Evaluation of the origins of gold hosted by the conglomerates of the Indian River formation, Yukon, using a combined sedimentological and mineralogical approach

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ABSTRACT

Conglomerates belonging to the Indian River formation (IRF), south of the Klondike goldfield, have recently become the focus of exploration activity owing to their potential as hosts for paleoplacer gold derived from the Klondike. However, textures within the conglomerate have been interpreted as indicative of hydrothermal activity, and the possibility exists of *in situ* epithermal gold.

Paleocurrents in conglomerates indicate dominant transport from the southeast, incompatible with gold transport from the Klondike. Gold grains from unconsolidated conglomerate at Montana Creek reveal an epithermal signature (20-50% Ag, 0.3 to 3% Hg and opaque inclusion suite containing complex polymetallic sulphotellurides and sulphosalts), distinct from the signature of placer and lode sources in the central and southern Klondike (12-20% Ag, Hg absent and opaque inclusion suite of simple base metal sulphides). Gold grain morphology and alteration textures within unconsolidated conglomerates suggests that Montana Creek gold is derived from *in situ* epithermal mineralization related to that previously reported at Eureka Dome.

RÉSUMÉ

Les conglomérats de la formation d'Indian River du Crétacé tardif, au sud du champ aurifère du Klondike, sont récemment devenus le point de mire des activités d'exploration en raison de leur potentiel comme sources d'or de paléoplacers dérivé du Klondike. Cependant, la texture des conglomérats a été considérée comme un indice d'activité hydrothermale, et il est possible que de l'or épithermal soit présent in situ.

Les paléocourants dans les conglomérats indiquent que le transport s'est principalement effectué depuis le sud est, ce qui est incompatible avec l'hypothèse du transport de l'or à partir du Klondike. Les grains d'or de conglomérats non consolidés au ruisseau Montana révèlent une signature épithermale (Ag [de 20 à 50 %], Hg [de 0,3 à 3 %], cortège d'inclusions opaques composées de sulfotellurures et de sulfosels polymétalliques complexes) distincte de celle des sources filoniennes et placériennes du centre et du sud du Klondike (Ag [de 12 à 20 %], Hg absent, cortège d'inclusions opaques composées de sulfures simples de métaux communs). La morphologie des grains d'or et les textures d'altération dans les conglomérats non consolidés suggèrent que l'or du ruisseau Montana est le produit d'une minéralisation épithermale in situ semblable à celle déjà signalée au dôme d'Eureka.

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INTRODUCTION

The Indian River drains the southern Klondike goldfield (Fig. 1), and continues to be a major producer of placer gold in the region. In addition to the exploitation of placer gold in recent gravel deposits, several attempts have been made to recover gold from the Indian River formation (IRF), a Cretaceous sedimentary sequence (Albian, *ca.* 100 Ma), which outcrops to the south of the Indian River in several north-draining tributaries. The McKinnon conglomerate bed of the IRF was mined as early as 1899 at McKinnon Creek, although the auriferous potential of the conglomerate at other localities remains unproven. Recently, interest in the IRF has been renewed during exploration by Boulder Mining (2004), and Klondike Star Mineral Corporation (2005). An improved understanding of the relationship between the auriferous conglomerate and the other known gold sources in the region would aid future exploration in the area, both in terms of recent placer, as well as paleoplacer deposits. This report discusses sedimentological data collected from several conglomerate exposures, together with other units of the IRF. In addition to fieldwork, several drill core samples from McKinnon Creek (stored at the Bostock Core Library in Whitehorse) were also re-examined. Finally, gold grains collected from an exposure of conglomerate at Montana Creek have been analysed by scanning electron microscope (SEM) methods to permit comparison with other signatures of placer gold grains throughout the region.

