The Paradise gravel: Evidence for a pre-White Channel Gravel in the Klondike

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Bond, J.D., 2016. The Paradise gravel: Evidence for a pre-White Channel Gravel in the Klondike. *In:* Yukon Exploration and Geology 2015, K.E. MacFarlane and M.G. Nordling (eds.), Yukon Geological Survey, p. 29-42.

ABSTRACT

New stratigraphic interpretations of exposures at Dago, Preido and Paradise hills on lower Hunker Creek suggest a more complex stratigraphic framework for the development of high-level bench gravels in the Klondike than has been previously put forward. A highly-altered gravel has formerly been interpreted to be part of the lower White Channel Gravel sequence and its degree of alteration attributed to enhanced groundwater diagenesis near the bedrock contact. New mining exposures indicate this altered gravel, here informally termed 'Paradise gravel', is laterally extensive and the alteration is not restricted to the bedrock interface. Furthermore, a cross-section reconstruction shows the White Channel Gravel is stratigraphically inset into the Paradise gravel. Alteration of the Paradise gravel is possibly a function of pedogenesis, suggesting a period of landscape stability followed its deposition. This pattern of sedimentation and potential stability was repeated within the lower White Channel Gravel and recorded by a zone of clay alteration and iron oxidation.

Economically, the Paradise gravel is significant. At each locality investigated, the primary pay streak occurs in the Paradise gravel. Conversely, the White Channel Gravel is only economic where it sufficiently erodes and reworks the Paradise gravel. In nearby drainages, including upper Hunker Creek, the White Channel Gravel more completely reworks Paradise gravel to bedrock and becomes the pay unit. Preservation of the Paradise gravel documented in lower Hunker Creek may be due to its broad valley morphology. Future studies are recommended on the sedimentology of the Paradise gravel to understand gold distribution both vertically and within the pay channel(s). In addition, research into the pedogenic alteration could provide information on past climates during the Neogene.

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INTRODUCTION

Gold placers have been mined continuously from the Klondike district, Yukon since gold discovery in 1896 (Fig. 1). Reported placer gold production exceeds 10 million fine ounces and extraction continues with 90 placer mines still active in the district (Van Loon and Bond, 2014). The White Channel Gravel, a high-level Neogene[1] bench gravel, has been previously interpreted as the oldest auriferous gravel in the Klondike (Fig. 1; McConnell, 1907). The gravel owes its name to the abundance of quartz clasts, which are a residual lithology derived from weathering of the underlying Klondike Schist and its associated orogenic veins (McConnell, 1907; Tempelman-Kluit, 1982; Mortensen *et al.*, 2004; Chapman *et al.*, 2010). Reworking of the White Channel Gravel into secondary stream and terrace gravels resulted in some of the richest placer creeks in the world. Estimates from a four mile-long pay streak in Eldorado Creek, a tributary to Bonanza Creek, suggest 1.3 million fine ounces of placer gold were produced between 1896 and 1907 (McConnell, 1907). Another significant pay streak, or portions of the primary pay streak, was preserved on many of the high-level White Channel Gravel benches. Over the years these resources have been exploited by underground mining, hydraulic mining and with modern heavy equipment.

Numerous studies have described the stratigraphy and sedimentology of the White Channel Gravel; however, McConnell (1905, 1907) provided the most detailed information on contact relationships. McConnell's cross-sections for upper Bonanza Creek and the Klondike River have been cited extensively and provide a distribution framework for the primary lithostratigraphic units (Fig. 2; Tempelman-Kluit, 1982; Dufresne and Morison, 1985; Morison and Hein, 1987; Froese *et al.*, 2000; Lowey, 2002).

The purpose of this paper is to present a stratigraphic re-interpretation of the White Channel Gravel based on exposures from Dago, Preido and Paradise hills on lower Hunker Creek (Fig. 1). Using the new stratigraphy, an idealized cross-section is developed that challenges the established deposit evolution, explains previously published observations and has implications for identifying new placer gold resources in the Klondike.

BACKGROUND

The high quartz content of the White Channel Gravel reflects prolonged weathering of the late Permian Klondike Schist and its gold-bearing quartz veins (Knight *et al.*, 1994; Knight *et al.*, 1999; Mortensen *et al.*, 2005). Sedimentological analyses by Morison and Hein (1987) described the White

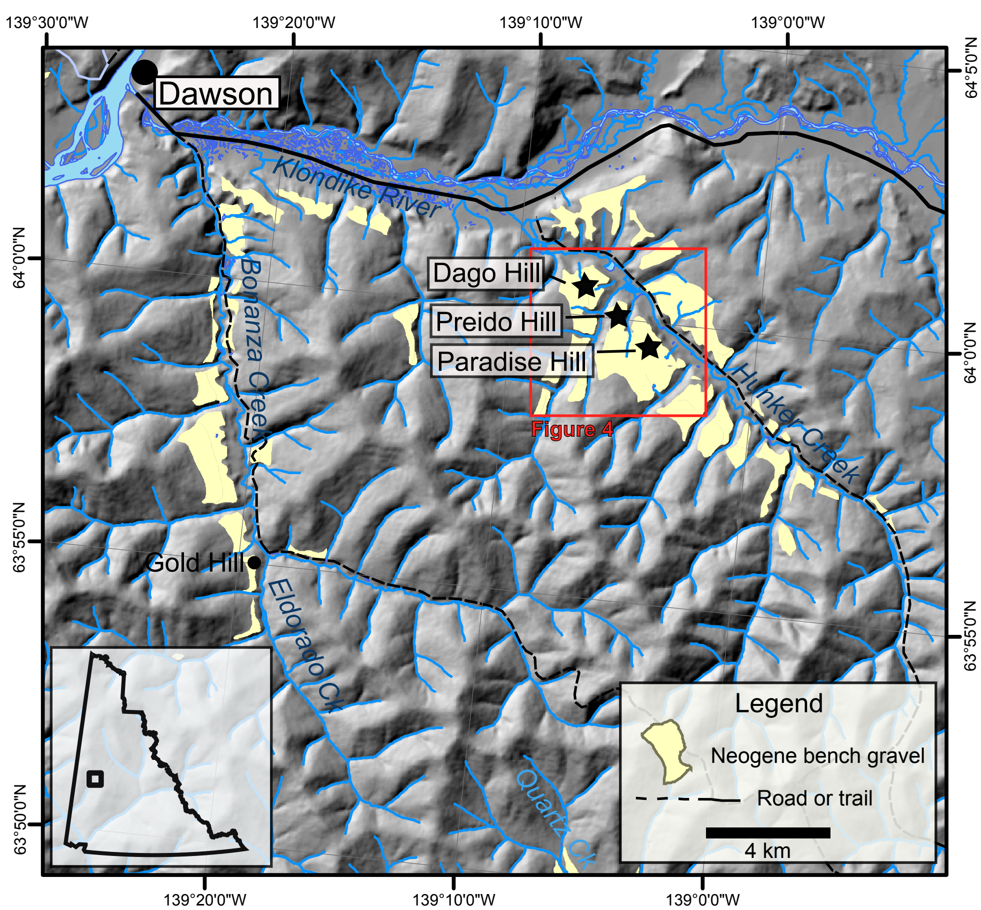

Figure 1. *Location map of the Neogene sediments in Hunker and Bonanza creeks (geology from: Froese and Jackson, 2005; McKenna and Lipovsky, 2014).*

