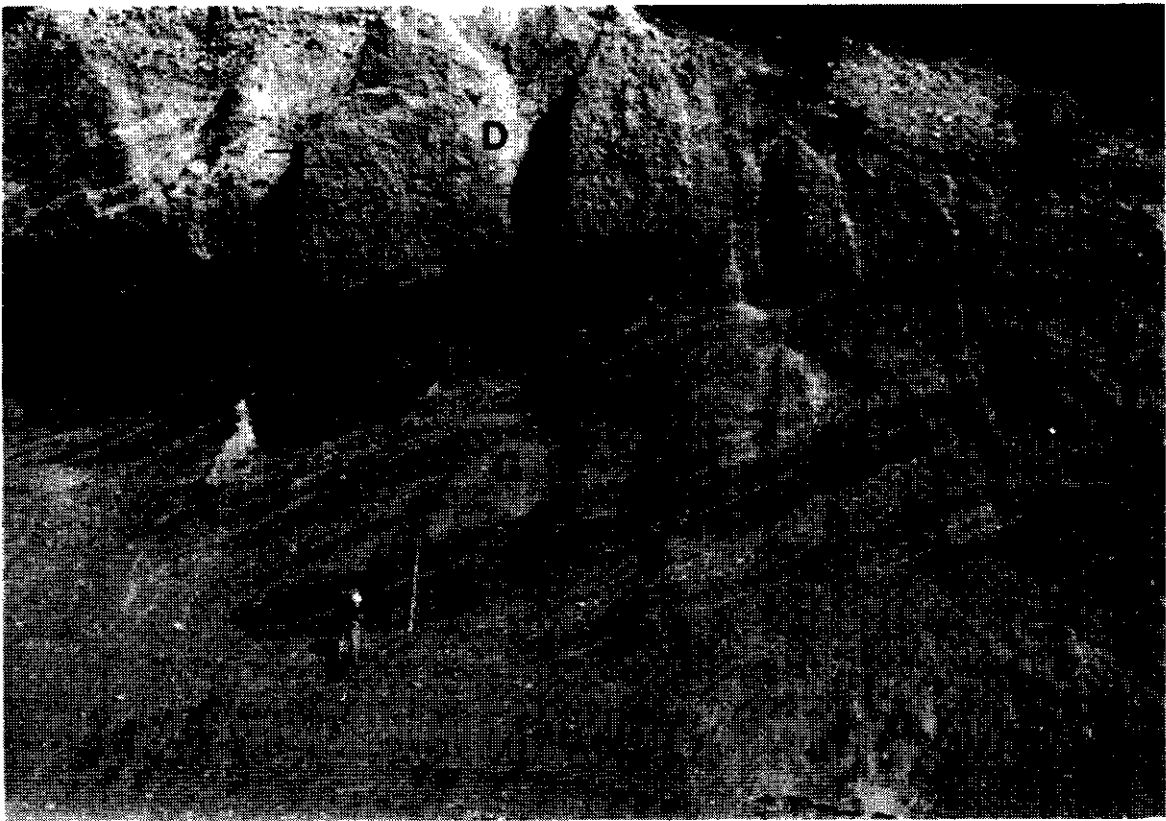


Plate 3-9-10. Delta foreset gravels (G) overlain by till and debris-flow deposits (D) on Otter Creek.