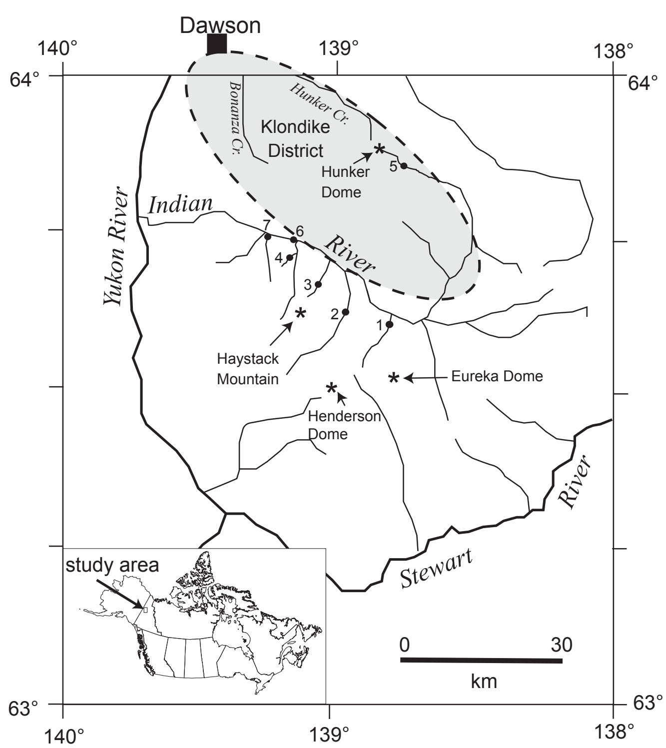

Figure 1. *Location map of study area (adapted from Chapman and Mortensen 2006). 1 = Eureka Creek; 2 = Montana Creek; 3 = McKinnon Creek; 4 = Diversion Creek; 5 = Upper Dominion Creek; 6 = road-cut near Arkenstall's camp; 7 = Boulder Mining pits. Klondike District is within dashed outline area.*

STRATIGRAPHY

The IRF has received little attention to date, and the most thorough investigation of the formation remains the PhD thesis of Grant Lowey (1984). Lowey (1984) presented a large amount of data which demonstrated the IRF to be a >500-m-thick, interbedded sequence of sandstone, shale, conglomerate and minor coal, deposited in a marginal marine basin by a southward-prograding fan-delta complex, during the Middle Albian (early Cretaceous). Lowey (1984) principally examined drill core samples collected during the 1970s and 1980s; these included cores 137-2 and 137-3 of Dome Exploration (also known as Yukon Revenue Mines), which are now stored in the Bostock Core Library, Whitehorse. Other drill core (e.g., IR-80-2) were examined and remain on site in the Indian River area. Outcrops were also studied by Lowey (1984), however, due to the nature of the terrain, outcrop exposures are of limited extent. One of the aims of the current project was to further identify exposures of outcrop with the help of local placer miners.

The IRF is in unconformable contact with a basement of Proterozoic/Paleozoic igneous and metamorphic rocks (including gneiss, schists and quartzite), and is locally intruded by, and overlain by, volcanic rocks belonging to the Haystack andesite and Carmacks Group (Fig. 2). It is bound to the north by the Indian River fault and to the west by the Ruby Creek fault. Documented outcrop exposures extend as far south as Henderson Dome and as far east as Eureka Dome (Fig. 2). At many localities, the IRF is overlain by recent gravel deposits and the contact may be indistinct where the conglomerate is unconsolidated.

The IRF consists of the following geologic units:

- Reindeer chert member (core 137-2 of Dome Exploration Ltd., depth 410.25-463 m; not observed in outcrop)
- Ruby quartz member (core 137-2 of Dome Exploration Ltd., depth 0-410.25 m)

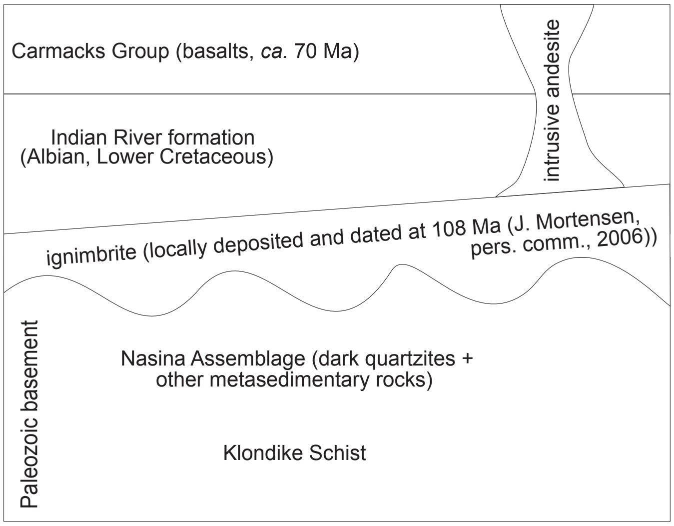

Figure 2. *Schematic diagram of stratigraphic relationships within the study area.*

- McKinnon conglomerate bed (part of the Ruby quartz member; outcrops along McKinnon Creek). Borehole P-75-1 of Dome Exploration Ltd. intersected at least 20 m of this unit.

The stratotype for the formation is the Dome Exploration drill core 137-2.

The McKinnon conglomerate bed is thought to be the regional equivalent of conglomerates of the Sixty Mile formation which outcrops to the north and northwest of Dawson, which suggests that they were deposited over a large area (Lowey, 1984). Conglomerates in the Indian River area are variable in terms of clast size, composition and degree of consolidation. In places, the conglomerate unit is highly silicified and consolidated, whereas elsewhere, it is poorly consolidated and breaks apart readily. In some instances, the boundary between these conglomerates and overlying, recent gravel deposits is diffuse, and difficult to identify.