[1]*Tertiary is no longer recognized as a formal time period by the International Commission on Stratigraphy. The time span was subdivided between the Paleogene (66 Ma to 23.03 Ma) and Neogene (23.03 Ma to 2.58 Ma) periods, which immediately precedes the Quaternary (2.58 Ma to present).*

Channel Gravel as a proximal to distal braidplain with colluvial sediment-gravity flow deposits within a confined valley. McConnell (1905, 1907) subdivided the gravel into two units: a lower 'white gravel' and an upper 'yellow gravel', and suggested the two units represented separate depositional events, consistent with a transition from preglacial to periglacial conditions as described by Froese *et al.* (2000; Fig. 2). Recent architectural analysis on sedimentary bedforms supports this interpretation by demonstrating an increase in aggradation rate (and reduction in channel size) from the lower White Channel Gravel to the upper White Channel Gravel (Lowther *et al.*, 2014). Lowther *et al.* (2014) further suggest a depositional hiatus likely occurred between the upper and lower White Channel Gravel and that it may have been caused by a tectonic event.

Alteration descriptions of the lower White Channel Gravel and underlying bedrock have been made by a number of authors. At Dago Hill, Tempelman-Kluit (1982) suggested that groundwater played a significant role in leaching the deposit and described the alteration as so intense that schist and porphyry clasts disintegrate upon thawing of permafrost. Dufresne et al. (1986) and Dufresne (1987) concluded that hydrothermal activity contributed to the alteration and subdivided the alteration into three zones: the 'Bleached Zone', the 'Iron Zone' and the 'Footwall Zone'. The alteration in all three zones is characterized by the development of secondary clay minerals with moderate to high crystallinities (Dufresne *et al.*, 1986). Furthermore, the 'Iron Zone' and 'Footwall Zone' have anomalously high concentrations of the elements Fe, Mn, As, Sb, Hg, Co, Ba and S. This hydrothermal origin for the alteration was challenged by Lowey (2002, 2006) who argued that weathering and diagenesis due to groundwater flow, coupled with time, was sufficient to explain the decomposition. Lowey (2002) also suggested the abundance of kaolinite in the 'white gravel' could be the result of deposition and weathering during a more temperate and humid climate. Lowey's arguments are consistent with McConnell's (1907) assessment that circulating surface waters had contributed to leaching.

The age of the lower White Channel Gravel is poorly constrained. McConnell (1907) estimated the gravel must date back to the Pliocene. Tempelman-Kluit (1982) thought that deposition of the White Channel Gravel was initiated in the Late Miocene or Pliocene (late Tertiary or Neogene) when differential uplift of the Klondike Plateau began. Paleomagnetic measurements indicate a change from reverse to normal polarity in the lower White Channel Gravel, attributed to the Gilbert-to-Gauss chron transition at 3.58 Ma; however, accurate placement of this change within the geomagnetic timescale is problematic (Froese *et al.*, 2000). Pollen data from the upper portions of the lower White Channel Gravel have an assemblage that is consistent with mid-Pliocene, preglacial deposits in Alaska (Ager *et al.*, 1994; Froese *et al.*, 2000; Lowther *et al.*, 2014).

The upper White Channel Gravel is a normally magnetized, unaltered gravel that exhibits periglacial weathering, including ice wedge casts and cryoturbation-related involutions (Froese *et al.*, 2000). The age of the gravel is well constrained by tephra and paleomagnetic measurements that place its age between 2.6-3.3 Ma (Froese *et al.*, 2000; Westgate *et al.*, 2003). Cordilleran Ice Sheet outwash, which overlies the upper White Channel Gravel in the Klondike River valley, dates to 2.64+0.20/-0.18 Ma, thus providing a minimum age for the cessation of White Channel Gravel deposition (Hidy *et al.*, 2013).

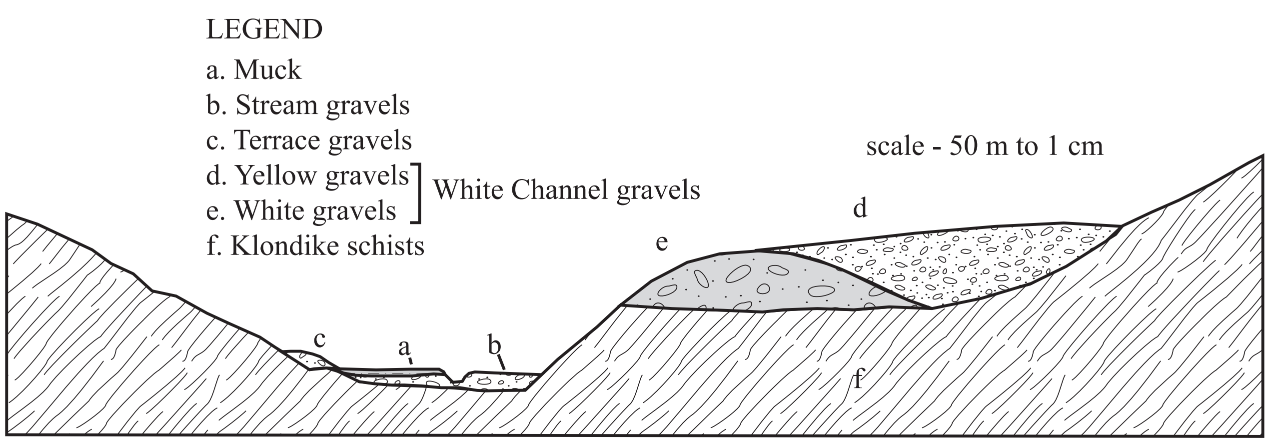

Figure 2. *Cross-section of Bonanza Creek near the mouth of Eldorado Creek. The contacts indicate that the 'yellow gravels' are cut into the lower 'white gravels' (after McConnell, 1907).*

McConnell's (1907) report on gold values in the White Channel Gravel provided a detailed account of the placer gold distribution. Throughout most of the Klondike, gold grades are considerably enriched in the lower 2 m of gravel on bedrock (Gleeson, 1970). For example, at Lovett Hill on Bonanza Creek the bottom 2 m of gravel contains the equivalent amount of gold as the overlying 44 m of gravel. In other words, 50% of the gold from a 46 m exposure is contained in the bottom 2 m. Furthermore, coarse gold is only found in this lower 2 m of gravel. An exception to this rule was documented by McConnell (1907) at Paradise Hill on Hunker Creek where the main gold zone lies 0.9-3.7 m above bedrock, at a contact with an underlying highly siliceous and coarse gravel.

