Feature

Klondike Gold

In 1896, the world's greatest gold rush descended on the Klondike, in northern Canada. The hardships endured on the journey there and then in hand-mining the frozen ground are the stuff of legends. But the 'mother lode' was never found, and only recently have the origins of the gold been recognized. After the madness and the extravagance of the initial rush, mining methods evolved, and there are miners still working the Klondike today.

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The Klondike is a modest river within the Yukon Territory of northwestern Canada; modest, except for the fabulous riches of its gold. It is a tributary of the Yukon River, which drains most of the interior of Alaska and the Yukon, its basin trapped between the coastal mountains along the Pacific rim and lesser ranges on the Arctic side.

Hardened prospectors and trappers were the first into the Yukon valley, and a trading post was established on the riverbank in 1874. Through the 1880s, gold was found in various basins that were largely in Alaska, and a mining camp grew at the mouth of the Fortymile River just inside Canada. By 1895, there were hundreds of prospectors and miners on most of the creeks draining into the Yukon River.

Robert Henderson was the first man to pan a little gold in Rabbit Creek (now known as Bonanza Creek), which is a tributary of the Klondike just above its confluence with the Yukon. On his advice, George Carmack and two Indian friends camped on Rabbit Creek, 15 km up from the big river. On 16 August 1896, they found gold richer than their dreams in the creek gravel. They staked their claims, and went to Fortymile to record them.

Within days, hordes of other miners from up and down the river followed the stories; by the end of 1896 most of the Klondike creeks had been staked as claims. The next year the river terraces high above the creek beds had also been prospected, had again been found to be rich in gold, and had subsequently been staked. Claims cost just $15 to register, and more than 30 claims on Bonanza and Eldorado Creeks each yielded a million dollars in gold. But in 1897 the Yukon was a very isolated place, and the outside world did not yet know of these golden riches.

Until the great gold rush, very few people penetrated beyond the coastal mountains into the sub-arctic wilderness of Alaska and the Yukon. It is a seriously hostile country, with vast expanses of wetland, forest and mountain defended by a climate that is rarely comfortable. The coastal mountains have peaks rising to over 4000 m between glaciers and icefields; only a few passes provide routes to the interior.

Beyond the mountains, the lowland of the Yukon basin is largely covered by forests of spruce and birch (Fig. 1). The climate is severe. Exposed to the Pacific Ocean, the coast mountains can receive 30 m of snowfall in a single winter. The interior lies in the rain shadow, has a thinner snow cover in winter, and has little summer rain. Winter lasts from October to

Fig. 1. The valley of Bonanza Creek, in the heart of the Klondike gold fields.

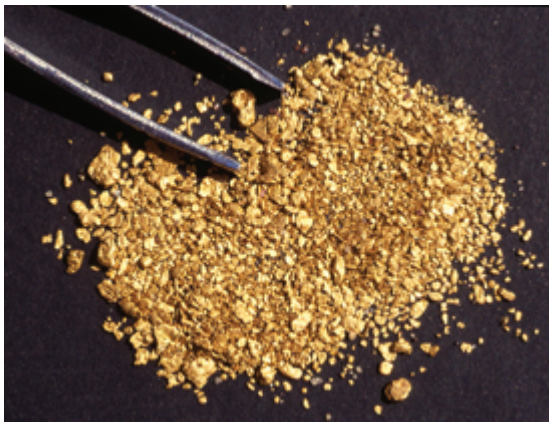

Fig. 2. Flakes of gold from the Klondike placer deposits.

May, and temperatures can stay below –40 °C for weeks at a time. With the summer thaw come voracious mosquitoes, which thrive until August. September offers a brief respite, with its explosion of autumn colour before the snows return.

When news of the gold leaked out, thousands of fortune seekers poured into this alien environment of horrendous cold, deep snow, bog, mosquitoes and frozen ground. Nobody in their senses would set off unprepared and on foot into the Arctic wilderness, but gold is the ultimate lure (Fig. 2).

