Geoscience Canada

History of Geology:
Placer Gold Mining in Pleistocene Glacial Sediments of the Cariboo District, British Columbia, Canada 1858-1988

N. Eyles et S. P. Kocsis

Volume 15, numéro 4, december 1988

URI : https://id.erudit.org/iderudit/geocan15_4fea02

Aller au sommaire du numéro

Éditeur(s)

The Geological Association of Canada

ISSN

0315-0941 (imprimé)
1911-4850 (numérique)

Découvrir la revue

Citer cet article

Eyles, N. & Kocsis, S. P. (1988). History of Geology:: Placer Gold Mining in Pleistocene Glacial Sediments of the Cariboo District, British Columbia, Canada 1858-1988. *Geoscience Canada*, *15*(4), 293–301.

Résumé de l'article

The Cariboo placer mining district of central British Columbia, based on the communities of Wells/Barkerville, is a classic gold rush area of the late 1850s where gold mining still continues. Production started in 1858 and by 1861 Barkerville was the largest town northof San Francisco and west of Chicago. Today the area accounts for almost 30% of the province's annual total placer gold output, valued at about $9M. Gold apparently concentrated in near surface positions by deep tertiary weathering and supergene enrichment of Mississippian-Permian metasediments, has been incorporated into unconsolidated sediments by Pleistocene glacial erosion. Much anecdotal information is available regarding past mining operations but geological data are few. On-going glacial sedimentological work in the area is trying to model the distribution of placers and to develop exploration strategies. This work is revealing much new data regarding the geology of historic and current placer mines.

History of Geology

Placer Gold Mining in Pleistocene Glacial Sediments of the Cariboo District, British Columbia, Canada 1858-1988

N. Eyles and S.P. Kocsis
Department of Geology
University of Toronto
Scarborough Campus
1265 Military Trail
Scarborough, Ontario M1C 1A4

Summary

The Cariboo placer mining district of central British Columbia, based on the communities of Wells/Barkerville, is a classic gold rush area of the late 1850s where gold mining still continues. Production started in 1858 and by 1861 Barkerville was the largest town north of San Francisco and west of Chicago. Today the area accounts for almost 30% of the province's annual total placer gold output, valued at about $9M. Gold apparently concentrated in near surface positions by deep Tertiary weathering and supergene enrichment of Mississippian-Permian metasediments, has been incorporated into unconsolidated sediments by Pleistocene glacial erosion. Much anecdotal information is available regarding past mining operations but geological data are few. On-going glacial sedimentological work in the area is trying to model the distribution of placers and to develop exploration strategies. This work is revealing much new data regarding the geology of historic and current placer mines.

Introduction

The enormous impact of successive gold rushes from Sutters Creek, California in 1849 north to Fairbanks, Alaska in 1903, on the social and political development of western North America is well known. In California, "The Miners came in '49, the whores in '51. And when they got together they produced the native son". Words like "motherlode", "pan out", "lucky strike", "bonanza", "paydirt" entered into the parlance of everyday speech. In Canada, in the late 1850s, the great influx of miners along the Fraser River resulted in the creation of the Province of British Columbia similar to the establishment of California as the 31st state of the Union in 1850. By 1861, Barkerville, in central British Columbia, was the largest city west of Chicago and north of San Francisco; the political geography of western North America had essentially been fixed by placer gold miners.

Much has been written of the miners in the Cariboo mining district of British Columbia and a rich anecdotal history exists (*e.g.*, Scholefield and Howay, 1914). Yet little is known of the geology of the placer deposits compared with other mining districts (Maurice, 1986; Morison and Hein, 1987; Schwarz and Wright, 1987). It is the purpose of this paper to briefly describe the results of sedimentological investigations in the Barkerville area which have shed new light on the geological setting of the rich placer deposits and the evolution of mining methods since 1858.

Placer mining in the Barkerville area has gone through several phases between 1858 and the present day. Initially, prospectors worked the surface of lucrative post-glacial fluvial gravels and modern river bars. This was succeeded by a second phase characterized by the construction of deep shafts to penetrate lodgement till, long regarded as bedrock, in order to reach buried interstadial gravels. Subsequent large-scale hydraulic operations involved the working of substantial volumes of low-paying sediment; this phase was terminated by World War II. Today's prospector is highly selective, seeking small-volume but high-paying deposits. The placers described here all occur in Late Pleistocene glacial facies deposited at, or under, the margins of a regional ice sheet, together with associated interstadial and post-glacial sediments. The area is unusual in that lucrative placers are contained within subglacially deposited lodgement tills and asociated sediments. Similar stratigraphic settings can be identified in Queensland, Australia where several hard-rock gold mines work paleo-placers in Lower Permian glacial sediments.

Regional Setting and Bedrock Geology

The area in which placer mining has historically taken place is shown in Figure 1; modern activity is centered on the communities of Wells/Barkerville and likely situated on the western flanks of the Cariboo Mountains. The district is of particular interest since it is a classic gold rush area of the late 1850s where much economic potential remains. However, despite a wealth of anecdotal information (Hong, 1978; Ludditt, 1980, 1980a; Barlee, 1984; Anon., 1987), systematic study of the geology exposed by placer operations has never been conducted. Records giving the location and character of profitable horizons are almost non-existent.

The Cariboo Mountains are part of the Omineca Crystalline Belt, one of the five physiographic divisions of the Canadian Cordillera that comprises a collage of allochthonous terranes accreted to western North America by convergent and transform plate motions. The mountains are underlain by a broad anticlinorium (the Purcell-Selkirk-Premier Cariboo anticlinorium; Price *et al.*, 1981; Jones *et al.*, 1983) that lies west of the Rocky Mountain Trench and defines the eastern boundary of the Cariboo District. The Fraser River Valley, about 80 km west of the study area (Figure 1), follows a major right lateral slip fault, part of an intra-continental transform fault system defining the western limit of the Omineca Crystalline Belt. Detailed geologic mapping has only been carried out in the Wells/Barkerville area (Figure 2).