Figure 3. *Aerial view to the south, looking up Hunker Creek. The Neogene benches (hills) are labelled on the west side of the valley.*

NEW STRATIGRAPHIC DESCRIPTIONS

The Neogene fluvial terraces of Paradise, Preido and Dago hills, on the southwest side of the Hunker Creek valley, were investigated for this study (Fig. 1, 3 and 4). Stratigraphic measurements, contact relationships and unit descriptions were made at each locality. The stratigraphy and sedimentology of the three sites has been described in the past and, where possible, this study relates new observations to earlier work (McConnell, 1907; Tempelman-Kluit, 1982; Dufresne *et al.*, 1986; Morison and Hein, 1987; Froese *et al.*, 2000; Lowey, 2002). Of particular relevance is the idealized stratigraphy proposed by Dufresne *et al.* (1986) that uses alteration to differentiate zones in the gravel (Fig. 5). These descriptions support a new lithostratigraphic framework that includes four units overlying a strath terrace.

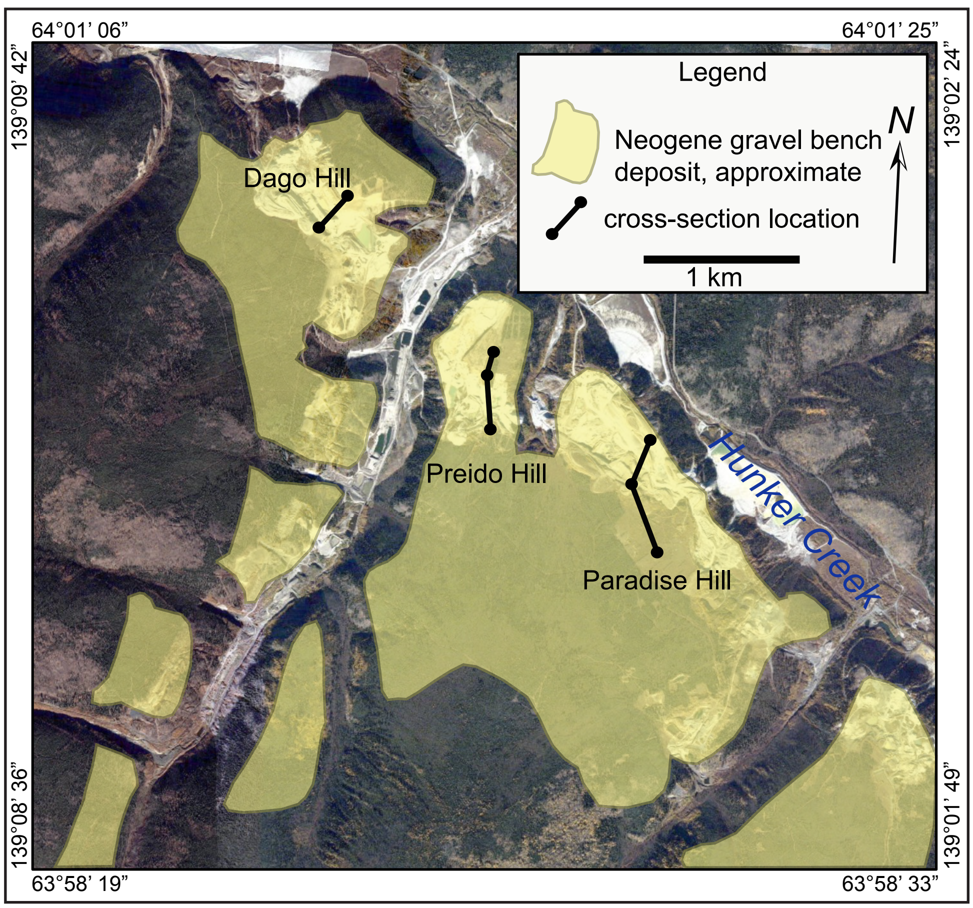

Figure 4. *Map showing the location of the cross-sections on Dago, Preido and Paradise hills. Also, the distribution of Neogene fluvial sediments are shown in yellow, which includes both Neogene pediment (thin fluvial/colluvial) and fluvial terrace (thick fluvial) deposits (geology from: Froese and Jackson, 2005; McKenna and Lipovsky, 2014).*

BEDROCK STRATH

The White Channel strath, as described by Lowey (2004), is the eroded bedrock surface that is in unconformable contact with the overlying gravel. At Paradise and Preido hills the strath lithology varies from siltstones and conglomerates of the Indian River Formation to Klondike Schist and ultramafic rocks. On Paradise Hill, a previously unmapped thin layer of Indian River Formation siltstone, pebble conglomerate and tuff overlie the Klondike Schist. At both Paradise and Preido hills the bedrock surface is intensely altered and decomposed into soft clay, and in isolated places is deformed and folded into the overlying gravel (Fig. 6). Alteration of the bedrock strath was described by Dufresne *et al.* (1986) as the 'Footwall Zone', which contained a secondary clay mineral assemblage (Fig. 5).