The Klondike gold rush

On 17 July 1897, a ship docked in Seattle carrying 68 miners and $700 000 in gold, and the world's most frantic gold rush began. More than a rush, it was a headlong stampede, and its ill-prepared participants were known as stampeders. Every ship on the west coast sailed north, packed with optimists and opportunists, each with his own mountain of supplies. Few had any idea of what lay ahead. For most the sea journey ended at the head of one of the two most northerly fiords in Alaska's Inside Passage (Fig. 3). Unloading the boats onto the tidal flats was just the first desperate task, but by the end of autumn 1897, there were 30 000 stampeders in the sprawling fiord-head camps at Skagway and Dyea, just two kilometres apart.

Directly out of Skagway, the White Pass took a pack-horse trail through the mountains. Although it was the easiest route north, 3000 horses died on its trail during the first winter. By July 1899 there was a railway over the White Pass, and Skagway thrived as the port town, while Dyea died. But that was too late for the stampeders of 1897, of whom few could afford the tolls on the original horse trail.

So most of the stampeders set off north from Dyea, on the old Chilkat Indian trail that climbed over the Chilkoot Pass (Fig. 3). Throughout the winter of 1897–98, some 25 000 of them hauled their supplies through deep snow over the Chilkoot trail, and over the 990-metre-high pass. Dyea is in Alaska, and the Canadian border was marked by an outpost of the North West Mounted Police on the crest of the pass. As there were no supplies in the Yukon wilderness, stampeders were only allowed to enter Canada if they had a year's supplies with them. Essential items included 160 kg flour, 70 kg bacon, one box of candles, two heavy blankets, two wood saws, 10 lbs pitch; the list was long, but gave no room for comfort.

Each man therefore had to haul about 700 kg of food and essential materials—mostly on their backs, as no horse could make the steep, rough trail. So the kit was ferried load-by-load, cache-to-cache, and it took up to 3000 km of trudging to and fro with a backpack to cover the 53 km to Lake Bennett. The suffering and endurance of that winter on the Chilkoot were legendary. The final ascent to the pass was a 40° ascent on a snow-covered scree slope (Fig. 4). An endless line of men carried their heavy packs up the Golden Stairs—steps stamped in the snow; only in 1898 were aerial tramways built to improve the route for the traders who came after the stampede.

Once over the Chilkoot Pass, the stampeders descended to the banks of Lake Bennett, where a huge tent city grew through that winter. There they cut down most of the surrounding forest—and used their saws, oakum and pitch to make boats that could survive a trip down the Yukon River. On 29 May 1898, the ice broke up on the lake, and within a few days 7124 boats were counted by the Mounted Police as they set off down the outlet river. The current carried them downstream, to start an un-powered journey of 900 km to the Klondike. Much of the Yukon River provided easy and steady floating, but there were some rude interruptions. Miles Canyon had wild water between walls of columnar basalt, and the Whitehorse Rapids were equally wild (but now lie submerged behind the dam at the town of the same name); Five Fingers Rapids, over a band of hard conglomerate, were not so troublesome.

In June 1898 the armada of stampeders floated into Dawson, the miners' town at the mouth of the Klondike River. Only then did the ultimate tragedy hit them—by the time that they arrived, every claim in

Fig. 3. The upper Yukon Valley and the gold rush routes in from Skagway and Dyea on the Pacific coast.

Fig. 4. Stampeders' supplies stockpiled on the Chilkoot Pass, while an unbroken line of men haul them up the snow slope of the Golden Stairs. These stampeders were late in the Rush, as the first of the aerial tramways was being built at the time (photo: E.A. Hegg, courtesy of Dawson City Museum).

the goldfields valleys had already been staked. The 30 000 new arrivals could only work for wages from the prospectors who had got there before them. Many departed, broke and broken. One stampeder wrote home: 'Martha. All the ground is taken. Everyone is a king but me. I'm off to Nome on the last boat out. Affectionately, Henry'. Those who did make it rich were mostly not gold-diggers—they were the thoughtful ones who had come equipped for trade in the Dawson boom-town.

Fig. 5. The town of Dawson today, looking up the Yukon River from Midnight Dome. The dark wedge of clear water is from the Klondike River, entering between the high terraces at the far end of the town.