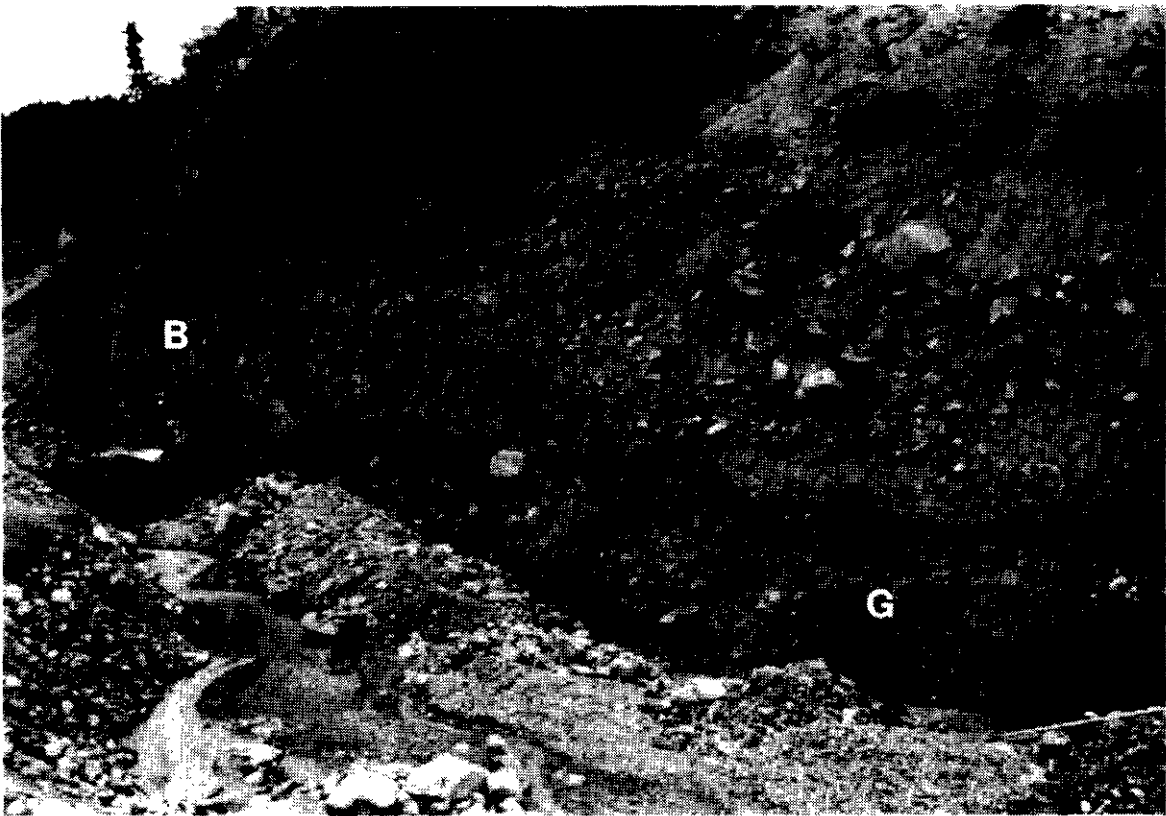


Plate 3-9-11. Excavating placer gravels (G) under Pleistocene basalts (B) on Ruby Creek.

exploited the lower gravel sequence in an area upstream from historical mining. There may be potential for further expansion of mining upstream, downstream and possibly also closer to the valley sides, but the thick glacial and glaciofluvial overburden inhibits exploration. Given the productivity of tributary creeks upstream from the Queenstake minesite, it seems probable that paleochannels of Pine Creek in that area would also be highly auriferous. However, depth of ice erosion and consequent preservation potential has not been documented.

### RUBY CREEK

The Ruby Creek placer deposits have a unique geologic setting as they are overlain by Pleistocene basalts and rock avalanche deposits that originated in the Ruby Mountain area (Figure 3-9-1). The gold-bearing gravels are clast supported, mainly matrix filled and poorly to well sorted. They consist mainly of cobble and boulder gravels with some pebble beds and they exhibit horizontal stratification, clast clusters and crude imbrication. Clasts are mainly sub-rounded to well rounded and there are numerous well-rounded clasts of local granitic bedrock. The contact with the overlying basalts is locally marked by beds of stratified sand and fine gravel composed almost entirely of scoria. Large basalt 'clasts' also occur within the upper part of the gravels.

The auriferous gravels are interpreted as high-energy fluvial channel gravels and hyperconcentrated flood-flow deposits. Scoria-rich sand and gravel beds are interpreted as subaqueous volcanoclastic deposits formed during the initial phases of volcanic activity. The large basalt 'clasts' may also have formed subaqueously as lava pillows. Most of the basalt sequence, however, is columnar jointed and cooled relatively slowly. Glacial deposits locally overlie the columnar basalts as do postglacial landslide deposits. The latter are composed mainly of angular scoria and vesicular basalt rubble but locally contain large intraclasts of glacial diamicton.

Two mining operations are currently active at the lower end of Ruby Creek, both working gravels underlying basalts on the valley sides. The richest gravels are typically below the water table and undercutting the columnar basalts creates an additional mining challenge. The Bonnell operation is mainly utilizing natural slope and weathering processes active during the winter to remove the potentially hazardous overhanging basalts. The Russo operation is mechanically undercutting the gravels (Plate 3-9-11) and has done some underground mining, with plans for further underground developments.