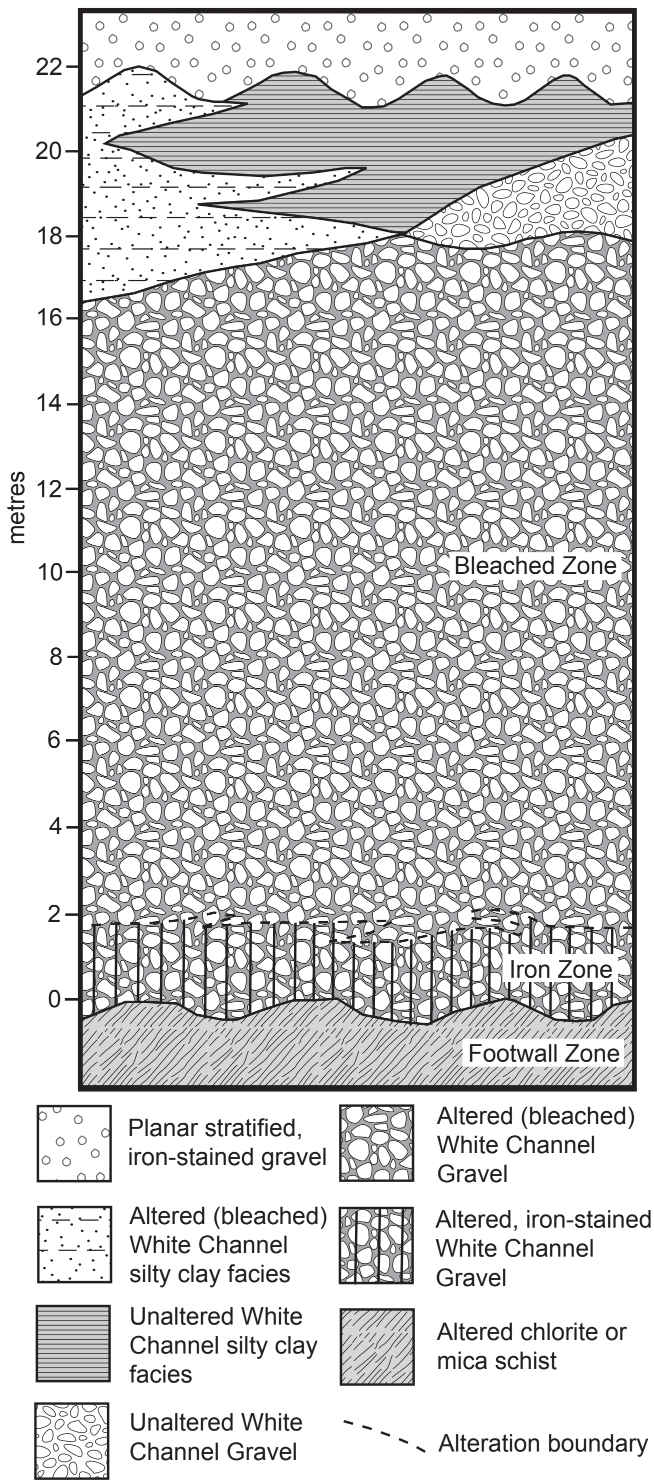

Figure 5. *Idealized section from Dago Hill showing the alteration zones within Neogene sediments (after Dufresne et al., 1986).*

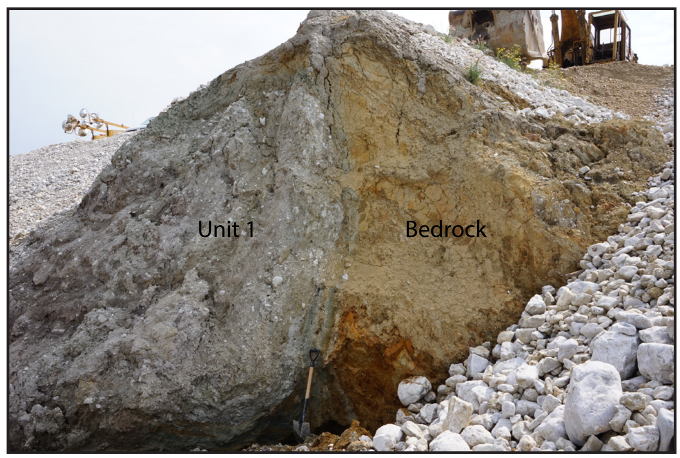

Figure 6. *Altered and deformed bedrock on Paradise Hill has produced a vertical contact between unit 1 and the Indian River Formation bedrock.*

Unit 1

The lowermost gravel unit consists of an unsorted to moderately sorted, iron-mottled to pervasively stained, intensely altered, quartz cobble-rich gravel (Figs. 7, 8 and 9). At Dago Hill, this unit is equivalent to the 'Iron Zone' as described by Dufresne *et al.* (1986; Fig. 5) and termed the 'lower White Channel Gravel' by Froese *et al.* (2000). Unpublished shafting reports from 1912-1913 on Paradise Hill refer to the lowermost gravel unit as "gumbo". Near the bedrock contact, unit 1 is clast supported, can locally resemble a diamicton due to the alteration and deformation, and contains subrounded to rounded boulders up to 100 cm in diameter (Fig. 10). Crude stratification and bedding is visible throughout and iron-staining increases upward. Dufresne *et al.* (1986) analyzed the geochemistry of the 'Iron Zone' and concluded there were anomalous concentrations of Fe, Mn, As, Sb, Hg, Co, Ba and S within the matrix. Quartz clasts represent 50-70% of the gravel with the remaining clasts