Dawson and the Klondike camps

The miners' camp on the mudflats at the mouth of the Klondike River had expanded steadily since 1896; its collection of tents and a scatter of log buildings was named Dawson, after a Canadian government geologist (Fig. 5). With the arrival of the stampeders, Dawson became Canada's largest town west of Winnipeg. An initial chaos of ragged tents in a sea of mud slowly evolved in the wake of the mining boom. A fleet of sternwheelers brought endless supplies up the river from Alaska—along with a few thousand more gold seekers. Timber buildings and raised sidewalks lined the muddy streets—which have never been tarred to this day.

The gold diggings started in the Klondike valley right at the back of town (Fig. 6). They stretched up every creek that drained into the Klondike from the south. Each claim had its own collection of log cabins, tents and makeshift shacks, and traders established posts wherever they could. Grand Forks became a key town with hotels, shops, saloons and a floating population of over 5000 above the junction of the two richest creeks, Bonanza and Eldorado. From 1906 to 1914, it was linked to Dawson by a railway through the heart of the goldfields, but nothing remains there today.

The wildest days of the gold rush ended in August 1899, when word came up the river of new gold discoveries on the beaches of Nome, on Alaska's Bering Sea coast. There was a new rush for the boats as most of the stampeders and itinerants without a claim of their own headed out of town. A slightly less crowded Dawson continued to thrive with the highs and lows of the mining industry. In 1953 the Yukon government moved from Dawson to Whitehorse, but there are still miners on the Klondike today.

Fig. 6. The Klondike goldfields on the Bonanza and Hunker Creeks. The marked placer areas include both the alluvial zones and the older terraces.

Origins of the gold

The geology of the northwestern tip of North America is essentially the product of convergent plate boundary activity and terrane accumulation. Northward movement of the Pacific plate in Mesozoic times had the effect of a massive conveyor belt that carried various terranes from distant sites, to be accreted onto the south coast of Alaska. Much of the terrane material was derived from huge greywacke sequences that accumulated along the western margin of the North American craton.

The Yukon–Tanana terrane included the Klondike Schists, and arrived in early Jurassic times; it now lies between the Denali and the Tintina Faults (Fig. 3). The latter fault is recognisable as the Tintina Trench, along a narrow graben that was created by an element of tension across it in Tertiary times. Collisions between the terranes and the American continental slab generated partial melting of the crust to create the huge coastal batholith of granite, now exposed around Skagway.

The Lower Palaeozoic Klondike Schist is the ultimate source of the Klondike gold. But, as in all the world's great gold rushes, the miners' targets on the Klondike were the enriched placer deposits. The richest gold was found as flakes and grains in loose alluvial sediments. As worked both in the first rush and today, most grains are less than a millimetre across, some is the finest of dust, and some is in nuggets formed where smaller grains are annealed together in the riverbed. All the gold occurs as the native metal, alloyed with smaller amounts of silver.

The placer deposits occur in an area of over 1000 km^2, along most of the creeks that drain the Klondike Hills between the Klondike River and Indian Creek (Fig. 3). The richest gravels, just a few metres thick, are mostly covered by up to 12 m of barren gravel, loessic silt and organic peat (locally known as muck). Late Tertiary gravels, 2–50 m thick, occur as terraces on the higher valley sides, at levels up to 100 m above the creeks; these also contain gold, with the richest in the White Channel, named after its clean, white, quartz sand (Fig. 7).

It had long been assumed that all the gold, in both the White Channel and in the modern gravels, was typical alluvial placer material, derived by mechanical erosion of gold-bearing quartz veins within the bedrock and then concentrated by selective deposition. But this is not entirely the case, as much of the gold is found in enriched zones within the schist just below rockhead.

The marine clays that now form the Klondike Schist originally contained low levels of gold. This was mobilized during Cretaceous metamorphism, at temperatures around 300 °C, and was concentrated into numerous, widely dispersed quartz veins (Fig. 8).

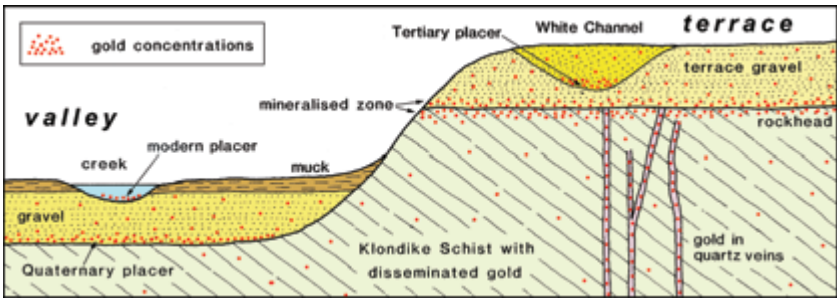

Fig. 7. Diagrammatic profile with the various features of gold mineralization in the Klondike schists and gravels.

