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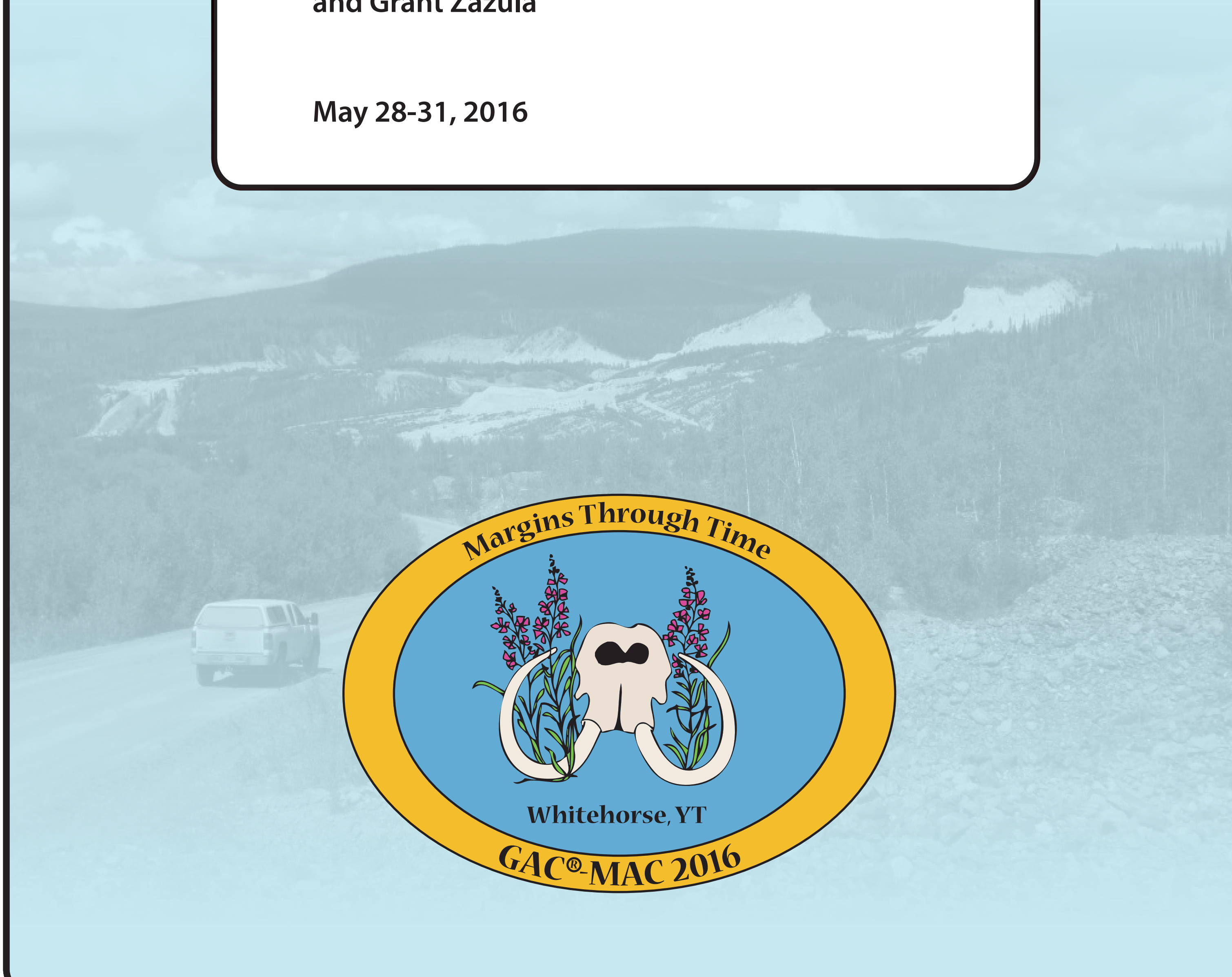
Veins to valleys: the Klondike District

Field trip leaders:
Jim Mortensen, Jeffrey Bond, Peter Tallman and Grant Zazula

May 28-31, 2016



Margins Through Time
Whitehorse, YT
GAC®-MAC 2016

INTRODUCTION

The goal of this field trip is to introduce participants to the bedrock geology, surficial geology and palaeontology of the Klondike District, as well as, gold-bearing orogenic vein systems that are currently being explored in the area and placer gold deposits from which 13(+) million ounces of gold have been mined.

KLONDIKE DISTRICT GEOLOGY OVERVIEW

Jim Mortensen, University of British Columbia

Bedrock Geology

The Klondike District is underlain by an imbricated structural stack that comprises three distinct assemblages of variably deformed and metamorphosed rock units (Fig. 1), including the Klondike, Nasina and Slide Mountain assemblages. The structurally highest units, which host all of the known lode gold occurrences, form part of the Middle to Late Permian "Klondike Schist" assemblage, which consists of mainly middle greenschist facies mafic and felsic metavolcanic rocks and their intrusive equivalents, together with interlayered non-carbonaceous siliciclastic rocks and rare carbonaceous schist. The felsic and mafic metavolcanic rocks are now represented by a variety of pyritic muscovite and quartz-muscovite schists and chlorite (± actinolite, epidote, Fe-carbonate) schist, respectively. Associated meta-intrusive rock units include metaporphyry (quartz-feldspar augen schist) and quartz monzonitic orthogneiss of the Sulphur Creek orthogneiss, and rare bodies of metagabbro (Fig. 1). Several separate thrust slices of Klondike assemblage rocks have been structurally emplaced on top of a lower package of carbonaceous metaclastic rocks (including minor marble) of the Late Devonian-Early Mississippian Nasina assemblage (Fig. 1). Massive to weakly phyllitic greenstone and variably sheared serpentinite of the late Paleozoic Slide Mountain assemblage occur as lenticular bodies along several of the main thrust fault contacts that separate individual panels of Klondike and Nasina assemblages.

Structural Geology

Rock units in the Klondike District record five separate deformation events (Mackenzie *et al.*, 2008a). Strong ductile deformation at middle greenschist to locally lower amphibolite facies during the D1 and D2 events in latest Permian time ("Klondike Orogeny" of Beranek and Mortensen, 2011) created a pervasive recrystallization foliation and transposed all contacts between separate rock units. Locally abundant barren quartz (± carbonate) segregation veins formed during the D1 and possibly D2 events. Thrust imbrication, emplacement of greenstone and serpentinite bodies of the Slide Mountain assemblage, folding of the dominant schistosity (and locally the thrust

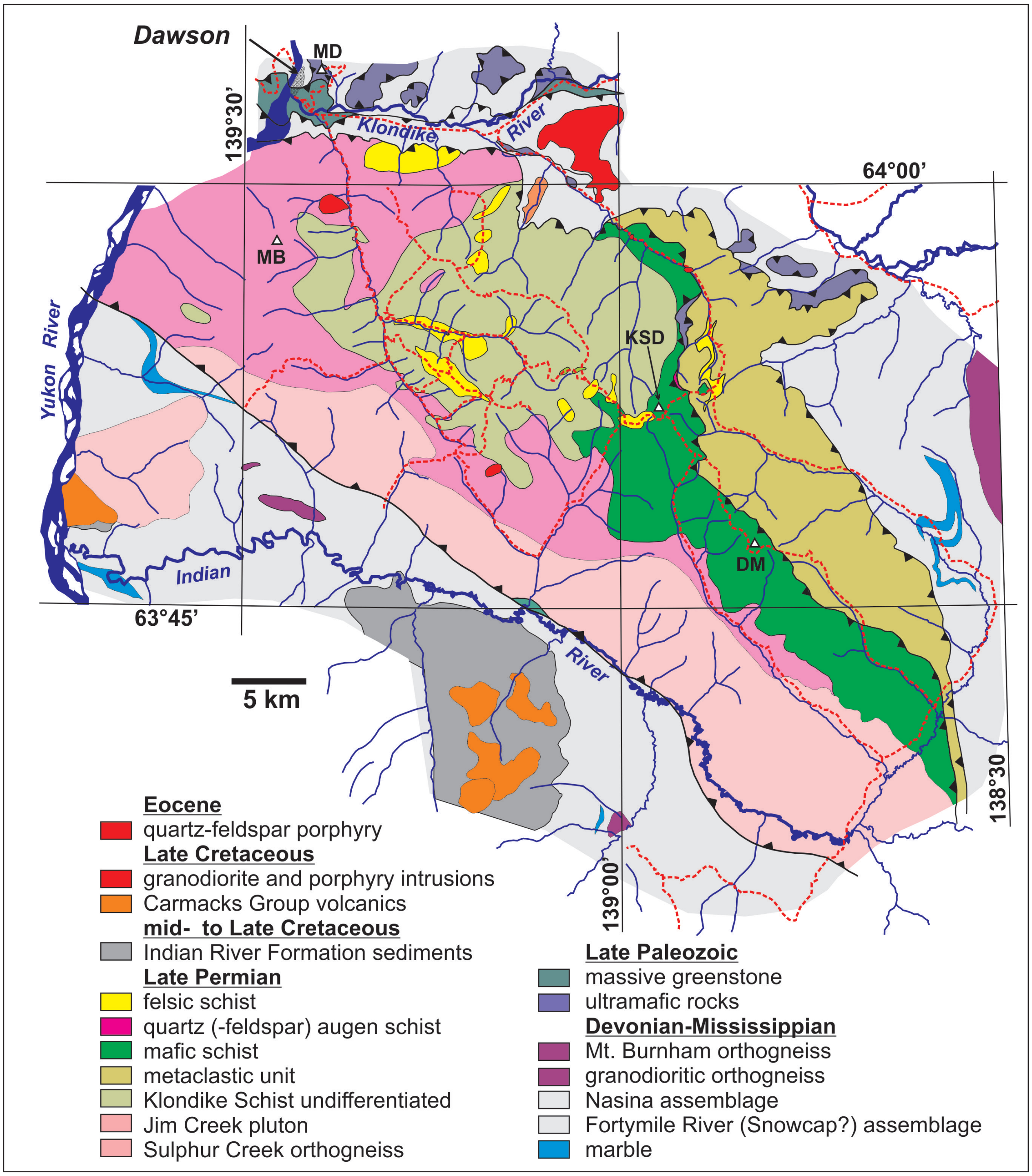


Figure 1. *Simplified geology of the Klondike District, based on mapping by Mortensen (1983-2012) and Mortensen and MacKenzie (2006-2007). MD - Midnight Dome; MB – Mt. Bronson; KSD – King Solomon Dome; DM – Dominion Mtn.*

surfaces) and development of a spaced cleavage comprise the D3 event. The D4 event produced localized, mainly north- and northwest-trending zones of kink folds and high-angle reverse faults. Finally the D5 event is characterized by normal faulting with abundant gouge development.

The sequence and nature of structural elements documented in the Klondike also appear to be recognizable elsewhere in the YTT in western Yukon (Mckenzie *et al.*, 2013; Allen *et al.*, 2013), suggesting that this structural interpretation may be applicable throughout much of the region.

Quartz Veins in the Klondike District

Quartz veining is very widespread in the Klondike, and some rock units locally comprise up to 10% vein material by volume. The vast majority of this quartz occurs as early, segregation veins that are parallel to compositional layering in the schistose lithologies, and are interpreted to have formed during the ductile deformation associated with the D1/D2 and D3 events (MacKenzie *et al.*, 2008a). Segregation veins in the Klondike contain neither gold nor sulfides. Gold-bearing quartz veins represent a later veining event, and occur at scattered localities throughout the Klondike. They form individual veins up to 3 m in width as well as swarms of veins at various orientations but typically with an overall north or northwest trend. The veins are discordant to the D1-D3 foliations in the rocks, and are interpreted to have formed late in, or immediately following, the D4 deformation event (MacKenzie *et al.*, 2008a). Veins typically consist almost entirely of quartz, together with rare ferroan carbonate, barite, scheelite, sulfides and sulfosalts, and gold. Gold generally occurs adjacent to or as inclusions within pyrite, especially in pyritic selvages that are present along the margins of some of the veins. Gold also occurs more rarely as free grains within vein quartz. Base metal sulfides and sulfosalts are very minor and, where present, are typically confined to the interiors of the veins. Hydrothermal alteration around the veins is generally only prominent where veins cut mafic metavolcanic rock units. In such settings the mafic host rocks show strong carbonate alteration up to 5 m from the vein margins, as well as pyritization (including replacement of pre-existing magnetite porphyryoblasts) within 2 m of the veins and locally intense sericitization immediately adjacent to the vein. In some localities (*e.g.*, the Mitchell and Sheba occurrences in the King Solomon Dome area; Fig. 1) the hydrothermal pyrite in the altered wall rocks also contains gold. It is likely that sulfidation of the wall rocks and resulting destabilization of bisulfide complexes in the mineralizing fluids was at least partially responsible for deposition of the gold (Rushton *et al.*, 1993). Where gold-bearing veins cut felsic schist host rocks (*e.g.*, in the Lone Star area; Fig. 1) visible wall rock alteration comprises only minor and local pyritization. In such settings gold precipitation is presumably related to cooling of the mineralizing fluids and/or pressure drops.

Most gold-bearing quartz veins in the Klondike appear to represent single stage infillings of extensional fissures, although locally (*e.g.*, at the Sheba vein) there is evidence for repeated fracturing and influx of hydrothermal fluids (MacKenzie *et al.*, 2008a; Allen *et al.*, 2013). The timing of vein formation in the Klondike is not completely resolved. The character, mineralogy, and stable isotope composition of the veins is broadly similar throughout the entire study area (*e.g.*, Rushton *et al.*, 1993), and we therefore interpret all of the gold-bearing veins in the Klondike to have formed at approximately the same time. Veins at the Sheba and Mitchell occurrences in the King Solomon Dome area (Fig. 1) have yielded consistent $^{40}Ar/^{39}Ar$ ages of ~140-145 Ma (latest Jurassic; Mortensen, unpublished data). However, rutile from a weakly gold anomalous orogenic vein in the Mackay zone approximately 1.5 km east of the Sheba vein has been dated at ~160 Ma (Mortensen, unpublished data). New $^{40}Ar/^{39}Ar$ ages from muscovite in wall rock schists near the Mitchell and Mackay zone veins range from ~135-141 Ma. This suggests that the $^{40}Ar/^{39}Ar$ ages reflect regional cooling of the veins and their host rocks rather than the actual age of hydrothermal activity, which probably occurred at ~160 Ma (same age as orogenic gold at the Golden Saddle deposit in the White Gold district; Allen *et al.*, 2013).