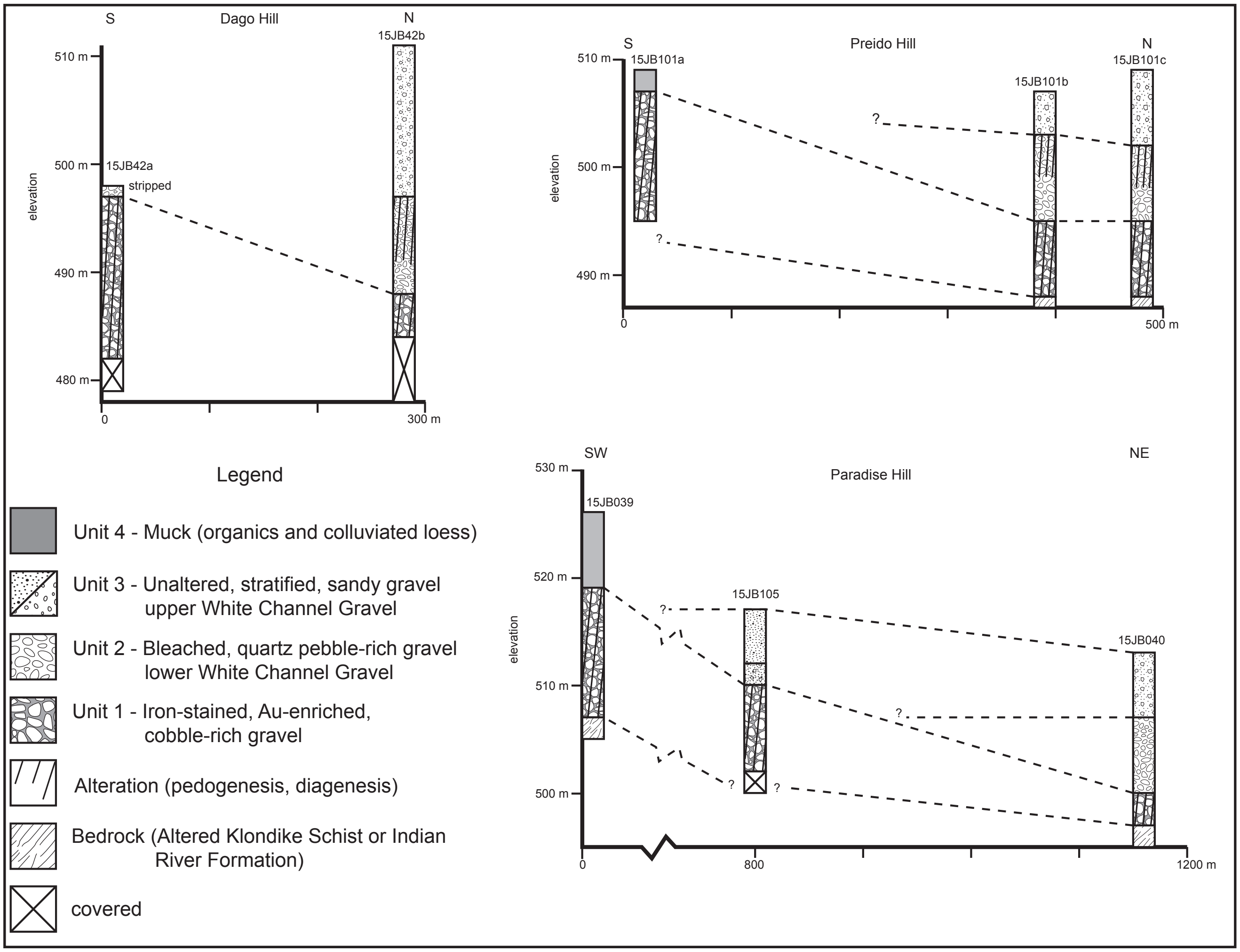

Figure 7. *Stratigraphic sections from Dago, Preido and Paradise hills. See Figure 4 for section locations.*

composed of sericite schist, mica schist, graphitic schist, rhyolite and gneiss. All of the non-quartz lithologies are soft and have been largely replaced by secondary clay minerals (Fig. 8; Tempelman-Kluit, 1982; Dufresne *et al.*, 1986). Upon thawing, the altered clasts turn to a soft incompetent clay (Tempelman-Kluit, 1982). Flattened weathered clasts are present where post-alteration deformation, perhaps from loading or mass wasting, has disturbed the gravel (Fig. 8). Unit 1 is 3.4-11.5 m thick and is consistently thickest toward the valley margin where it is overlain by muck (unit 4; Fig. 7). Unit 1 is the primary pay at Dago, Preido and Paradise hills (pers. comm., Favron Enterprises, Tamarack and Moonlight Mining, 2015).

Figure 8. *Close up photograph of unit 1 at Paradise Hill. The gravel is highly altered and clasts are visibly deformed.*

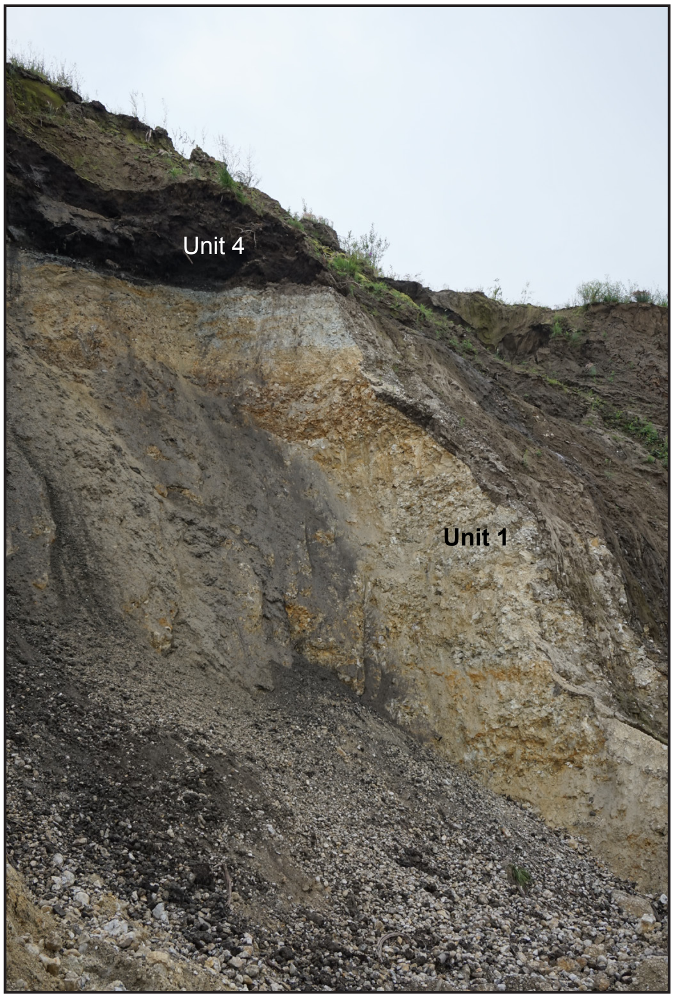

Figure 9. *View of units 1 and 4 at Paradise Hill (see Fig. 6 section 15JB039). Unit 1 is the equivalent of the 'Iron Zone' gravel described by Dufresne et al. (1986).*

Figure 10. *A small boulder exposed in unit 1 at Paradise Hill (see Fig. 6 section 15JB105). Boulders exceeding 1 m in diameter are present in unit 1. The pick is 60 cm in length.*

Unit 2

Unconformably overlying unit 1 is the bleached to iron-stained, quartz-rich gravel of unit 2 (Fig. 7 and 11). This gravel shows increased alteration towards the upper contact with unit 3, and is a stratified, moderately sorted, clast-supported, cobble-pebble gravel with less than 1% boulders. Unit 2 ranges in thickness from 2.0 to 10 m (Fig. 12). Quartz clasts comprise >70% of the unit. The composition of non-quartz clasts is similar to unit 1 although they exhibit less decomposition (Tempelman-Kluit, 1982). Unit 2 is thickest near the bench rims or proximal to the middle of the paleo-valley (Fig. 7). Unit 2 is equivalent to the 'Bleached Zone' as described by Dufresne *et al.* (1986; Fig. 5) and is part of the lower 'white gravel' subunit of the White Channel Gravel sequence described by McConnell (1907; Fig. 2). At Preido and Dago hills a pronounced weathering gradient is visible at the top of the unit (Fig. 12 and 13). The weathering gradient consists of a 5 m-thick lower zone of oxidation that is overlain by a 1.5 m-thick zone of cemented, bleached, and clay-altered gravel and capped with organic material.