POSSIBLE ORIGINS OF GOLD WITHIN THE CONGLOMERATE OF THE IRF

Relatively little information is available regarding the occurrence and nature of gold within the conglomerate. There are several possibilities for the origins of the gold, which are summarized as follows:

a) The gold resulted from *in situ* epithermal mineralization, related to the Carmacks volcanism (*ca.* 70 Ma).

b) The gold is detrital in origin and was transported from the Klondike goldfield located to the north and redeposited, together with other sediments, forming the conglomerate unit.

c) The gold is detrital in origin and was originally deposited in Quaternary placer gold deposits and was subsequently reworked into the underlying unconsolidated conglomerates of the IRF. The origin of the detrital gold may or may not be the Klondike goldfield.

In order to evaluate these possibilities, a combined sedimentological and mineralogical approach was adopted which involved inspection of outcrops for any textures indicative of post-depositional hydrothermal activity, reconstruction of paleocurrent directions, observations of the relationships of clasts to local and regional bedrock types, and comparison of the microchemical signatures of gold grains obtained from the study area to those of placer gold from Eureka Creek and the Klondike placer area.

SEDIMENTOLOGICAL INVESTIGATIONS

Exposures of the IRF conglomerate are rare, and where present, difficult to access. Outcrop exposures were identified at Boulder Mining's pits along the Indian River, McKinnon Creek, Montana Creek and Diversion Creek, as well as at a road-cut exposure 2 km east of Arkenstall's camp on the Indian River (Fig. 1). Drill core from the Indian River area were examined at the Bostock Core Library, Whitehorse. Although the drill core have sedimentary rocks that are cross-bedded, they do not provide paleocurrent data since the orientation of the drill core cannot be determined.

BOULDER MINING PIT

The IRF unconformably overlies Klondike Schist in Boulder Mining pit 2. In a poorly exposed section, a thin coal bed overlies the schist. The section is incomplete and most beds have been destroyed by mining activity. However, in places, 10-30-cm-thick beds of sandstone, and thin (<5 cm) beds of shale and pebbly sandstone are observed. No conglomerate beds are observed at this locality. This series of rocks is incised and overlain by recent gravel and sand deposits. Bedding appears to be sub-horizontal. The IRF in this section has largely been eroded and the total thickness of IRF is probably only a few metres. In the nearby Boulder Mining pit 1, the IRF is not observed and the Klondike Schist is overlain by recent gravel and sand deposits, which incise the schists and reflect a series of channel fills.

It is apparent from this location and others in the area, that where the IRF is not overlain by volcanic rocks of the Carmacks Group, it has been almost, or entirely eroded away.

MCKINNON CREEK

A section of the IRF is exposed from the old Brittania shaft (NAD 83, Zone 7, 0591630E, 7065083N), and extends northeastwards for 2 km. This shaft is now flooded, although the old workings include one of the best exposures of conglomerate in the area.

Previous work along McKinnon Creek

The McKinnon brothers discovered gold in conglomerate at McKinnon Creek in 1899 while establishing a winter route to the Klondike from the south. This unit is now known as the McKinnon conglomerate bed. The brothers continued investigation of the conglomerate for the remainder of their lives (T. Liverton, pers. comm., 2006). A 2.5-ton (2.3 tonnes) bulk sample from the 60-foot (18-m) level in the Britannia shaft on McKinnon Creek is quoted as yielding a grade of 0.69 g/t (0.02 oz/ton) by amalgamation of the stamp-mill product. This original work by the McKinnon brothers represents the only bulk sampling of subsurface conglomerate horizons; all other samples taken of the conglomerate unit were surface grab samples and core assays. Several other exploration programs have since been carried out and resulting grades from sampled ore are summarized in Table 1.

Comparison of these data concluded that the highest grades were obtained from the subsurface conglomerate samples.

Field observations

The area surrounding the shaft provides the best exposure of the McKinnon conglomerate bed. The conglomerate is clast supported. Clasts are predominantly vein quartz pebbles and fewer black quartzite clasts belonging to the basement Nasina Assemblage (Fig. 3). The matrix is a poorly sorted, fine to coarse sand. In places, the matrix is poorly consolidated, while elsewhere, it is much better consolidated and has been extensively silicified.

Bedding in the conglomerate can be difficult to identify. Bedrock faces that are exposed in an adit approximately 5 m from the Britannia shaft have strike and dip measurements of 010°/40° W and 012°/26° W. These may be localized dips due to faulting of the sequence, given that the large-scale geometry (according to the mapping of Bostock (1942) and the study of Lowey (1984)) suggests only very shallow dips for the IRF. Imbrication was not observed in the conglomerate.

