Morphological and compositional analysis of placer gold in the South Nahanni River drainage, Northwest Territories

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ABSTRACT

Placer gold has been reported in small amounts throughout the South Nahanni river drainage; however, the original source of the gold is uncertain. This study focuses on two types of placer gold in the area: (1) locally abundant grains derived from near Selena Creek, and (2) scattered grains recovered from streams throughout the South Nahanni drainage area. A shape analysis of all gold grains was completed and representative grains from each sample population were selected for imaging on the scanning electron microscope, along with analysis for Au-Ag-Cu-Hg values on the electron microprobe. The gold grains are typically >700 fineness and mercury is below detection levels (<0.20%). Approximately half the grains analysed from the Selena Creek area registered near to, or slightly greater than, detection levels of copper (<0.04%), whereas the majority of grains from the isolated showings had copper contents below detection levels. The results are compared with published morphological and compositional data for placer and lode gold in other regions.

RÉSUMÉ

La présence d'or placérien a été signalée en petite quantité dans l'ensemble du bassin versant de la rivière Nahanni Sud dans les Territoires du Nord-Ouest, mais une grande conjecture persiste quant à son origine. Cette étude est focalisée sur les deux types d'or placérien trouvés dans la région : 1) les grains abondants par endroits près du ruisseau Selena et 2) les grains épars récupérés dans des cours d'eau dans l'ensemble du bassin. Une analyse de la forme de tous les grains d'or a été effectuée et des grains représentatifs de chaque population échantillonnée ont été sélectionnés à des fins d'imagerie au microscope électronique à balayage suivie d'analyses pour Au-Ag-Cu-Hg à la microsonde électronique. De manière caractéristique le titre des grains est supérieur à 700 et leur teneur en mercure est inférieure aux seuils de détection (< 0,20 %). Approximativement la moitié des grains provenant de la région du ruisseau Selena ne présentaient que des concentrations de cuivre légèrement supérieures aux seuils de détection (< 0,04 %), alors que la majorité des grains provenant d'indices isolées renfermaient des concentrations de cuivre inférieures aux seuils de détection. Les résultats obtenus sont comparés aux données de morphologie et de composition publiées pour l'or placérien et l'or filonien provenant d'autres régions.

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INTRODUCTION

Since the 1920s, the South Nahanni River has been known as a 'dangerous river' by the people entering the region for various reasons (e.g., trapping, route to the Klondike, adventure, etc.), including the prospectors who were searching for gold in the area. An account of their efforts has been partially preserved by the names of the lakes, creeks and felsic intrusions, many of which are named after many of the early prospectors; Deadman and Headless valleys give some indication of the fates of those who did not survive their time in the region. The stories are also documented in books such as R.M. Patterson's "Dangerous River" (1953) and P. Berton's "The Mysterious North" (1956). Certainly the fate of the McLeod Brothers, who are alleged to have been discovered without their heads in the early 1900s after reportedly having found a mother-lode, or a 'good prospect', made for much speculation as to the cause of their deaths (e.g., cannibal Indian tribes, eight-foot-tall sasquatches, scavenging grizzly bears), and even more so with respect to the location of their lost gold mine (Turner, 1975).

While literature on the legends abounds (with varying degrees of exaggeration), the geological understanding of the source of the placer gold has lagged far behind. A study of placer gold-grain morphology and composition for the South Nahanni River watershed of the Selwyn and Mackenzie mountains, Northwest Territories, was undertaken in order to investigate the nature of, and to make inferences as to the origin of, the placer gold (Fig. 1). The study was initiated as part of the Mineral and Energy Resource Assessment (MERA II) conducted by the Geological Survey of Canada for Parks Canada over the 2004-2005 field seasons (Falck and Wright, 2007, in press). The purpose of the MERA II was to evaluate the precious- and base-metal potential of the South Nahanni River area; however, the question as to the source of scattered deposits of placer gold in the area was not fully addressed. This study aims to develop a preliminary characterization of the known placer gold in the area, in order to determine whether or not the gold is locally derived. This study will also make suggestions for possible mineral deposit settings from which the gold may have been derived (e.g., intrusion-related skarns or sheeted veins, Carlin-type sediment-hosted disseminated, orogenic vein, etc.).