The Downey Creek Succession is the most significant rock assemblage in the study area because there is a good geographic correlation between rocks of this succession and the location of placer mines (Figure 2). These rocks comprise variably metamorphosed slates, phyllites, quartzites, metatuffs, carbonates and clastics and are in part of Mississippian age (Struick, 1981, 1982a,b, 1986). The rocks form a belt varying in width from 1 to 3 km trending northwest/southeast through the Cariboo mining district (Figure 2). Outside this area, the bedrock source for gold found in placers to the south is not known, since the bedrock geology is poorly understood.

In the Barkerville area, "lode" gold occurs in two types of deposits associated with the Downey Creek Succession. (1) Native gold and tellurides occur in hydrothermal quartz veins usually associated with iron sulphides but which are not chemically combined (*e.g.*, the Cariboo Gold Quartz Mine, Wells). (2) Very fine-grained native gold is associated with disseminated pyrite and arsenopyrite occuring as replacement sulphides in limestone beds where gold is not chemically combined with sulphides (*e.g.*, Mosquito Creek Gold Mine, Wells).

Major lode gold mining in the Cariboo Gold Quartz mine began in 1927 at Wells, on the northern ridge of the Cow Mountain near Jack 'O' Clubs Lake (Figure 2). Boulders of gold-bearing quartz were found on the adjacent Lowhee Creek, which led prospectors to believe that Cow Mountain contained the "mother-lode". In 32 years, the Cariboo Gold Quartz mine produced 627,300 ounces of gold, yielded from 1.5 million tons of ore, valued at the time at $22 million. Rising costs and unfavorable prices forced the closure of the mine in 1961, although a sizeable reserve remains. Large vein systems host native gold which occurs in association with pyrite and arsenopyrite. These steeply dipping veins strike northeast, occasionally reach 100 metres in length and up to 2 metres wide.

The Island Mountain Gold Mine, less than 2 km northwest on the opposite side of the Jack 'O' Clubs Lake (Figure 2), was operated by Newmont and later by Cariboo Gold Quartz Mining Co. Between 1934 and 1961, it produced 450,000 ounces of gold valued at $17 million. Gold that is currently being mined by the Mosquito Creek Mining Co. occurs within massive fine-grained pyrite/arsenopyrite and has assayed up to 2 ounces/ton, but values generally fall between 0.5 to 1 ounce/ton. Today the Mosquito Creek Gold Mining Co. operates at the fork of Mosquito Creek and Red Gulch.

Origin of Placer Gold

Johnston and Uglow (1926) conducted a study of quartz veins in the Barkerville area, along Williams Creek, and concluded that veins do not appear to host the quantity needed to supply the $19,000,000 in placer gold that had been found along the 4 km mined section (gold values taken at $20/ounce). In addition, placer gold is coarse whereas *in situ* vein gold is disseminated. It may be that present vein exposures are remnants of a much larger system now eroded. However, the weathering of auriferous sulphides may provide an alternate source of placer gold. Common sulphides such as pyrite and arsenopyrite provide sulphuric acid whereas manganiferous siderite would generate manganese dioxide, an important agent in gold solution (Guilbert and Park, 1986). Deep weathering, and reprecipitation of gold, probably occurred during a lengthy episode of Tertiary weathering prior to the onset of Quaternary glaciation and erosion by ice sheets. Regardless of the precise origin of placer gold, the close association of placer operations with the Downey Creek Succession in the Barkerville area (Figure 2) indicates that the placer gold is of local derivation. The general absence of glacial deposits older than the last (Wisconsin) glaciation suggests that pre-existing valley fills and associated placers were largely reworked during the Wisconsin, being either transported from the area or disseminated or recycled into later placer deposits.

Pleistocene Geology

Most placer mining activity occurs north of Horsefly Lake extending north to the vicinity of Cariboo Lake (Figure 1). Clague (1980) and Fulton (1984) documented the regional glacial geology of British Columbia and identified glacial deposits from the early (125,000-60,000 years B.P.) and late (30,000-10,000 years B.P.) phases of the last (Fraser) glaciation; this is broadly equivalent to the Wisconsin Glaciation of mid-continent. These phases are separated by a long non-glacial interval (the Olympia Interstadial) that began sometime prior to 59,000 years B.P. and which was characterized by a climate resembling present-day cool temperate conditions. This non-glacial episode is

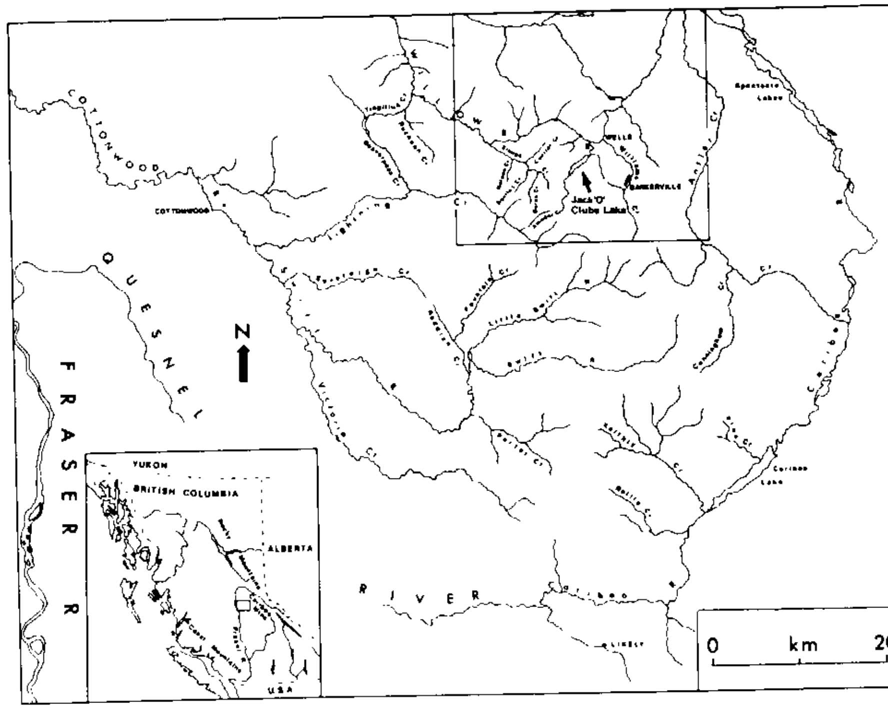

Figure 1 *Location of Wells/Barkerville area in the Cariboo placer mining district, north-central British Columbia and sites of placer pits. A detailed bedrock map of the area outlined is shown in Figure 2.*