A short distance downstream from the Britannia shaft (NAD 83, Zone 7, 0591794E, 7065282N), the conglomerate has a striking black appearance (Fig. 4), where the matrix is derived almost entirely from weathered Nasina quartzite. Intriguingly, the clasts have a bimodal size distribution: common, angular clasts of vein quartz measuring 0-2 cm along the long axis, and

Table 1. *Summary of gold grades reported from McKinnon Creek area.*

Exploration	Method/target	Au grade (g/t)
McKinnon brothers (Tough, 1987)	2.5-ton (2.3-tonne) bulk sample at 60-ft (18-m) level in Britannia shaft	0.69
Lisle, 1974	surface soil geochemistry	<0.01, with isolated anomalies of 0.01 – 0.25
Dome Exploration Ltd., 1979	assay of diamond drill core from McKinnon Creek road	values reported as 0.01
	assay of diamond drill core from McKinnon Creek road (935 to 939 ft [285 to 286 m] depth in hole 137-2)	0.18
Tough, 1987	cyanidation (60-ft level [18-m], Britannia shaft)	5.0 – 10.9
Davidson, 1994	assay of split core samples; drilled by Volcano Resources (43.5 to 48.5 ft [13.3 to 14.8 m] depth)	1.47
	assay of split core samples; drilled by Volcano Resources (73 to 76 ft [22 to 23 m] depth)	4.03
	bulk samples (500 kg) of conglomerate	0.04 – 0.118

Figure 3. *McKinnon conglomerate, exposed by the Britannia shaft. The conglomerate has a consolidated matrix containing vein quartz and minor basement clasts.*

Figure 4. *Striking black matrix and weak bedding in the McKinnon conglomerate, downstream of the Britannia shaft (notebook for scale).*

probably sourced locally; and rarer, large clasts (up to 10 cm along the long axis) of well rounded quartz, which presumably have been transported over a greater distance. Bedding at this location has a strike and dip of 005°/05° W, more in keeping with the regional dip.

The poorly exposed section of IRF can be observed northeastwards from the Britannia shaft, along the east bank of McKinnon Creek. The section is composed of conglomerate at the shaft and progresses into a sequence of volcanic rock (dacite), black conglomerate (as described above), andesite, mudstone, shale and sandstone (presumably IRF, but very poorly exposed), and finally a thick, andesite flow. The andesite flow is exposed for several hundred metres until the end of the section where the exposed bedrock intersects a ford in the creek. The precise relationship between the IRF and the volcanic rocks is not apparent, but it is probable that the volcanic rocks intruded the sediment locally.

MONTANA CREEK

A 3-m section of sedimentary rocks is exposed above Montana Creek (NAD 83, Zone 7, 0598575E 7054875N) and consists of pale-grey, coarse-granule conglomerate, interbedded with medium-grained sandstone. The granule conglomerate is poorly sorted and contains clasts of white quartz up to 2 mm in diameter. Several beds are cross-laminated, or cross-bedded. Talus near the outcrop has clearly defined, long tool marks and flute casts, however, these were not found *in situ* and thus can not be used to provide paleocurrent data. There is also a significant amount of organic material present, mostly as <1-cm fragments of coal and wood. Pyritic nodules up to 2 cm in diameter are also present. Strike and dip measurements of the sandstone beds are as follows: 128°/28° NE, 155°/32° NE and 155°/17° NE.

Lower down in the Montana Creek valley (NAD 83, Zone 7, 0598151E, 7055885N), recent placer mining activity has focussed on unconsolidated, Quaternary gravel deposits. The recent gravel deposits have been extensively mined, and it is possible that mining activity may have extended down into the uppermost portions of bedrock, that is, the underlying conglomerate of the IRF. It is very difficult to discern the contact between recent, Quaternary gravel deposits and the conglomerate of the Cretaceous IRF.

At Montana Creek, mine tailings are composed of large boulders (up to 1 m) of predominantly black Nasina quartzite, and lesser amounts of orthogneiss. These are

Figure 5. *Fractured and healed boulder of Nasina quartzite, from conglomerate at Montana Creek.*

extremely well rounded and polished, and many have fractures which have been subsequently healed by quartz (Fig. 5). Some blocks of consolidated conglomerate are also present and have a micaceous, sandy matrix, which is not silicified.

