Compositional studies of placer and lode gold from western Yukon: Implications for lode sources

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ABSTRACT

On-going compositional studies of gold from placer and lode deposits and occurrences in western Yukon provide new insights into their nature and origin. Two main compositional populations are present in placer and lode deposits in the Klondike District. The dominant population has high fineness and low mercury content, and appears to be mainly derived from lode sources in the Lone Star, King Solomon Dome and lower Gold Run Creek areas. A second population of low fineness, high-mercury-content gold is derived from lode sources on the left limit of Eldorado Creek and in the headwaters of Bear and Last Chance creeks. Placer gold in the Sixtymile District was not derived from epithermal vein occurrences like those in the Sixtymile River valley but rather has compositions more similar to Klondike-type metamorphogenic veins. Placer gold in Scroggie Creek in southern Stewart River map area appears to be derived from intrusion-related vein occurrences.

RÉSUMÉ

Des études en cours sur la composition de l'or provenant de gisements placériens et filoniens ainsi que d'occurrences dans l'ouest du Yukon apportent un nouvel éclairage sur leur nature et leur origine. Deux principales populations statistiques de la composition sont présentes dans les gisements placériens et filoniens dans le district de Klondike. La population dominante, présentant un titre élevé et une faible teneur en mercure, semble dériver principalement de sources filoniennes dans les régions de la mine Lone Star, du dôme King Solomon et du cours inférieur du ruisseau Gold Run. Une deuxième population, à titre faible et à teneur élevée en mercure, est dérivée de sources filoniennes à la limite gauche du ruisseau Eldorado et dans le cours supérieur des ruisseaux Bear et Last Chance. L'or placérien du district de Sixtymile ne provient pas d'occurrences filoniennes épithermales comme celles de la vallée de la rivière Sixtymile, mais présente plutôt des compositions qui s'apparentent davantage à celles des filons métamorphogéniques de type Klondike. L'or placérien du ruisseau Scroggie dans le sud de la région de la carte Stewart River semble provenir d'occurrences filoniennes apparentées à des intrusions.

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INTRODUCTION

We are continuing our study of the composition and shape evolution of placer and lode gold in various localities in western Yukon. We aim to investigate the nature and evolution of placer gold and specifically the relationship between placer gold and potential lode sources. In this contribution, we report new analytical results from the Klondike and Sixtymile districts as well as Scroggie and Matson creeks (Fig. 1). These creeks contain smaller and poorly understood placer gold deposits for which no lode sources have yet been identified.
Yukon MINFILE occurrences cited in this document refer to Deklerk and Traynor (2005).

ANALYTICAL METHODS

Placer gold samples were either donated by individual placer miners or obtained by the authors by panning and/or sluicing. Placer gold grains were mounted in epoxy, ground down approximately half-way through the grain such that the interior of the grain was exposed, and then brought to a high polish. The grains were first examined using a scanning electron microscope to establish the assemblages of inclusion species and to determine the nature and thickness of leached high fineness rims. Compositions of cores were determined using an electron microprobe at The University of Leeds, United Kingdom. Individual spots were analysed for gold, silver, iron, mercury and copper.

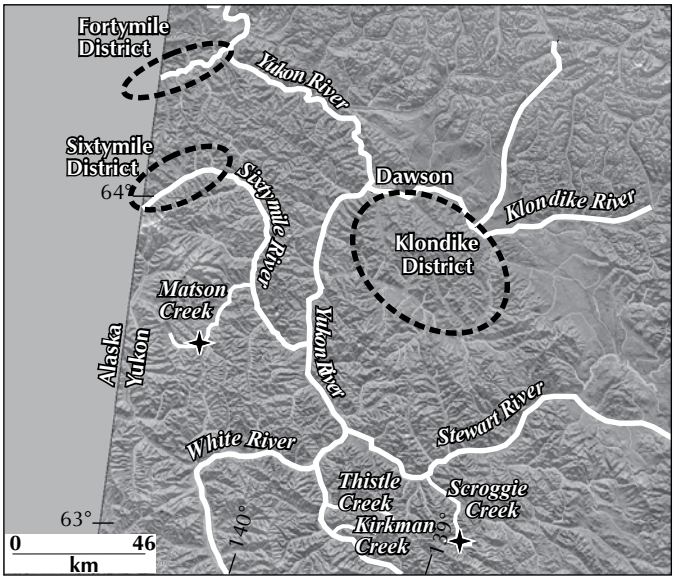

Figure 1. *Location map of western Yukon showing major placer districts and specific placer streams that are discussed in the paper.*