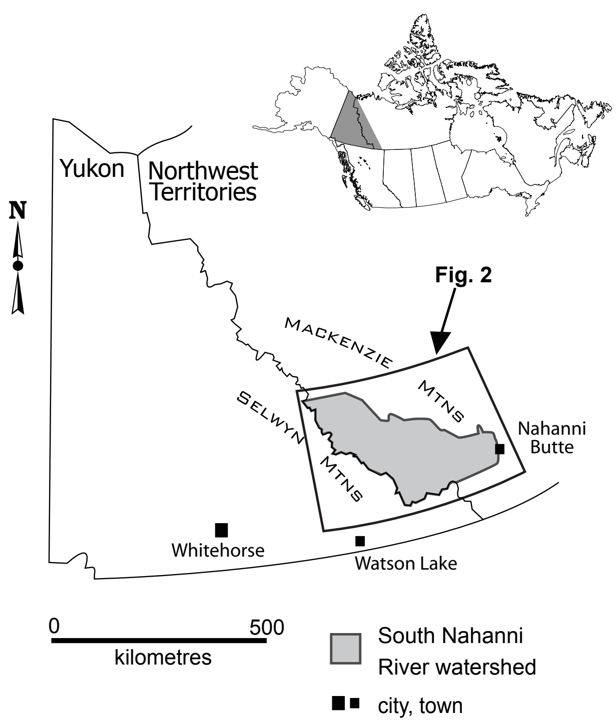

Figure 1. *Location of the South Nahanni River watershed in the Selwyn and Mackenzie mountains, southwestern Northwest Territories (adapted from Mortensen et al., 2000).*

To characterize and determine the source of the placer gold in the area, samples from two 'types' of placer occurrences were investigated:

(1) Locally abundant placer gold grains were recovered from Chuck Creek, in the Selena Creek area (referred to as the 'Chuck sample'). This sample was collected adjacent to the intermediate to mafic volcanic rocks hosting the Chuck copper (-gold) mineral showings documented in the Northern Minerals Database[4] (NORMIN) (Fig. 2). This area also has several known placer gold occurrences, as documented in NORMIN. Locations of these placer occurrences are shown in Figure 2. Gold grains were panned from a sample of light-coloured, clay-rich material with small limestone fragments. In the field, this material underlies an immature, cobble-boulder lag in the streambed. It is uncertain whether the clay-rich material is an oxidized till forming a basal layer of the creek, or part of an underlying linear feature, such as a fault (T. Christie and H. Smith, writ. comm., 2006). The gold grains were separated by hand from a concentrate composed predominantly of ilmenite-magnetite-barite, but includes specular hematite and an iron- and/or calcium-rich garnet (no sulphide minerals were present).

[4]*NWT Geoscience Office, Government of the Northwest Territories, 2006. Northern Minerals Database (NORMIN), www.nwtgeoscience.ca/normin*

(2) A collection of placer gold grains referred to as ‘isolated samples’ (36 grains from 8 sample locations and 18 unidentified/unlocated grains) were recovered from approximately 450 stream silt and heavy mineral concentrate (HMC) samples (Fig. 2). These samples were collected during the 1985-1987 field seasons for an earlier Mineral and Energy Resource Assessment (MERA I) conducted over the Ragged Ranges and Nahanni Karst and Tlogotsho Plateau regions (Spirito *et al.*, 1988; Jefferson and Pare, 1991) of the watershed (Fig. 2).

The distribution of the isolated samples is biased due to the limited HMC sample coverage within the entire South Nahanni River watershed. Areas that are not represented by the ‘isolated placer gold samples’, and which are thought to have a high potential for locally derived placer gold, are the southwestern corner where several placer gold occurrences are documented in NORMIN and where the Chuck sample is located, as well as the northern portion of the field area that has at least one primary intrusion-associated gold showing documented in NORMIN (Fig. 2). We are also restricted by the relatively small number of gold grains included in the isolated