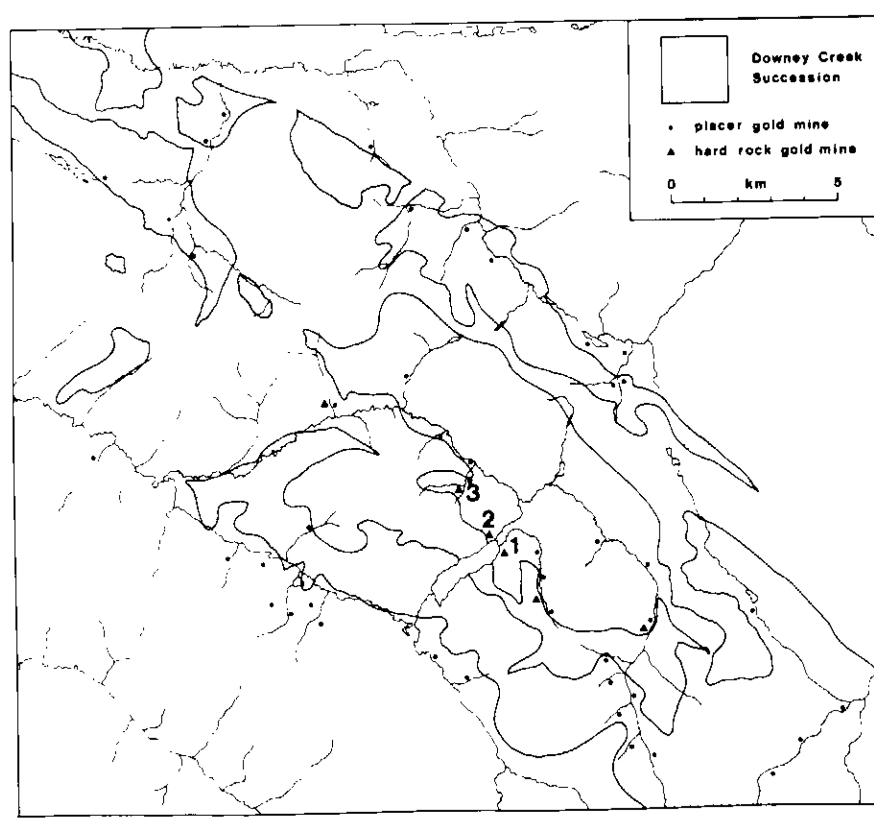

Figure 2 *Bedrock geology of the Wells/Barkerville area showing the Downey Creek Succession (dotted), the distribution of hard rock gold mines and past and present placer operations. Location shown on Figure 1. (1) Cow Mountain, (2) Island Mountain, (3) Mosquito Creek.*

recorded stratigraphically by a widespread erosion surface; this is veneered by a boulder lag horizon recording fluvial downcutting into older valley fill sediments. The sedimentology of early and late-Wisconsin deposits has been described most recently by Eyles *et al.* (1987), Eyles (1987) and Clague (1987).

The Cariboo Mountains (maximum elevation: 3600 m asl) was an important source area for ice during Pleistocene glaciations (Figure 3). During the latest stages of the Wisconsin glaciation, starting about 30,000 years B.P., a complex of piedmont and alpine glaciers coalesced in British Columbia to form the Cordilleran Ice Sheet. Drumlins suggest a northeastward flow of ice across central British Columbia from the Coast Mountains toward the Rocky Mountains (Tipper, 1971). The Wells/Barkerville area was covered by ice flowing west from the Cariboo Mountains and deflected to the northwest near Cottonwood by ice flowing from the Coast Mountains (Figure 3).

River valleys are filled with many tens of metres or more of glacial sediments. Drill reports disclose thicknesses of over 30 m of sediments filling the Willow River near Mosquito Creek, while more than 80 m of sediments fill Slough Creek adjacent to Mount Nelson (Figure 1). Many pre-glacial valleys are completely plugged with glacial sediments (Clague, 1987). There is no known documentation of sediments older than the Wisconsin glaciation, although they may be preserved in overdeepened bedrock lows. Valleys generally contain a tripartite infill consisting of (1) interstadial and older braided river gravels that began to accumulate before 59,000 years B.P., (2) sub-glacial lodgement tills and lee-side deposits deposited after 30,000 years B.P. and (3) late-glacial and post-glacial gravels. Bedrock terraces are common, appearing as a series of benches; elevations greater than 1500 m are generally devoid of Pleistocene sediments.

The first phase of placer mining (1858-1863) "Poor Man's Diggings"

In 1858, nearly 25,000 prospectors, mostly Californians, moved into the lower Fraser River Valley after the discovery of gold-bearing gravel bars. The paystreaks were mostly surficial, not extending more than 1 m deep. However, their richness was reflected by examples such as Hill's Bar, south of Yale in southern British Columbia, where less than one square kilometre yielded nearly 5% of the total value of gold mined in British Columbia from 1858 to 1875 (about $40 million at 1860 prices).

The term "poor man's diggings" is a reference to the minimum of equipment needed to work the gravels. A simple rocker-box usually sufficed. Discoveries further north prompted exploration of tributary streams and a prospector named Peter Dunlevey is credited for finding the first gold in the Cariboo. Dunlevey and his fellow Californians believed that the flour/flakey gold of the Fraser would lead to coarse gold upstream and *in situ* mother lode deposits. Dunlevey and party, near the mouth of the Chilcotin River (Figure 3), met with a Shuswap Indian, named Tomah, who said a cousin named Long Bacheese (Baptiste) would bring them to a location of pea-size gold nuggets. In the spring of 1859, they were taken to the Horsefly River and shown the promised nuggets. More than 15,000 ounces of gold had been mined along the Horsefly River by 1945. This figure is a considerable underestimate because recording only began after 1874, long after the bulk of extraction more than 10 years earlier.