Figure 11. A close-up view of the sharp contact between unit 1 and unit 2 (lower White Channel Gravel) at Dago Hill (dashed line). Non-quartz clasts are more abundant and are more decomposed in unit 1 compared to unit 2.

Figure 12. View of units 2 and 3 (lower and upper White Channel Gravel) at Preido Hill. The paleosol separating the two units is truncated. Where unit 3 erodes completely through the clay-rich horizon in the paleosol, the contact between the units becomes less clear. Pick for scale.

Unit 3

Unit 3 is 5.3 to 15 m thick and consists of unaltered, planar stratified, iron-stained, cobble-pebble gravel (Fig. 7 and 13). Unit 3 is in unconformable contact with unit 2 and the depth of erosion is variable, based on discontinuous preservation of the weathering gradient in unit 2. On Preido Hill, the contact is wavy and, in many places, erodes completely through the clay-altered zone in unit 2 (Fig. 13). Where the depth of erosion exceeds the clay-altered zone in unit 2, the contact between the two units is less obvious and unit 3 becomes diluted with clasts reworked from unit 2 (Figs. 12 and 13). Lithologically, unit 3 contains less quartz than the previous units. The distribution of unit 3 is similar to unit 2 in that it thins progressively towards the valley sides (Fig. 7). Froese et al. (2000) documented ice wedge casts in this unit and called it the upper White Channel Gravel or the 'yellow gravel' as described by McConnell (1905, 1907; Fig. 2).

Unit 4

Unit 4 is a massive to bedded silt containing organic-rich beds and wood. This material, also referred to as muck, is pervasive throughout the Klondike and often contains massive and disseminated ice (Fig. 9), vertebrate fossils and volcanic ash (Froese *et al.*, 2009). The muck increases in thickness towards the valley sides (Fig. 7).

Figure 13. *Photograph showing the contact between units 2 and 3 at Preido Hill. Unit 2 (lower White Channel Gravel) is highly altered at its upper contact, which is interpreted to be a possible Neogene paleosol. Note the erosional contact between units 2 and 3 (dashed line). Unit 3 (upper White Channel Gravel) contains more silt and sand beds compared to unit 2, which tends to be coarser.*

DISCUSSION

STRATIGRAPHY

The stratigraphy of lower Hunker Creek includes three distinct gravel sequences with consistent lithological composition and unique alteration characteristics (degree of clast decomposition). The gravel sequences are separated by erosional contacts, and units 2 and 3 are inset into unit 1 (Fig. 14).

Unit 1 is interpreted as a predecessor gravel to the White Channel Gravel and is informally referred to as 'Paradise gravel'. The Paradise gravel is defined as a distinct unit on the basis of the following observations: its position in contact with the bedrock strath (Fig. 7); contact relationships with units 2 and 3 (Figs. 7 and 14); fewer quartz clasts relative to unit 2 (Figs. 8 and 11); high gold content; high degree of clast decomposition (Fig. 8); abundance of boulders; and anomalous matrix geochemistry relative to units 2 and 3. Previous studies grouped the Paradise gravel into the lower White Channel Gravel and argued the alteration gradient was a product of hydrothermal alteration or groundwater diagenesis (Dufresne *et al.*, 1986; Lowey, 2001, 2006). However, the degree of clast decomposition in the Paradise gravel is not limited to the bedrock interface, is present where the gravel exceeds 11 m in thickness and occurs near the modern surface (Fig. 9). Importantly, the characteristically high degree of alteration does not extend into unit 2 (or unit 3) and therefore occurred prior to deposition of unit 2 (Fig. 7).

Unit 2 is interpreted to be lower White Channel Gravel (Fig. 14). This unit is inset into the Paradise gravel and its compositional character is likely a reflection of erosion and reworking of the Paradise gravel. McConnell (1907) noted that sand grains in the matrix of the White Channel

Gravel have an angular shape, suggesting limited transport. Reworking of decomposed clasts in the Paradise gravel would cause clast disintegration and a pulse of angular sand grains into the lower White Channel Gravel. Furthermore, destruction of non-quartz lithologies would have a refining effect on the lower White Channel Gravel resulting in a relative enrichment of quartz (resistant) clasts compared to the Paradise gravel (Figs. 11 and 12).

As described previously, the upper contact of the lower White Channel Gravel is marked by a variably eroded weathering gradient containing oxidation, clay alteration, cementation and organics (Fig. 13). This weathering gradient marks a hiatus in gravel sedimentation that allowed weathering and alteration to occur. Dufresne *et al*. (1986) termed this the 'Bleached Zone' and also recognized that the alteration preceded deposition of the overlying 'yellow gravel' (unit 3). Lowey (2001) argued that alteration of the 'Bleached Zone' was a product of weathering and diagenesis due to groundwater flow. Based on the weathering gradient observed at Preido Hill, consisting of organics, a leached zone and a zone of iron enrichment, it appears the alteration may be a product of pedogenesis (Fig. 13). A paleosol within the lower White Channel Gravel has not been suggested previously; however, Lowther *et al*. (2014) argue that a fluvial depositional hiatus may have occurred around this time. They identify an organic-rich lacustrine unit at the contact between the lower and upper White Channel Gravel and suggest it is related to tectonic process, such as back-tilting, causing a fluvial shut-down. Alternatively, a change in sedimentation could reflect fluvial responses to climate change.

The final phase of White Channel Gravel sedimentation is marked by unit 3, interpreted to be the upper White Channel Gravel or 'yellow gravel' (Figs. 13 and 14).