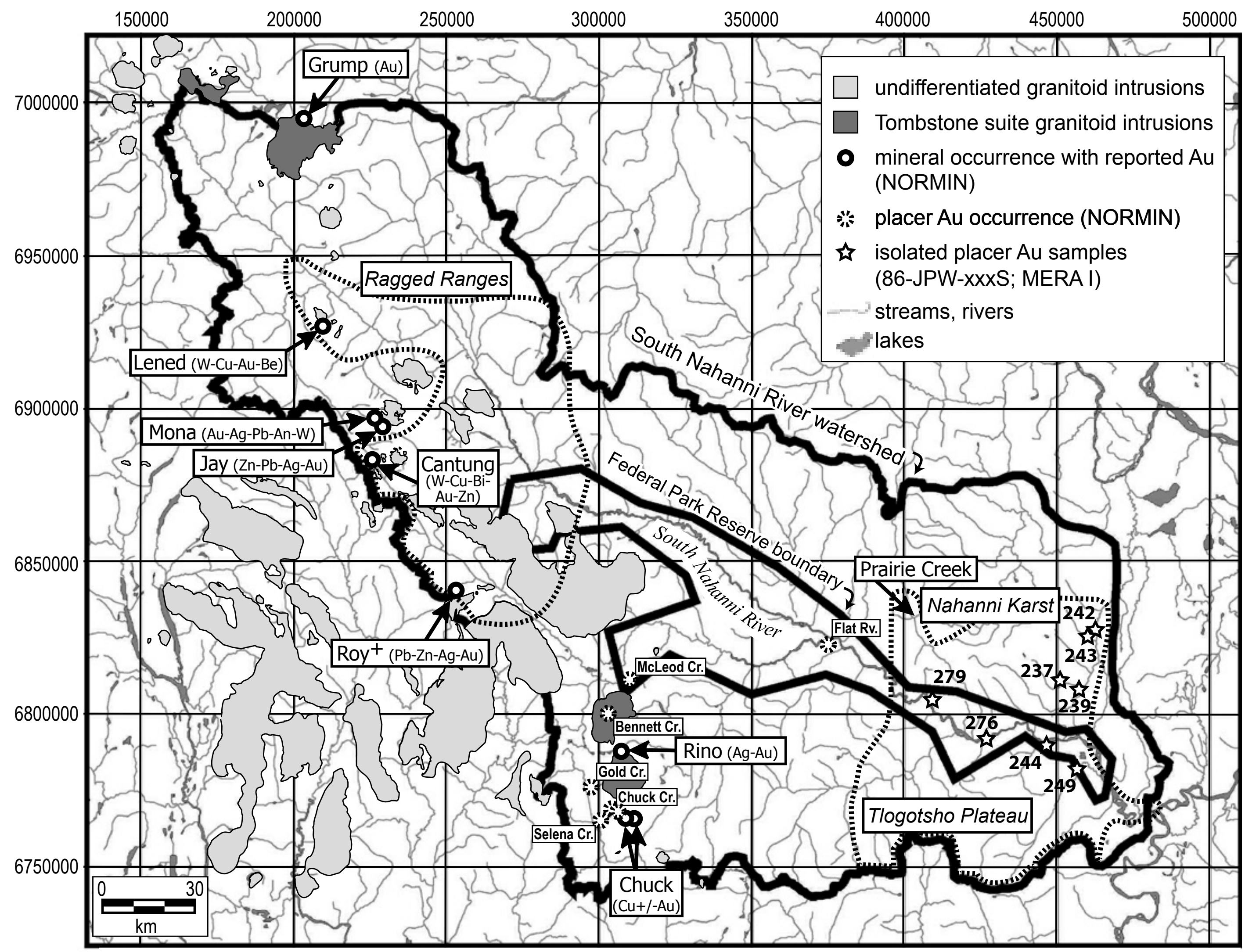

Figure 2. *Map of the South Nahanni River watershed area (Heffernan, 2004; Rasmussen et al., 2006). Approximate Ragged Ranges and Nahanni Karst-Tlogotsho Plateau HMC sampling regions from the MERA I are outlined by dashed black lines (Spirito et al., 1988). Locations of lode and placer gold occurrences (NORMIN) are also shown. Isolated samples of placer gold grains collected by C.W. Jefferson within Nahanni MERA I areas and made available for this study are represented by star symbols (Spirito et al., 1988; Jefferson and Spirito, 2003). The map grid is NAD 83, Zone 10 UTM coordinates.*

samples. A larger sample size is preferred in order to statistically characterize gold grain morphologies and compositions. This, in turn, limits the inferences we can make regarding the source of these samples. The Chuck sample, however, consisted of enough grains (>250) to completely characterize the placer gold morphology and composition for the Chuck placer gold showing.

PREVIOUS WORK IN THE SOUTH NAHANNI RIVER WATERSHED

Prospecting in the South Nahanni River region began near the turn of the 20th century, most likely as a result of historical reports by local First Nations (Dene) groups. The Dene discovered and mined large gold nuggets from local streambeds (as described by R.M. Patterson in "Dangerous River", 1953). This prospecting along the river and its tributaries has continued sporadically up until present day and has resulted in the filing of assessment work on six placer gold occurrences in the Nahanni region (Fig. 2; NORMIN). The majority of follow-up work was conducted on the five showings in the southwestern corner of the South Nahanni River watershed, which consist of the McLeod Creek, Bennett Creek, Gold Creek, Chuck Creek and Selena Creek placer occurrences (Fig. 2). The placer deposits were discovered either by prospectors panning, or during large regional stream sediment surveys (Gallup, 1973; Lenters, 1984). Following discovery, only a limited amount of work was conducted on these showings and consisted mainly of test pits on the placer deposits and minor prospecting to identify the source of the gold. Investigations of a select few of the claims included soil sampling and geophysical surveys, as well as geological mapping and prospecting (White and Cruz, 1973; Vulimiri and Crooker, 1989). The most comprehensive documented work has been in the Selena Creek area (Fig. 2), where there has been prospecting of two copper showings in the creek headwaters (McDougall, 1976; Stammers, 1983; Vulimiri, 1986) combined with several investigations of the placer gold deposits (Rowan and von Kursell, 1989; Cairns *et al.*, 1995).