Gold nuggets are typically about 2 millimetres in diameter and subrounded to angular. The largest recently recovered nugget was 180 grams (5.75 ounces) but nuggets up to 1.37 kilograms (44 ounces) have been reported. Gold grades in the lower metre of the pay gravels vary from 30 to 150 grams (3 to 5 ounces) per cubic metre and are up to 15 grams per cubic metre in the overlying 3 to 4 metres (Mike Bonnell, personal communication, 1991). Bedrock rises sharply on the valley walls and follows low-gradient benches along the valley-bottom margins which slope

approximately 2° to 3° down valley. Gold contents are high where the bedrock is altered to a red granular sand or even a light-coloured silt. Ridges and knobs of unaltered bedrock are common.

### SNAKE CREEK

Holocene fluvial gravels are mined on this small creek draining from a low pass on the east side of Spruce Mountain. The gold is relatively coarse with nuggets commonly 2 to 3 grams in weight, the largest recently recovered nugget weighed approximately 30 grams. Local bedrock consists of graphitic argillite with disseminated pyrite. A strong foliation strikes at 180° and dips 48° to the west. The bedrock is overlain by 4.5 metres of poorly sorted, large-cobble gravels interbedded with pebble gravels and horizontally laminated sands. The gravels are clast supported, matrix filled, horizontally bedded and crudely imbricated. They are overlain by a massive, matrix-supported, sandy silt diamicton. Gold has been recovered mainly from the Holocene Snake Creek channel but the possibility of a deeper buried channel is indicated at one site along the present creek where an excavation revealed a sharp drop in the bedrock of more than several metres. The bedrock depression apparently crosses the creek obliquely and is buried by an additional several metres of glacial and glaciofluvial deposits to the east.

### SPRUCE CREEK

Spruce Creek has produced more placer gold than any other creek in British Columbia, as well as the province's largest nugget weighing 2.6 kilograms (85 ounces). Most mining activity is currently concentrated at the lower end of the creek (Figure 3-9-1). Some open-pit mines higher up on the creek have heavy equipment on site but little current activity was seen other than hand operations. The main placer operation in the valley in recent years was the Queenstake mine on lower Spruce Creek. Several distinct stratigraphic units occur in the area, including possible preglacial, interglacial and postglacial deposits (Figure 3-9-2). Up to 4 metres of the lowermost auriferous gravels overlying bedrock have been mined. They are generally poorly sorted with a silty sand matrix, clast supported and crudely stratified. Gold also occurs in cobble and boulder beds in gravels that erosionally overlie the main, basal gold-bearing sequence, but in lower concentrations. These gravels are exposed just above water level at the northwest (downstream) end of the minesite (Figure 3-9-2). Stratigraphically higher gravel units are locally interbedded with diamicton and well-sorted sand beds and they are largely barren. The entire sequence is capped by massive diamicton beds and sands and gravels.

The gold-bearing gravels are interpreted as high-energy fluvial channel deposits. The paleochannel orientation is oblique to the trend of the modern valley as indicated by paleocurrent measurements (Figure 3-9-2). Drilling south and west of the property has been conducted in an attempt to delineate the buried channel geometry and extensive underground workings have been developed in the past to exploit the gravels. Gold occurs in lower concentrations and is