KLONDIKE DISTRICT

Previous studies of compositions and shapes of gold from placer deposits and lode occurrences in the Klondike District (Knight *et al.*, 1999a,b; Mortensen *et al.*, 2005) led to the following main conclusions:

- Preliminary shape studies of placer gold grains from the main drainages in the Klondike indicate that most gold appears to have originated from four main source areas; these are the King Solomon Dome area, the Lone Star mine area between Eldorado and upper Bonanza creeks, lower Gold Run Creek and middle and upper Bear and Last Chance creeks (Fig. 2)
- Two main compositional populations are represented in Klondike placer gold. The first and most widespread yields fineness values (purity out of a possible maximum value of 1000) in the range of ~700-850 with negligible to low mercury contents and rare trace amounts of copper, whereas the subordinate population is typified by lower fineness (~550-700) and up to 5 wt.% Hg.
- The high-fineness gold population contains nearly all gold from Dominion, Sulphur, Quartz, Eldorado and upper Bonanza creeks, as well as upper and middle Hunker Creek; it also comprises most of the placer gold on lower Bonanza Creek. Gold from lode occurrences in the King Solomon Dome area, Lone Star mine area and lower Gold Run Creek area show the same compositions as placer gold in streams draining those areas.

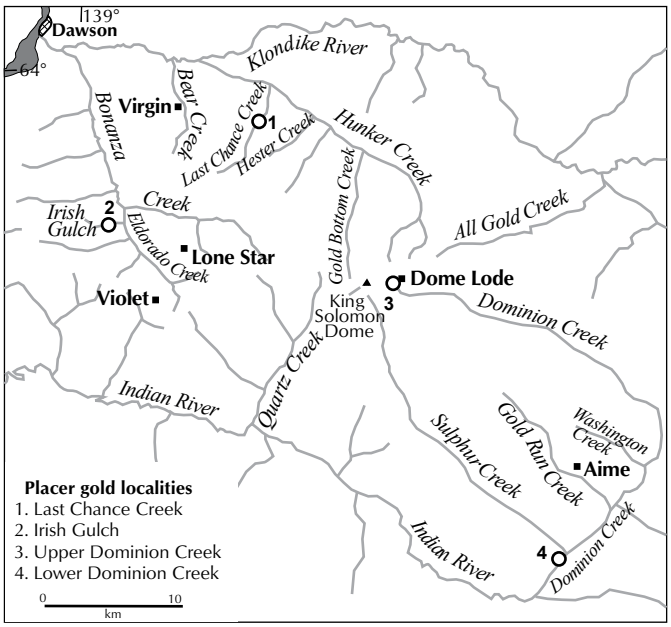

Figure 2. *Location map of the Klondike District showing the main placer streams and locations of specific placer gold samples (○) and lode gold (■) occurrences.*

- The low-fineness gold population is mainly restricted to north-draining streams in the northern part of the Klondike, including Bear, Last Chance and Hester creeks. Gold of this same composition is present at the Virgin lode occurrence on middle Bear Creek and at the Violet occurrence on the left limit of Eldorado Creek.

We have obtained and determined compositions for placer gold from four additional sites in the Klondike; these are Irish Gulch, uppermost Dominion Creek, lower Dominion Creek and middle Last Chance Creek (Fig. 2). We also analysed additional gold grains from the Aime lode occurrence on lower Gold Run Creek (Fig. 2) for comparison with placer gold in lower Dominion Creek. Compositions for gold from these localities are shown graphically, together with previously determined compositional data, in the form of cumulative frequency plots for silver and a plot of % Ag *vs.* % Hg for selected data sets in Figure 3. Mineral inclusions are very uncommon in placer gold grains from the Klondike, and there is currently insufficient data to facilitate analysis of placer populations using this criteria.

Placer gold recovered from an operation at the very head of Dominion Creek (Fig. 2) is rough and angular, with abundant attached quartz. Compositions are identical to gold from the Dome Lode occurrence on the ridge immediately to the east (Fig. 2), supporting the argument that the placer gold was derived from the Dome Lode veins or similar vein systems in the immediate King Solomon Dome area.