DIVERSION CREEK

Bedrock exposures of sand and gravel are located along the banks of Diversion Creek (NAD 83, Zone 7, 0584877E, 7070584N) and are overlain by recent, gold-bearing gravel deposits (Fig. 6). Based on composition and the presence of bedding and cross-bedding, this bedrock exposure has been identified as IRF. It is a poorly consolidated, clast-supported conglomerate, in a matrix of coarse, granular sand. Clasts vary in size from 1 mm to 4 cm across, and are generally sub-angular to sub-rounded. The composition is dominated by quartz, dark grey Nasina quartzite and weathered sandstone. The pure white vein quartz that characterizes the conglomerate at McKinnon Creek appears to be absent at this location.

Two hundred metres downstream of the above-mentioned outcrop, the conglomerate unit is a thick bed with much larger clasts, up to 30 cm across, in a matrix of medium sand. This conglomerate is composed of Nasina quartzite, vein quartz, schist, gneiss, kyanite and volcanic rocks of rhyolite. This composition, together with the notable absence of Carmacks basalts, suggests that this conglomerate belongs to the IRF.

Where the conglomerate is texturally finer (at the locality discussed above), bedding and cross-bedding are observed (Figs. 6, 7 and 8). Strike and dip measurements of the thinly bedded conglomerate at this location are as follows: 044°/05° NW, 050°/06° NW and 070°/04° NW. These shallow dips are consistent with the regional dip of the IRF.

The cross-bedding in finer grained gravel deposits has dips of 30° towards 320°, 34° towards 000°, and 24° towards 340°. The excavated cross-bedding plane revealed a strike and dip of 045°/30° NW (Fig. 8). All of these values are consistent with paleocurrents from the southeast.

Figure 6. *Exposure at Diversion Creek of thinly bedded, near-horizontal conglomerate overlain by recent gravel deposits.*

Figure 7. *Cross-bedding defined by lags of coarse-grained material within thinly bedded conglomerate at Diversion Creek.*

Figure 8. *Weak cross-bedding at Diversion Creek; pen in photo is parallel to cross-bedding. This face was excavated in order to obtain a strike and dip of cross-bedding.*

ROAD-CUT NEAR ARKENSTALL'S CAMP

Sandstone of the IRF are exposed in a road-cut on the north side of Indian River, 2 km east of Kam Arkenstall's camp (NAD 83, Zone 7, 0584094E, 7072601N). Outcrop in this section consists of a blocky, medium-grained, pale grey sandstone, unconformably overlying the metamorphic basement (Fig. 9). The sandstone contains dark flecks (coal?), is micaceous and well consolidated. Some blocks have wavy lamination, and in places, millimetre-scale cross-bedding. The sandstone beds have strike and dip measurements of 072°/22° N and 080°/20° N.

Two sets of cross-bedding were measured in different sandstone beds that are 20 m apart. The first set has an apparent dip of 32° towards 280°, implying paleocurrent from the southeast (Fig. 10). The second set has an apparent dip (planes are not visible) of 14° towards 120°, i.e., implying a paleocurrent from the northwest (Fig. 11). The former is consistent with that recorded at Diversion Creek. The latter is the opposite paleocurrent direction to that recorded at Diversion Creek. It should be noted that this data is in part consistent with some paleocurrent directions suggested by Lowey (1984), who indicates both southwest- and northwest-oriented transport directions for different parts of the IRF. It is clear that further study of paleocurrent directions is required, but this is largely hindered by the lack of suitable outcrop exposure.

Figure 9. *Contact (dashed line) between the metamorphic basement and the overlying sandstone of the IRF, at the Indian River road-cut. Approximately 6 m of section is exposed.*

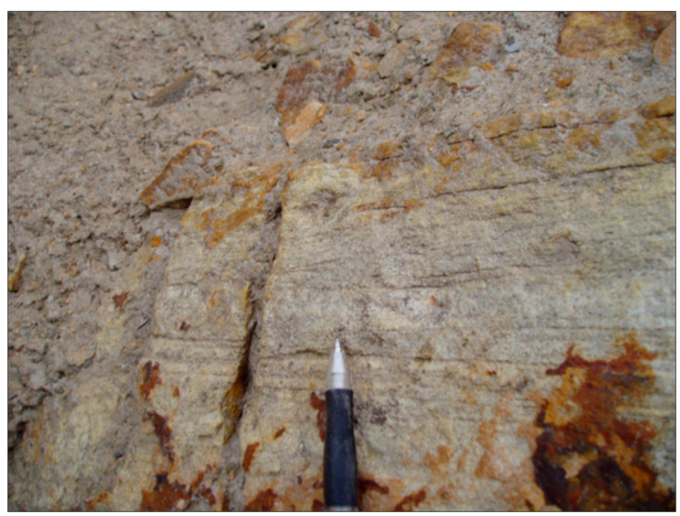

Figure 10. *Set of northwest-trending, millimetre-scale cross-beds at the Indian River road-cut.*