Few of these are large enough or rich enough to warrant underground mining on even the smallest scale.

Overlying the schist, the oldest drift sediments, occupying the highest topographical positions, are the braided channel sediments of the White Channel terrace. These are of Plio-Pleistocene age, but they are also mineralized. Their lower parts show clear signs of low-temperature hydrothermal alteration; most notably there is kaolinization with new growths of clay minerals. Similar alteration also occurs in the top few metres of the immediately underlying schists. This second phase of gold mobilisation concentrated the metal to economic levels just above and below rockhead (Fig 7); its medium of transport was largely rainwater draining through the drift and weathered bedrock, but it is distinct from conventional secondary mineral enrichment that occurs purely by weathering processes. Gold/silver ratios vary from creek to creek, indicating local variability in the sources of the metals and their emplacement systems.

Erosion and reworking of both the mineralised sediment and the shallow bedrock, by the contemporary early Pleistocene rivers, produced further gold concentrations in the White Channel; these were traditional placer deposits, which provided the richest pay-streaks in the terrace gravels. All the White Channel alluvium was left above the valley floors by a phase of incision and rejuvenation that probably occurred when the local base level declined in response to downward movements on the rifts along the Tintina Trench.

The Yukon basin is today a periglacial environment—and most of it has been so throughout the Quaternary. In each cold phase of the Pleistocene, a Cordilleran ice sheet developed in the basin's southern sector by the coalescence of glaciers and ice caps on the coastal mountain ranges. Farther to the east, the Laurentian ice sheet advanced in the same cycles, but only ever covered the upper reaches of the Yukon River (Fig. 3). Most of the Yukon basin was not glaciated, due to the lack of snowfall in its land-locked rain shadow. This cold environment is characterised by very low erosion rates—which were critical to the preservation of the Klondike gold deposits.

If Pleistocene ice had reached the Klondike, it would have dispersed the gold into glacial till spread over huge areas. Instead, fluvial erosion of some of the mineralised schist and terrace sediments produced successive generations of placer deposits in the modern creek gravels, in various intermediate terraces, and in the modern creeks (Fig. 7).

Within the placer gravels of both the modern valley floors and the terraces, the pay streaks with the very richest gold lie immediately above the rockhead and follow ancient channels cut into the bedrock. This is typical of placer deposits, and the exact positions of the channel floors cannot be predicted from surface observation. To the frustration of the weary miners, the rich pay-streaks were only found by sinking shafts through the entire thickness of the muck and gravel, and then digging adits along rockhead until gold-rich ground was discovered.

This interpretation of the ore enrichment mechanism explains the lack of any mother lode in the Klondike. Most of the world's richer placer deposits were created by fluvial deposition after erosion of hydrothermal minerals in one or more veins—the mother lodes; these were generally found merely by tracing the placer ores to their upstream limits. The veins commonly provided a second phase of mining, albeit not as rich or as easily worked as the placer ores. But hard-rock mining in the Klondike has only ever revealed a few isolated and rather meagre vein deposits.

Mining in the Gold Rush

Panning for gold entails swirling water out of a shallow bowl fast enough to take the light sediment with it, and so leave behind the heavy gold. With this quick and simple technique, the prospector worked his way up the creeks, panning the streambed gravels, until he produced a rich pan. Then he staked his claim, to 500 feet (150 m) along the creek and 1000 feet (300 m) up each side, and had to start digging into the deeper gravels, as the richest gold was always down at the rockhead. Panning has always been the tool of the prospector, but methods of mining have evolved through the years, largely in response to the nature of the gold ores, and were the best available at any particular time.