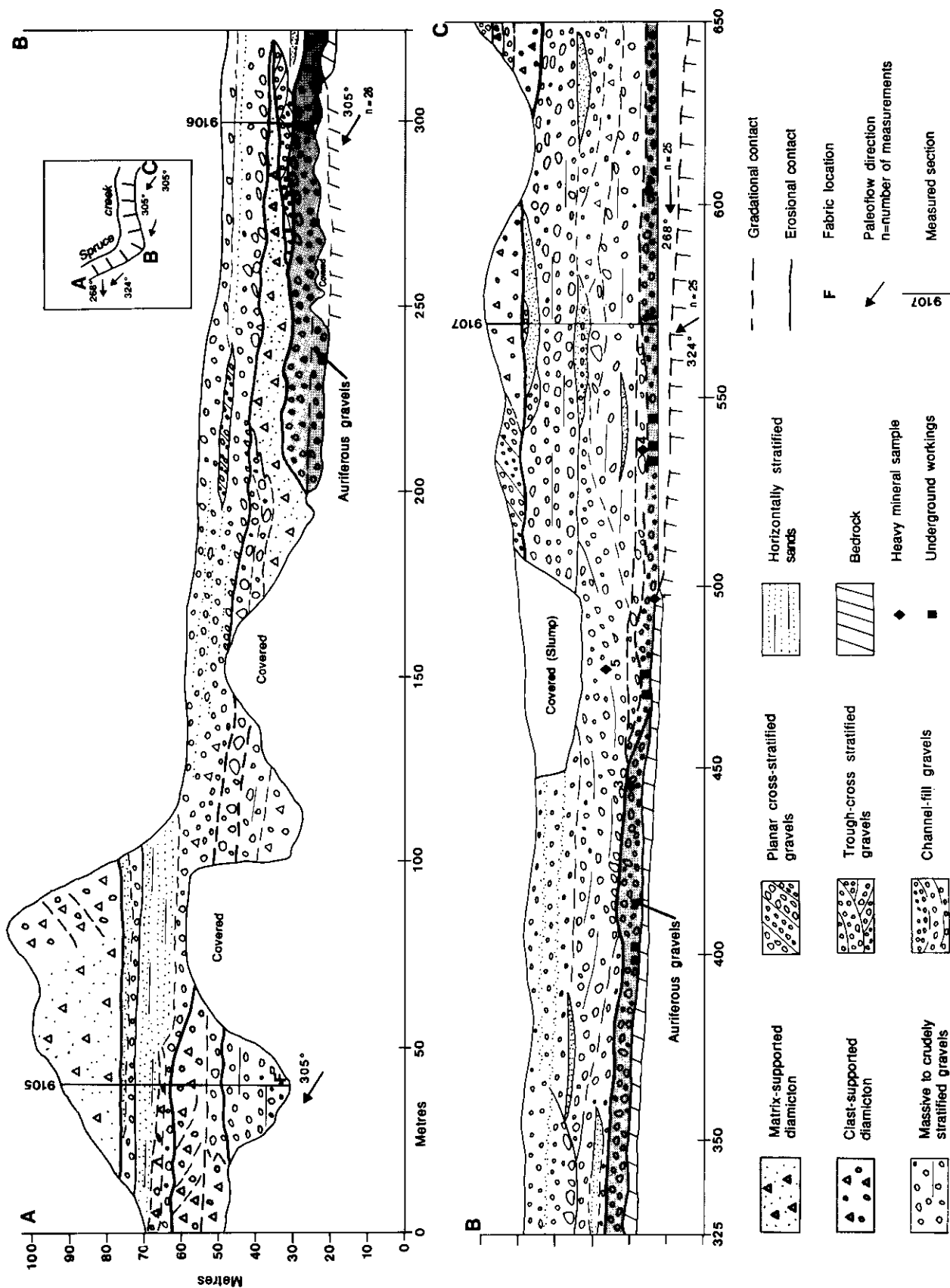


Figure 3-9-2. Longitudinal cross-section of Quaternary sediments exposed south and west of the former Queenstake Resources mine on Spruce Creek.

confined mainly to coarse gravel facies in younger gravel units, presumably because it was eroded from the older gravels and redeposited too quickly to allow significant reconcentration. Overlying gravels are believed to be glaciofluvial in origin and the uppermost diamictons are interpreted as till and ice-proximal debris-flow deposits. The uppermost sands and gravels comprise part of a postglacial, glaciofluvial esker and kame complex.

The Arnold Ellis mine, located just downstream from the area mined by Queenstake, has exploited mainly channel-bottom sediments missed by earlier operations and is currently mining basal cobble-gravels and the upper few metres of altered basaltic bedrock along the valley side. The gravels are heavily oxidized, clast supported and are poorly sorted with a high percentage of medium to coarse sand matrix. They locally grade into diamicton or very poorly sorted pebble gravel with a silty matrix. The underlying bedrock forms a bench that is defined by a ramp rising at a slope of about 15° from stream level onto a surface that dips gently (about 5°) toward the valley centre. The bedrock is locally strongly altered to red-coloured sand and silt-sized material that contains little placer gold. The gold-bearing gravels are overlain by about 5 metres of crudely imbricated, pebble to cobble gravels with crude horizontal stratification marked by coarse clast concentrations. These gravels are in turn overlain by 10 to 12 metres of massive diamicton grading up into crudely stratified diamicton with sandy interbeds.