Rock units of the Klondike Schist assemblage that host gold-bearing veins in the northwestern Klondike District mainly comprise felsic metavolcanic rocks (variably pyritic quartz-muscovite schist), as well as metaporphyry (quartz ± feldspar augen schist) and metaplutonic rocks (Sulphur Creek orthogneiss; Fig. 1). Most known lode gold occurrences in the northwestern part of the Klondike are concentrated in the Lone Star Ridge area (Fig. 2). Only a limited number of these occurrences (Lone Star, Nugget, Veronika, Dysle, Hilchey, Buckland) have been explored extensively. Some of the lode occurrences shown on Figure 2A and 2B (Plinc, Parnell, Pioneer, 310 Zone) appear to contain only trace amounts of gold. MacKenzie *et al.* (2008b) demonstrated that the pyritic felsic schists that host some of the gold-bearing veins in the Lone Star Ridge area contain low levels of disseminated gold.

Placer Gold Deposits in the Klondike

The nature and evolution of placer gold deposits in the Klondike District have most recently been described by Lowey (2006). Much of west-central Yukon Territory, including the Klondike District, was not affected by Pleistocene glaciation; hence the evolution of placer deposits in the Klondike can be linked directly to the specific uplift and erosional events that affected the area. Placer gold occurs in two main settings in the Klondike. Much of the gold was initially concentrated in sinuous paystreaks within the lower few meters of the "high-level" White Channel Gravel unit of Pliocene age (Fig. 2A), which was deposited in mature, broad, flat-bottomed valleys formed by braided streams. The erosional surface on which the White Channel Gravel was deposited is referred to as the White Channel "strath". Erosional downcutting in the Pleistocene to Holocene led to incision of modern streams into this older drainage

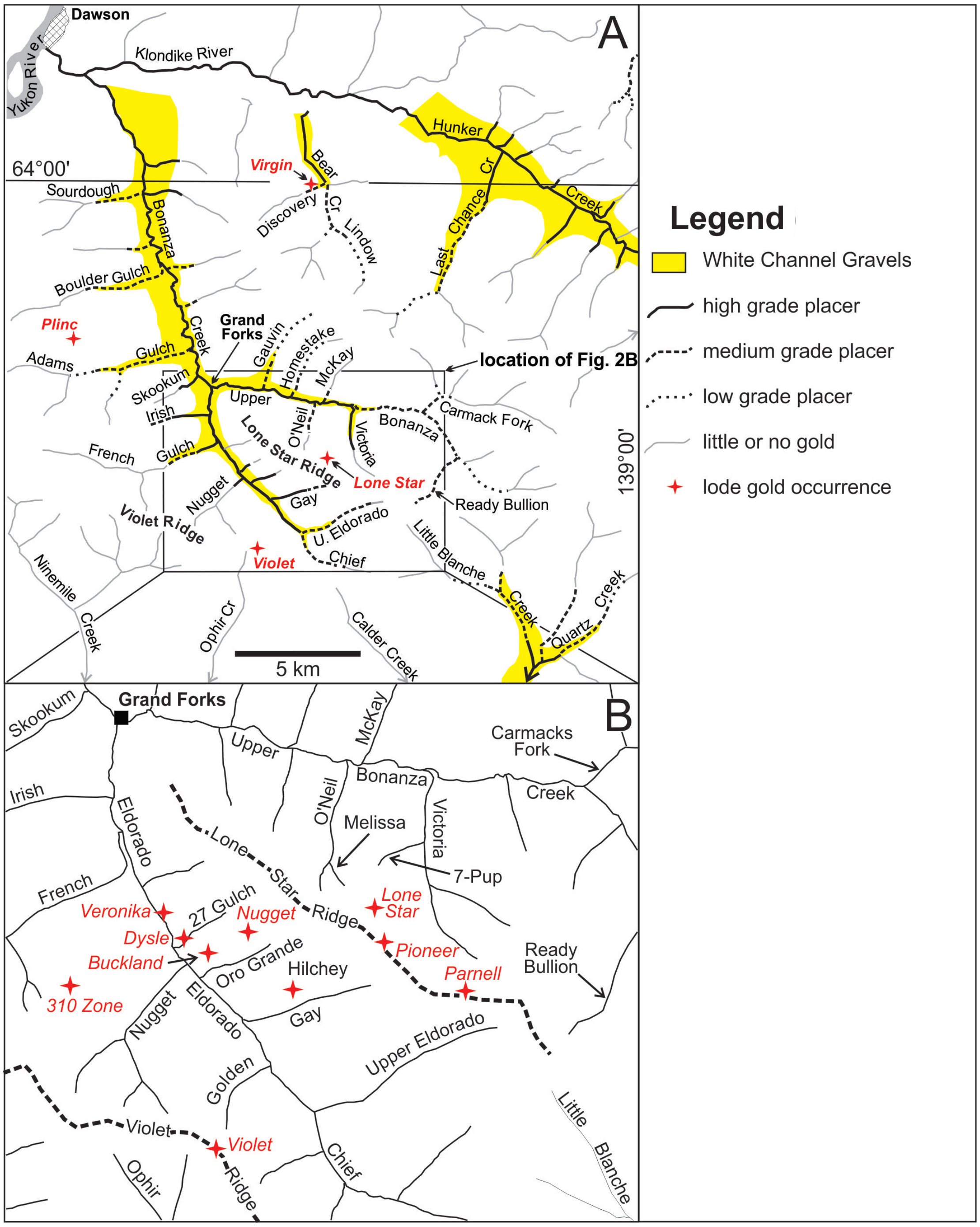


Figure 2. *Distribution of lode and placer gold occurrences in the northwestern part of the Klondike District (modified from Chapman et al., 2010a).*

system, with the beds of present streams lying up to 70 m below the White Channel strath (Fig. 3). Gold in these younger streams, which have historically been the most important producers in the area, includes gold that has been reworked and re-concentrated from eroded paystreaks within the White Channel Gravel as well as gold that has been newly eroded directly from bedrock sources. It is important to note that the modern drainages are for the most part simply incised into the pre-existing White Channel Gravel drainage system (Fig. 2A). Almost all of the placer gold in the Klondike (including both the White Channel Gravel deposits and those in younger streams) was deposited in fluvial settings; however, colluvial gold is also present, especially immediately downslope from lode gold occurrences near the headwaters of some placer streams. Nuggets were not very common in the Klondike, although a significant number of nuggets were recovered from Bonanza and Eldorado creeks (including one 18 oz nugget from lower French Gulch on Eldorado Creek; J. Archibald, pers. comm., 2007). A nugget (gold plus quartz) weighing a total of 122 oz was recovered from upper Dominion Creek. Most placer gold that has been recovered in the Klondike, however, was relatively fine grained.

Figure 3. *A view to the south looking up Hunker Creek. The Pliocene (Neogene) terraces or hills are visible above the modern valley bottom. Active placer mining operations are visible on the terraces.*

DAY 1 WHITEHORSE – DAWSON CITY

9:00 am Meet behind Elijah Smith Building at the corner of 3rd Avenue and Steele Street– central to downtown hotels
9:30 am Depart Whitehorse for Dawson City

Stop 1 Five Finger Rapids, Beringia and White River Ash (Z 8V 430289 E, 6905288 N)

Jeffrey Bond, Yukon Geological Survey

Five Finger Rapids

Five Finger Rapids is marked by resistant islands of Jurassic conglomerate that were deposited at the edge of an inland sea called the Whitehorse Trough. These conglomerate pillars created a navigational hazard for steam boats operating between Whitehorse and Dawson City. The strong current required the large river boats to be winched through the rapids when traveling upstream.

Glacial Limits and Beringia

During the Pleistocene, central Yukon and Alaska was glaciated numerous times. The northern extent of the Cordilleran ice sheet was a complex of independent ice lobes that coalesced to form a continuous carapace of ice. However, precipitation was restricted in the interior and this resulted in limited ice extents marked by multiple glacial limits (Fig. 4). The most extensive glaciations occurred during the early Pleistocene, whereas late Pleistocene advances were slightly less extensive. This resulted in glacial surfaces of varying age in central Yukon. West of the most extensive Pleistocene glacial limit in central Yukon is the unglaciated terrain of Beringia. Also referred to as a subcontinent, Beringia was most extensive during glacial maximums when sea level reached its lowest point and a 1000 km-wide land bridge connected North America and Asia. The drive from Whitehorse to Dawson provides a unique opportunity to traverse these glacial surfaces and to enter the eastern edge of Beringia. At this location we are 15 km south of the last glacial limit (McConnell glaciation), which began its recession approximately 16,000 years ago. McConnell outwash deposits are visible across the valley above the Yukon River.

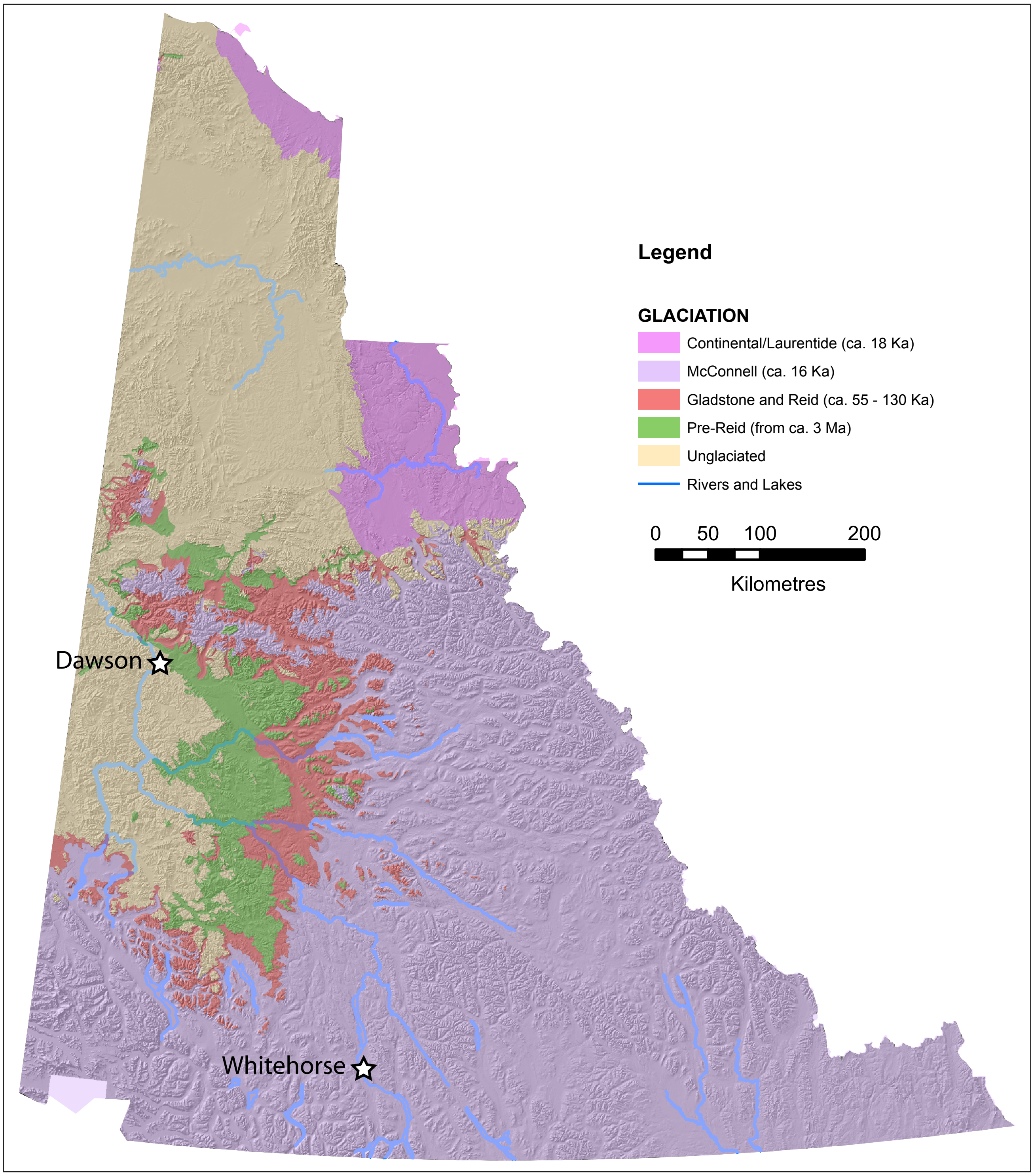


Figure 4. *The glacial limits of Yukon. Multiple glacial limits are evident in green, red and purple. The beige colour represents unglaciated terrain (after Duk-Rodkin, 1999).*

White River Ash

The eruption of Bona-Churchill massif (A.D. 847 ± 1), a volcano in the Wrangell volcanic field near the Yukon-Alaska border, deposited tephra across central and southern Yukon (Lerbekmo, 2008; Jensen *et al.*, 2014). The northeast trajectory of the tephra deposited a visible layer in road cuts along this section of the Klondike Highway and glass shards in bogs have been detected as far away as northern Europe (Jensen *et al.*, 2014). The east lobe eruption produced an eruptive cloud that reached a height of ~45 km and contained a volume ~47 km^3 of tephra (Lerbekmo, 2008).

Deposition of the White River Ash is thought to have dispersed First Nation populations in southern Yukon.

Stop 2 Stewart River/McQuesten Airstrip: Historic placer mining on the Stewart River (Z 8V 373379 E, 7055199 N)

Jeffrey Bond, Yukon Geological Survey

The discovery of gold on the Stewart River bars is linked with the opening of the Chilkoot Pass. The Chilkat First Nation guarded the pass and it required negotiations with the U.S. Navy for the pass to eventually be opened to prospectors in 1880. In 1883, Lt. Schwatka's party prospected the Stewart River and reported very encouraging results (Gilbert, 1989). In 1885, Steamboat bar was discovered and during one season a man could recover up to 300 ounces of gold using a rocker box on the modern point bar (~3 oz/day). The richest deposits on the bar yielded up to 8 ounces of gold per day per man but were quickly exhausted due to their limited extent. The discovery eventually reached Juneau and prompted 100 miners to climb the Chilkoot pass and head to the Stewart River in 1886. This increase in prospecting activity lead to the discovery of gold on the Fortymile River (downstream from Dawson) and firmly established the mining industry in Yukon.