In June 1859, with news of the Dunlevey and MacDonald strikes on the Quesnel River, an influx of miners arrived. By 1860, the town of Quesnel Forks had been constructed at the confluence of the Quesnel and Cariboo Rivers. This was the beginning of the Cariboo gold rush in a region where caribou roamed in the alpine meadows. Most gold was mined upstream from Quesnel Forks along the Quesnel River and its tributaries toward the present town of Likely, about 10 km southeast.

As prospectors moved further north and east, Doc Keithly and his partner, J.D. Diller, discovered rich ground to the southwest corner of Cariboo Lake, on a creek later named Keithley Creek. Within a year, the area became heavily staked and the town of Keithly sprung up. More than 48,000 ounces of gold were recovered from Keithly Creek and a tributary named Snowshoe Creek between 1874 and 1945. Doc Keithly, Benjamin MacDonald, John Rose and George Weaver headed north across the Snowshoe Plateau to find northerly flowing streams. In one canyon, they discovered gold, readily picked up and described as "sun-burn gold" because of oxidization of iron oxide coatings by prolonged exposure. In the early days, pans containing several ounces of gold were extracted from this newly discovered creek, later named Antler because of the numerous antler tracks found in the snow at the time of its discovery; by the spring of 1861, over 1200 miners were at work there. In total, more than 33,600 ounces of gold was mined on Antler Creek between 1874 and 1945 (Holland, 1980), but much more was mined prior to 1874 of which no records are available.

During the winter of 1861, "Dutch Bill" Dietz and several companions travelled to the headwaters of Antler Creek and across the alpine plateau named Bald Mountain where they came down on a north-flowing stream later called Williams Creek. Dietz tested the gravels and recovered gold worth about $1.25 per pan. Word quickly spread of the Dietz strike and over 1000 miners began working in the narrow valley. The paystreak

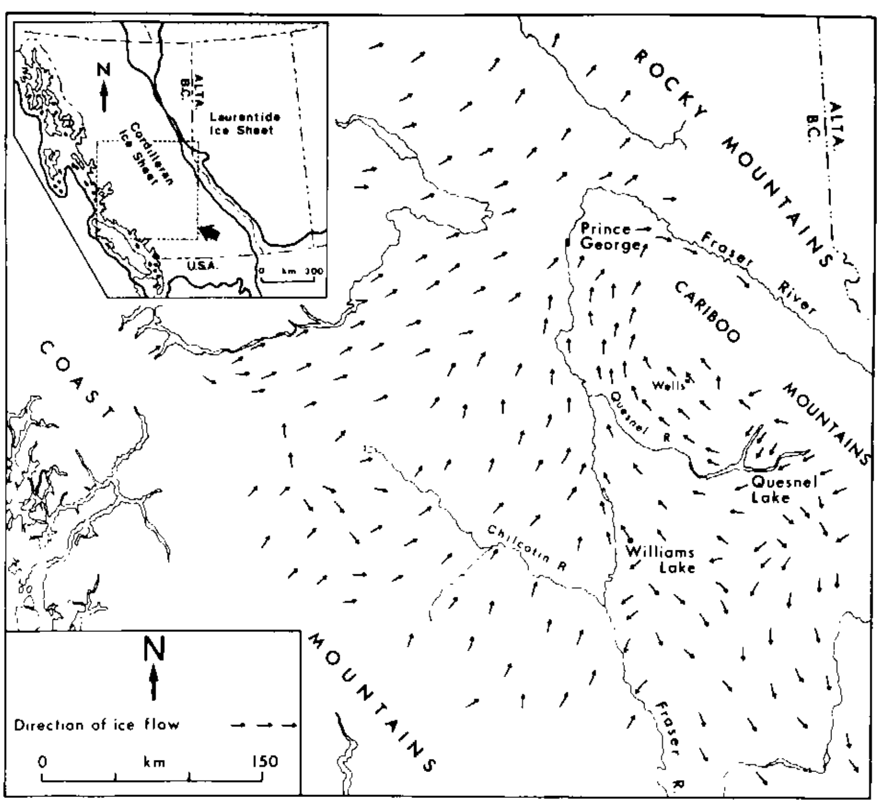

Figure 3 *Ice flow directions in the Cariboo mining district during the late Wisconsin (Fraser) glaciation after 30,000 years B.P. (After Tipper, 1971).*

consisted of shallow surface gravels above an uneconomic hard layer called "blue clay" (lodgement till; see below). Miners initially mistook the blue clay for bedrock and did not penetrate below this layer.

The second phase of placer mining (1863-1870) "Shaft and Tunnel"

The second phase of mining in the area was opened in late 1862 when miners on Abbott's and Jourdan's claim penetrated below the "blue clay" and recovered 50 ounces of gold. The town of Richfield developed along Williams Creek. In August 1862, Billy Barker, a Cornishman, and seven English partners staked 800 feet of ground and commenced digging a deep shaft. A "Cornish pump", a water wheel-powered piston-type water pump, was used to drain the shaft as the miners worked beneath the water table. Barker, in a dream, had a vision that pay would be found at 12 m, and paying gravels were found at 15 m. Sixty-two ounces of gold, worth $1000 at the time, were taken out in the first 48 hours. Other shafts were sunk into the buried bedrock channel ("gutter") of Williams Creek, some paying and others not. The town of Barkerville was erected and at one time housed over 2000 residents. About 2 km further downstream, Camerontown merged with Barkerville. Between 1861 and 1896, 111 claims were scattered across the rich grounds of Williams Creek adjacent to Barkerville; these produced in total $19,320,000 (values at about $16/ounce). The Aurora Claim, located at the northerly part of Barkerville town, produced $800,000 in gold, while other claims averaging $50,000 to $200,000 were common.

The realization that good prospects lay below "false bedrock" prompted further exploration and shaft digging. Good prospects were discovered on Stouts Gulch, Lowhee Creek, Lightning Creek and its many tributaries. By 1865, a more sophisticated approach was employed using shafts and tunnelling to reach interstadial gravels deeply buried below later glacial deposits. This was made possible by the completion of the Cariboo Wagon Road. Running from Vancouver *via* the present-day city of Quesnel, this road provided all weather access to the goldfields and allowed the introduction of better technology and equipment such as steam-operated pumps. Shaft and tunnel construction was slow, dangerous and only capable of working limited volumes of sediment hauled at great effort to the surface. A particular problem was the presence of the saturated glaciolacustrine sediments at depth. These defeated many attempts to penetrate deeper, the oozing mud being known as "slum".