Although anecdotal evidence suggests that small-scale placer gold testing and mining by individuals has taken place historically throughout the southwestern corner of the South Nahanni River watershed, records in NORMIN detailing exploration in the Selena Creek area only date from the early 1980s. The following geological summary of the Chuck occurrences is sourced from the NORMIN assessment files 095DNE0007 to 095DNE0010. From this area, anomalous placer gold and bedrock-hosted gold and copper (malachite, bornite and chalcopyrite) values were reported. The lode occurrences are hosted in intensely sericitized and locally highly silicified, intermediate to mafic volcanic rocks of the Lower Cambrian Sekwi Formation. The volcanic rocks are overlain by the calcareous Rabbitkettle Formation and crop out in the core of the southwest-plunging Caribou anticline. More recent work that has resulted in the completion of a second MERA in the South Nahanni River watershed (Falck and Wright, 2007, in press), as well as ideas proposed by Emsbo *et al.* (2006), have highlighted the possibility that the gold in the southwestern portion of the watershed may be derived from a Carlin-type gold deposit in the sedimentary and/or volcanic strata.

The results of the MERA I, conducted from 1986-1987 (Spirito *et al.*, 1988), also addressed the source of placer gold grains recovered by HMC sampling throughout the Ragged Ranges (none of which were available for this study), Nahanni Karst and Tlogotsho Plateau areas. The lack of evidence for continental glaciation in the western half of the South Nahanni River watershed led Spirito *et al.* (1988) to suggest that placer gold recovered from the Ragged Ranges area was locally sourced from intrusion-related vein or skarn mineralization. The most prospective suite of intrusions for hosting gold mineralization is the Tombstone suite (Fig. 2), which has a known affinity for gold mineralization both in the study area (Fig. 2) and elsewhere in Yukon (Mortensen *et al.*, 2000; Hart *et al.*, 2005). Some anomalous gold values are also associated with the tungsten skarns related to Tungsten suite intrusions (as documented in NORMIN) in the western part of the study area; however, no gold grains have been reported in proximity to the larger tungsten skarn occurrences, such as Lened or Cantung (Fig. 2), despite HMC sampling in that area. Unfortunately, none of the placer gold grains recovered from the western portion of the field area during the MERA I were available for this study.

Spirito *et al.* (1988) suggested two other possible sources for the fine placer gold recovered from isolated sample locations in the Nahanni Karst and Tlogotsho Plateau areas, south and east of the Prairie Creek minesite (Fig. 2). One hypothesis is that gold may have been locally derived from tetrahedrite-bearing sulphide veins with heterogeneous gold concentrations, such as those that crosscut base metal occurrences at Prairie Creek (Fig. 2). The spatial location of gold-bearing samples, that is, following a northerly trend not paralleled by till deposits, and at the intersection of north- and northwest-trending faults where gold-bearing quartz veins may occur, was thought to support such a local provenance for the gold grains (Jefferson and Pare, 1991; Jefferson and Spirito, 2003). Alternatively, gold may have been derived from the greenstone-hosted gold mineralization in the Precambrian basement of the Canadian Shield. This gold is believed to have been transported by continental glaciers from the east and concentrated by glaciofluvial reworking. The latter possibility has recently taken precedence based on the presence of granite clasts and garnet grains in glacial till, the lack of other precious- or base-metals with the gold, and the random locations of gold anomalies (Jefferson and Spirito, 2003).

ANALYTICAL TECHNIQUES

The shapes of gold grains were studied using image analysis employing ImageJ software, with which minor, intermediate and major axes lengths of grains were measured. This allowed the calculation of various flatness indices such as the Cailleux flatness index[5] (Cailleux and Tricard, 1959) as well as a statistical comparison of grain size and the degree of flattening each gold particle has undergone. Representative grains selected from the Chuck sample and all grains from the isolated placer samples were subsequently imaged with the minor axis of each grain parallel to the surface of the slide, using the secondary electron (SE) detector on the scanning electron microscope (SEM) in order to document surficial textures and particle morphologies (e.g., folding, crystallinity, etc.). Following SE imaging, a representative population of the Chuck sample (~180 grains) and all grains from the isolated samples were mounted in epoxy with the long axis of each grain perpendicular to the surface of the slide. The grain mounts were then brought to a high polish using 1 µ diamond paste, and analysed for gold, silver, copper and mercury on a fully automated CAMECA SX-50 electron microprobe (EMP) operating in wavelength-dispersion mode. The operating conditions were as follows: excitation voltage, 20 kV; beam current, 20 nA, peak count time, 40 s; background count time, 20 s; and spot diameter, 5 µ. The standards, X-ray lines, and crystals used for gold, silver, copper and mercury were as follows: Au element, AuMa, PET; Ag element, AgLa, PET; Cu element, CuKa, LIF; and HgTe, HgMb, PET. Data reduction was done using the 'PAP' (phi-rho-Z) method of Pouchou and Pichoir (1985). Detection limits for gold, silver, copper and mercury, respectively, were 0.30, 0.15, 0.07, 0.30 (wt% minimum), and 0.20, 0.10, 0.04, 0.20 (wt% limit). No sulphide inclusions were observed in any grains using the backscattered electron detector (BSE) on the EMP.