William Ogilvie entered the Territory as the Department of the Interior's head surveyor as part of a Canadian government's Yukon expedition in 1887. He defined the Yukon-Alaska boundary, completed extensive claim surveys in the Klondike goldfields following their discovery in 1896 and became the second Commissioner of the Yukon (1898-1901). After leaving the civil service in 1902, William Ogilvie became the managing director for the Golden Crown Company (Stewart River Gold Dredging Co. Ltd.) and embarked on establishing dredging operations on the Stewart River at Steamboat bar. The first dredge was considered a prospecting dredge and capable of processing 800-1000 cubic yards per day to bulk test the low grade gold concentrations ($1.12 per yard @ $20.67/oz) prevalent on the bar (Dawson Daily News September 13, 1902). This venture was a success and initiated a second larger dredge in 1908 under the company name Yukon Basin Gold Dredging Company. According to newspaper reports clean ups from Steamboat Bar amounted to $3000.00 per day at $20.67/oz (145 oz/day).

In 1909, the same company invested in a third dredge for operations on Steamboat Bar. Despite having significant plans to establish dozens of dredges on the Stewart and McQuesten rivers, the Yukon Basin Gold Dredging Company only managed limited production due to financial difficulties.

Stop 3 Tintina Trench Lookout

This stop provides a view across the Tintina Trench, a major structural valley (graben) that developed in the late Miocene along the Tintina fault. The northwest-striking Tintina fault is a dextral strike-slip fault with about 430 km of Paleogene displacement and forms a prominent geological feature in Yukon. Rocks of Ancestral North American affinity are visible on the northeast side of the trench (Ogilvie Mountains), whereas allochthonous Intermontane terranes occur to the southwest (Klondike Plateau).

DAY 2 HUNKER CREEK - QUARTZ CREEK - BONANZA CREEK

8:30 am Assemble in the parking lot on Front Street in Dawson, across from St. Paul's Church and the Commissioner's Residence (just past the white graveled ramp with flowers).

Yukon River outcrop on west side of Yukon River

A large exposure on the west side of the Yukon River consists mainly of greenstone of the Slide Mountain assemblage. These rocks include altered mafic volcanic and volcaniclastic rocks with local bodies (dikes and/or sills?) of microgabbro and diabase. These rocks have not been mapped in detail. We will examine this unit at Stop 2. There is a vague fabric (spaced fracture cleavage) in the outcrop that dips shallowly to the south. Near the northern end of the exposure (~1 km upstream from the ferry landing on the west side of the river) there is a shallowly south-dipping contact (inferred, not actually observed) between the greenstone package and an underlying, south-dipping tabular body of porphyritic granodioritic orthogneiss that has given a U-Pb zircon age of 348.6 ± 0.7 Ma. This body is approximately 15 m thick. Strongly sheared (fish-scale) serpentinite is present in local float along the trace of the contact between the greenstone and orthogneiss, and the contact is interpreted to be a thrust fault. The orthogneiss is structurally underlain by weakly to moderately carbonaceous, fine-grained quartz-muscovite schist and phyllite with interlayers of fine-grained quartzite and calcareous schist to impure marble, all assigned to the Nasina assemblage. The WEST DAWSON occurrence consists of small patches of skarn containing Ag-rich galena, sphalerite, chalcopyrite and pyrite developed within one of the narrow calcareous horizons in the Nasina package near dikes of Eocene quartz-feldspar porphyry and plagioclase-phyric mafic dikes. Veins with an identical sulphide assemblage (and identical Pb isotope signatures) occur locally within one of the Eocene mafic dikes. A short adit was driven into the mineralized zone, and small amounts of hand-sorted ore were shipped out in the early 1900s. Locally evidence is found that indicates magma mingling between the mafic and felsic end-members of the bimodal Eocene igneous suite.

Stop 1 Midnight Dome (Z 7W, 578216 E, 7105552 N)

Jim Mortensen, University of British Columbia

Jeffrey Bond, Yukon Geological Survey

Midnight Dome offers an unparalleled view of the Dawson-area landscape and local landmarks (Fig. 5). The Yukon River flows northward, cutting through the unglaciated terrain of the Klondike Plateau. The underfit valley of the Yukon River is best viewed to the north. The immature nature of the valley was caused by the reversal of the Yukon River during the first Plio-Pleistocene glaciation at 2.64 Ma (Hidy *et al.*, 2013; Tempelman-Kluit, 1980). Prior to this first regional build-up of ice, the Yukon River flowed south through the Coast Mountains and into the Gulf of Alaska. The growth of ice in southern Yukon blocked the southward drainage and forced the river to establish a new course into eastern Alaska. This reversal had profound impacts on the local landscape by causing a dramatic reduction in the base level of the Yukon River and its tributaries in west-central Yukon. Today, the Neogene base level is visible 100+ m above the modern valley bottoms. This erosional process reduced the fluvial accommodation space and facilitated the concentration of placer gold from the Neogene deposits and into the modern floodplain deposits (Lowey, 2004).

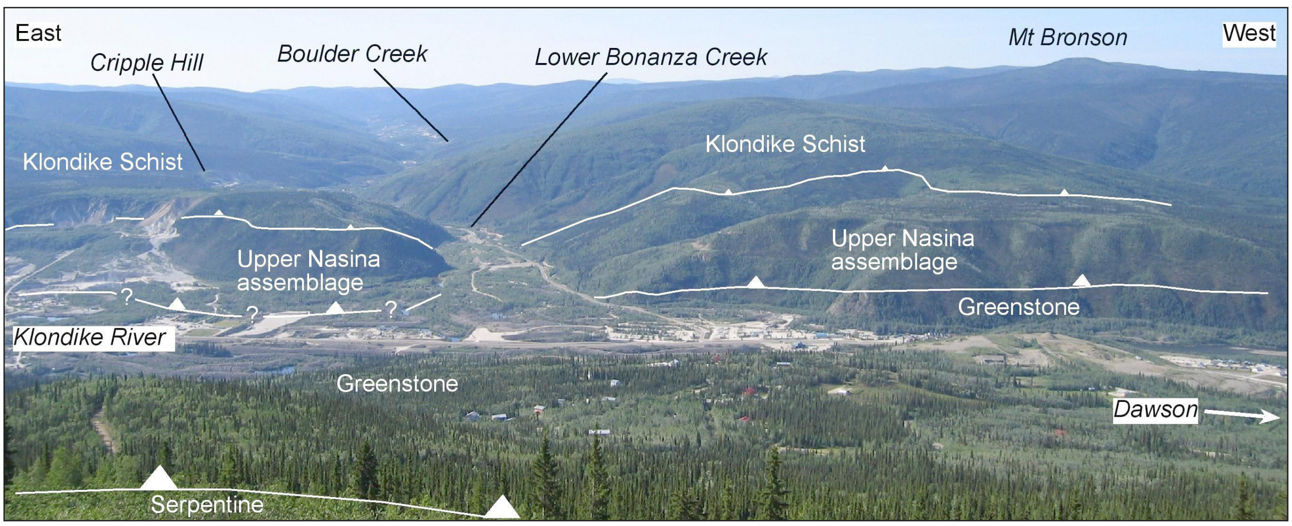


Figure 5. *View looking south up Bonanza Creek from Midnight Dome.*

There are excellent exposures of serpentinized harzburgite of the Slide Mountain assemblage, containing scattered veins of asbestos, near the parking area at the top of Midnight Dome. This is part of a lens-shaped, SSW-dipping slab of serpentinite that structurally underlies the main greenstone unit that was seen across the river from Dawson. It is also exposed in the upper part of the Moosehide Slide on the immediate N side of the Dawson townsite. This and similar bodies of serpentinite farther N and NW in the Moosehide Hills were extensively explored for asbestos in the 1970s.

From this vantage point we get excellent views to the W along the Top-of-the-World Highway (@300°), down the Yukon River (@320°), up Bonanza Creek (@170°) and towards King Solomon Dome (microwave tower on highest point on the skyline @140°).

Stop 2 Greenstone/Nasina assemblage on Dome Road (Z 7W, 578758 E, 7104577 N)

Jim Mortensen, University of British Columbia

Massive greenstone of the Slide Mountain assemblage is exposed in a large roadcut. This is a fairly typical exposure of this unit. It consists of massive to weakly foliated (probably S3) greenstone derived from mafic volcanic and volcaniclastic rocks together with abundant diabase and microgabbro. There is much evidence for brittle faulting and abundant randomly oriented, unmineralized quartz-calcite veins. van Staal *et al.* (2012) reported a ~265 Ma (late Middle Permian) U-Pb zircon age from this greenstone unit.

Stop 3 Ultramafic rocks at Last Chance Creek turnoff (Z 7W, 592632 E, 7100374 N)

Jim Mortensen, University of British Columbia

This is a good exposure of quartz-carbonate altered ultramafic rocks (“listwanite”) of the Slide Mountain assemblage. The rock is generally massive and rusty orange-brown weathering. It consists mainly of Fe-carbonate, along with abundant quartz both intermixed with the carbonate and as veins. Coarse-grained calcite and Fe-carbonate is also present as veins. Dark green to bright green splotches of very fine-grained micaceous material is likely a mixture of chlorite and Cr-mica (fuchsite). Three samples of fuchsite from this locality have given $^{40}Ar/^{39}Ar$ plateau ages that range from ~110-134 Ma. Fine grains of spinel are present locally, along with magnetite. The altered ultramafic rocks in this locality appear to form a moderately north-dipping slab 10-20 m thick that is structurally overlain and underlain by sheared dark grey schist of the Nasina assemblage. Many outcrops of ultramafic rocks in western Yukon are strongly altered to “listwanite” or to talc-Fe carbonate schist (“steatite”); this has led to many of these bodies having been misidentified or not recognized in the past.

Stop 4 Tatra Ventures Hunker Creek placer mine and dredge 11 (Z 7W, 593091 E, 7099657 N)

Jeffrey Bond and Sydney van Loon, Yukon Geological Survey

This stop highlights some of the placer potential remaining within the dredged valley bottoms in the Klondike (Fig. 6). In 2014 Tatra Ventures began testing their claims at the mouth of Last Chance Creek by re-sluicing surface dredge tailings. This paid expenses but provided little extra profit. In a gamble they decided to open a cut to expose bedrock and potentially missed pay gravel by dredge 11. To their surprise significant virgin pay gravel remained near the dredge. A section was measured in 2015 near the south end of the pit and consisted of:

- **Unit 1 (0-1 m):** of decomposed dark grey phyllitic bedrock
- **Unit 2 (1-2.5 m):** poorly sorted, clast-supported cobble-pebble gravel. Laterally discontinuous due to partial excavation by the dredge buckets (pay gravel)
- **Unit 3 (2.5-6.8 m):** Sandy to pebbly dredge sluice slickens
- **Unit 4 (6.8-9.8 m):** Coarse stack dredge tailings

Figure 6. *A view to the south of Tatra Ventures mining operation around dredge 11 on Hunker Creek near the mouth of Last Chance Creek in 2015.*

Dredge 11

Dredge 11 was built in the summer of 1939 and contained recycled components dating back to 1905. Many of the parts originate from the Canadian Number 1 dredge that was built for the Canadian Klondike Mining Company by the Marion Steam Shovel Company of Marion Ohio. In 1905, the Canadian Number 1 dredge operated at the mouth of Bear Creek before moving to Hunker Creek in 1913 and Dominion Creek in 1920 (Fig. 7). It was rebuilt in 1920 and renamed the North West Number 1 dredge. By 1935 the Yukon Consolidated Gold Corporation had taken over dredging operations in the Klondike and renamed it Y.C.G.C. Number 1. In 1938, the Yuba Manufacturing Company dismantled the dredge and used parts of the machinery to build Dredge 11 for Y.C.G.C. The bucket capacity was 7.5 cubic feet and it could process 200 cubic yards per hour. The dredge worked successfully on Hunker Creek and lower Last Chance Creek until approximately 1963. On Saturday August 21st 1999 it was ravaged by fire.

Average cents per yard in 1960 season = 69.6 ($24/yd @ $1200/oz)

Average cents per yard in 1961 season = 43.8

Figure 7. *Historic photo of the Bear Creek dredge, which was used to eventually construct dredge 11.*

Stop 5 Preido Hill and Neogene gravel stratigraphy (Z 7W, 593177 E, 7098442 N)

Jeffrey Bond, Yukon Geological Survey

The Hunker Creek benches preserve a history of Neogene fluvial sedimentation dating back an estimated 6 million years. These terrace deposits, also known as 'Hills', are also found in the Klondike River, Bonanza Creek, Quartz Creek, Dominion Creek and the Indian River valleys. Not long after gold was discovered in the modern floodplain deposits did the prospectors realize there was gold on the hillsides. In 1905 and 1907 Geological Survey of Canada geologist R.G. McConnell completed a comprehensive analysis of the 'White Channel Gravel' that included detailed descriptions of the gravel distribution, lithological content, stratigraphy, gold grade and gold distribution (Fig. 8). McConnell divided the White Channel gravel into two units: the lower 'white' gravel and the upper 'yellow' gravel, based on lithological content (quartz content) and iron-staining. He also completed detailed vertical sampling for gold content and surmised that in a 46 m-thick deposit of White Channel Gravel 50% of the gold is contained in the lowermost 2 m and the remainder is distributed throughout the overlying 44 m.