The experience of Fred Laird along the portion of the Willow River Valley near Mosquito Creek was typical. Laird secured nearly 7 km² of mining leases around the turn of the

a

b

c

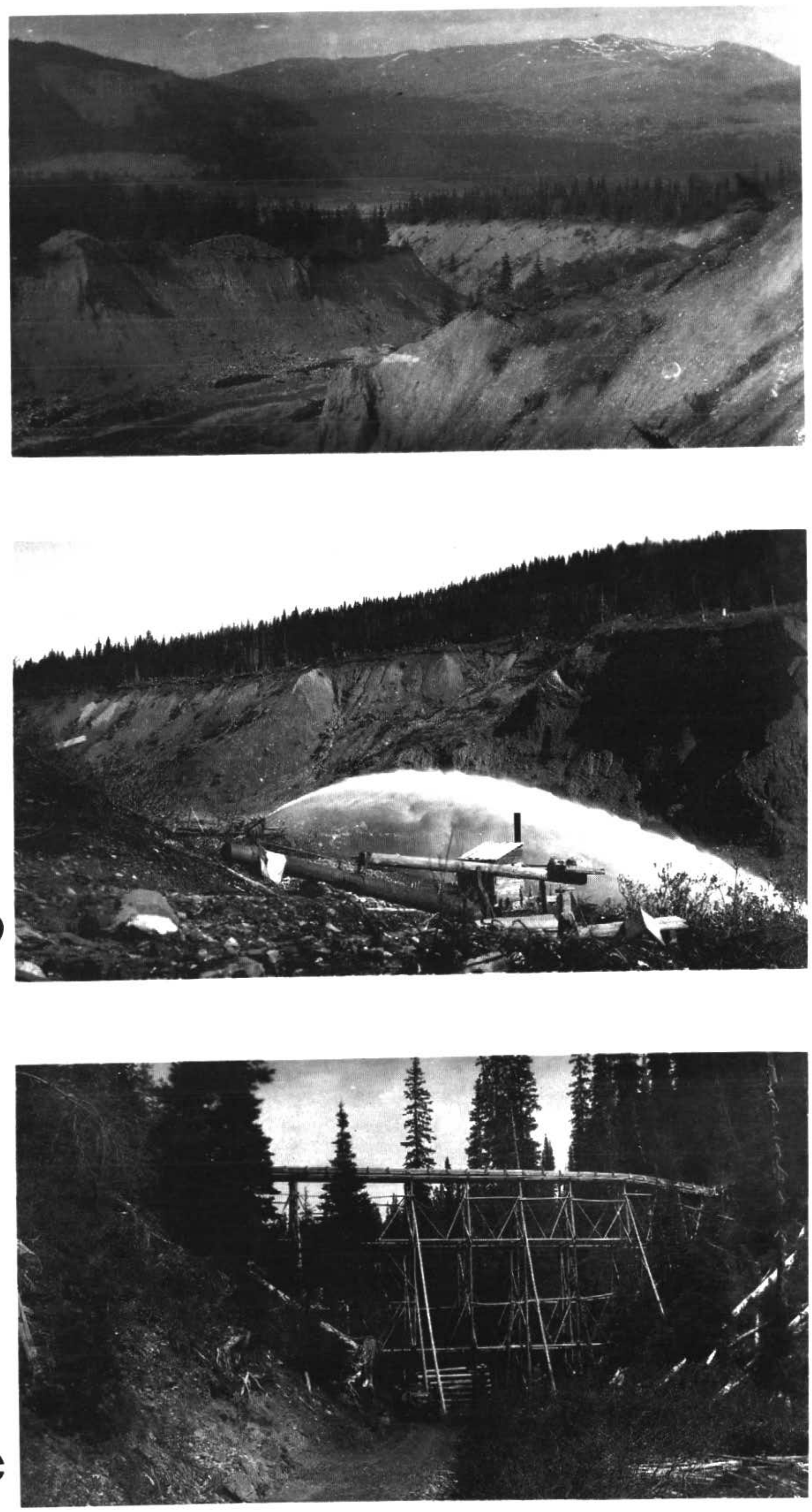

Figure 4 (a) ***(upper)*** *Ketch Mine pit looking east towards Wells, 1930s.*
(b) ***(middle)*** *Active hydraulic monitor along the face of the Ketch Mine on the south side of Slough Creek.*
(c) ***(lower)*** *Flume crossing Devil's Canyon east of Wells to supply water for the hydraulic operations at the Ketch Mine.*

d

e

Figure 4 ***(cont'd)*** **(d)** ***(upper)*** *Ketch Mine pit showing contact of lodgement till with underlying interstadial gravels (arrowed).*
(e) ***(lower)*** *Washing lodgement till with a 3-inch monitor at the Ketch Mine.*

century and sank seven holes to bedrock; the bedrock gutter was found at 30 m. An attempt was made to sink a shaft from directly above the gutter, but flooding became too severe. About 100 m west of the original shaft, Laird drifted south into the hillside where at a total length of 100 m bedrock was encountered. A shaft 2 m by 4 m was raised 30 m to the surface and another drift was run north for 160 m, where Laird broke through into well-consolidated and good paying gravels. The state of consolidation and permeability of the "lower gravels" was always a major safety concern during mining because of the high cost of pumping water, timbering the sides of the shafts and adits, and securing firewood for the boilers. Air compressors and air locks were installed in many drifts.

By 1897, the basic stratigraphy of the placer deposits in the Barkerville area had been established. "Lower gravels" were identified below "boulder clay" (then thought by many to be a volcanic deposit), which was overlain by "top gravels". The lower gravels are equivalent to the interstadial gravels recognized today; the boulder clay is identified as Late Wisconsin lodgement tills, which are in turn overlain by late- and post-glacial gravels ("top gravels"). Photographs of the time show lodgement till resting on lower gravels (Figures 4d and 6b).