RESULTS

Chuck gold grains display relatively consistent morphologies, with somewhat flattened, smoothed grain outlines and limited local folding (Fig. 3a-f). Some grains, however, display complicated shapes with delicate protrusions; sub-spherical grains are rare. Gold grains from the isolated samples tend to have a more variable range of morphology, including commonly folded protrusions and/or grain margins (Fig. 3g-l). Some of these grains display smoothed but relict crystalline shapes, whereas others are almost spherical. Chuck gold grains also display less complex surficial textures than the isolated samples, which have abundant smear and groove marks, scratches, and dents (Fig. 3). It should be noted, however, that the isolated samples have been handled much more frequently with tweezers, which may explain some of the scratch marks or dents. Gold grains from the isolated samples also tend to be smaller in size compared to those grains from the Chuck sample (Fig. 3). Furthermore, the minor and major axes typically measure <0.05 mm and <0.20 mm respectively for gold grains of the isolated samples, while the gold grains from the Chuck sample have minor and major axes measuring <0.15 mm and <0.50 mm, respectively (Fig. 4).

Gold grains from the Chuck sample have a range of low Cailleux flatness index values, typically between one and six, which do not appear to be a function of gold fineness[6] (Fig. 5a). The gold fineness values are relatively high, typically from 800 to 975. In the Chuck sample, copper and mercury were typically below standard detection levels (wt% minimum), but approximately one-third contain copper concentrations between 0.04 (wt% limit) to 0.11 wt% (Fig. 5b). At copper concentrations above 0.04%, there is a clear covariant relationship between copper and gold fineness for gold grains of the Chuck sample. Despite the range of grain morphology

[5]*Cailleux flatness index is a simple measure of the mass redistribution a malleable particle undergoes due to hammering and/or folding during transport in fluvial systems (Youngson and Craw, 1999); if (a), (b) and (c) are the lengths of the long, intermediate and short axes of a particle, respectively, the Cailleux flatness index* $= (a + b) / 2c$