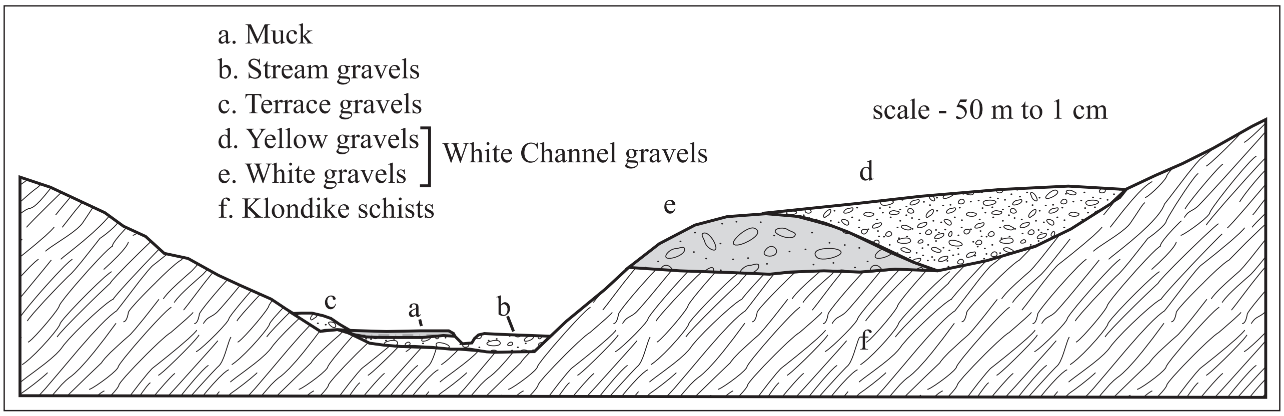


Figure 8. *Cross-section of Bonanza Creek near the mouth of Eldorado Creek. The contacts indicate that the 'yellow gravels' are cut into the lower 'white gravels' (after McConnell, 1907).*

Previous sedimentological and geomorphological studies on the White Channel Gravel suggest it represents a proximal to distal braidplain within a confined valley (Morison and Hein, 1987). Origins of the quart-rich gravel are related to prolonged weathering of the late Permian Klondike Schist and its gold-bearing quartz veins. The differences in sedimentology between the lower and upper White Channel Gravel are related to a transition from preglacial (early to mid-Pliocene) to periglacial (late Pliocene) conditions (Froese *et al.*, 2000). This is supported by the presence of ice wedge casts and cryoturbation-related involutions within the upper White Channel Gravel deposits.

Variable alteration in the form of secondary clay accumulations (*eg.*, kaolinite), iron oxidation and clast weathering has been studied within the White Channel Gravel (Tempelman-Kluit, 1982; Dufresne *et al.*, 1986; Dufresne, 1987). Two hypotheses have been developed for the origin of the alteration: low temperature hydrothermal activity and groundwater diagenesis (Dufresne, 1987; Lowey, 2002).

Recent geological studies on the lower Hunker Creek White Channel Gravel benches have revealed that the stratigraphy may be more complex and the alteration could represent paleo-weathering surfaces (Fig. 9; Bond, 2016). An older gravel, informally called the Paradise gravel, is proposed based on stratigraphic contacts, relative alteration, lithological content, geochemistry, clast size and gold content. On the lower Hunker Creek benches the modern miners target the stratigraphically lowest unit, Paradise gravel, for economic placer gold concentrations. The implications of this interpretation are that the White Channel Gravel is only economically enriched where it completely reworked the Paradise gravel and its associated gold.

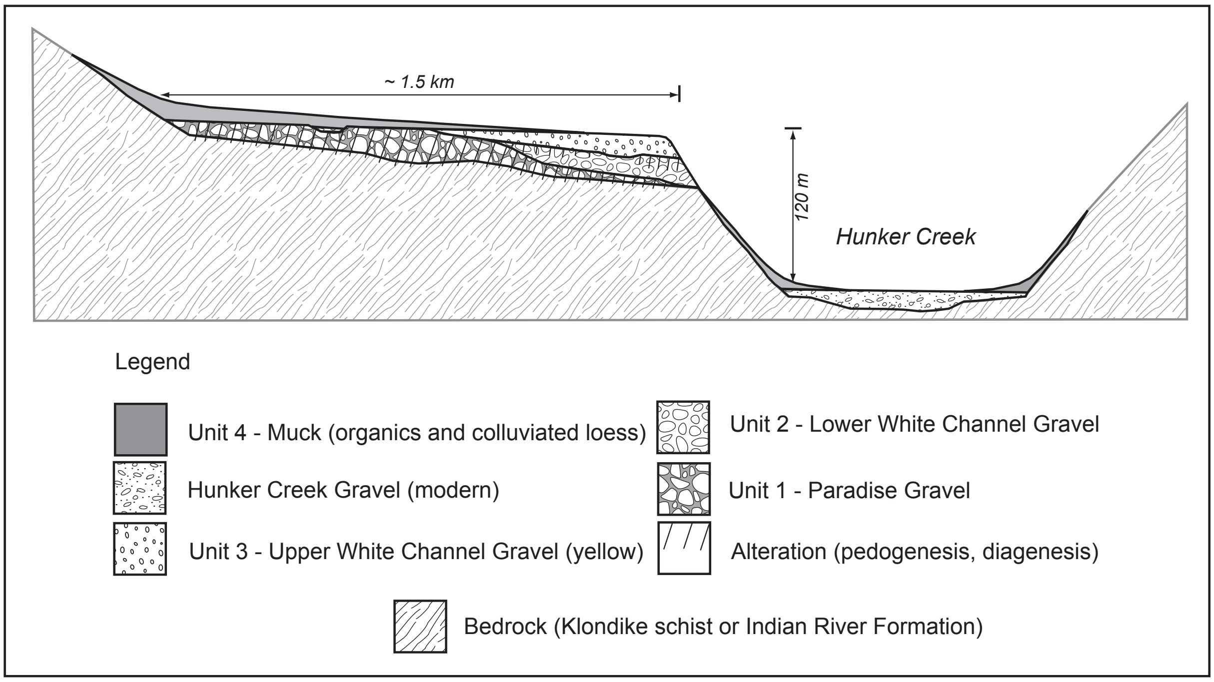


Figure 9. *Cross section of the lower Hunker Creek Neogene bench deposits showing the lateral contacts between the Paradise gravel and overlying White Channel Gravel (Bond, 2016).*

Stop 6 Eocene quartz-feldspar porphyry (Z 7V, 597116 E, 7097003 N)

Jim Mortensen, University of British Columbia

Outcrop of quartz-feldspar (±biotite) porphyry. Biotite from a nearby outcrop of this body has given a $^{40}Ar/^{39}Ar$ biotite age of 58.6±0.7 Ma. This unit may be either a large plug (as it is currently mapped) or a dike/sill complex. The felsic porphyry is extremely fluorine-rich, and rocks of this suite are probably the source of abundant topaz and wood tin that is found in many of the Klondike placers. This body is part of a strongly bimodal suite of Eocene felsic and mafic intrusions that intrude the Yukon-Tanana terrane in a band ~20 km wide that parallels the Tintina Fault Zone from the southeastern part of the Klondike District to well into the northern Eagle quadrangle in Alaska. These intrusions do not occur either within the Tintina Fault Zone or north of it in western Yukon, and they are interpreted to be part of a bimodal igneous province of Eocene age that originally straddled the Tintina Fault and was dissected by post-Eocene dextral displacement on the fault zone. The offset portion of this igneous province is located northeast of the Tintina Fault in the Faro-Ross River area in southeastern Yukon (Pigage, 2004; Gabrielse *et al.*, 2006).

Stop 7 Chlorite schist (Z 7V, 600478 E, 7094227 N)

Jim Mortensen, University of British Columbia

This is an outcrop of the typical "mafic schist" phase of the Late Permian Klondike Schist assemblage (Fig. 1). It consists of medium green, chlorite-quartz-muscovite (±calcite, actinolite, magnetite) schist with abundant foliaform quartz lenses. This lithological package is typically too strongly strained to preserve primary volcanic features; however, small chloritic "spots" that occur locally may represent either flattened amygdules or altered and stretched mafic phenocrysts. In rare exposures one can see what appear to be flattened darker green patches, suggesting that at least some of this mafic schist may have had a volcaniclastic protolith. Elsewhere the mafic schist can be seen to pass gradationally into lenses of moderately to strongly foliated metagabbro that are interpreted to be transposed comagmatic dikes and/or sills. Reconnaissance lithogeochemical studies of mafic and felsic schists of the Klondike assemblage (Piercey *et al.*, 2006; Piercey, Mortensen and Liverton, unpub. data) indicate eruption in a continental arc setting.

Stop 7 to Summit Roadhouse

Jim Mortensen, University of British Columbia

A small body of hornblende-biotite granodiorite (the Whiskey Hill pluton) that has given a U-Pb titanite age of 69.1±0.1 Ma intrudes Klondike assemblage metaclastic rocks approximately 2.5 km past Stop 7. This is one of a number of widely scattered small bodies of intermediate composition in the Klondike that are compositionally similar to, and the same age as, Late Cretaceous volcanic rocks assigned to the Carmacks Group. Minor chalcopyrite and pyrite occur as disseminations and stringers in the intrusion at this locality.

Continue up the Hunker Creek road past scattered roadcuts and "ditch-crops" along the road of greenish-weathering mafic schist and tan to orange-weathering pyritic felsic schist, both of the Klondike Schist assemblage. One of the felsic schist units has yielded a U-Pb zircon age of 254.9 ± 2.6 Ma.

Summit Roadhouse

Summit Roadhouse (some old buildings still remain) is located on Hunker Summit at the drainage divide separating Hunker and Dominion creeks. This was the site of a windlass and long rope operated by a boiler and engine used to haul sleighs over the pass.

Stop 8 Sheba and Mitchell veins (Z 7V, 600948 E, 7084994 N)

Jim Mortensen, University of British Columbia

Notice that as you drove along the lower road to the ridge crest you cross a number of zones of vein quartz in local float. There are a large number of mainly N-S-trending, steeply dipping to vertical, discordant quartz veins throughout this area (red lines on Fig. 10). The Sheba vein (Fig. 11a) is one of the largest and best exposed of the gold-bearing discordant quartz veins in the Klondike. Several lode gold occurrences such as this were explored sporadically since the Gold Rush by surface trenching, shafts and adits. Some of the features of the Sheba vein that are typical of the orogenic quartz vein systems in the Klondike include:

- The veins contain low sulphide contents; they are massive, and mainly non-ribboned, and for the most part appear to be simple extensional veins;
- Pyrite is most abundant in vein selvages – gold is typically closely associated with the pyrite;
- Base metal sulphides and sulphosalts occur sporadically in the interior of the veins;
- Wall rock alteration includes a wide (up to 10 m) zone of ferroan carbonate alteration and a much narrow (<50 cm; commonly absent) zone of sericitic alteration immediately adjacent to the vein; and
- Pyritization of the wall rocks is present for up to several metres on each side of the vein. In the case of the Sheba and Mitchell veins this wall rock pyrite contains a significant amount of gold (Fig. 11b).

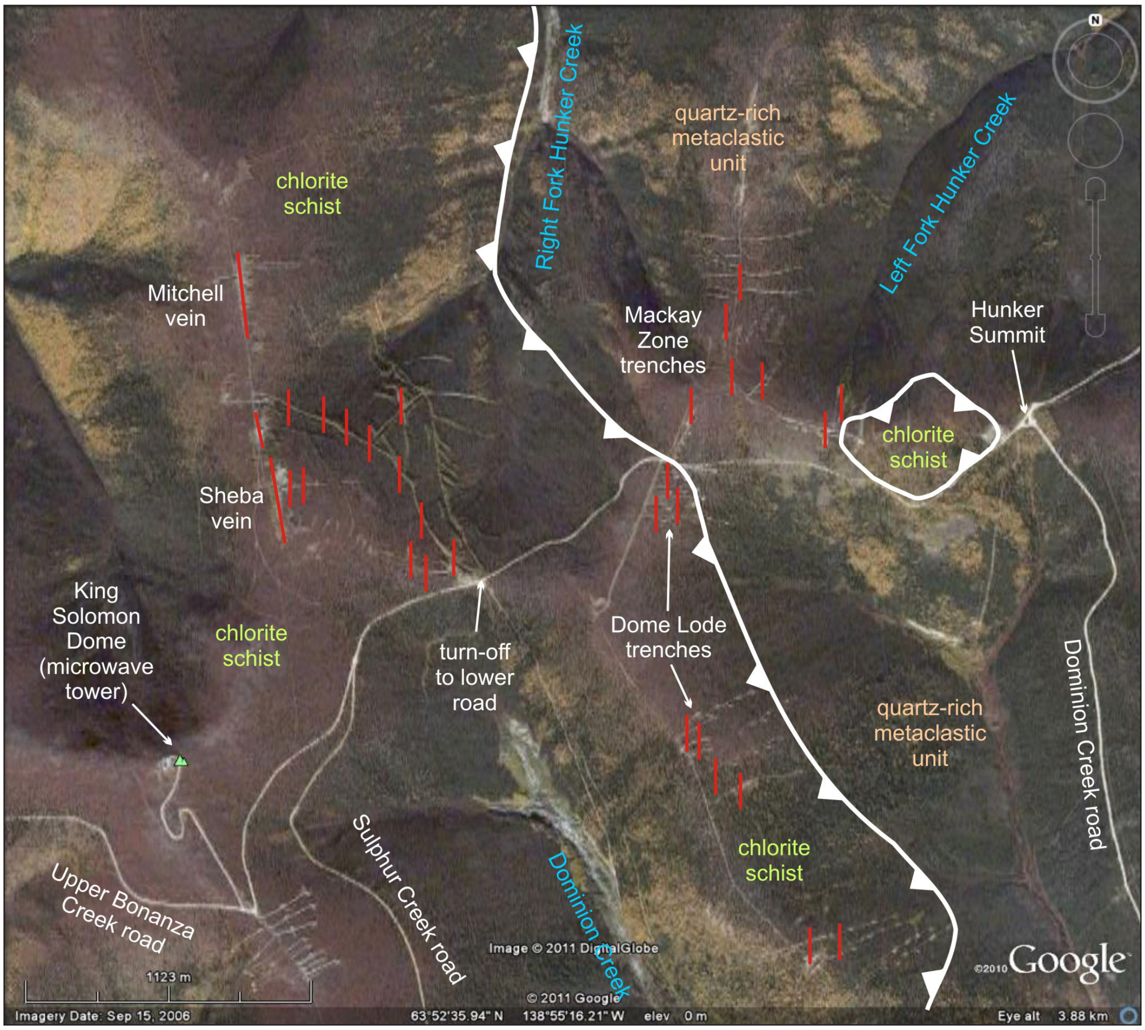


Figure 10. *Map showing locations of main quartz vein systems (red lines) in the King Solomon Dome–Hunker Summit area.*