Current mining operations expose interstadial auriferous gravels around Tregillus Lake (Figure 1) that have been worked since the 1930s. Examination of these "lower gravels" provides much information on the sedimentology of the deposits worked by Barker, Laird and others. High gold values are found in "nests" or "clusters" of boulders within massive to crudely bedded gravels. Cross-bedded facies are not common. These gravels are typical of the deposits of braided (multi-channelled) rivers formed by aggradation of longitudinal bars; massive gravels predominate because of shallow water depths, the low relief of bars and the restricted depths of channels (*e.g.*, Rust and Koster, 1984). The boulder "clusters" are similar to those described by Morison and Hein (1987) from the Klondike placer mining district in the Yukon and are interpreted as recording flood transport of large boulders (*e.g.*, Brayshaw, 1984). Many old reports refer to favoured "runs" of gold near the inner curves of gravel-filled channels. The fluvial regime during deposition was probably similar to that found across central British Columbia at the present day (*e.g.*, Desloges and Church, 1987).

Hydraulic mining (*ca.* 1880-1939) "Where there's Muck ..."

During the later part of the 1870s, emphasis was directed toward hydraulic mining and the industry entered its third phase, which was to last until World War II. This costly and large-scale technique employed hundreds of

Chinese labourers in the construction of long ditches high on the mountain sides to collect water from streams diverted many kilometres distant (*e.g.*, Sharpe, 1939). The construction phase could last several years. In a typical operation at Slough Creek along Mount Nelson, 200 gallons of water per second dropped down 60 m of pipe that tapered to a "7-inch" nozzle or monitor. The jet of water produced by the monitor was directed at the unconsolidated sediments washing them through a lengthy sluice box where the gold was collected within riffle-lined boxes (Figures 5 and 6). Good snowfalls and resulting high spring runoff were critical to the success of the operation. Steel pipe was scarce and expensive because of freight charges, so hand-sewn canvas pipe was often used. However, because of the low water pressures, it was necessary for the operator to be close to the working face with the risk of slope collapse and fatalities.

Hydraulic mining provided a method of high volume production and did not require either the high gold concentrations found in the early days or a very sophisticated approach to prospecting. The overriding consideration was the presence of large volumes of sediment or "muck"; buried channel fills were ideal targets (Sharpe, 1939; Clague, 1987; Figure 7). An additional need was to sustain a fair slope in the working area (at least 5°) to allow the removal of washed sediments through a system of flumes. In some areas, the ground could not be worked to bedrock and good paying sediments remain. Also, it is believed that much fine gold was lost through the system.

It was not usually possible to work the lowest grade gravels because of insufficient rainfall during the summer; the area lies in the rain shadow of the Coast Ranges (Figure 1). Hydraulicking usually commenced in April, when advantage was taken of the spring run-off and slumping of newly thawed pit slopes. A full 24-hour supply of water could be maintained until early August, when the monitors were restricted to 4 to 8 hours a day until freeze-up in early November. The lack of water was especially problematic in breaking up lodgement till; adits and explosives often had to be used, which added greatly to costs (Figure 6b). The general scarcity of water often resulted in very inefficient sluicing, with the result that spoil heaps were, and still are, reworked at profit. The Chinese were particularly adept at reworking old operations.

Large-scale hydraulic operations were effectively ended by the Second World War, when men and materials were needed elsewhere, and by low gold prices.

a

b

Figure 5 (a) ***(upper)*** *Townsite at the base of Lowhee Creek just south of the present town of Wells, 1920s.*
(b) ***(lower)*** *Hydraulicking lodgement till and underlying gravels on the upper part of Lowhee Creek, 1930s.*

a

b

Figure 6 (a) ***(upper)*** *Hydraulic operations at the upper end of Stouts Gulch adjacent to Lowhee Creek. Note the flume carrying away the tailings.*

(b) ***(lower)*** *Close-up of a face being hydraulicked at Stouts Gulch. Note large blocks of overconsolidated lodgement till fallen from face. Such blocks often had to be broken up by explosives at considerable cost.*

The Present Day
"There's gold in them thar tills ..."

Given environmental pressures, large-scale hydraulic operations are no longer feasible. Considerable attention is now being focussed on small, but lucrative, placers contained within Late Wisconsin lodgement tills which have incorporated gold from the erosion of bedrock and auriferous interstadial gravels. The Devils Lake Canyon area was a large gold producer from auriferous lodgement tills between 1880 to 1946, over 30,000 ounces being recovered from two hydraulic operations at the Ketch Bench near Burns Creek and the Point Benches near Nelson Creek (Figures 1 and 4). Over 40 Crown Grant mineral claims presently cover the area, which is highly regarded for its potential. Study of active pits and test holes shows that gold is dispersed throughout the lodgement tills, but especially high values are found within intraformational boulder pavements. These pavements consist of large boulders, lying end to end, up to several tens of metres long. Their origin can be likened to sub-glacial "traffic jams" where one boulder, lodged on the underlying bed, forms an obstacle to other boulders being transported at the ice base (Boulton, 1975, 1982). The lodged boulders act as nuclei around which other boulders and associated coarse gold are accumulated. These pavements are very favourable exploration targets, but unfortunately they are difficult to discriminate in drilling programs from the bedrock surface.

In unconsolidated Pleistocene deposits, gold placers most commonly occur in glaciofluvial and fluvial gravels (see Cobb, 1973; Cook 1983; Shilts and Smith, 1986; Maurice, 1986; Morison and Hein, 1987). The presence in the Cariboo area of high gold values in lodgement tills sufficient to allow working of the till itself, is very unusual. Mineralized "float" in till more commonly occurs in subeconomic concentrations and is used as an indicator to identify *in situ* bedrock sources in the up-ice direction (*e.g.*, Shilts, 1976). In contrast, the presence of rich gold-bearing sub-glacial deposits in the Cariboo district is the product of glacial incorporation of auriferous interstadial gravels. Working of such deposits is not without problems, however. Because of the extremely large size range of boulders and highly overconsolidated nature of the tills these deposits often require either blasting or exposure to deep frost before they can be disaggregated (see above). Clumps and balls of lodgement till are observed to pass completely through sluice boxes, showing that disaggregation and gold recovery is even then not entirely successful.