[6]*fineness* $= Au/(Au + Ag) * 1000$, *if Au and Ag are in wt%*

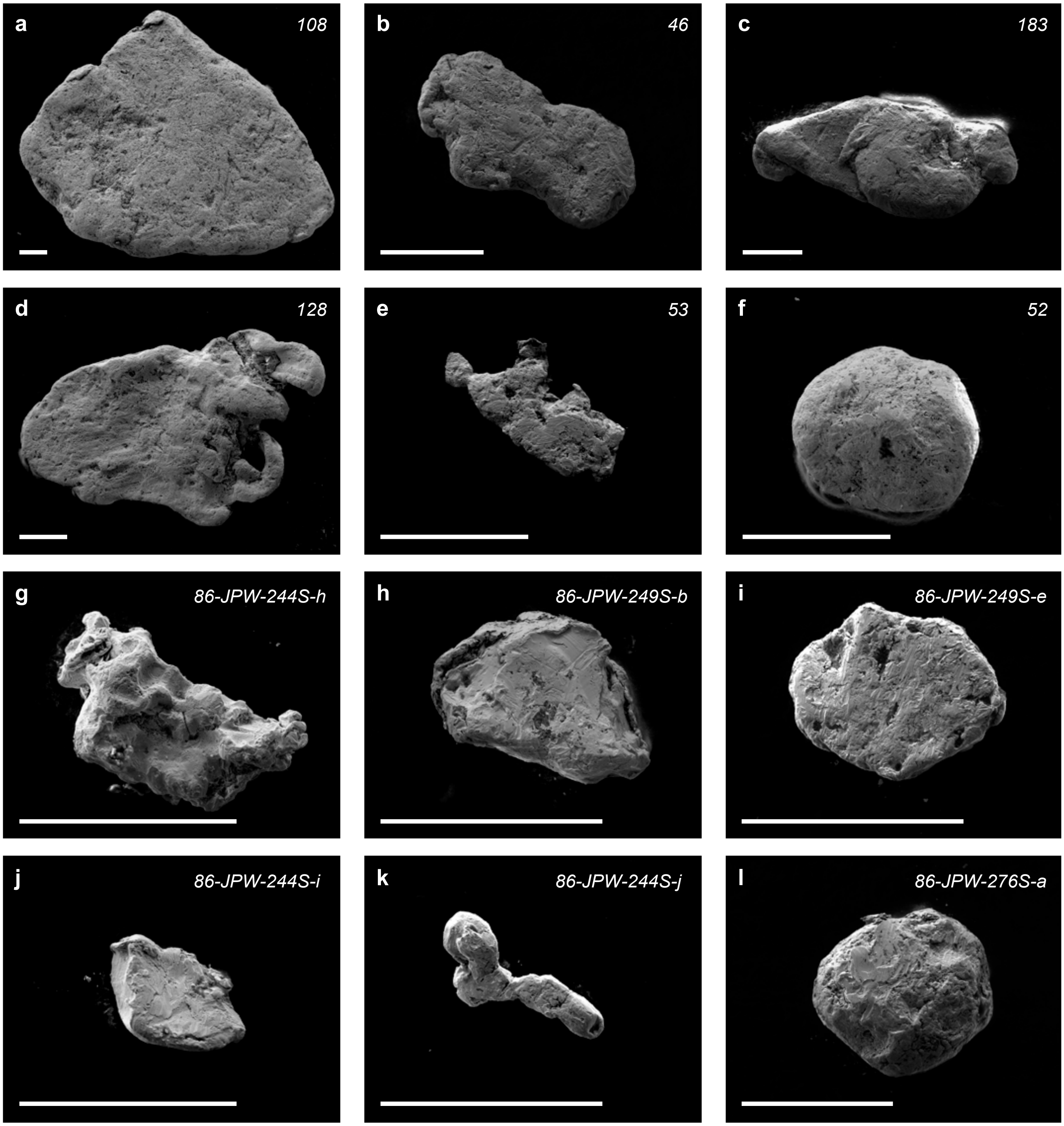

Figure 3. *Placer gold grain morphologies for grains from the Chuck sample (a-f) and grains from the isolated sample locations (g-l). Grain numbers for the Chuck sample, as well as sample number and grain letter for the isolated samples are noted; the minor axis of each grain is perpendicular to the surface and the white bar represents 200 microns.*

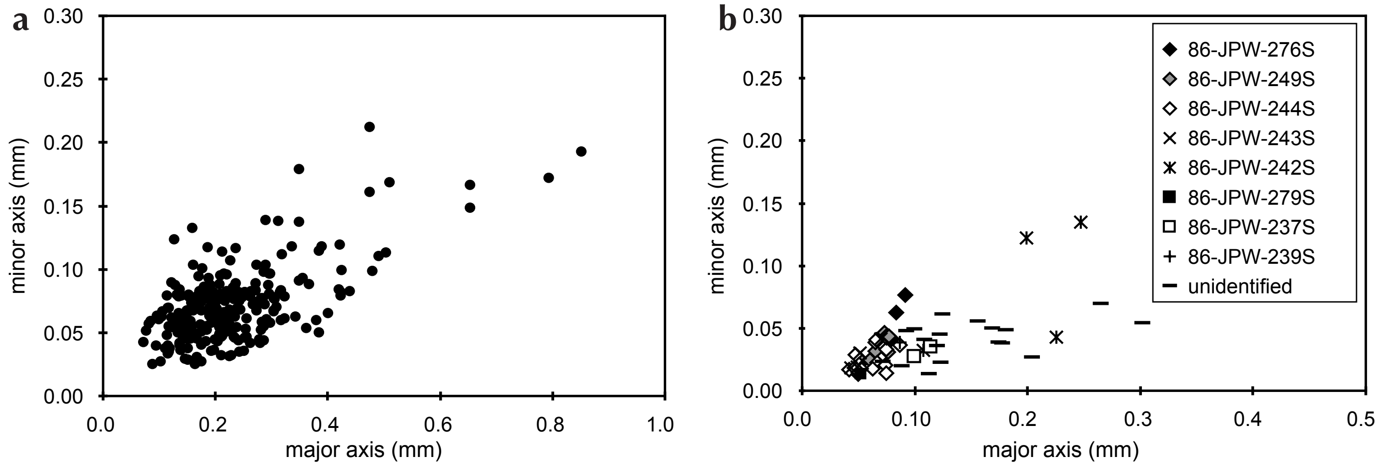

***Figure 4. (a)** Plot of minor axis vs. major axis for gold grains from the Chuck sample; **(b)** plot of minor axis vs. major axis for gold grains from isolated samples; note the different scales on the x-axis.*