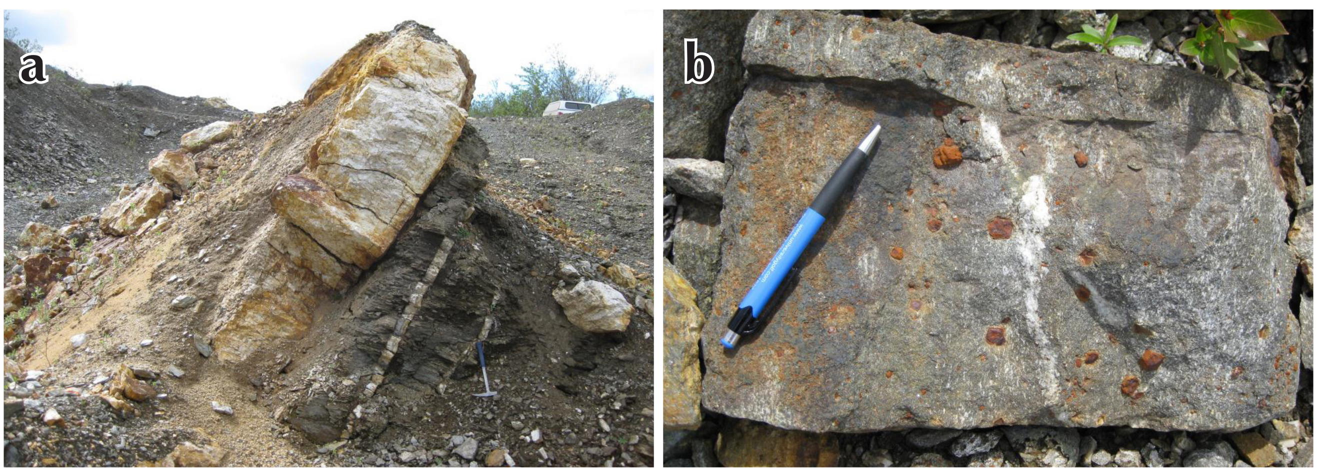


Figure 11. *View of Sheba vein (facing N) on left (a); gold-bearing pyrite in altered mafic schist immediately adjacent to the vein on right (b).*

Stop 9 King Solomon Dome (Z 7V, 600591 E, 7083929 N)

Jim Mortensen, University of British Columbia

This is the highest point in the Klondike District, and all of the main placer gold bearing streams radiate out from this point, leading to the commonly held (but not entirely correct) belief that the main bedrock source of gold (or "Motherlode") in the Klondike was in the vicinity of King Solomon Dome. This is an excellent vantage point to get geographically oriented in the area. The NW trending low area in the distance to the NE is the Tintina Trench, which is the topographic expression of the Tintina Fault Zone. Bearings to various landmarks are as follows:

000° - Tombstone Range on the north side of the Tintina Fault

015° - Tombstone Mountain

030° - Two bare knobs in middle distance are Mt. Leotta, which consists of small klippe of serpentinite structurally overlying Nasina schist

030° - Main valley in far distance is the valley of the North Klondike River

060° - Area of stripping on the far side of the Tintina Trench is the Brewery Creek gold mine

110° - Placer workings in the headwaters of Dominion Creek

150° - Highest point in middle distance is Dominion Mountain

180° - Placer workings in the headwaters of Sulphur Creek

220° - Placer workings on Quartz Creek

295° - The old railway grade of the Klondike Mines Railroad can still be seen on the slopes in the near distance.

350° - Placer workings in the headwaters of Gold Bottom Creek

The rocks exposed at this locality are silvery grey to greenish grey to brown weathering muscovite-chlorite-quartz (±Fe-carbonate) schist with abundant foliaform quartz±carbonate veins.

Stop 10 Quaternary stratigraphy, paleoecology and paleontology of Canyon Creek "muck" (Z 7V, 595230 E, 7078125 N)

Grant D. Zazula[1]. Britta Jensen[2], Alberto V. Reyes[3], Bram W. Langeveld[4], Elizabeth Hall[1]

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2. Royal Alberta Museum, Edmonton, Alberta
3. Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta
4. Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, The Netherlands

The Klondike goldfields is one of North America's most prolific regions for Quaternary vertebrate fossils and associated paleoenvironmental information. Ever since the early days of the fabled Klondike gold rush of 1898, miners in search of gold have uncovered the frozen fossils of ice age mammals from Pleistocene sediments (Froese *et al.*, 2009; Zazula and Froese, 2011). Along with news of rich gold deposits, stories about fantastic mammal fossils also spread globally, leading many institutions such as the Smithsonian, the American Museum of Natural History and the Natural History Museum in Paris to send expeditions to the Klondike to retrieve collections for their museums during the early 20th century. The 1960s and 1970s saw the first systematic study of ice age fossils from the region when Richard Harington, the now-retired curator of Quaternary Mammalogy at the Canadian Museum of Nature, conducted his doctoral research on Quaternary mammals of the Yukon (Harington, 1977). Harington's work resulted in a world-class collection of mammal fossils in Ottawa (Harington, 2011), and his legacy lives on today in the goldfields because of the friendly, collaborative work and relationships built with many placer mining families.

Most of the fossil vertebrates recovered in the Klondike are found within the frozen, unconsolidated gravel and silt deposits exposed in narrow creeks and gulches that are tributaries to some of the larger gold bearing creeks. Fossils are most often found at the stratigraphic contact between the underlying gold-bearing gravel and the overlying silt commonly known as "muck". Most often, these bones are released by placer miners during hydraulic stripping or "monitoring" of the frozen overburden using large water cannons. Although literally tens of thousands of bones have been released and collected from the frozen deposits through mining activity, it was only recently that geologists have made significant advances in understanding the stratigraphic framework of the gravel and muck deposits.

On first glance and by all early accounts, the towering walls of frozen muck seemed to be a chaotic mess of fine grained sediment, buried vegetation and large ice bodies. Major advances in our understanding of the stratigraphy of the mucks emerged in the mid-1990s, leading to a plethora of interdisciplinary Quaternary scientific studies in the Klondike. Detailed stratigraphic and sedimentological studies revealed that these fine-grained sediments are largely composed of aeolian silt, or loess, some of which was deposited by primary air-fall and some representing colluviated loess that was transported downslope and accumulated in valley-bottoms (Fraser and Burn, 1997; Kotler and Burn, 2000). The fine-grained sediments in the mucks of Alaska and Yukon are considered analogous to the widespread Pleistocene "yedoma" complex of perennially frozen, organic-rich silt in unglaciated Siberia, which has received much recent attention as a major source of labile carbon that is vulnerable to permafrost warming (*e.g.*, Tarnocai *et al.*, 2009). The recognition of numerous distal tephra beds in Klondike mucks has been integral to the establishment of site-specific chronologies that can be correlated stratigraphically across sites throughout the unglaciated areas of Yukon and Alaska (Froese *et al.*, 2006; Westgate *et al.*, 2008; Preece *et al.*, 2011b; Jensen *et al.*, 2013, 2016). The establishment of site specific and regional chronologies has led to much improved understanding of subarctic earth system response to Quaternary environmental change, including permafrost dynamics, paleoecology, and paleoclimate (Zazula *et al.*, 2007, 2011a; Froese *et al.*, 2008, 2009; Porter *et al.*, 2016; Reyes *et al.*, 2010).

Hydraulic stripping began at Canyon Creek, near its confluence with Quartz Creek (63.82°N, 139.06°W), by Schmidt Mining Co. in 2013. Since then, removal of the frozen muck has revealed an impressive stratigraphic section of Pleistocene sediments and fossil vertebrates. One important consideration in establishing a stratigraphic profile for these sites is that they are ephemeral and new mining activity continuously exposes new areas and potentially new units, while at the same time previously productive exposures tend to disappear as mining activity progresses. As such, sites such as this are visited several times annually to develop a robust reconstruction and ensure that sampling occurs before exposures are lost.

Sediments at Canyon Creek comprise four main lithostratigraphic units. Several metres of horizontally bedded and laminated silt with two prominent peat beds are exposed continuously at the down-valley end of the exposure (Fig. 12). Several tephra beds are present in this unit, including Snag tephra near the base, and "OCTL" tephra within the upper peat. Both of these tephra are present at several other sites in eastern Beringia (Fig. 13). These sediments are sharply overlain by several meters of weathered sub-angular gravel, which in turn is crosscut by a complex fill of ice-rich muck. The mucks contain large ice-wedges that crosscut all underlying units. Sheep Creek-Klondike tephra – a well-defined regional chronostratigraphic marker - is abundant throughout the muck silts at various elevations and in ice-wedge foliation, indicating that this rapidly aggrading unit was deposited about 80,000 years ago during the onset of the Marine Isotope Stage (MIS) 4 glacial (early Wisconsinan) interval . The exposure may be capped by an unconformity that is present between the ice-rich silt and overlying ice-poor silts. Two tephra are present in the ice-poor silts, one of which is potentially correlated to the EB tephra in the Fairbanks gold mining district that may be younger than 30,000 years.

Figure 12. *Annotated photos of the Canyon Creek section from 2014 (upper) and 2015 (lower).* ***(1)*** *Horizontally laminated organic/peat within silt, ice-poor but frozen;* ***(2)*** *Lower peat unit;* ***(3)*** *Upper peat unit;* ***(4)*** *Gravel unit;* ***(5)*** *Frozen silt with abundant ice-wedges, SCt-K (~80,000 years old) is present throughout both in silt and ice-wedges;* ***(6)*** *Silt above ice-wedge tops, contains unknown tephra;* ***(7)*** *Ice-poor silt above wedges, contains potential EB tephra;* ***(8)*** *Location of Snag and Snag-like tephra;* ***(9)*** *Location of tephra in upper peat that correlates to Thistle Creek tephra "OCTL";* ***(10)*** *Ice wedges truncated by placer mining; Sheep Creek-Klondike tephra in wedge foliation (note: ice wedges exposed in 2014, but melted and not visible in this 2015 photo).*

Preliminary paleoecological analyses of the two main peat units demonstrate the presence of boreal forest environments during the relatively warm MIS 5 interglacial sensu lato, roughly between 80,000 and 115,000 years ago. The age of these peats can be further constrained to the MIS 5c or MIS 5a substages of the broader MIS 5 interglacial based on the presence of Snag tephra at the base of the exposure. Snag tephra has been located at several sites across Yukon and Alaska within loess overlying MIS 5e and the Old Crow tephra (Fig. 13). This latter tephra is ubiquitously present in eastern Beringia as a marker horizon for the warm MIS 5e substage of the last interglacial (Preece *et al.*, 2011a), and its absence here at Canyon Creek indicates a lack of MIS 5e deposits (Preece *et al.*, 2011b). Although pollen and spore content is very low, pollen of Picea (spruce), Betula (birch), and Alnus (alder), combined with macrofossils of Betula, reveal forest conditions similar to those at present in the region. Macrofossils of sphagnum and other mosses demonstrate ground cover typical of poorly drained, boggy lowlands within the boreal forest with shallow permafrost. Beetle remains are present in the peats and analyses are underway to determine their paleoecological significance.

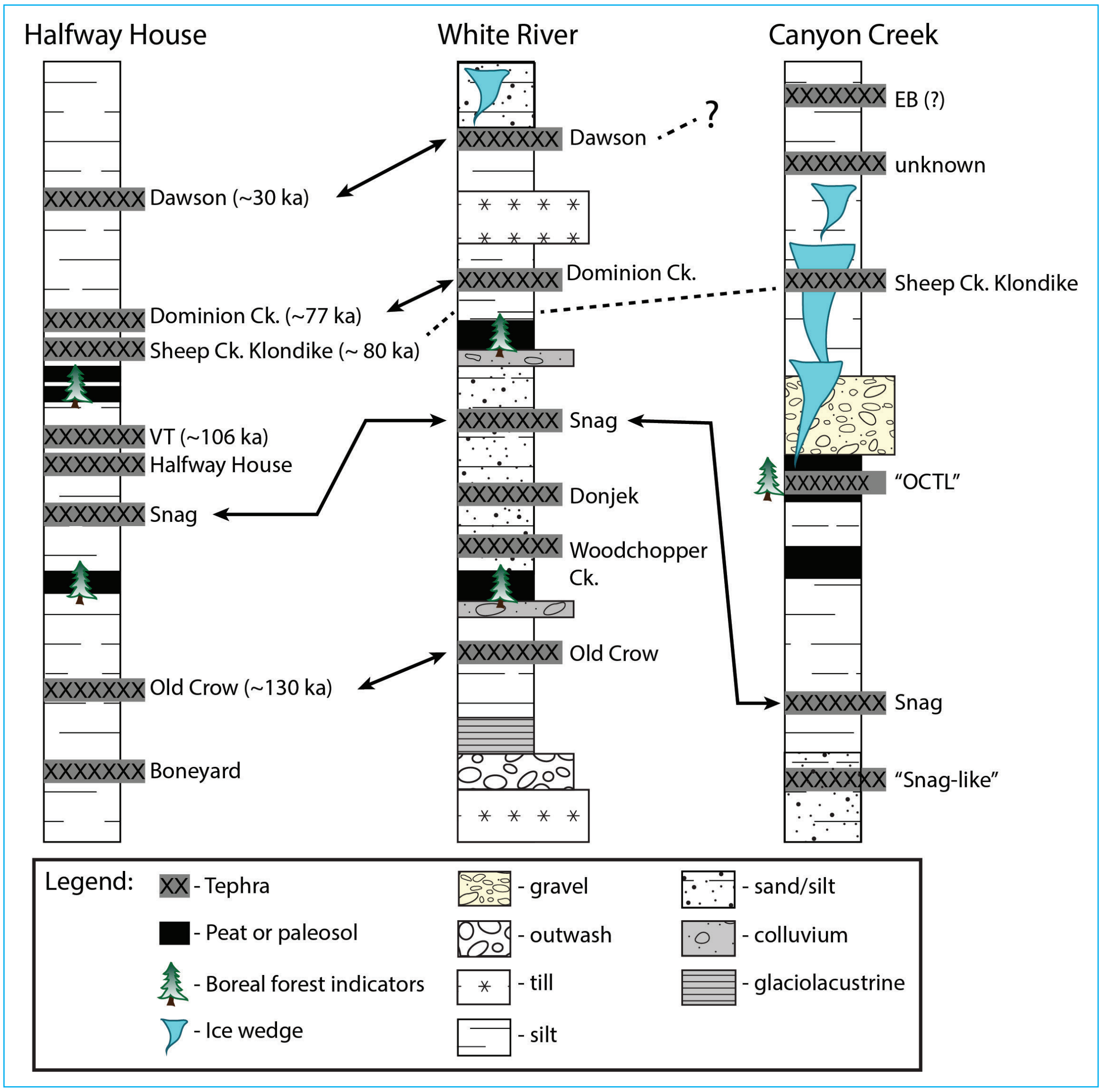

Figure 13. *Canyon Creek stratigraphy in context with two selected sites in Halfway House (Alaska; Jensen et al. 2016) and White River (Southwest Yukon; Turner et al., 2013). Snag and Sheep Creek-Klondike tephras constrain the age of the site from post-MIS 5e to MIS 4 time, or about 105,000 to 60,000 years ago. "OCTL" tephra has been described at Thistle Creek in the south Klondike, where it is also present within a peat unit and associated with Snag tephra (unpublished data). Thistle Creek, Halfway House, and White River sites host Old Crow tephra, a regionally prominent marker tephra for the warmest MIS 5e substage of the last interglacial (about 128,000 to 116,000 years ago); the absence of this marker at Canyon Creek strongly suggests that deposits there post-date MIS 5e.*

Vertebrate remains recovered at Canyon Creek are, for the most part, typical for late Pleistocene deposits in the interior of Alaska and Yukon (Fig. 14). These faunas represent the Rancholabrean Land Mammal age, dominated by fossils of steppe-bison (Bison priscus), horse (Equus spp.), and woolly mammoths (Mammuthus primigenus). However, the site has also yielded a surprising collection of fossils representing relatively rare taxa, including western camel (Camelops hesternus) (Fig. 15), short-faced bear (Arctodus simus), brown bear (Ursus arctos), grey wolf (Canis lupus), fox (Vulpes) and Beringian lion (Panthera leo spelaea). This is only the fourth locality in Yukon where specimens of the rare western camel have been discovered (Zazula *et al.*, 2011b; Heintzman *et al.*, 2015). The emerging fossil collection of rare species, from a locality with well-constrained chronology that seemingly places it during the broad Last Interglacial interval, has made this one of the more important recently discovered sites in the Klondike.