The lower gravel sequence was probably deposited by sediment-rich flood flows with the basal gold-bearing gravels deposited during the final phases of channel degradation. The overlying barren gravels were probably deposited during valley aggradation, possibly induced by changes in base level and sediment input associated with the onset of glaciation. The capping diamictons are inferred to be till and other glacial sediments deposited during and immediately after glaciation.

Although the bulk of unmined placers in the Spruce Creek area are buried under thick overburden, some paleoplacers still remain in the valley bottom in areas where water problems have prevented mining. At the Springer Kyle property at the lower end of Spruce Creek (Figure 3-9-1), a channel 7 to 10 metres deep and approximately 20 metres wide has been mined in recent years and preliminary drilling results indicate the presence of another possible channel. An artesian aquifer, encountered in one hole at a depth of 8 metres, was still flowing at a rate of a several litres per minute a few weeks after drilling and indicates the probable presence of a highly porous gravel bed.

Oxidation of older gravel units in the Spruce Creek area is ubiquitous. It is often most intense in permeable strata but locally cross-cuts facies boundaries. It may reflect an early period of subaerial weathering, preferential incorporation and weathering of iron oxide rich bedrock, oxide precipitation from groundwater moving through permeable strata or hydrothermal alteration. Evidence for the latter is provided by zoned quartz veins in strongly altered bedrock and the presence of strongly altered clasts in the lower part of the gravels. Only the lowermost 0.5 to 4 metres of the oxidized gravels are highly auriferous, locally containing up to about

25 grams of gold per cubic metre. The gravels have been extensively mined underground and old workings are continuously encountered in modern open-pit mines (Figure 3-9-2).

## WRIGHT CREEK

The only current operation on Wright Creek is in the upper part of the valley where a small mine run by Andy Didac is exploiting remnant channel gravels and Holocene alluvial fan sediments issuing from Eagle Creek, a small west-flowing tributary of Wright Creek (Plate 3-9-12). A maximum of about 4 metres of fan sediments are mined. Sandy, clast-supported, large-pebble gravels are overlain by cobble to boulder gravels with some diamicton interbeds. The lower few metres of the gravels contain approximately 0.5 gram of gold per tonne. Bedrock at the base of the fan consists of argillite with chert interbeds. Some gold-bearing gravels occurring on low bedrock terraces along Wright Creek are strongly cemented with iron and manganese oxides. Their hardness is comparable to the local bedrock and they may have been sufficiently resistant to have survived glaciation.

Lower Wright Creek was the site of an underground operation that temporarily exploited a rich gold-bearing gravel at approximately 30 metres depth but otherwise was unsuccessful due to water problems (Andy Didac, personal communication, 1991). The area has generated some recent interest as indicated by evidence of several deep drill holes. In addition, geophysical exploration for a possible buried channel between Wright and lower Otter creeks south of Surprise Lake is ongoing.

## CONCLUSIONS

### QUATERNARY HISTORY AND CHRONOLOGY

Glaciation of the Atlin area was preceded by an extensive period of fluvial valley incision during which many of the placer deposits in the area accumulated. Some of the placer deposits may be interglacial in age but most are probably preglacial. All are overlain by till deposits of the last glaciation. Infinite radiocarbon dates reported by Reeburgh and Springer-Young (1976) indicate that the gravels minimally predate the late Wisconsinan glaciation. Wood fragments from the bedrock-till interface in a underground placer mine on McKee Creek were dated at more than 36 000 years B.P. (AU-114) and peat at the base of compacted till at the mouth of Boulder Creek yielded a radiocarbon date of more than 31 000 years B.P. (AU-59).

In the Ruby Creek area, a period of Pleistocene volcanism occurred after deposition of the main gold-bearing gravel sequence. The lava, initially flowing into Ruby Creek, was deposited subaqueously, whereas subsequent flows cooled more slowly to form a thick sequence of columnar basalts.