Easy digging into the loose sediments has long made placer deposits the favoured target of gold prospectors. But the Klondike had an extra problem—permafrost—with the gold hidden in ground that was largely frozen solid. Continuous permafrost occurs where the mean annual air temperature is lower than about –8 °C. Mean temperature is about –5 °C in most of the Yukon basin, so there is discontinuous permafrost, and in the Klondike it is about 20 m deep.

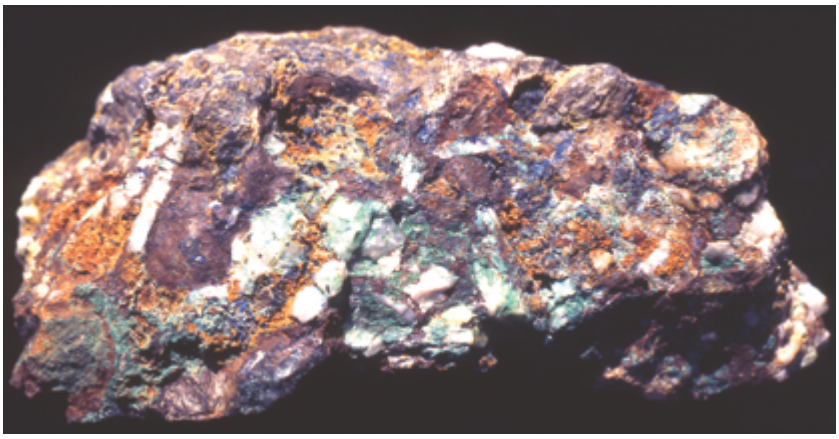

Fig. 8. Hand specimen of vein ore from the Klondike, with sub-visible gold and colour from secondary copper minerals.

Above the permafrost, the active layer has its winter ground ice thawed by the summer sun; it becomes an undrained, unstable quagmire just a few metres deep during each short Arctic summer. In the Klondike's marginal permafrost zone, frozen ground survives under an insulating blanket of undisturbed vegetation; clearance or destruction of the trees and their organic soils leads to ground thawing—and was often intentional to facilitate mining operations.

Hand mining was the technique of the frantic Gold Rush years, but was employed on the Klondike only until 1904. A shaft was sunk straight down until bedrock was reached, and then horizontal adits were driven to find, and then follow, the pay-streaks. Permafrost ice cemented the drift sediments to the extent that these tunnels could not be dug without powered machinery. At first the ground ice was melted by fire-setting, but this was horribly inefficient. More effective was steam from boilers at the mine entrance, but its production needed huge quantities of wood—and contributed to the complete removal of the forest in the entire Klondike region. The permafrost did keep the mine galleries stable, but the entrance shafts through the thawed active layer became unsafe during the summer. So the miners worked underground through the winter, and the gravel that they dug out was stockpiled on the surface, where it froze solid. Then in summer, the stockpiles were sluiced in running water—which was not available during the winter.

Separation of gold from the barren quartz and rock gravel was by sluicing. The original sluices used in the Gold Rush were inclined wooden channels about 400 mm wide and deep, with wooden riffle bars across their floors; water cascaded through them, and the channels were as long as the miners could afford to make them (Fig. 9). Gravel and dirt from the stockpile was shovelled into the sluices, where the lighter quartz and rock was washed down the channel by its cascading water. The gold was trapped behind the riffles, as it was too heavy to be washed over by the water flow; the finest gold dust was

trapped on coconut matting beneath the riffle bars. Sediment from behind the riffles was then panned to separate the gold from the other heavy minerals that were also trapped by their weight.

Most of the first miners used rocker boxes to recover the gold. Each box was about 500 mm wide and 800 mm long, with riffles on its base. Loaded with water and a few shovel loads of dirt, it was rocked back and forth by hand until the gold was trapped on its floor. A rocker box was a cross between a pan and a sluice; it was popular with miners of limited resources because it required less water and timber, but it was hard work to run.

Fig. 9. Early summer on the creeks, with a group of miners shovelling into their timber sluice the ore and debris from a winter's underground digging. The photographer's inscription refers to the twenty-first claim downstream of the first claim on Hunker Creek (photo: Turnbull Collection, Dawson City Museum).