Figure 11. *Set of larger, southeast-trending cross-beds at the Indian River road-cut.*

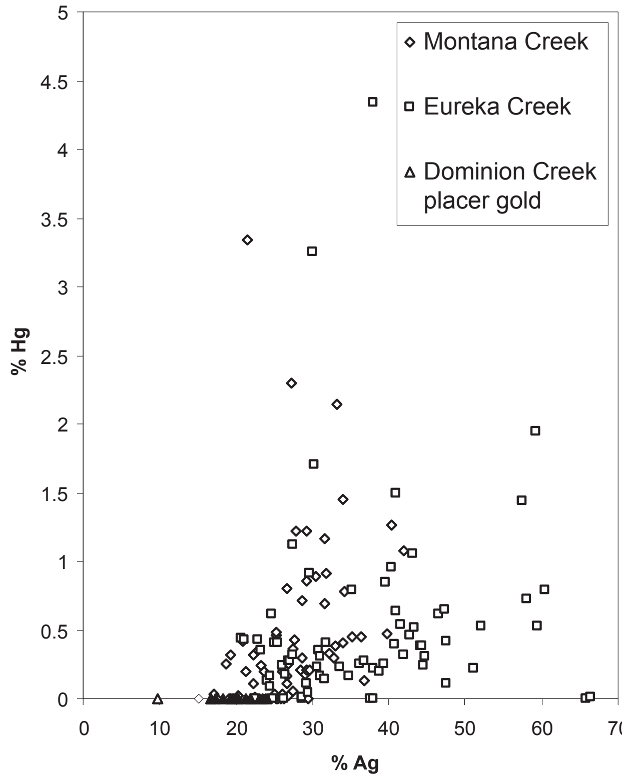

Figure 12. *Compositional variation in populations of placer gold from Montana Creek, Eureka Creek and Upper Dominion Creek. Orogenic gold from the south of the Klondike, typified by that from Upper Dominion Creek, has a relatively tight compositional field on the % Ag axis.*

MICROCHEMICAL ANALYSIS OF GOLD GRAINS

Populations of placer grains may be characterized in terms of the alloy compositions, internal textures and suites of opaque and transparent mineral inclusions. These data may be combined to provide a 'microchemical signature' which can be related to the style of source mineralization and also used to differentiate between placer gold grains derived from distinct sources.

Alloy compositions of gold from the Klondike have been reported by Knight *et al.*, (1999) and Mortensen *et al.*, (2004). The lode gold occurrences on Hunker Dome have been described as the orogenic type, and have a relatively simple mineralogy of gold (containing between 12% and 20% by mass Ag) and base metal sulphides (Table 2). This signature is also prevalent in placer gold from a drainage to the south of this lode occurrence (Knight *et al.*, 1999; Chapman and Mortensen, 2006). Study of placer gold grains from Eureka Creek and some grains from alluvium on Eureka Dome (Fig. 12) revealed a completely different chemical and mineralogical signature, and was interpreted as having an epithermal origin (Dumula and Mortensen, 2002). Further detailed studies of the mineralogy of the opaque inclusion suite by Chapman and Mortensen (2006) concluded that the source mineralization was of the low-sulphidation epithermal type and a temperature

Table 2. *Gold grain inclusion assemblages from Hunker Dome lode deposit, Eureka Creek placer deposit, and Montana Creek conglomerate. Py = pyrite, Ga = galena, Sph = sphalerite, Cpy = chalcopyrite, Arg = argentite, AgCuS = unidentified Cu-Ag sulphide, Asp = arsenopyrite, Hs = hessite, Tet = tetrahedrite, Cer = cervelleite, CuAgSbS = unknown Cu-Ag sulphosalt.*

		Number of grains containing inclusions of...										
	No. of grains	**Py**	**Ga**	**Sph**	**Cpy**	**Arg**	**AgCuS**	**Asp**	**Hs**	**Tet**	**Cer**	**CuAgSbS**
Hunker Dome lode	132	47	1	1	8	1	0	0	0	0	0	0
Eureka Creek placer	98	10	1	5	8	9	5	1	12	2	6	0
Montana Creek conglomerate	67	10	3		1	1	1	0	1	1	3	2