The main Dominion Creek paystreak begins at the head of the drainage but has largely disappeared by the mouth of Washington Creek (Fig. 2). A separate paystreak picks up at the mouth of Gold Run Creek and continues southwest past the mouth of Sulphur Creek to the junction with the Indian River. The placer paystreak on lower Dominion Creek extends several kilometres up lower Gold Run Creek, suggesting that a major lode gold source existed in this area. Preliminary analyses of rough to highly flattened gold grains from a placer operation on lower Dominion Creek near the mouth of Sulphur Creek (Fig. 2) shows the same general compositional range as gold from upper Dominion Creek and lode occurrences in that vicinity. Although it is unclear how much of the gold from the lower Dominion Creek locality was derived from Sulphur Creek, we note that gold derived from quartz veins at the Aime lode occurrence on the left limit of lower Gold Run Creek is identical in composition to the lower Dominion Creek gold. Additional samples are currently being analysed from Gold Run Creek itself to help evaluate how much of the lower Dominion Creek gold derived from Gold Run Creek rather than Sulphur Creek.

Placer gold from middle Last Chance Creek (Fig. 2) is mainly moderately flattened. Compositional studies indicate relatively low fineness (most silver contents in the range of 26 to 40 wt.% and low to moderate mercury contents (up to 0.9 wt.%). These compositions are similar to those previously reported from Bear Creek and from the Virgin lode occurrence on middle Bear Creek (Fig. 2).

Placer gold from Irish Gulch (Fig. 2) is typically very crystalline in character (B. and R. Johnson, pers. comm., 2005). A sample of gold from the middle portion of this short, steep drainage shows very low fineness values (most grains with silver contents of 26 to 46 wt.%) and moderate to very high mercury contents (up to 4.6 wt.%). Mercury contents in some of the Irish Gulch gold are so high that caution should be exercised by anyone melting this gold to make jewelry. In general, compositions of the Irish Gulch gold are similar to that from the Violet lode occurrence on the ridge southwest of Eldorado Creek, approximately 6.5 km southeast of Irish Gulch (Fig. 2). Our data suggests that the Irish Gulch placer gold was likely derived from Violet-like quartz veins that presumably occur for a considerable distance from the Violet occurrence along the ridge to the northwest. Interestingly, this low-fineness, high-mercury gold population appears to represent only a minor component of placer gold in Eldorado and lower Bonanza creeks (based on data reported by Knight *et al.* 1999a), suggesting that the lode sources on the left limits of these drainages were not significant contributors to the placer gold deposits.

SIXTYMILE DISTRICT

The Sixtymile District (Figs. 1, 4) is underlain by metamorphic rocks of the Yukon-Tanana Terrane that are overlain by mainly flat-lying Cretaceous sandstone and pebble conglomerate of the Tantalus Formation and subsequently by andesitic flows and breccias of the Late Cretaceous Carmacks Group (Mortensen, 1988; Fig. 4). Small high-level intrusions that represent subvolcanic feeders to the Carmacks volcanic rocks are also locally present. The structure of the Sixtymile District is dominated by a set of northeast-trending normal faults. Most of these structures are southeast-side down; however, a major fault along the southern side of the Sixtymile River valley is northwest side down (Fig. 4).