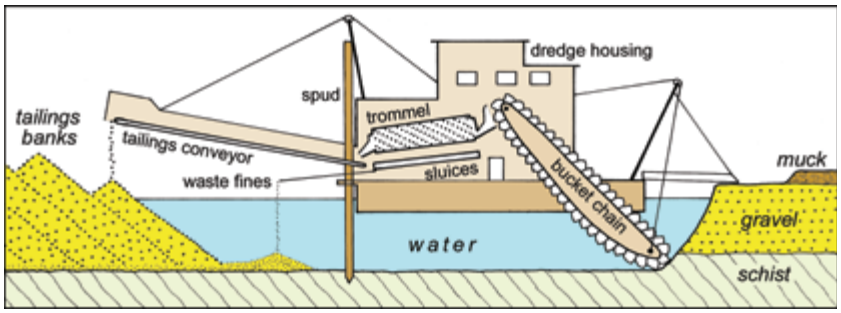

Fig. 10. The main features of a Klondike gold dredge.

The hand-mining was all very crude, and it relied on the huge supply of labour represented by the influx of stampeders. In the first 10 years, the Klondike miners shipped out 161 tonnes of gold, with a peak production of 30 tonnes in 1900.

Improved mining methods

Hand mining was too expensive to maintain, especially when the ore grades became leaner. It was replaced by mechanical methods as soon as heavy machinery was transported to the Klondike, soon after the rush of stampeders had moved on to newer fields. Dredging was the great gold producer in the years 1905–66, when up to 35 dredges operated on the creeks. Annual production was around 8 tonnes in the early 1910s, but fell off to around three tonnes per year after 1920.

A typical floating dredge weighed up to 3000 tons, and sat in a lagoon of its own making. At its front, a chain of 75 buckets, each holding half a cubic metre, scooped up 8000 cubic metres of gravel per day (Fig. 10). It could reach to a depth of 17 m, and scraped up the top 3–4 m of altered schist—which had the high gold values. All the broken rock and alluvium was fed into a revolving, perforated cylinder known as a trommel; these were 2–3 m in diameter and 10–15 m long, through the interior of the dredge housing. Coarse waste debris went straight through the trommel onto the tailings disposal conveyor belt. The fines dropped through the perforations, onto the vibrating sluice tables, which trapped the gold with impressive efficiency. One dredge could gather up to 800 ounces (11 kg) of gold in a day, from ground that averaged about one part per million; but dredging had to stop when the sluices froze each winter.

Before the dredge could advance, the ground was prepared by washing off the vegetation and organic muck. Then the permafrost was thawed by pumping cold water into holes bored into the alluvium; it was slower than steam, but was far more economical. The dredge advanced through the cleaned and thawed alluvium by winching itself forward on cables attached to temporary ground anchors. Once in a new position, its central steel spud was sunk into its lagoon bed. The whole dredge could then rotate around the spud, so that its bucket chain could scrape up the gravel from a wide arc. This rotating motion also swung the tailings conveyor belt at the back of the dredge, so that the barren debris formed its distinctive crescentic banks (Fig. 11). Finer tailings from the sluices were dropped directly into the lagoon. Each dredge ploughed through the valley alluvium, leaving its own sinuous ridge of tailings and debris to mark its route. The upper coarse material was then washed through by rainfall, to leave the crenulated banks of clean cobbles that distinguish the goldfields today.

Fig. 11. Ribbed ridges of dredge tailings on the floor of the Klondike Valley, just upstream of the Bonanza Creek confluence. Tailings in the background have been graded to allow re-use of the land.

Fig. 12. Monitor pumps at a hydraulicking operation on Hester Creek cut into a thick cover of organic muck overlying gold-bearing gravels. The end of the rainbow is on mineralised Klondike Schist that is also washed out by the water jets.

Gold output from the Klondike declined after the last dredge closed down in 1966. Then in 1972, the price of gold was allowed to float above the $35/ounce that had been fixed in the interests of international currency control. In 1980, gold peaked at $800/ounce—and gold mining had become a lot more attractive. It has wavered since in the range of $300 to $700/ounce, and has fuelled a new generation of Klondike miners who achieve an annual production of 2 or 3 tonnes. Their methods are combinations of hydraulicking and cat mining.