Figure 14. *Assorted Pleistocene fossils collected at Canyon Creek locality July 9, 2015. Palaeontologists (left to right) Erik Magenheimer, Dick Mol, and Bram Langeveld in background.*

Figure 15. *Detail of Camelops hesternus metapodial bone fragment.*

Stop 11 Quartz Creek – Schmidt Mining Corporation (Z 7V, 594022 E, 7076156 N)

Jeffrey Bond, Yukon Geological Survey

The first accounts of placer gold being discovered in the Klondike District came out of Quartz Creek and Indian River in 1894-5. Robert Henderson prospected these drainages for at least two seasons before heading over the Quartz Creek summit in 1896 to prospect Gold Bottom Creek. He managed moderate success in Gold Bottom Creek (8¢/pan @ $16/ounce) and it was during a supply run to Ogilvie Post that Henderson had a chance encounter with George Carmack at the mouth of the Klondike River. He invited George to try his luck on Gold Bottom Creek. The following day, George Carmack, Skookum Jim and Dawson Charlie headed for Gold Bottom Creek and enroute discovered gold on Rabbit (Bonanza) Creek.

Much of the early hand mining on Quartz Creek focused on underground workings that targeted the right limit (west side of valley) White Channel Gravel bench. Unlike Bonanza and Hunker creeks where the Neogene pay streak was intermittently reworked by the modern creek, much of the placer gold in Quartz Creek remains on the right-limit bench and is contained in the Neogene sediments. Excavations in 2014 by Schmidt Mining exposed large underground mining chambers, rail-lined tunnels and sumps excavated into bedrock left behind from years of hand mining. These old-timer workings can significantly affect the economic viability in historic areas and their impact are not fully realized until after the overburden is stripped and the workings are exposed.

Modern Mining on Quartz Creek

Schmidt Mining Corporation operates one of the largest placer mines in Yukon on the Quartz Creek bench. Excavation and removal of low grade gravel is facilitated using Caterpillar D10N and D11R crawler tractors, Hitachi EX700 excavators, a rock truck and a series of conveyors. Pay gravel is processed at a rate of 200 loose cubic yards per hour using a conveyor feeder, 2.4 m (8 ft) wide trommel and three sluice runs on either side of the conveyor stacker (Fig. 16). Two shifts operate 24-hours per day throughout the summer.

Figure 16. *Schmidt Mining Corporations wash plant on Quartz Creek. The plant processes approximately 200 loose cubic yards per hour. This is facilitated by the even feed produced by the conveyor on the left. The sediment is classified using a screen trommel and the gold is isolated using three sluice runs on either side of the plant.*

The White Channel Gravel in Quartz Creek ranges in thickness from 24-28 m near the edge of the valley to 5-12 m near the rim of the bench. Two general units have been identified in the White Channel Gravel consisting of an upper yellow gravel and a lower grey gravel. The lower gravel exhibits greater decomposition within the non-quartz clasts, which consist of sericite schist, mafic schist and orthogneiss. The Paradise Gravel, or an equivalent highly decomposed gravel, has not been observed in the Quartz Creek sediments, which may reflect greater reworking during White Channel sedimentation. The interval processed for placer gold includes the lower 2.4 m (8 ft) of gravel and 1.8 m (6 ft) of bedrock. The pay gravel consists of coarse cobble-rich gravel with small boulders. Quartz cobbles and boulders within the pay channel on bedrock exhibit better rounding and this characteristic is often used by miners for targeting zones with higher gold concentration.

In 2014, a mafic dike was discovered protruding 10 m into the lower White Channel gravel and was subsequently dated by Ar-Ar and U-Pb to 55.9 ± 0.6 Ma (Fig. 17). The contact relationships invoke a number of possible process mechanisms. Three possible mechanisms for emplacing the dike in the gravel have been considered:

1. The dike intruded the gravel as molten material suggesting the gravel is much older than previously thought. Under this scenario the gravel may have been partially lithified at the time of intrusion and subsequent weathering caused decomposition back to a non-lithified state. No fluvial clasts have been found inside competent dike rock.
2. The dike represents an erosional remnant that was exposed after preferential erosion of the surrounding friable orthogneiss country rock. Subsequent fluvial aggradation encased the dike in fluvial gravel. This theory is generally not supported because there is no evidence of erosion of the dike such as a train of basalt clasts within the White Channel Gravel.
3. The dike was thrust into the White Channel Gravel by tectonic activity (compression?) along a pre-existing fault. Evidence of fault disturbance within the overlying gravel appears to be present making this the most plausible theory.

Figure 17. *A view to the northeast of Schmidt Mining Corporation's cut on the right limit of Quartz Creek. An Eocene dike (highlighted) is contained within the lower White Channel Gravel.*

Stop 12 Orofino Hill (Z 7V, 581283 E, 7092554 N)

Jim Mortensen, University of British Columbia

An adit was driven into Orofino Hill on the left-hand (W) side of the road. Rocks exposed at the adit are quartz-feldspar augen schist (metaporphyry) of the Klondike Schist assemblage, which have given a U-Pb zircon age of ~261 Ma. The schist is cut by discordant quartz veins that contain pyrite, galena and arsenopyrite and anomalous gold values. This adit goes approximately 400 m into Orofino Hill and is one of the most extensive underground developments in the Klondike District. It was driven in the winter of 1916 by the Yukon Gold Corporation. Although mineralized veins are present near the portal, the adit was actually driven for placer mining. The owners of Orofino Hill wanted to hydraulic mine their bench gravel and transport the placer tailings down to their claims on Bonanza Creek. Unfortunately their claims were not adjoining and could not come to an agreement with the intervening claim owner. The result was an adit to transport tailings under the placer claim they did not own.

Lower Bonanza Benches

There are excellent information signs alongside the road below Cripple Hill. The large white bluff to the north of this locality is an excellent exposure of White Channel Gravels that have been mined extensively by hydraulicking, which produced the large fans of tailings down into the Bonanza Creek valley (Fig. 18).

Figure 18. *View looking down Bonanza Creek near Cripple Hill at the thick White Channel Gravel deposits resting on the nearly horizontal White Channel "strath".*

Stop 13 Nasina Assemblage (Z 7W, 578763E, 7101381N)

Jim Mortensen, University of British Columbia

A low bluff on NE side of Bonanza Creek consists of strongly folded (D3 recumbent M-folds), weakly carbonaceous quartz-muscovite schist of the Nasina assemblage, in the footwall of a S-dipping, regional scale thrust fault. These folds deform an earlier fabric (S2), and may be related to the emplacement of the thrust panel of Klondike Schist above them (Fig. 19a,b).

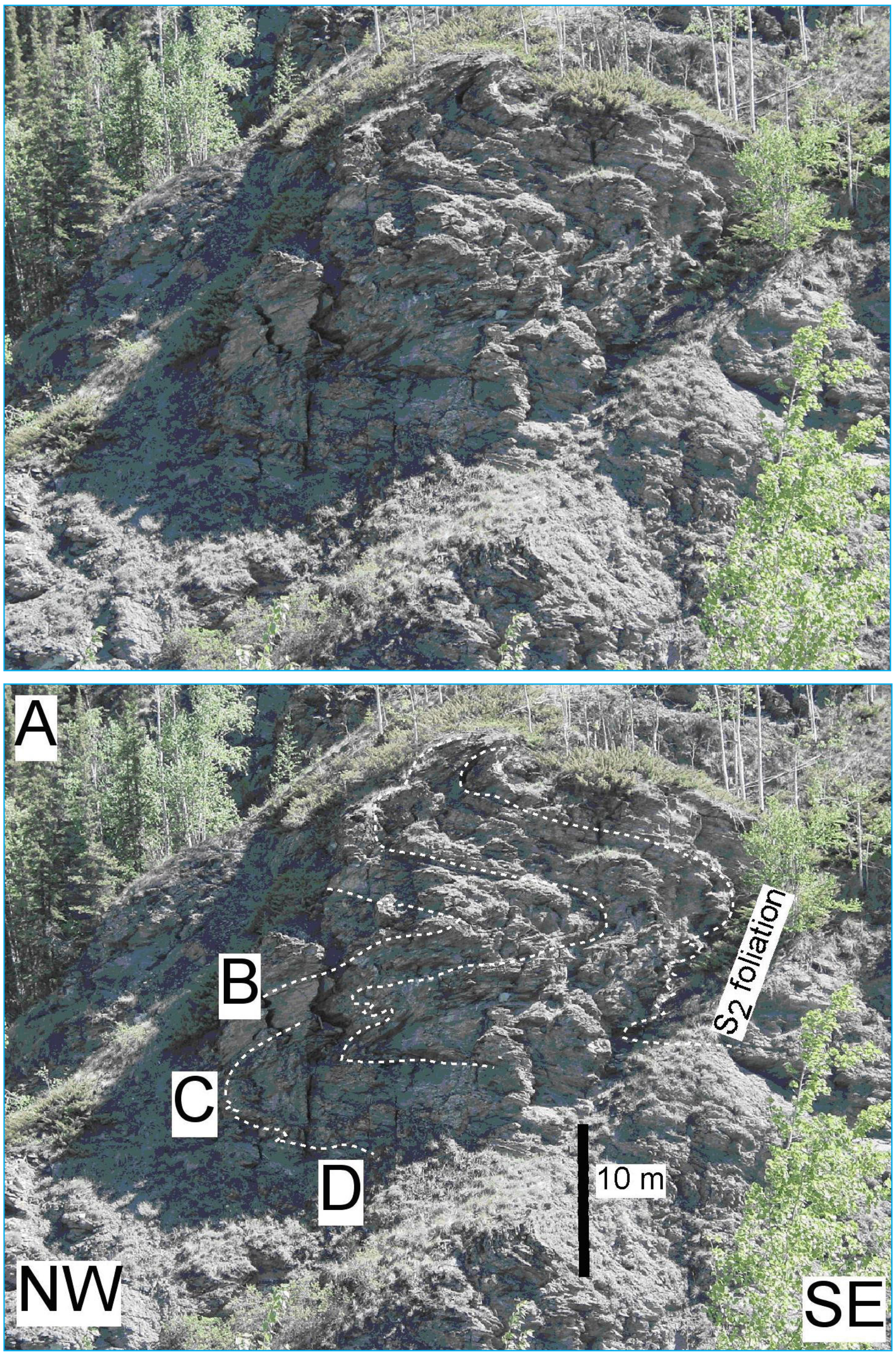

Figure 19. *View to the NE of recumbent folds in carbonaceous metaclastic rocks of the Nasina assemblage (a) and with structural elements ornamented on below (b).*

DAY 3 BONANZA CREEK - ELDORADO CREEK - LONE STAR PROPERTY

8:30 am Assemble in the parking lot on Front Street in Dawson, across from St. Paul's Church and the Commissioner's Residence (just past the white graveled ramp with flowers).

Placer gold and its sources in the Bonanza – Eldorado creek drainage

The "official" amount of placer gold produced from the Klondike District, based on royalties paid, is usually estimated to have been between 10 and 13 million ounces; however, it is generally accepted that the actual total is probably at least double this amount, because government royalties were likely not paid on a substantial proportion of gold produced, especially during the early stages of exploitation of the area (*e.g.*, Burke *et al.*, 2005). The Bonanza and Eldorado drainages were the richest and most productive in the Klondike, having produced well over half of the total gold mined in the entire district. It is therefore likely that at least 10 million ounces of gold came from the main modern streams and paystreaks within the older White Channel Gravel deposits in this relatively small part of the Klondike. Detailed investigations of the compositions of placer and lode gold grains from this region by Chapman *et al.* (2010a) demonstrated that the vast majority of gold recovered from lower and upper Bonanza Creek, and from Eldorado Creek, is very similar in composition to that in lode occurrences on "Lone Star Ridge", between upper Bonanza and Eldorado creeks (Fig. 2b, and quite distinct from that in lode occurrences and drainages on the southwest side of Eldorado and lower Bonanza creeks (below Grand Forks), and to the north of upper Bonanza (Fig. 2). This information, together with the observed distribution of placer-bearing streams in the area (Fig. 2), led Chapman *et al.* (2010a) to conclude that most of the gold that has been recovered from Bonanza and Eldorado creeks, and from the bench gravels along these drainages, was therefore derived from lode sources in a very small area (rough 3.5 x 5 km) centred on Lone Star Ridge (Fig. 2b).