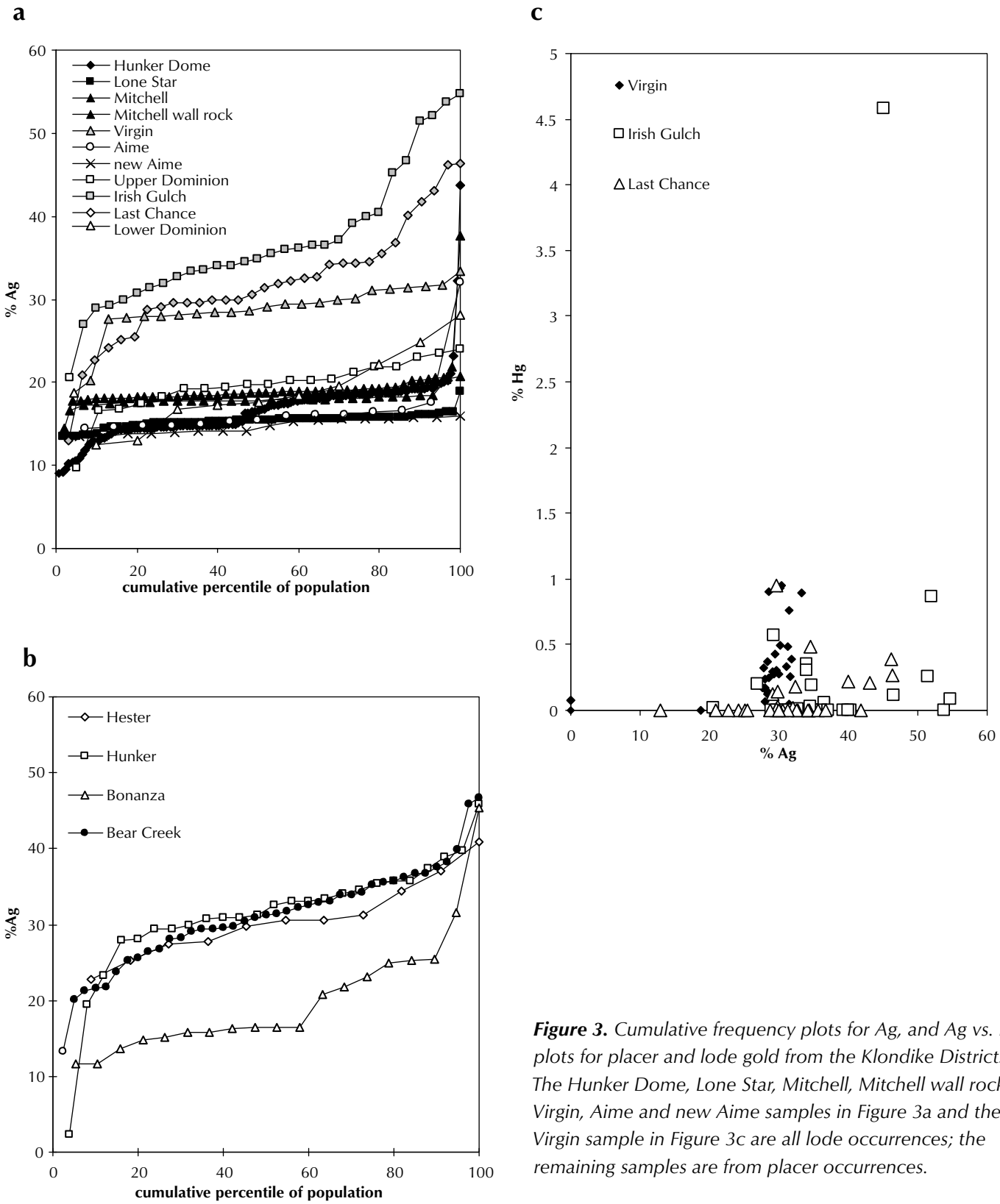

Figure 3. *Cumulative frequency plots for Ag, and Ag vs. Hg plots for placer and lode gold from the Klondike District. The Hunker Dome, Lone Star, Mitchell, Mitchell wall rock, Virgin, Aime and new Aime samples in Figure 3a and the Virgin sample in Figure 3c are all lode occurrences; the remaining samples are from placer occurrences.*

Thus, the Sixtymile River in the Sixtymile District flows along an asymmetric graben structure that progressively down-drops flat-lying panels of Tantalus Formation and Carmacks Group volcanic rocks to the level of the valley bottom. Numerous veins cut the Tantalus Formation, Carmacks Group and the metamorphic basement rocks. These veins commonly show crustiform banding and cockade textures, and fluid inclusion studies by Glasmacher and Friedrich (1992a) indicate that the veins are epithermal in nature. Only minor gold has been recognized within these veins; however, veins of this type are widespread in the Sixtymile River valley. This observation, together with the occurrence of abundant cinnabar in placer deposits on lower Miller Creek (Fig. 3), has led many workers to suggest that most of the placer gold in the Sixtymile District was derived from epithermal veins.