Hydraulicking uses powerful water jets, which are blasted out of monitor pumps and are very effective at washing gravel and dirt from an exposed slope (Fig. 12). The washed debris is then scooped up and dumped into sluices, just as in hand mining. The technique was introduced on the Klondike in 1902, long remained the favoured method on the terraces, and is still used on the larger mines that are worked today. It is quicker than digging, but requires a good water supply. A major step forward in the early mining was the construction of the Yukon Ditch, a sequence of canals, flumes, iron pipe syphons and vast timber aqueducts, totalling 115 km in length, that brought water to the Klondike terraces from unused rivers to the north.

Cat mining was started on the Klondike in 1973. It uses a caterpillar bulldozer to clear away the muck and barren gravel, before piling up the gold-bearing gravel ready for sluicing. Crude and simple, it is still used on small exploratory operations and where there is not enough water for hydraulicking.

For both methods of mining, separation techniques have evolved only slightly from the older practices (Fig. 13). As all the gold is of dust, sand and small nugget size, sieves (known as screens) remove all the gravel coarser than about 10 mm. Plane vibrating screens, a few metres across, are used on

Fig. 13. Loading gravel into a small screening plant at a Klondike placer mine.

smaller mines, while larger operations feed the dirt, rock and gravel into rotating trommels. Both the screens and the trommels have hole sizes, gradients and feed rates selected to be most efficient for the grain size distribution of the particular deposit being worked. The final sluicing is on short and wide steel tables that are vibrated by electric motors, and catch the finest gold on carpets of nylon.

The Klondike today

There are currently about 400 miners working around Dawson, on about 100 small mines that extract the placer gold with monitor pumps and

Fig. 14. A miner holds a Pleistocene mammoth tusk that he washed out of the gravel at his hydraulicking mine. The string around it allows him to pull the tusk out of the pond where he keeps it underwater to stop the ivory breaking up as it dries out.

Fig. 15. Old houses in Dawson, subsided over thawed permafrost.

bulldozers. Numbers fluctuate and sites are worked out, but there are many active workings along the Hunker and Bonanza Creeks (Fig. 6); another dozen mines lie further up Hunker Creek, and there are now nearly as many operations on the northern tributaries of Indian Creek (Fig. 3).

Typical is a hydraulicking operation worked by two men on Hester Creek. Overburden of 5–20 m of muck and gravel is washed away—and frequently reveals large bones and tusks from Pleistocene mammoths (Fig. 14). The lower gravels have good gold values, but, unlike in true placer ores, the richest gold occurs over bedrock ridges where it is associated with hydrothermal graphite mineralization in the schist. Monitor pumps, blasting out 5000 litres of water per minute, rapidly cut through the unfrozen sediments and into the upper zone of altered and mineralized schist. Washed out debris is then scooped up by a front-end loader and tipped into a small screening plant. The ground is already thawed because earlier miners dumped their tailings and killed the insulating blanket of moss, although the organic muck re-freezes each winter to depths of about two metres. Though it can only be worked through the summer thaw season, it's an efficient operation that has plenty of gold in its reserves.

With no mother lode to follow down with years of deep mining, the Klondike is in its declining years. But the region may have hidden potential. Practically every creek along the Yukon has been checked and panned, but the forest-clad terraces have attracted few of the traditional prospectors. Another White Channel in a terrace gravel above more mineralised bedrock could re-start major activity.

Meanwhile, Dawson remains a fascinating outpost of civilization. Tourists may out-number miners on some days in July or August. The few buildings remaining from the early days have been conserved, and attract attention—as they subsided when the permafrost was thawed out beneath them by their own heat (Fig. 15). The creeks are chaotic landscapes of worked gravels, but a dredge abandoned in 1959 has been restored as a visitor site up Bonanza Creek (Fig. 16).

The Klondike is a part of history, and its statistics remain spectacular. It has yielded more than 300 tonnes of gold from about 100 million tonnes of rock, gravel, sediment and dirt shifted and sluiced by the miners. It is difficult to know what yields the first miners achieved by picking off the rich pay-streaks, but the best claims on Bonanza and Eldorado Creeks were the richest the world has ever known. No other gold field or gold rush will quite match the Klondike.

Suggestions for further reading

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Fig. 16. Bonanza Creek today, with the preserved dredge amid endless tailings banks.