Numerous gold-bearing orogenic vein systems have been discovered in various locations on Lone Star Ridge (Fig. 2b), including the historic Lone Star mine. Most of the systems discovered thus far are controlled by N or NW-trending D4 deformation zones, and appear to have relatively limited areal extent. Diamond drilling by Klondike Star Minerals in the vicinity of the Lone Star mine in 2005, and subsequent re-analysis of the drill core by Klondike Gold Corporation in 2012, showed that a substantial body of felsic schist in that area contains significant levels of gold that appears to be associated with disseminated pyrite and is not associated with quartz veins (MacKenzie *et al.*, 2008b). This disseminated gold is typically fine grained, unlike that in the orogenic quartz veins, and is unlikely to have reported to the placer deposits. Mortensen *et al.* (2006) interpreted this gold-enriched schist unit to be a low grade, gold-enriched volcanogenic massive sulphide system. Mortensen (2011) demonstrated that gold-bearing orogenic quartz veins in the Lone Star Ridge area appear to be largely confined to, or closely associated with, the gold-bearing schist unit, and argued that the gold in the veins has been locally remobilized from very local sources within the schist. Mortensen (2011) also showed that the various sub-units within the felsic schist assemblage that underlies Lone Star Ridge have distinctive lithogeochemical signatures that can be utilized to trace stratigraphy and better constrain map patterns and major structures in the Lone Star Ridge area.

Stop 1 Anton Stander (Fireplace) – A Klondike Gold Rush Story (Z 7V, 582717 E, 7088078 N)

Peter Tallman, Klondike Gold Corporation

Anton Stander (June 16, 1867 – April 2, 1952), born Anton Prestopec from the Javor district, Slovenia (~80 km NW of Zagreb), sailed to New York in 1887, and thence overland to Colorado to work prospecting with his uncle. At age 29, he left his uncle and travelled north into Canada along the Yukon River, ultimately arriving in Dawson in August 1896.

On August 16, 1896, prospector George Carmack, his Tagish wife Kate Carmack (Shaaw Tláa), her brother Skookum Jim (Keish) and their nephew Dawson Charlie (Káa Goox) discovered gold in 'rabbit creek', immediately renamed Bonanza Creek.

By August 30, Anton, and prospecting partners J.J. Clements, Frank Phiscater, "old man" Whipple, and Frank Keller had failed to find any good claims on Bonanza Creek. Instead they turned up a 'small creek' trending south off Bonanza. Results initially were very poor. The story goes that Anton stubbornly, and against the inclination of his partners, continued to dig test holes, wanting to reach a gravel to pan that would provide a true test of potential. On August 31, the first pans containing gold from Eldorado Creek were obtained by Anton Stander and Frank Keller (Fig. 20).

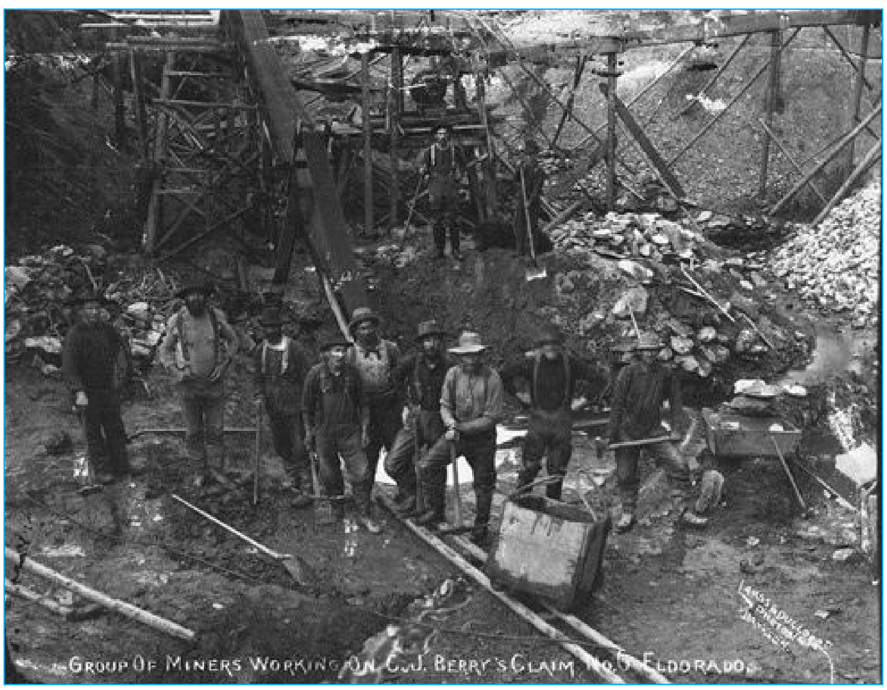

Figure 20. *A view of claim no. 6 (Stander and Berry) on Eldorado Creek in 1900.*

"The spot where gold was discovered [on Eldorado] was, like the discovery on Bonanza, at the edge of the creek on the line of Nos 2 and 3. It was taken from a cut in the bank, and was practically surface gold that had slid down from the old channel on the hill side. From a hole 18 inches deep in the creek-bed, and under water, as high as $2 [0.12 oz Au] was taken out. Bedrock, where the real riches lay, was fifteen or sixteen feet below the surface, under muck and gravel."

Stander staked No 6 Eldorado, and built a large log cabin; the stone fireplace remains (Fig. 21).

While recording the claim in Forty Mile, Stander traded 50% of his interest in the claim to Clarence Berry, in return for a 50% interest in Bonanza claim 40 and a grub stake of gear and food. Stander and Berry purchased Eldorado 4 and 5 from Standers former prospecting partners Clements and Keller in 1897.

Figure 21. *Anton Standers fireplace situated above one of the richest stretches of Eldorado Creek.*

Stander's original prospecting partners were all on the first ships out of the Klondike to arrive in Seattle, and are among the richest to exit the Klondike; two of the "Klondike Kings" who unloaded a ton of gold in Seattle in June 1897. Stander remained because he had fallen in love with a "Good Time Girl", Violet Raymond, an opera singer and dancer from Juneau who performed at the Gold Hill Hotel in Grand Forks. Stander bought Violet "every diamond in the area and gave her a necklace that reached almost to her knees. He gave her $20,000 in gold dust [~1,000 oz Au] and a lard pail full of nuggets. He gave her $1,000 a month to keep her happy." (from Klondike News, 1898).

In 1901 the couple were married in San Francisco. They moved to Seattle and built a luxury 250-room hotel. In 1906, they were divorced with Violet taking all the assets. Anton Stander died in 1952, still penniless, at the Pioneer Home in Sitka Alaska. Clarence Berry, Standers financial partner, had endowed Pioneer Home in 1913 to help pay for care of penniless sourdough prospectors in their old age.

Stop 2 Orogenic quartz veins: Lone Star Ridge and the Christy Pits

Peter Tallman, Klondike Gold Corporation

The upper ridge road from Eldorado to Lonestar was probably first a First Nations hunting trail, then in 1896-1897 a prospecting access trail. Exploration pitting and panning along the road discovered numerous quartz veins which were trenched and/or shafted. The Christy vein is an example. Large and small blocks of quartz were excavated and lie along the road. These late white quartz veins contain minor ankerite, rare cubic pyrite (usually weathered out), and very rare cubic galena. QV/wallrock orientation in the boulders suggests veins are perpendicular to foliation. At this locale the veins typically contain nil to 50 ppb Au; (rare) samples containing galena assay to 2 g/t Au.

These veins are developed adjacent to a 2.5 km long prominent magnetic low (latest) fault oriented 320° passing 50 m north of the Christy workings and parallel to the road at this point. This structure is one of the pinnate "horsetails" that terminates the 'Klondike' Fault.

Stop 3 Boulder Lode (Z 7V, 586862 E, 7086133 N)

Peter Tallman, Klondike Gold Corporation

Jim Mortensen, University of British Columbia

Jeffrey Bond, Yukon Geological Survey

The Boulder Lode gold vein occurrence was discovered and staked in November 1897. By 1912 a 105 m open cut, 225 m of underground drifting on 2 levels, several shafts, and a 1.1 km ore tramway to Victoria Gulch feeding a Hendy 4-stamp mill had been completed/constructed. From 1912 to 1914, an estimated total of 7,650 tonnes produced ~1,100 ounces gold (grading about 5.1 g/t Au). This is by far the largest bedrock gold "producer" known so far in the Klondike.

Permian (~260 Ma) host rocks include strongly sericitized felsic volcanic, currently interpreted as syngenetic volcanogenic alteration with perhaps minor local gold enrichment. Multiple phases of deformation ("D1-D4") occur to Upper Triassic (~200 Ma). Orogenic quartz veins post-date and cross-cut all visible deformation and were introduced following Jurassic age rapid uplift/shearing (~160+ Ma).

The 4 parallel veins exhibited in the Boulder Lode open cut face are continuous, parallel, each 0.3 m wide and spaced 2 to 10 m apart, and are cross-cutting perpendicular to foliation. They each assay around 1 oz/t Au (10-90 g/t Au) and were not the focus of the Klondike era mining effort. The veins are similar to the Christy veins, and to Nugget and Gay Gulch veins (this afternoon), and are the ubiquitous source of gold in the Klondike schist.

The original mined vein set is in the opposite wall. These veins were rediscovered in 2014 and assayed up to 1,766 g/t gold (50 oz/t Au), with 400 g/t silver. This quartz vein is located adjacent to what was the Boulder Lode first level underground and is in the orientation of the Boulder Lode (*i.e.*, this is what the miners were chasing). The Boulder Lode vein is 5 to 10 cm wide, cross-cutting to foliation, and 7 m long. A second similar vein was located to the left of the photo, suggesting a vein array similar to the spaced veins in the opposite wall.

The Boulder Lode is situated adjacent to a prominent north-south magnetic low pinnate fault structure. All the drilling here has been parallel to this structure.

Colluviated weathered bedrock soils and exploration geochemistry

Upland exposures at this site offer the opportunity to study unglaciated soils of the Klondike Plateau in their context with mineral exploration. Typical upland soil profiles with little permafrost disturbance consist of an organic-rich humus and A-horizon layer, a B-horizon consisting of loess (wind-blown silt), a BC-horizon consisting of mixed colluviated weathered bedrock and loess and a C-horizon comprised of variably colluviated weathered bedrock (Fig. 22; Bond and Sanborn, 2006). This general stratigraphy is affected by slope angle, slope position and slope aspect. On permafrost affected slope aspects the soils are affected by cryoturbation resulting in less stratification and more mixing of the loess layer in with weathered bedrock component. From an exploration geochemistry perspective, loess is a geochemical dilutant and its distribution within the soil column needs to be considered. Introduction of the dutch soil auger for soil sampling has greatly improved the quality of samples in recent years. The manual auger allows samplers to easily penetrate below the loess-affected horizons and obtain reliable geochemical values on the unglaciated Klondike Plateau. The result has been new discovers on old properties, such as the Coffee property south of Dawson, where mattocks were originally used to sample the uppermost (loess) mineral horizon and discoveries were missed.

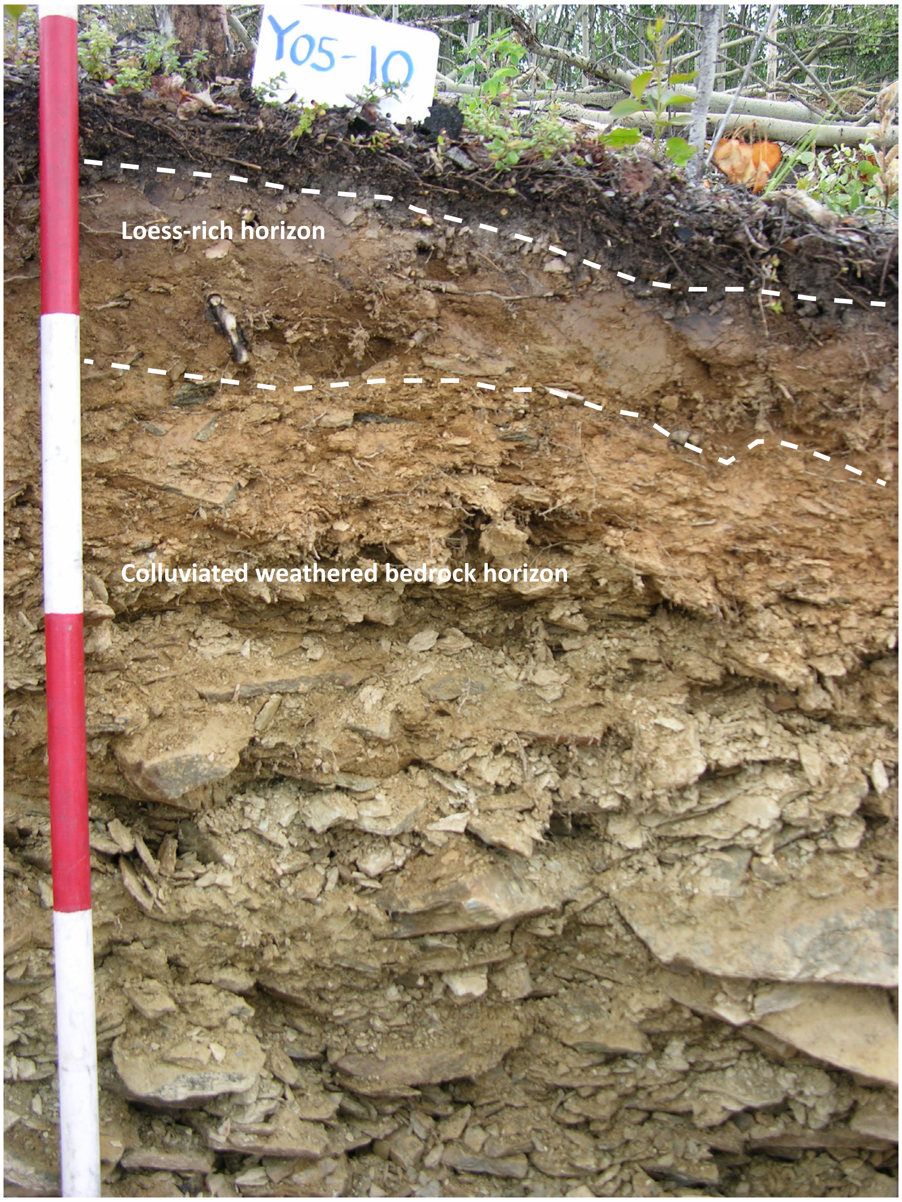

Figure 22. *Typical soil profile from a warm-aspect slope that is free of permafrost. The loess-rich horizon occurs immediately below the organic layer and consists of silt-size material representing wind-blown sediment deposited during a glacial climate.*

Stop 4 Nugget Zone (Z 7V, 586862 E, 7086133 N)

Peter Tallman, Klondike Gold Corporation

Jim Mortensen, University of British Columbia

Gold at Nugget was originally discovered in 1899. Nugget was trenched by KG/Kennecott in 1994 which sampled 2.35g/t over 12.0m including 26.5g/t over 2.0m. Two 'bulk' samples of the Nugget veins, totaling 1,886 kg and 2,769 kg, assayed 6.5 and 8.6 g/t Au respectively in 2005. Systematic chip sampling in 2015 yielded 8.0 g/t Au over 4.3 m.