We have studied three samples of placer gold from the Sixtymile District. A large sample of gold from lower Miller Creek was donated by Jayce Murtagh; another sample from the Sixtymile River valley below the mouth of Little Gold Creek was donated by Greg Hakonson; and a final sample was obtained by panning from the middle reaches of Glacier Creek (Fig. 4). An additional small sample was panned from the headwaters of Moose Creek, which is a small stream that drains north from the Top-of-the-World Highway near the Yukon-Alaska border (Fig. 4), approximately 15 km north of the mouth of

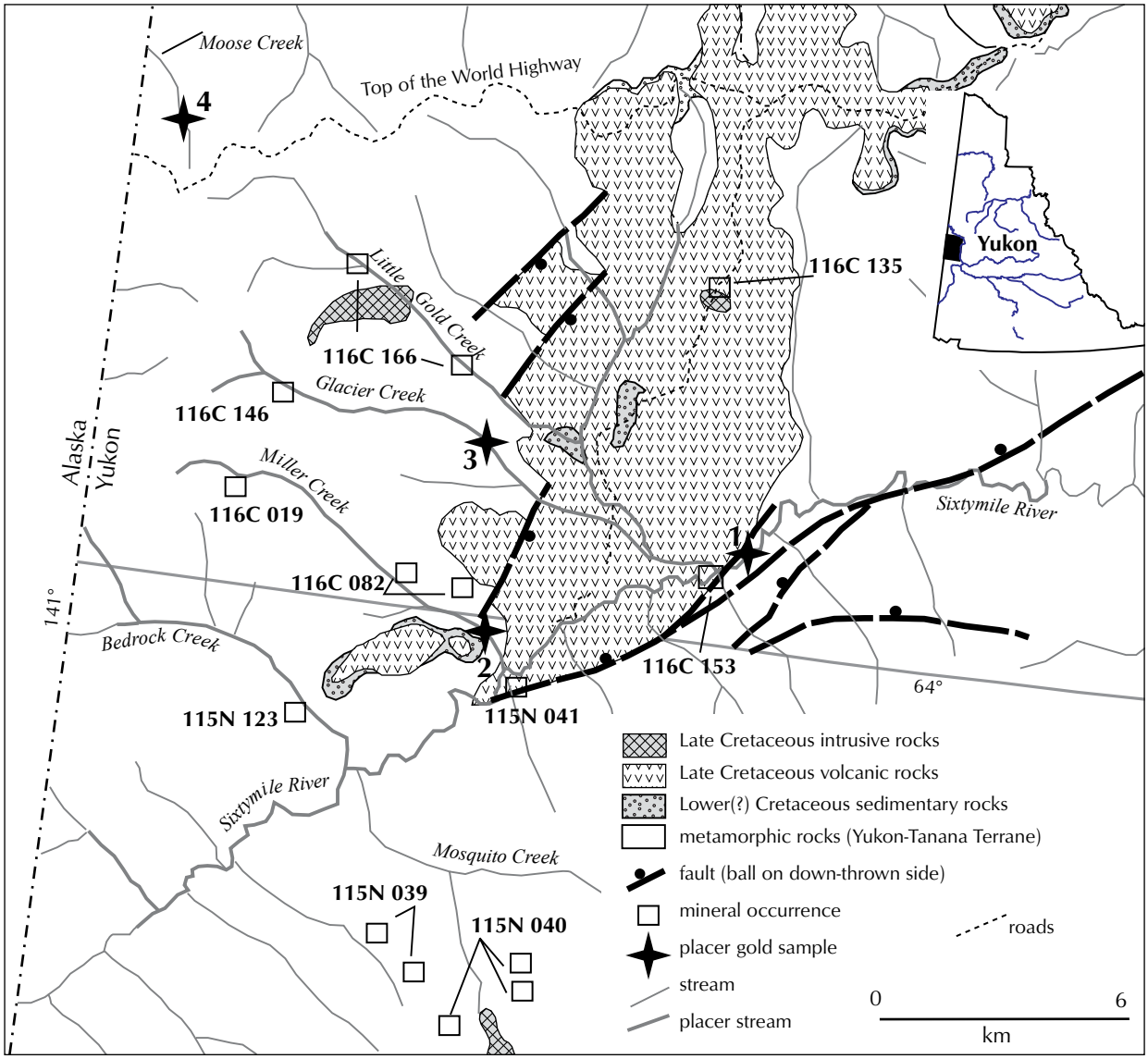

Figure 4. *Simplified geology map of the Sixtymile District (simplified from Mortensen, 1988, and unpublished mapping) showing locations of known vein occurrences and placer gold samples discussed in the paper.*

Miller Creek. Analytical data from the Sixtymile District placer gold are shown graphically as cumulative frequency plots for silver in Figure 5.