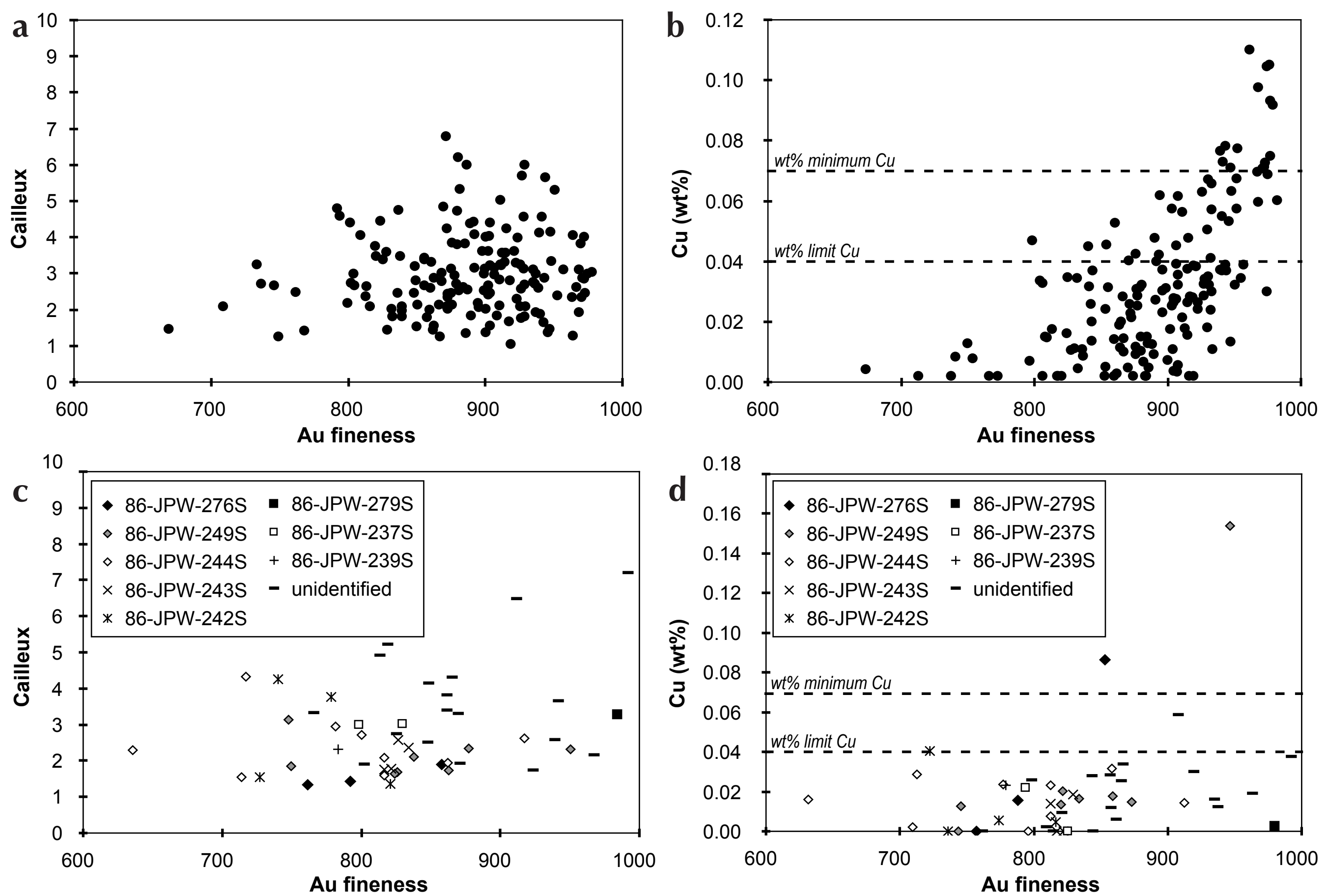

***Figure 5. (a**) Plot of Cailleux flatness index vs. gold fineness for the Chuck sample; **(b)** plot of copper content vs. gold fineness for the Chuck sample; **(c)** plot of Cailleux flatness index vs. gold fineness for isolated samples; **(d)** plot of copper content vs. gold fineness for isolated sample locations.*

observed, placer gold from the isolated samples are relatively consistent with respect to the Cailleux flatness index, typically between one and five for samples with known locations (Fig. 5c). Gold fineness values are also high, from 700 to 950, but have a greater range than the Chuck sample. Mercury (not shown) and copper were not detected by EMP analysis in the majority of these grains (Fig. 5d).

DISCUSSION

TRANSPORT DISTANCE

Measurements of the degree of flattening is one of the most useful parameters in determining approximate distances of transport for placer gold grains in fluvial systems (e.g., Knight *et al.*, 1999a; Youngson and Craw, 1999). Detailed work on placer gold grain morphologies from known lode sources in the Klondike District, western Yukon, and the Otago Schist Belt of South Island, New Zealand, has resulted in semi-quantitative curves relating observed transport distances to the degree of flattening of a population of gold grains (Knight *et al.*, 1999a; Youngson and Craw, 1999). The Shotover/Arrow-Kawarau-Clutha fluvial system in Otago, New Zealand, transects a back-arc region currently undergoing active exhumation, but with relatively low topographic gradients and low levels of precipitation (Youngson and Craw, 1999). This setting is similar to the tectonic regime experienced in the Selwyn and MacKenzie mountains from the mid-Jurassic through to at least the Cretaceous (e.g., Gordey and Anderson, 1993). Placer gold in Otago is sourced from sparse quartz veins hosted in schistose metasedimentary rocks of the Otago Schist. Youngson and Craw (1999) have shown that the Cailleux flatness index of placer gold grains increases with transport distance in the Otago Schist Belt. Flatness index ranges from approximately 1 (spherical or cubic) to just over 130 (highly flattened and folded discoids, or elongate/irregularly folded discoids, or sub-spherical/ellipsoidal) for the most far-traveled grains in Otago. Based on the data compiled by Youngson and Craw (1999), gold grains with maximum Cailleux flatness values of less than seven are found in proximal primitive-placer zones and are largely undeformed; they have traveled 1 to 10 km from the lode gold source. Furthermore, grains with maximum Cailleux flatness values of 1 to 3 are found in primary or colluvial sources and have crystalline and delicate morphologies; they in turn have traveled less than 1 km from the lode gold source. Although the distances determined in the Otago study apply specifically to Otago placer gold (Youngson and Craw, 1999), the validity of their data is extended to our study area based on a similar tectonic and geographic regime.