The last glaciation largely obscured any evidence of earlier events, with the possible exception of some old glacial sediments at the lower end of Otter and Boulder creeks. Ice in the last glaciation initially moved into the Atlin region down major valleys from accumulation areas in

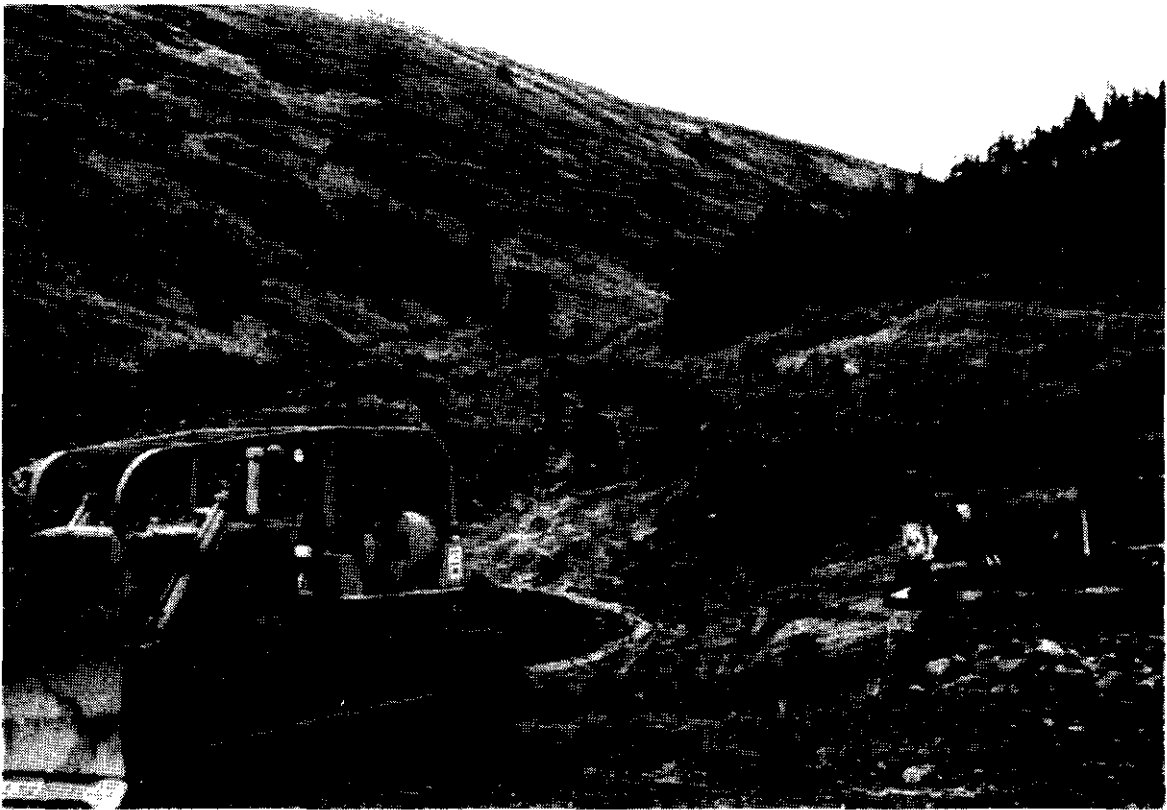


Plate 3-9-12. Small mine exploiting Holocene alluvial fan sediments at the mouth of Eagle Creek valley (background).



Plate 3-9-13. Glaciofluvial delta complex on lower Boulder Creek.

the Coast Range. Ice apparently occupied the Atlin Lake valley before smaller tributary valleys, resulting in damming of creeks such as McKee and Spruce. Ice damming in the Boulder and Otter Creek valleys may also have been caused by a glacier flowing up the Pine Creek valley. Prograding glaciofluvial delta complexes (Plate 3-9-13) formed in all these ice-dammed lakes. During full glacial times the region was almost entirely ice covered by a northeasterly flowing regional ice sheet resulting in a ubiquitous surficial cover of glacial sediments. Well-developed moraines are rare, but recessional moraines occur locally, as in the upper Ruby Creek valley (Plate 3-9-1).