The lower Miller Creek sample mainly consisted of blocky to tabular grains with a few thin flakes; out of the 99 grains analysed from this sample, >90% of the grains contained 10-24 wt.% Ag. Only three grains contained mercury contents above detection limit on the microprobe; these grains had 1.3-4.0 wt.% Hg. A small number of gold grains were recovered by panning on Glacier Creek and nine grains were analysed. Silver contents range from 12.6-44 wt.% and none of the grains

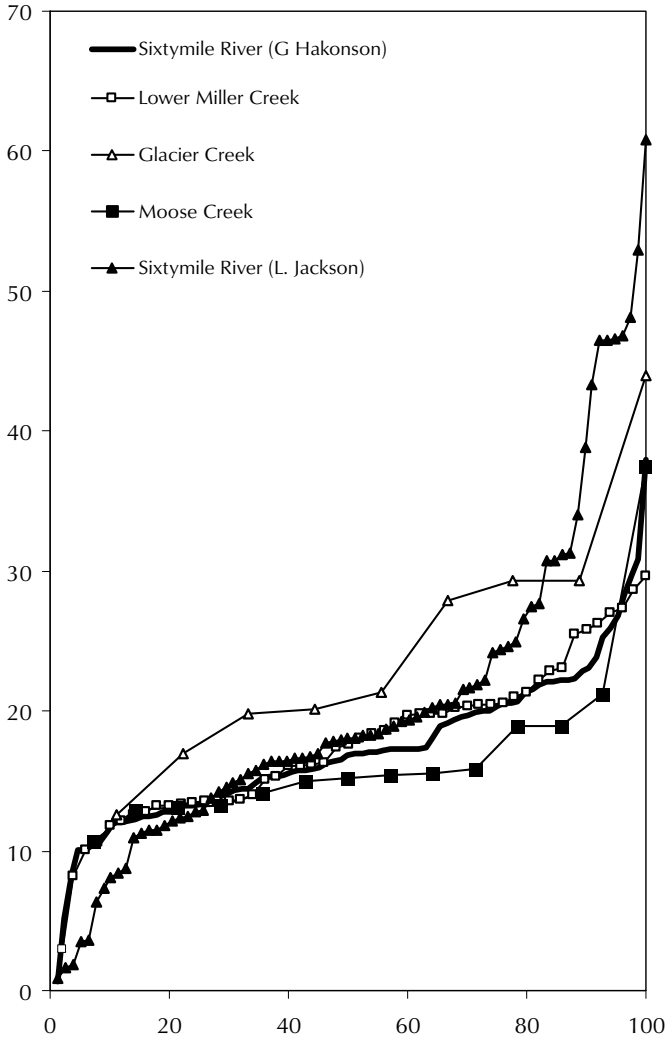

Figure 5. *Cumulative frequency plot for silver for placer gold from the Sixtymile District and Moose Creek. Additional data previously determined from a separate sample of placer gold from the Sixtymile River (exact location is uncertain) is shown for comparison and is labelled as "Sixtymile River (L. Jackson)".*

contained measurable mercury. Placer grains from the Sixtymile River sample (Fig. 4) range from rough and irregular to rounded to strongly flattened. Since this sample should be reasonably representative of all the placer gold in the Sixtymile District, we analysed a large number of grains. Measured compositions are very similar to gold from lower Miller Creek, with >90% of the grains yielding 10-24 wt.% silver and mercury mostly below detection limit (only two grains from the Sixtymile sample contain measurable mercury). Compositional data from another sample of placer gold, collected by L. Jackson from the Sixtymile River in approximately the same location as our sample, are shown on Figure 5 for comparison; data from the two samples are in very close agreement. A small number of placer grains analysed from near the head of Moose Creek, immediately north of the Sixtymile District, yielded compositions similar to the Miller Creek and Sixtymile River samples (silver-contents of 10-19 wt.% and trace amounts of mercury). Opaque mineral inclusions are uncommon in these samples; however, the sulphide- sulpharsenide assemblage observed in some of the grains was atypical of an epithermal signature (Chapman and Mortensen, in press).