Another type of subglacially deposited placer is associated with lee-side deposits. These consist of talus-like accumulations of coarse bouldery gravels lying on the down-ice side of bedrock highs. Subglacial cavities are formed where ice velocity is sufficiently high and ice separates from its bed in the lee of a bedrock high (Hillefors, 1973; Boulton, 1982). Subglacial meltwater under high hydrostatic pressure reworks talus-like accumulations of debris fallen from the ice base, forming a subglacial sluicing system which concentrates any gold present. The preservation potential of lee-side accumulations is dependent on ice-velocity, since cavity size is known to fluctuate in time; the greater the ice-velocity, the larger the cavity, and *vice versa*. If the cavity fill survives deglaciation it may be preserved simply as a skirt around bedrock highs; commonly, however, the deposits are draped by lodgement till as a result of cavity closure (Hillefors, 1973). In the Cariboo area, lee-side deposits show evidence for several episodes of erosion within the deposit; these may record partial cavity closure and the removal of the upper parts of the deposit. The mechanisms whereby gold is concentrated in lee-side cavities can be directly compared with a sluice box; the irregular subglacial bed is flushed by large volumes of subglacial meltwater and the subglacial bedrock high serves the same function as a riffle.

Channels cut by subglacial meltwaters are also favourable sites for gold accumulation. Figure 7 shows a typical crevice, exposed by the working of overlying lodgement till along Cunningham Creek, cut into the underlying bedrock. Over 600 ounces of gold were removed from a ten metre length of the crevice no more than 1.5 m deep. The crevice forms part of a subglacial drainage network cut by meltwaters on the bedrock surface under high hydrostatic pressures. These "notches", or "gutters", are especially favourable exploration targets.

Future Prospects

Much economic potential exists in the Cariboo mining district. Realization of this will depend on highly selective exploration of the bedrock surface and overlying subglacial deposits using ground-based geophysics (*e.g.*, shallow imaging radar), drilling and seismic work. It would be very instructive, in developing exploration strategies, to compare the sedimentological setting of the Cariboo placers with the geological setting of the glacial placers in Northern Australia. The auriferous lodgement tills of the Cariboo are strikingly similar to those of the Clermont gold field in central Queensland. That field extends over about 350 km² and works gold from early Permian glacial sequences, the bulk of production being from a "basal till" found below Blair Athol Coal Measure, a thick series of cold-climate coals. Large boulders within the till are associated with gold values of up to 1 oz per ton. The gold originates from supergene enrichment under tropical conditions during the Silurian and Devonian and concentrated into placers by Permian glaciers. In addition to diamonds, cassiterite and gem-quality corundum, large striated nuggets are common (l'Ons, 1983). Detailed comparison of the Cariboo and Clermont placer mining districts would be a valuable exercise.

The current phase of mining in the Cariboo area is typified by small-scale operations of a speculative and usually short-lived duration. Very strict environmental safeguards apply in terms of the amount of suspended sediment that is allowed in rivers. In this regard, the placer mining industry in western North America faces strong pressures from environmental groups. Space prohibits a full discussion of these problems, but there is much to learn from the Alaskan situation. In Alaska, pressures against placer mining are much more advanced, as witnessed by the injunctions against placer miners obtained

a

b

Figure 7 (a) ***(upper)*** *The Bullion Pit near Quesnel Forks 1987. Since the 1920s the pit has yielded more than 120,000 oz of gold. The pit following a infill of a buried river valley.*
(b) ***(lower)*** *Bedrock crevice or "gutter" cut by subglacial meltwaters along Cunningham Creek. These are especially lucrative exploration targets.*

by the Sierra Club. This has shut down 80% of all mining on federal lands managed by the Bureau of Land Management. Mining may not commence until extensive and costly environmental reviews have been completed. This would effectively bankrupt a substantial majority of miners. Furthermore, all mining on state lands is threatened by water quality regulations and a recent court decision that ruled that the state lease system collects insufficient rents or royalties. Within this recent case emerged the common law doctrine of the "public trust" in which it is claimed that all natural resources are held in "public trust". All mining on any land in Alaska is further threatened by a unique requirement that, before any "dredge or fill" occurs in wetlands, a permit must be obtained from the Army Corps of Engineers. Any sort of mining activity includes such work; moreover, the Sierra Club is threatening a lawsuit against the Corps of Engineers since they are unhappy at the way the program is being administered.

The situation in western and northern Canada is not so restrictive, but the ongoing battle in the Yukon between placer miners and the Department of Indian and Northern Affairs over implementation of the Northern Inland Water Act may cause problems for the industry.

Acknowledgements

The authors wish to thank the many placer miners of the Cariboo district who allowed us to work on their property. We are particularly grateful to Barkerville Historic Park for access to, and permission to publish Figures 4d, 4e, 5, and 6. Figures 4a,b,c are from the collection of A.P. Coleman at the Royal Ontario Museum, Toronto. We are especially grateful to James S. Burling of the Pacific Legal Foundation in Anchorage and Philip S. Barnett of the Sierra Club, Juneau, for the information regarding the present legal status of placer mining in Alaska and Western Canada. The manuscript was reviewed by William Sarjeant. It is a pleasure to acknowledge funding for this work by the British Columbia Geoscience Research Grant Program, the Natural Sciences and Engineering Research Council and the Federal Department of Employment and Immigration.

References

Anon., 1987, Cariboo Gold Rush: Heritage House Publishing Co., 95 p.

Barlee, N.L., 1984, Gold Creeks and Ghost Towns: Hancock House, Surrey, B.C., 193 p.

Boulton, G.S., 1975, Processes and patterns of glacial erosion, *in* Glacial Geomorphology: Publications in Geomorphology, State University of New York, Binghampton, p. 41-87.

Boulton, G.S., 1982, Subglacial processes and the development of glacial bedforms, *in* Davidson-Arnott, R., *et al.*, eds., Research in Glacial, Glaciofluvial and Glacio-lacustrine Systems: Geo-Books, Norwich, p. 1-31.

Brayshaw, A.C., 1984, Characteristics and origin of cluster bedforms in coarse-grained alluvial channels, *in* Koster, E.H. and Steel, R.J., eds., Sedimentology of Gravels and Conglomerates: Canadian Society of Petroleum Geologists, Memoir 10, p. 77-86.