During deglaciation ice-contact kame and esker complexes formed in a number of areas and a large glacial lake developed in the Atlin Lake valley. Outwash from Pine and Spruce creeks deposited glaciofluvial deltas northeast and east of Atlin. As the lake level dropped, deltas and correlative outwash terraces were constructed at successively lower levels. The highest lake level in the area, determined by the distribution of glaciolacustrine sediments and by maximum delta elevations, was at about 780 metres above sea level. A glacial lake also formed in the McDonald Lakes area (Figure 3-9-1) as a result of damming by Atlin valley ice retreating down the Fourth of July Creek valley (Tallman, 1975). The elevation of large pitted deltas along Fourth of July Creek northeast of McDonald Lakes indicates a maximum glacial lake level higher than 1000 metres above sea level.

During and following deglaciation, previously deposited glacial sediments were extensively reworked by coluvial processes under paraglacial conditions. Resedimented glacial deposits are common at the base of steep slopes. Similarly, paraglacial alluvial-fan sedimentation was probably very active during deglaciation and has continued to the present. Holocene glacial activity was restricted to high cirques in the northeast part of the map area. At high elevations, periglacial processes have played a large role in the evolution of geomorphic features throughout much of the Holocene (Tallman, 1975). Rock glaciers, solifluction lobes and stone stripes are common high-elevation features. At least one major postglacial landslide has occurred in the area. Fluvial terrace, floodplain and active channel deposits have also formed along valley bottoms during the Holocene. Postglacial sediments currently supporting placer mines are uncommon but locally include Holocene alluvial fan and fluvial deposits.

## FUTURE PLACER PROSPECTS

In identifying potentially productive placer settings from geomorphic and stratigraphic points of view, it is necessary to first consider the potential for bedrock in the area to yield gold to the placer environment. For example, a probable connection between altered ultramafic rocks (listwanites) and lode and placer gold production in the Atlin area has recently been suggested (Ash and Arksey, 1990 b, c). These studies suggest that areas with placer potential may occur downstream from known ultramafic outcrops or in areas where it can be determined by geological inference that ultramafic rocks previously occurred and have since been

eroded. Such inferences can be made, for example, on the basis of structural cross-sections or simply by the presence of altered ultramafic clasts or related mineral suites in the placer deposits under investigation.

In addition to specific potential developments discussed above for each of the main placer mining areas, a number of other general areas with placer potential can be suggested. Although the Pine Creek valley has been extensively mined, it is wide and there is good potential for undiscovered buried channels, particularly to the north and east of previously mined areas. On the north side of the valley, broad, linear topographic lows are recognizable on airphotos and may represent surface expressions of former gold-bearing paleochannels. Similarly, the area between the Birch Creek confluence and Surprise Lake has not been mined and, given the historical productivity of upstream tributaries such as Otter, Boulder and Ruby creeks, it seems probable that paleochannels in that area would also be gold bearing.

Good potential for rich buried-channel placer deposits also exists in the Spruce Creek valley. In addition to the area downstream and west of the Queenstake property, much of the valley upstream of the Nolan underground mine has good potential. Depth of ice erosion and thick glacial and glaciofluvial overburden are the main factors limiting the location and exploitation of these deposits.

Confined channel gravels below Pleistocene basalts and rock avalanche deposits in the Ruby Mountain area have good potential. Undiscovered paleochannel deposits on this creek and on others such as Boulder and Birch creeks, will mostly be small channel remnants on the valley sides, but there is local potential for more extensive deposits in areas where these valleys widen. Similarly, the broad alluvial flat on Wright Creek, downstream from the point where it bends from a northwest to a northerly trend, has good potential for deeply buried fluvial channel deposits. The valley is narrow and oriented obliquely to the regional ice-flow direction and therefore may have escaped deep glacial erosion.

Although postglacial placers are less productive than buried channel deposits and have not been heavily exploited to date, they may have potential for efficient mining operations with improved recovery systems. Large-volume, relatively low-grade surface placers include alluvial fan deposits at the mouths of Boulder, Ruby and Birch creeks and to a lesser extent fans on lower Otter, Wright and McKee creeks. In addition, fluvial terrace deposits such as are recognized on upper Spruce Creek and in the Wilson Creek area just south of the study area have potential.

Other regions with placer potential, not investigated in this study, include Davenport, Lincoln, Cassiolen and Volcanic creeks north of the map area, Cracker Creek to the northeast and Burdette, O'Donnell and Bull creeks to the south. Productive placers have also been recorded in the Graham Creek area west of the study area. Further study of these placer deposits is needed to identify their extent and potential.

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