In the Nugget trenches, an extensional quartz vein set hosted by mafic volcanics is exposed along strike for 50 m and across a width of 5-10 m (Fig. 23). The gold-bearing veins form perpendicular to wallrock foliation; a diagnostic feature. Note the (rotated?) large quartz crystal within the vein and (contradictorily) the vein margins of some which locally exhibit vein-parallel shear. These white quartz veins contain coarse and fine visible gold, ankerite, rare cubic pyrite, and very rare galena.

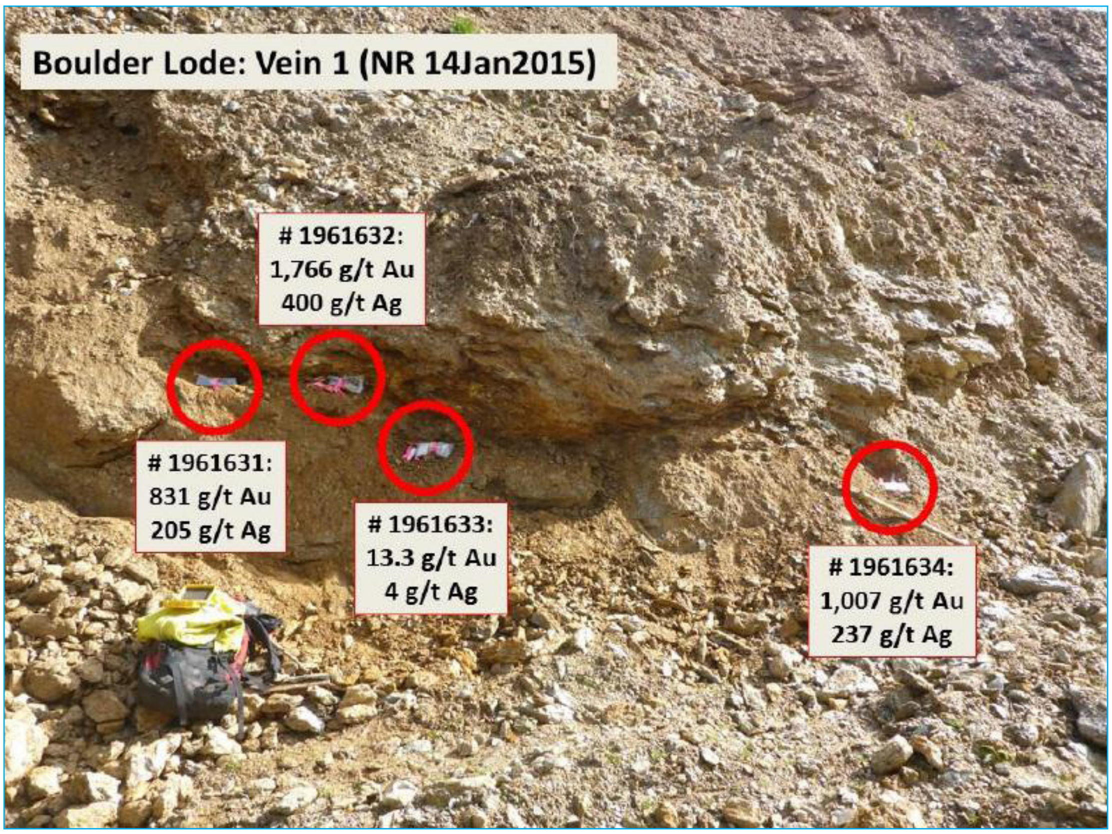

Figure 23. *A view of the Boulder Lode vein with associated gold concentrations from samples.*

Gold is distributed unevenly along the strike of the exposed veins. Gold occurs as rare fine specks, locally increasing in abundance to areas with many fine specks and flakes, then to many speck, flake and nugget size particles within a 0.5 m area. Gold distribution here is an example of the geostatistical concept of "clustering" which accentuates the nugget effect leading to very high constitution heterogeneity. Clustering is common in orogenic gold deposits and is a characteristic of all Klondike gold-bearing veins.

Individual quartz veins containing visible gold can be 0.1 to 1.0 m in thickness. Zones are comprised of several to many related quartz veins ("vein arrays") occurring over widths of up to ~10 m true thickness and these exhibit along-strike and down-dip continuity. The volume of quartz veining relative to wallrock expressed as "% quartz veining" is an important exploration indicator.

Table 1. *Summary of Nugget zone drilling assay results.*

Hole ID	Dip	From (m)	To (m)	Interval (m)	True Thickness (m)	Grade Au g/t	% QV	Vein Array
EC15-01	-45	3.8	11.45	7.65	7.65	4.6	27	Upper
EC15-02	-85	4.4	11.6	7.2	5.7	2.3	15	Upper
EC15-03	-85	4.4	12.0	7.6	6.1	5.3	22	Upper
EC15-03	-85	47.8	49.6	1.8	1.4	7.4	27	Lower
EC15-04	-45	21.1	24.1	3.0	3.0	5.7	58	Lower

Stop 5 Gay Gulch (Z 7W, 585897E, 7084524N)

Peter Tallman, Klondike Gold Corporation

Gay Gulch was discovered by trenching in 1988 and 1990. Gold bearing quartz veins were found in two trenches 100 m apart. It wasn't recognized until 2015 that these veins are connected. Grab samples from 1988 to 2015 assay from 1 g/t Au to 43 g/t Au.

Visible gold occurs in the farther trench, where the quartz vein array hosted by felsic volcanics dissipates at a contact with graphitic sediment. Quartz veins here are again white, contain ankerite, cubic pyrite, very rare cubic galena and are formed perpendicular to foliation.

Six 2015 drill holes encountered brittle felsic volcanics, fractured and cut by a quartz vein array. The best intersection hit a 50 cm quartz vein containing 10 cm of gold-ankerite with individual gold clots at 2 cm size, assaying 420 g/t Au over 0.5 m with the coarse gold not included in the assay. Quartz veining is related to a prominent (magnetic low) fault that extends for 2.6 km from Gay Gulch. This is part of the horsetail structure that terminates the 'Klondike' fault. The Gay Gulch drilling is located adjacent to Eldorado Creek on the right limit bank of Eldorado placer claim 36. By 1900, a 34 ounce gold nugget had been discovered on placer claim 36 and a larger 72 ounce nugget was discovered on placer claim 34 located 250 m downstream. The Gay Gulch fault transects both of these placer claims. The clot of gold in hole EC15-10 visually represents one of the bedrock sources to the Klondike's nuggets.

Table 2. *Summary of Gay Gulch drilling assay results.*

Hole ID	Dip	From (m)	To (m)	Interval (m)	True Thickness (m)	Grade Au g/t	% QV
EC15-08	-85	41.90	47.25	5.35	4.00	1.6	16
EC15-09	-50	19.30	20.40	1.10	1.10	1.9	18
EC15-10	-85	23.90	26.70	2.80	2.10	75.6	33
	Including	23.90	24.40	0.50	0.40	420.0	100
EC15-11	-50	21.20	23.05	1.85	1.85	1.0	
EC15-12	-85						
EC15-13	-50	19.45	21.00	1.55	1.55	10.9	10

Stop 6 Gold Hill and Cheechako Hill (Z 7V, 582232 E, 7089234 N)

Jeffrey Bond, Yukon Geological Survey

Gold and Cheechako hills are located near the former town site of Grand Forks that was first settled in 1896 immediately following the discovery of gold less than a kilometre downstream. The town grew rapidly and approximately 4,000 people lived in or by Grand Forks during the gold rush (Fig. 24). By 1899, the town boasted dozens of local businesses and services including a public bath, dentist, hotels (including the Grand Forks Hotel), hospital, photo studios, liveries, telephone service to Dawson City ($30/month), three churches and electric lights. Amalgamation of claim blocks causing a reduction in population, arrival of the Klondike Mines Railway in 1905 bringing corporate equipment, the coming dredges and the rich ground underlying the settlement resulted in destruction of the town in 1921 (Gates, 2009; McLaughlin CKRW News Nugget).

Oliver Millet was among the first stampeders to reach the Klondike in October of 1897. Despite this, most of the obvious ground was staked but he was able to obtain a lease on an Eldorado Creek claim. His claim contained no gold and he wondered why when so many claims below his were so rich. At this time it dawned on him that the channel might be located high on the hills, adjacent to his claim. To test his theory he started shafting on Cheechako Hill above George Carmack's discovery claim. The characteristic white gravel started to appear and he knew his theory was right despite the creek

Figure 24. *A view east of Grand Forks and upper Bonanza Creek in its early days. The photo was likely taken from Gold Hill.*

miners calling him crazy. His efforts paid off during his first day with a rocker box when he discovered 40 ounces of gold. He is credited with discovering the White Channel Gravel and one of the richest areas in the district (McLaughlin, CKRW Yukon Nuggets).

Gold and Cheechako hills with their prime locations at the mouth of Eldorado Creek became a hub of activity (Fig. 25). Surface working focused along the edge of the bench where the bedrock surface could be easily accessed. From here drifts were driven along the bedrock contact in order to extract the high grade pay. Up to 1000 people were working on Gold Hill during the early years.

Recent placer mining on Gold Hill has exposed a complete section of the White Channel Gravel. The total gravel thickness measures 33 m and grades from an iron-stained, stratified upper gravel containing abundant sand lenses to a poorly sorted minty white lower gravel. The lower 3 m (10 ft) of the gravel on bedrock is processed as pay. The lower gravel contains subangular clasts, has a high density perhaps due to high decomposed bedrock content (sericite schist) and is cobble dominant. The pay is challenging to sluice due to the high clay content. In order to facilitate gold recovery the pay is mixed with the sandier gravel and processed slowly.

Figure 25. *A view west of Gold Hill showing numerous camps and hand excavation pits.*

Stop 7 Discovery Claim (Z 7V, 582164 E, 7090006 N)

This is the site where George Carmack, Skookum Jim and Dawson Charlie discovered gold in Rabbit Creek (Bonanza Creek) in August 17th, 1896. George Carmack recorded the discovery claim in Forty Mile and gold fever quickly spread. Two weeks later all of Bonanza Creek was staked.

Stop 8 Dredge 4 (Z 7V, 581557 E, 7091798 N)

Gold Bottom Tours

Dredge 4 is a bucketline sluice dredge that was operated by Yukon Consolidated Gold Corporation between 1941 and 1958 on Bonanza Creek. Like many dredges in the Klondike it was contructed using components from an earlier dredge, in this case, one that operated between 1912 and 1940 on the Klondike River by the Canadian Klondike Mining Company. Dredge 4 is considered the largest wooden hull dredge in the world. It processed 22 buckets per minute and operated 24 hours a day for approximately 200 days per year. During its best day it recovered 800 ounces of gold.

Stop 9 Jackson and Lovett hills (Z 7W, 580043E, 7101235N)

Jeffrey Bond, Yukon Geological Survey

Jim Mortensen, University of British Columbia

The Jackson Hill exposure is located at the mouth of Bonanza Creek and overlooks the Klondike River valley (Fig. 26). Bedrock here consists of carbonaceous Nasina assemblage metasediments. Jackson Hill contains a large reserve of White Channel gravel with an estimated 150,000 ounces remaining (Crawford pers. comm., 2016). Geographically, Jackson Hill differs from most of the Neogene benches. Most Bonanza Creek White Channel benches are located on the edges of the valley and at most, contain a half-cross section of the Neogene valley sediments. As a result, some of the pay streak remains on the benches and some was reworked into the valley bottom. With the initiation of base level changes following the first glaciation 2.6 million years ago, the mouth of Bonanza Creek down-cut along the far western side of the valley (left limit). This left the bulk of the Neogene sediments, including the entire central paleo-channel preserved in Jackson Hill.

Figure 26. *Aerial view of Jackson Hill looking up Bonanza Creek.*

Recent mining on the upstream side of Jackson Hill (Lovett Hill) by Northern Shoveler targets the ancestral White Channel pay streak. The stripping ratio is 20:1 and the bottom 3.6 m (12 ft) of gravel is sluiced. Grade concentrations are upwards of $540/cubic yard at $1200/fine ounce. When factoring in the stripping ratio the entire section is worth $6.00/cubic yard and the target cost for extraction and sluicing is $3.00/cubic yard. The economics of Lovett Hill are facilitated by its lack of permafrost (south-facing) and the high concentration of gold, which reduces the sluicing volume and cost.

Jackson and Lovett hills, along with Australia Hill at the mouth of Hunker Creek, record a unique period of time in the Plio-Pleistocene history of northwestern Canada. Meltwater from the first Cordilleran Ice Sheet (2.64 Ma) overtopped a ridge to the east of Hunker Creek and deposited a thick sequence of glaciofluvial gravel in the Klondike River valley (Hidy *et al.*, 2013). This sediment, termed the Klondike Wash, buried the White Channel Gravel deposits at Jackson, Lovett and Australia hills and is visible in the section (McConnell, 1907; Froese *et al.*, 2000). The Klondike Wash contains foreign clast lithologies derived from the sedimentary rocks north of the Tintina Trench. The sedimentary environment of the Klondike Wash is described as a braided river deposit with planar-tabular cross-beds and, locally at Jackson Hill, has a thickness of 40 m (Froese *et al.*, 2000). In valley margin positions the Klondike Wash is clearly interbedded with the upper White Channel Gravel indicating conformable deposition.

This exposure was created by hydraulic mining, which extracted gold while washing the White Channel Gravel into the Klondike River valley. This process buried virgin Klondike River pay gravel under the hydraulic tailings.

DAY 4 DAWSON CITY TO WHITEHORSE

8:30 am Assemble in the parking lot on Front Street in Dawson, across from St. Paul's Church and the Commissioner's Residence (just past the white graveled ramp with flowers).

Stop 1 Bear Creek – Yukon Consolidated Gold Corporation

David Rohatensky, Superintendent, Klondike National Historic Sites

Stop 2 Moose Creek Lodge – lunch

Stop 3 Carmacks – pit stop

Arrive in Whitehorse @ 5 pm

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