Campbell, R.B., Mountjoy, E.W. and Young, F.G., 1973, Geology of McBride Map Area, British Columbia: Geological Survey of Canada, Paper 72-55.

Church, M. and Ryder, J.M., 1972, Paraglacial sedimentation: a consideration of fluvial processes conditioned by glaciation: Geological Society of America, Bulletin, v. 83, p. 3072-3095.

Clague, J.J., 1980, Late Quaternary geology and geochronology of British Columbia. Part I: Radiocarbon Dates: Geological Survey of Canada, Paper 80-13, p. 1-28.

Clague, J.J., 1987, A placer exploration target in the Cariboo District, British Columbia: Geological Survey of Canada, Paper 87-1A, p. 177-180.

Cobb, E.H., 1973, Placer deposits of Alaska: United States Geological Survey, Bulletin 1374.

Cook, D.J., 1983, Placer mining in Alaska: University of Alaska, School of Mineral Industry, Mineral Industry Research Laboratory, Report 65, 157 p.

Desloges, J.R. and Church, M., 1987, Channel and floodplain facies in a wandering gravel bed river, *in* Ethridge, F.G., Flores, R.M. and Harvey, M.D., eds., Recent Developments in Fluvial Sedimentology: Society of Economic Paleontologists and Mineralogists, Special Publication No. 39, p. 99-110.

Eyles, N., 1987, Late Pleistocene debris flow deposits in large glacial lakes in British Columbia and Alaska: Sedimentary Geology, v. 53, p. 33-71.

Eyles, N., Clark, B.M. and Clague, J.J., 1987, Coarse grained sediment gravity flow facies in a large supraglacial lake: Sedimentology, v. 34, p. 193-216.

Eyles, N. and Kocsis, S., 1988, Gold placers in Pleistocene glacial deposits, Barkerville, British Columbia, Canada: Canadian Mining and Metallurgical Bulletin, v. 81, p. 71-79.

Fulton, R.J., 1984, Quaternary Glaciation, Canadian Cordillera, *in* Fulton, R.J., ed., Quaternary Stratigraphy of Canada: Geological Survey of Canada, Paper 84-10, p. 39-48.

Guilbert, J.M. and Park, C.F., 1986, Ore deposits: W.H. Freeman and Co., New York, 985 p.

Hillefors, A., 1973, The stratigraphy and genesis of stoss and lee-side moraines: Bulletin of the Geological Institute, Uppsala University, v. 5, p. 139-154.

Holland, S.S., 1980, Placer Gold Production of British Columbia: Province of British Columbia Ministry of Energy, Mines and Petroleum Resources, Bulletin 28.

Hong, W.M., 1978, And So ... That's how it happened. Recollections of Stanley-Barkerville, 1900-1975: W.M. Hong, Quesnel, B.C., 255 p.

Johnston, W.A. and Uglow, W.L., 1926, Placer and Vein Gold Deposits of Barkerville, Cariboo District, British Columbia: Geological Survey of Canada, Memoir 149.

Jones, D.L., Howel, D.G., Coney, P.J. and Monger, J.W.H., 1983, Recognition, character and analysis of tectonostratigraphic terranes in western North America, *in* Hasimoto, M. and Uyeda, S., eds., Accretionary Tectonics in the Circum-Pacific Regions: Terra, Tokyo, p. 21-35.

Ludditt, F.W., 1980a, Barkerville Days: Mr. Paperback, Langley, B.C., 158 p.

Ludditt, F.W., 1980b, Campfire Sketches of the Cariboo: F. Ludditt, Penticton, B.C., 104 p.

Maurice, Y.T., 1986, Distribution and origin of alluvial gold in southwest Gaspésie, Quebec: Geological Survey of Canada, Paper 86-1B, p. 785-795.

Morison, S.R. and Hein, F.J., 1987, Sedimentology of the White Channel Gravels, Klondike area, Yukon Territory: Fluvial deposits of a confined valley, *in* Ethridge, F.G., Flores, R.M. and Harvey, M.D., eds., Recent Developments in Fluvial Sedimentology: Society of Economic Paleontologists and Mineralogists, Special Publication No. 39, p. 205-216.

Rust, B. and Koster, E.H., 1984, Coarse alluvial deposits, *in* Walker, R.G., ed., Facies Models: Geological Association of Canada, Geoscience Canada Reprint Series 1, p. 15-38.

Scholefield, E.O.S. and Howay, F.W., 1914, British Columbia - Historical Volume II.

Schwarz, E.J. and Wright, N., 1987, Buried placers in Chaudiere River sediments indicated by ground magnetometer survey, Eastern Townships, Quebec: Geological Survey of Canada, Paper 87-1A, p. 423-428.

Sharpe, R.F., 1939, The bullion hydraulic mine: The Miner, v. 12, p. 37-40.

Shilts, W.W., 1976, Glacial till and mineral exploration: Royal Society of Canada, Special Publication 12, p. 205-224.

Shilts, W.W. and Smith, S.L., 1986, Stratigraphy of placer gold deposits; overburden drilling in Chaudiere Valley, Quebec: Geological Survey of Canada, Paper 86-1A, p. 703-712.

Struick, L.C., 1981, A re-examination of the type area of the Devono-Mississippian Cariboo Orogeny, Central British Columbia: Canadian Journal of Earth Sciences, v. 18, p. 1767-1775.

Struick, L.C., 1982a, Snowshoe Formation (1982), Central British Columbia. Project 680066, Cordilleran Geology Division, Vancouver: Geological Survey of Canada, Paper 82-1B, p. 117-124.

Struick, L.C., 1982b, Bedrock Geology of the Cariboo Lake (93A/13), Spectacle Lake (93H/3), Swift River (93A/13) and Wells (93H/4) map areas, Central British Columbia: Geological Survey of Canada, Open File 858.

Struik, L.C., 1986, Imbricated terranes of the Cariboo Gold Belt with correlations and implications for tectonics in southeastern British Columbia: Canadian Journal of Earth Sciences, v. 23, p. 1047-1061.

Tipper, H.W., 1971, Multiple glaciation in central British Columbia: Canadian Journal of Earth Sciences, v. 8, p. 743-752.

Accepted, as revised, 18 June 1988.