GOLD DISTRIBUTION

Detailed studies into the distribution of gold in the Paradise gravel were not completed as part of this study. General information gathered from placer miners indicates the target placer deposit at Paradise, Preido and Dago hills is the lowermost gravel at the bedrock contact (Paradise gravel). The pay channels reflect high energy conditions, marked by an abundance of subrounded to rounded quartz boulders in channels that are cut into bedrock (pers. comm., Moonlight Mining Ltd., 2015; Fig. 10). Lower grade placer concentrations occur marginally to these channels and can be economic. According to historic records, the 'heavy pay channel' in a yellow-stained gravel

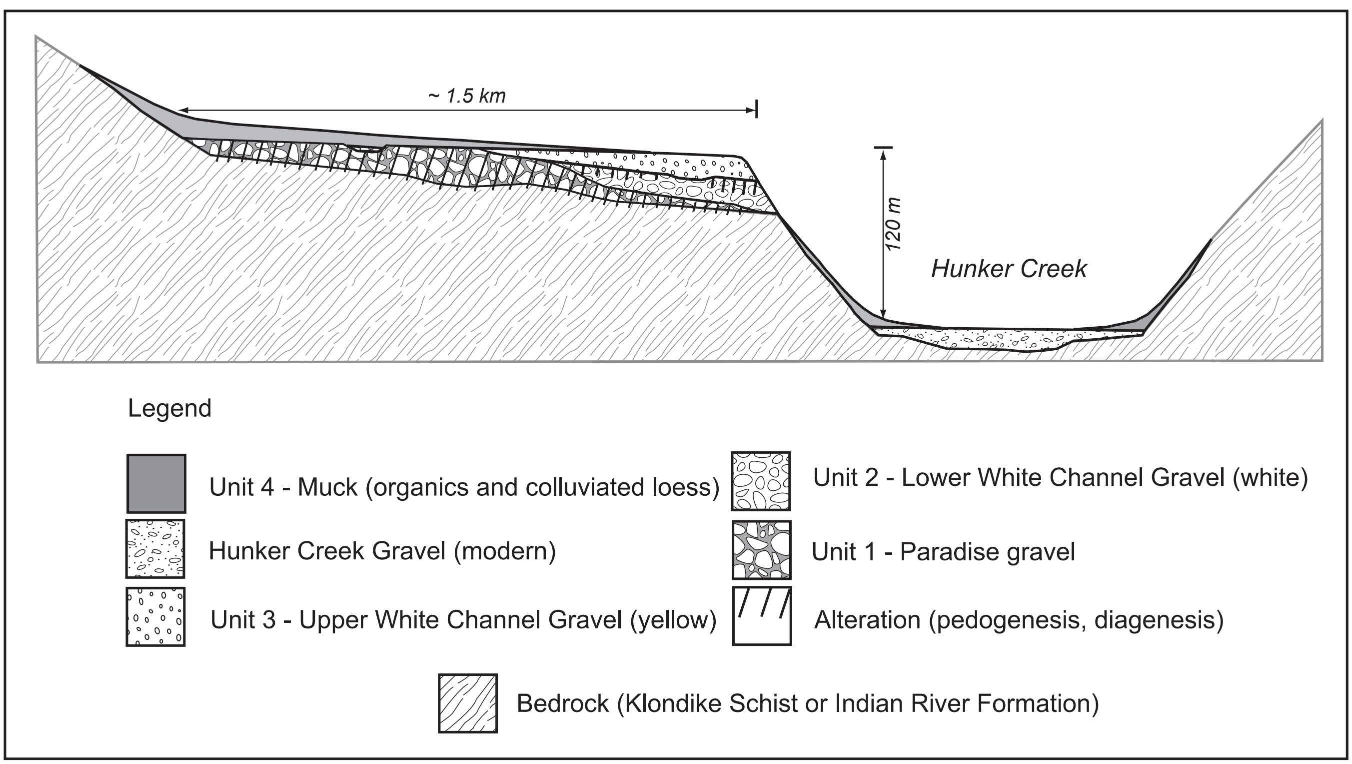

Figure 14. *An idealized cross-section (view downstream) for lower Hunker Creek depicting the Neogene stratigraphy. Note: units 2 and 3 (upper and lower White Channel Gravel) are inset into the Paradise gravel (unit 1).*

on Paradise Hill measured 50-150 m wide and 6 m thick suggesting a large channel was responsible for its deposition (Yukon Gold Company, 1913). In terms of pay thickness and modern mining, the entire 11.5 m section of Paradise gravel at Paradise Hill is processed. Locally, zones of gold enrichment occur at the upper contact with the overlying muck (Fig. 7); this is likely related to past surface weathering of the Paradise gravel and winnowing of decomposed clasts by intermittent surface runoff. At Paradise Hill, McConnell (1907) noted that there was a zone of gold enrichment on an undulating surface of siliceous gravel. This enrichment was likely emplaced when the lower White Channel Gravel incompletely eroded through the Paradise gravel and deposited a lag of placer gold. At Dago Hill, McConnell (1907) noted an important coarse gold channel on or near bedrock. This supports the economic significance of the Paradise gravel and that the White Channel Gravel is only economically enriched where it sufficiently reworks auriferous Paradise gravel.

Gold anomalies may not be the only elemental differences between the White Channel Gravel and the Paradise gravel. Dufresne *et al.* (1986) analyzed the 'Iron Zone' gravel (Paradise gravel) and concluded there were anomalous concentrations of Fe, Mn, As, Sb, Hg, Co, Ba and S within the matrix. A near-surface hydrothermal origin for the enrichment was suggested; however, these values could also reflect lithological differences associated with basin bedrock geochemistry at the time of deposition. In other words, the Paradise gravel may have been eroding bedrock containing more gold and associated pathfinder elements. However, Dufresne (1987) attempted to address this by comparing rhyolite and mica schist cobbles from different zones and concluded there were no noticeable geochemical changes. Given the decomposed nature of the Paradise gravel, his analyses may have only targeted competent clasts and ignored the decomposed lithologies. A reassessment of the clast geochemistry is recommended in order to evaluate the basin bedrock geochemistry at the time of Paradise gravel emplacement. In addition, the geochemistry of the newly mapped Indian River Formation on Paradise and Preido hills should be assessed to understand its contribution to the geochemistry of the Paradise gravel.

FLUVIAL GEOLOGY

Adding a pre-White Channel Gravel sedimentation event to the fluvial geomorphology of the Klondike has implications for placer reserves. Sedimentological studies used to reconstruct a paleoenvironment were largely focused on the upper and lower White Channel Gravel (Morison, 1985; Morison and Hein, 1987; Lowther *et al.*, 2014). The confined braided river system-model proposed for the White Channel Gravel does not necessarily apply to the Paradise gravel. Likewise, architectural element analysis completed by Lowther *et al.* (2014), while useful for characterizing the White Channel Gravel, does not address the sedimentology of the Paradise gravel. The stratigraphic reinterpretation presented here indicates that there is very little known about the river system responsible for eroding the bedrock strath and emplacing the primary placers. In particular, knowledge of channel morphology, such as width, sinuosity and number of channels has important implications for placer gold distribution.