The results of our study of Sixtymile District placer gold are somewhat surprising. In general, gold from epithermal veins commonly displays a wide range of silver contents and includes relatively high silver values (typically >25 wt.%, or fineness <750) and measurable to high mercury-contents (e.g., mean values of around 0.5%, with maximum values of about 10%; Chapman and Mortensen, submitted). Most of the gold from the lower Miller Creek and Sixtymile River samples has silver- and mercury-contents that are lower than those expected from epithermal vein sources. Glasmacher and Friedrich (1992a) described the mineralogy, mineral chemistry and fluid chemistry for several veins that are interpreted to be epithermal in origin in the Sixtymile District. For example, the Glasmacher occurrence (Yukon MINFILE[4] 116C 153), located in the bed of the Sixtymile River near the mouth of Little Gold Creek, contained trace amounts of gold. Analyses of gold formed during three interpreted stages of deposition yielded 4.8 wt.%, 24.6 wt.% and 19.8 wt.% Ag. The gold contained trace levels of tellurium and bismuth, but no detectable mercury. These silver-contents are on the low end of the compositional range normally associated with epithermal veins; however, fluid inclusion data reported for the vein by Glasmacher and Friedrich

[4]*Yukon MINFILE mineral occurrences listed in this report are from Deklerk and Traynor, 2005.*

(1992a) are fairly typical of epithermal veins. Only a single vein occurrence was studied, however, and it is unclear how representative these measured values are of gold in epithermal veins in the Sixtymile District. Other vein occurrences in the Sixtymile District that are thought to be epithermal in nature include the Per (Yukon MINFILE 115N 041), hosted by Carmacks Group volcanic rocks south of the Sixtymile River and the Guch (Yukon MINFILE 116 135), which is hosted by a small Late Cretaceous stock (Fig. 4).

There are two possible explanations for our gold compositional data for the Sixtymile District samples. Either the gold was derived from epithermal veins that represent an unusual end-member of the epithermal style (perhaps formed at relatively deep levels in an epithermal system), or the gold was mainly derived from an entirely different style of vein. Other styles of quartz veins have been recognized in the Sixtymile District, and some of these contain precious metals (mainly silver). Arsenopyrite-rich quartz-sulphide veins are widespread along and north of the ridge crest on the right limit of Sixtymile River (e.g., the Lerner occurrence — Yukon MINFILE 115N 039, and the Connaught occurrence — Yukon MINFILE 115N 040; Glasmacher and Friedrich, 1992b). These veins are relatively high in silver but are typically low in gold. Very little gold has been recovered from streams that drain this area (e.g., Mosquito Creek), suggesting that this set of veins do not represent a viable source of placer gold. A separate set of quartz-sulphide (± carbonate) veins cut metamorphic rocks on lower Bedrock Creek and on the middle and upper portions of Miller, Glacier and Little Gold creeks (e.g., the Bedrock occurrence — Yukon MINFILE 115N 123, the Yaremico 116C 082, the Miller 116C 019, the Cedar 116C 146, and the Little Gold 116C 166). These veins yield temperatures and salinities that are considerably higher than those typical of epithermal veins (temperatures of 320-350°C and salinities >18 wt.% NaCl equivalent). They are mineralogically and texturally very different from the epithermal-style veins that cut the overlying Tantulus Formation sedimentary rocks and Carmacks Group volcanic rocks (Glasmacher and Friedrich, 1992a,b). Lead isotopic studies of the two different styles of veining (Mortensen, unpublished data) also suggest that the vein systems are unrelated. The veins cutting metamorphic bedrock are weakly anomalous in gold, and locally, contain minor scheelite (U. Glasmacher, pers. comm., 1995), and therefore are the likely source of barite, scheelite, wolframite and possibly placer gold that occur in the placer deposits on lower Miller Creek. The veins within the metamorphic bedrock in the Sixtymile District are somewhat similar to gold-bearing orogenic quartz veins in the Klondike District.

SCROGGIE AND MATSON CREEKS

We have investigated gold compositions from samples of placer gold from Scroggie and Matson creeks (Fig. 1), for which no lode source has ever been identified. The drainage basins for both of these streams are underlain mainly by metamorphic rocks of the Yukon-Tanana Terrane; however, exposure is very limited in both areas and the geology of the local bedrock is poorly understood. The placers on Scroggie Creek have yielded considerable relatively coarse gold and gold nuggets. The gold that we analysed from this locality was finer grained and moderately to highly flattened. Gold analysed from Matson Creek mainly consisted of thin to thick tabular morphologies. Analytical data are shown graphically in the form of cumulative frequency plots for silver in Figure 6. Also shown for comparison in Figure 6 are silver-contents for gold from Thistle, Kirkman and Blueberry creeks, which are located west of Scroggie Creek. These data are from samples previously studied by Dumula and Mortensen (2002).