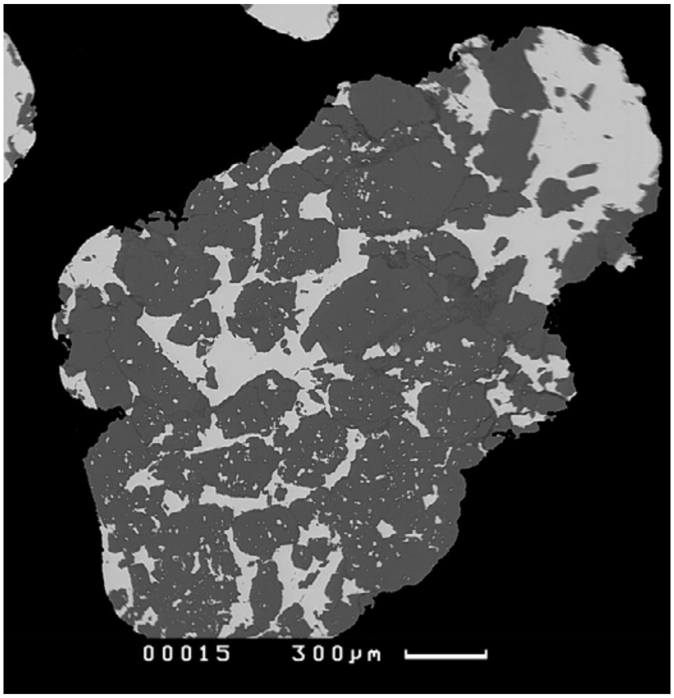

Figure 13. *Backscattered electron (BSE) image of a polished section of a composite gold-quartz grain from Montana Creek.*

of emplacement of around 200°C. These gold grains were characterized by elevated levels of Hg in the alloy (Fig. 12) and an opaque inclusion suite containing complex polymetallic tellurides, sulphotellurides and sulphosalts (Table 2). The opaque inclusions frequently occurred as tiny intergrowths (5 microns), a texture suggestive of post-depositional equilibration.

A sample of relatively coarse gold grains (0.5-3 mm) was obtained from an exploratory pit dug in unconsolidated conglomerate by Klondike Star in 2005 at NAD 83, Zone 7, 0598064E, 7055855N (V. Matkovitch, pers. comm., 2006). The grains are angular and many grains contain a large proportion of quartz; this was observed while examining polished sections by Scanning Electron Microscope (SEM) (Fig. 13). The results of microchemical characterization of these grains are included in the Montana Creek sample population (Fig. 12; alloy compositions) and Table 2 (opaque inclusion suite). The signature of the population is similar to that previously obtained for gold from Eureka Creek (Chapman and Mortensen, 2006); an epithermal origin is inferred.

DISCUSSION

Paleocurrent data were interpreted and transport is believed to have been towards the northwest in the conglomerate at Diversion Creek and within sandstone at the Indian River road-cut. This is consistent with data presented by Lowey (1984). Cross-bedding measured in another sandstone bed at the Indian River road-cut was interpreted as having a paleocurrent direction flowing to the southeast. Although unusual, it is not impossible that channels could flow in opposite directions from one time to another. Lowey (1984) also records southwestward transport for the IRF. Paleocurrent directions cannot be reconstructed from drill core because the orientation of these is unknown. The clasts observed in the conglomerates are all representative of local lithologies, some of which are present in the Klondike area. The clasts present are not indicative of any particular source area.

Present knowledge of the distribution of gold within the conglomerate (both in terms of geographical extent and depth in the unit) is insufficient to draw any firm conclusions regarding potential transport by fluvial action. However, far more information is available from the study of the gold grains themselves. This work has demonstrated that the gold obtained from the conglomerate at Montana Creek is not derived from the Klondike, but from epithermal mineralization, presumably associated with Carmacks Group volcanism.

The timing of the generation of the textures observed within the conglomerate and the large quartzite boulders contained therein at Montana Creek is unknown. It is possible that quartz veins were already present within the boulders prior to deposition of the conglomerate and that these quartz veins are related to the white vein quartz clasts within the conglomerate. If alteration occurred following deposition of the conglomerate, it can be explained by the following model:

a) long-range fluvial transport by a powerful flow, generating large, rounded boulders;

b) conglomerate deposition followed by matrix silicification, resulting in a competent rock;

c) fracturing of boulders during tectonism;

d) healing of fractured boulders by hydrothermal activity; and

e) subsequent partial degredation of the conglomerate cement during further hydrothermal activity.

However, hydrothermal fluids flowing through silicate rocks cool below about 400°C, and they become oversaturated in silica and precipitate quartz. Quartz dissolution requires either a pressure increase (unlikely for a fluid flowing through a conglomerate), or a high pH. Fluid buffered by silicate rocks, however, tends to be near-neutral to mildly acidic. Thus, the origins of the features described above remain problematic.