Paradise gravel sedimentation was probably not localized at Hunker Creek. The paleovalley of lower Hunker Creek is exceptionally wide, which may have permitted stratigraphic preservation towards the valley margins. The apparent absence of Paradise gravel in Bonanza, Quartz, upper Hunker or Dominion creeks may be due to more complete reworking within these narrower valleys. Also, exposure of the lowermost gravel on the lower Bonanza Creek benches is limited in the current mining cuts. Exposures of the pay channel on the Quartz Creek bench and Gold Hill (Bonanza Creek at the mouth of Eldorado Creek) in 2015 contained relatively unaltered gravel; however, at both localities there was an abundance of subrounded quartz boulders similar to those documented in the Paradise gravel on Hunker Creek. These boulders, and a component of the placer gold, may be a residual feature of a reworked Paradise gravel.

Reworking of the Paradise gravel by the streams that deposited the White Channel Gravel, and the effect this would have on redistributing the placer gold, is poorly understood. McConnell (1907) touched on the topic of gold distribution resilience to reworking when he documented the complementary relationship between the creek and hill pay channels, despite 50-100 m of vertical incision separating the pay channels. This observation suggests that reworking may not completely destroy gold distribution patterns established during earlier emplacement events. Therefore, where the lower White Channel Gravel has completely reworked the Paradise Gravel, the gold distribution may still reflect the Paradise fluvial system. This concept of gold distribution resilience to reworking should be considered when conducting future sedimentological studies of placer deposits.

PEDOGENIC ALTERATION

Long periods of weathering and uplift were responsible for liberation of the gold-bearing veins into the Klondike fluvial environment (Morison and Hein, 1987). Our current knowledge of these weathering environments is limited, mainly because paleo-environmental information is poorly preserved. For example, no Neogene paleosols are preserved on the Klondike upland slopes due to Quaternary and Holocene periglacial weathering (Bond and Sanborn, 2006). Lowther *et al.* (2014) and Pound *et al.* (2015) provide a paleo-flora reconstruction from the middle of the White Channel Gravel sequence that suggests a much warmer climate during the Neogene. Confirmation that alteration at Paradise, Preido and Dago hills is a product of pedogenesis would present a unique opportunity to understand the interactions between Neogene climate and the fluvial, hillslope, and weathering processes that contribute to the placer emplacement and distribution.

AGE IMPLICATIONS

Paradise gravel is older than the lower White Channel Gravel, which in turn is poorly constrained to mid-Pliocene based on biostratigraphy of one pollen sample (Froese *et al.*, 2000). Accurate placement of the sample within the lower White Channel Gravel is challenging due to the cut and fill relationship between the upper and lower White Channel Gravel. A good example of this was described at Preido Hill where the lower White Channel Gravel is variably eroded by the upper White Channel Gravel. The contact between the two units is obvious where the clay-rich weathering zone is not eroded; however, if the clay altered zone is eroded then the contact between the two units is less clear (Fig. 12). For these reasons, it is possible that the pollen sample was collected within the upper White Channel Gravel and does not reflect a lower White Channel Gravel vegetation assemblage. Pound *et al.* (2015) describe a pollen assemblage from the contact between the lower and upper White Channel Gravel in upper Bonanza Creek as being similar to Late Pliocene environments from Alaska. This study adds further confirmation that the upper White Channel Gravel is Late Pliocene and is a minimum age for the lower White Channel Gravel. Additional pollen samples should be collected from the lower White Channel Gravel in sections where the contact relationships are clearly preserved. Similarly, samples for pollen analyses should be collected from the Paradise gravel. Additional studies using Terrestrial Cosmogenic Nuclides or weathering geochronology may provide an alternative technique to derive an age for the Paradise gravel.

SUMMARY

A stratigraphic reanalysis of the high-level gravel deposits on lower Hunker Creek show that a highly altered gravel is much more extensive on the bench surface than previously recognized. This gravel is responsible for eroding the bedrock strath and pre-dates the deposition of the White Channel Gravel. It is informally termed 'Paradise gravel'. Alteration of the Paradise gravel, possibly due to pedogenesis, preceded erosion and deposition of the White Channel Gravel, which facilitated the enrichment in quartz clast content in the lower White Channel Gravel. Primary gold concentrations on lower Hunker Creek bench surfaces are contained within Paradise gravel and are reworked into lower White Channel Gravel when erosion is sufficiently deep. Preservation of Paradise gravel may be due to the width of the Neogene valley at this location. Elsewhere in the Klondike, valleys are narrower, and were more likely to experience complete re-working of the primary Paradise gravel deposits.

A second alteration zone within the lower White Channel Gravel may represent a paleosol that formed prior to deposition of the upper White Channel Gravel. This period of quiescence is potentially correlative with the fluvial shut-down model proposed by Lowther *et al.* (2014). Paleosol studies are recommended as an important next step to understand whether or not surface weathering has affected these deposits. Identification of a paleosol would be significant for understanding Neogene paleo-climates in Yukon.

The paleo-river systems that deposited the Paradise gravel are poorly understood. Previous sedimentological studies have focused on the upper and lower White Channel Gravel, which typically have better exposure. Future exploration for undiscovered pay channels on the high-level benches in wide Klondike valleys will benefit from increased understanding of the Paradise gravel fluvial system. In addition, placer gold distribution within the Paradise gravel should be evaluated as thicker gravel sequences are exposed.

ACKNOWLEDGEMENTS

Advancing our geological understanding of placer deposits in Yukon depends on relationships with the placer miners. This research benefited from site access and knowledge shared by Tony and Minnie Beets (Tamarack Inc. – Paradise Hill), Kyle Bruce (Moonlight Mining Ltd. – Preido Hill), Neil Loveless and Lisa Favron (Favron Ent. – Dago Hill) and Don Ruman (Gold Hill). Appreciation is also owed to Stuart Schmidt (Schmidt Mining - Quartz Creek) for encouraging me on this Neogene stratigraphic tangent. Thank you to Alberto Reyes (University of Alberta) and Kristen Kennedy (YGS) for providing valuable technical feedback on this manuscript. Additional editorial improvements and layout were completed by Monica Nordling and Karen MacFarlane (YGS). Field tripping with Jim Mortensen (UBC) and Jim Ryan (GSC) on Paradise Hill helped identify new exposures of Indian River Formation. Finally, conversations with Sydney van Loon (YGS) on Paradise Hill helped confirm that the Paradise gravel is something different.

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