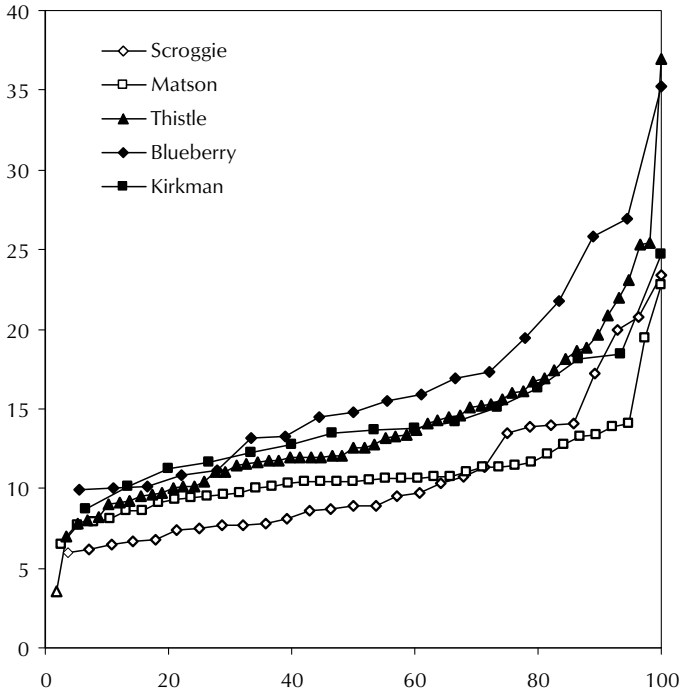

Figure 6. *Cumulative frequency plot for silver from Scroggie, Matson, Thistle and Kirkman creeks in southern Stewart River area.*

Gold compositions from Scroggie and Matson creeks are generally similar, with silver contents ranging from 5-13 wt.% (corresponding to fineness of 870-950). Gold from Thistle, Kirkman and Blueberry creeks gives slightly higher silver contents (8-20 wt.% Ag, corresponding to fineness of 800-920). Scroggie and Matson gold has mercury contents at or below detection limits and copper contents below detection limits. The similarity in gold compositions from these various creeks suggests a common source, and the low silver content is consistent with this being an intrusion-related source. Two tellurium-bearing inclusions were detected in gold grains from Scroggie Creek, which is suggestive of a magmatic component to the mineralizing fluids, and sets this gold apart from Klondike-style lode sources. Late- and post-tectonic intrusions of several ages (Early Jurassic, Early Cretaceous and Late Cretaceous) are present within the drainage basins of these placer streams and it is likely that the gold was derived from vein systems related to some of these bodies. The generally poor exposure in the Stewart River map area has made prospecting difficult; however, several mineral occurrences are known in the Scroggie and Thistle creek drainages and could have contributed gold to the placer deposits. The Mariposa occurrence (Yukon MINFILE 115O 075) on Mariposa Creek, a tributary of upper Scroggie Creek, is characterized by well developed gold-in-soil anomalies and some minor quartz-pyrite veining with anomalous gold values, although a substantial vein system has yet to be identified. The Black Fox and Hakonson occurrences (Yukon MINFILE 115O 014 and 106), on Lulu and Blueberry creeks, respectively (both tributaries of the upper Thistle Creek), are quartz-sulphide veins with negligible to moderately anomalous gold, and could be representative of the style of lode source from which the placer gold was derived. There are no gold-bearing occurrences known in the vicinity of the Matson Creek placer deposits and the ultimate source of the gold is uncertain. Porphyry-style molybdenum-copper (± gold) mineralization, thought to be associated with Late Cretaceous or Early Tertiary intrusions, occurs in the general vicinity. These occurrences include the Ladue (Yukon MINFILE 115N 026, located ~25 km southwest of the placer deposits) and the Pax (Yukon MINFILE 115N 029, in the Dawson Creek drainage ~10 km upstream from the placers). This style of lode occurrence may have been the ultimate source of the placer gold on Matson Creek.

ON-GOING RESEARCH

We continue to work on these and a large number of additional samples of placer and lode gold from western Yukon. We are focusing particularly on using laser ablation ICP-MS methods to more completely characterize the geochemical 'fingerprint' of the gold by expanding it to include a large number of trace elements. We are also developing a systematic, semi-automated image analysis procedure for quantifying the shapes of placer gold grains. This latter development will make it possible to apply a statistical approach to evaluating the evolution of the shape of placer gold grains during transport and construct better constrained correlation curves for grain shape *vs.* transport distance.

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