Lowey (1985) considered the extent of clay and quartz cementation of the conglomerate to be indicative of epithermal mineralization, but to date, there has been no reliable detections of gold within consolidated conglomerates. If this is indeed the case, it suggests that the most important gold values would be associated with the unconsolidated conglomerates belonging to the IRF, which are revealed only as a consequence of placer mining.

The texture of the gold grains from the conglomerate at Montana Creek is indicative of very limited fluvial transport. The angular morphology of the gold grains and the large amount of associated quartz is suggestive of transport distances of < 50 m (Townley *et al.*, 2003), however, the model of erosion from an epithermal source followed by rapid burial and fluvial reworking into the underlying conglomerate demands a proximal significant source, which has been completely eroded. Furthermore, although gold is capable of a significant amount of settling in unconsolidated sediments, this process is controlled by differential density; many of the gold particle grains studied here exhibit a low bulk density as a consequence of the amount of associated quartz (Fig. 13). The observations mentioned above lend further support to the possibility that the gold present in these sediments may have formed from *in situ* epithermal mineralization.

CONCLUSION AND FURTHER WORK

It is unlikely that gold found in the IRF originated from the Klondike area as is indicated by paleocurrent data. Furthermore, the chemical and mineralogical signature of gold grains extracted from unconsolidated conglomerate at Montana Creek is distinct from that of gold grains derived from orogenic lode sources in the Klondike goldfield. However, the chemical and mineral signature is consistent with that of gold grains obtained from Eureka Creek, which were previously characterized as low-sulphidation epithermal. The current hypothesis that unconsolidated conglomerates of the IRF host low-temperature epithermal mineralization can only be proven by the identification of gold-bearing mineralization *in situ*, and further work is currently ongoing to study the textures and mineralogy of conglomerates from various localities, as well as the signatures of populations of placer gold grains throughout the Indian River drainage.

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REFERENCES

Bostock, H.S., 1942. Ogilvie, Yukon Territory. Geological Survey of Canada, “A” Series Map , 711A, 1:253 440 scale (1 in to 4 mi).

Chapman, R.J. and Mortensen, J.K., 2006. Application of microchemical characterization of placer gold grains to exploration for epithermal gold mineralization in regions of poor exposure. Journal of Geochemical Exploration, vol. 91, no. 1, p. 1-26.

Davidson, G.S., 1994. Exploration report on the McKinnon Creek project, Indian River, Dawson Mining District. Energy, Mines and Resources, Government of Yukon, Assessment Report 093167 for Richlode Investments Corp.

Dome Exploration (Canada) Ltd., 1979. Drill logs for holes 137-1 to 137-4. Energy, Mines and Resources, Government of Yukon, Assessment Report 091354.

Dumula, M.R. and Mortensen, J.K., 2002. Composition of placer and lode gold as an exploration tool in the Stewart River map area, western Yukon. *In:* Yukon Exploration and Geology 2002, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 1-16.

Knight, J.B., Mortensen, J.K. and Morison, S.R., 1999. Lode and placer gold composition in the Klondike district, Yukon Territory, Canada: Implications for the nature and genesis of Klondike placer and lode gold. Economic Geology, vol. 94, p. 649-664.

Lisle, T.E., 1974. Preliminary geological report on the Mac, Ray and Tom mineral claims approximately 25 miles southeast of Dawson City. Energy, Mines and Resources, Government of Yukon, Assessment Report 060902 for Andac Resources Ltd.

Lowey, G.W., 1984. The stratigraphy and sedimentology of siliciclastic rocks, west-central Yukon, and their tectonic implications. Unpublished PhD thesis, University of Calgary, Alberta, Canada, 310 p.

Lowey, G.W., 1985. Auriferous conglomerates at McKinnon Creek, west-central Yukon (115O/11): paleoplacer or epithermal mineralization? *In:* Yukon Exploration and Geology 1983, K.J. Grapes and J.A. Morin (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 69-78.

Mortensen, J.K., Chapman, R.J., LeBarge, W. and Jackson. L., 2004. Application of placer and lode gold geochemistry to gold exploration in the western Yukon. *In:* Yukon Exploration and Geology 2004, D.S. Emond, L.L. Lewis and G.D. Bradshaw (eds.), Yukon Geological Survey, p. 205-212.

Tough, T.R., 1987. Preliminary geological report on the McKinnon Creek property. Energy, Mines and Resources, Government of Yukon, Assessment Report 092156 for Volcano Resources Corp.

Townley, B.K., Herail, G., Maksaev, V., Palacios, C., de Parseval, P., Sepuldeva, F., Orellana, R., Rivas, P. and Ulloa, C., 2003. Gold grain morphology and composition as an exploration tool: application to gold exploration in covered areas. Geochemistry, Exploration, Environment, Analysis, vol. 3, 29-38.