The majority of gold grains in the Chuck sample have variable, but anomalously low, Cailleux flatness indices of <7, indicating that they have been transported very little distance (e.g., 1-10 km) in a fluvial environment. Similarly, gold from the isolated samples also have anomalously low Cailleux flatness values, which for many of the samples is <3. The limited flattening of the grains could also indicate a local provenance rather than the glacially transported hypothesis first suggested by Spirito *et al.* (1988) for the isolated samples. Other possibilities are: (1) grains reworked from a local primitive paleoplacer; or (2) grains sourced from a nearby primary lode gold source (Youngson and Craw, 1999). Due to the statistically small number of grains recovered, each of the isolated samples cannot be fully or statistically characterized with respect to the degree of flattening, although the lack of highly flattened grains or higher Cailleux flatness index values significantly lowers the likelihood that the grains have traveled more than 10 km in a fluvial system, regardless of whether or not glacial transport was involved at some point in time.

POSSIBLE LODE GOLD SOURCES

As discussed previously, several possible lode sources have been suggested for the placer gold grains in the South Nahanni river watershed, including:

(1) intrusion-related mineralization, either in intrusion-hosted vein systems (similar to the Dublin Gulch deposit west of Mayo, Yukon; e.g., Mortensen *et al.*, 2000), or possibly disseminated in skarn, or siliceous contact aureoles (Spirito *et al.*, 1988);

(2) a Carlin-type lode source for at least the Chuck samples (e.g., Emsbo *et al.*, 2006; Falck and Wright, 2007, in press);

(3) tetrahedrite-bearing sulphide veins cross-cutting fault-controlled base-metal mineralization such as at Prairie Creek (Spirito *et al.*, 1988; Jefferson and Pare, 1991); and/or

(4) glacially transported gold derived from orogenic quartz veins in the Slave craton to the east (Spirito *et al.*, 1988; Jefferson and Spirito, 2003).

Other possibilities include epithermal-related mineralization and gold formed within the fluvial system by chemically or microbially induced precipitation (authigenic). A derivation of placer gold from an epithermal lode is rejected because of the relative homogeneity and high levels of gold fineness for all the samples in the study area; a gold fineness range of 0-1000 is typically present in most epithermal systems. This is even the case within individual deposits, due to variable temperatures, mixing of mineralizing fluids and changing sulphidation states (McCready *et al.*, 2003; Shikazono and Shimizu, 1986, 1987; Morrison *et al.*, 1991; Knight *et al.*, 1999b; Chapman and Mortensen, 2006). The absence of pristine, sharply crystalline gold grains with very high fineness cores (>980; e.g., McCready *et al.*, 2003) eliminates the possibility of authigenic gold (e.g., Loen, 1994; McCready *et al.*, 2003).

Western portion of drainage

As described above, an intrusion-related lode source for placer gold in the western portion of the study area has been proposed for isolated placer gold grains (not available for analysis) by Spirito *et al.* (1988), and there is a spatial association between placer gold showings and Tombstone suite intrusions in the southwestern portion of the study area (Fig. 2). Specific to the Chuck sample, the increased or measurable copper concentrations in the gold grains are not unexpected as the gold was sampled from a creek near the Chuck lode copper (-gold) occurrences. The relationship of increasing copper concentration with gold fineness (as is demonstrated by the plot in Figure 5b) has been described by other researchers (e.g., Knight and McTaggart, 1990) and is explained as a copper-saturation curve in copper-poor and gold-rich mineralizing systems (Knight *et al.*, 1999b). This increase in copper with gold fineness indicates some form of environmental variation during formation of the lode gold source, perhaps a change in temperature, or pH over time. The occurrence of relatively high fineness gold, measurable copper and low mercury (not shown) is relatively consistent with various intrusion-related sources for gold (Fig. 6a) from several placer camps in the Stewart River map area, western Yukon (Dumula and Mortensen, 2002). Furthermore, the presence of Fe- and/or Ca-rich garnet in the heavy minerals collected with the gold grains and limestone fragments indicates some form of silicate-fluid reaction with iron-rich and/or calcareous rocks during the initial gold mineralizing event(s); this in turn could also point towards a skarn-type lode source adjacent to an intrusion. Anomalous gold values are also reported in the NORMIN database for the Rino skarn occurrence, which is adjacent to a Tombstone suite intrusion near the Chuck sample location (Fig. 2). However, the lack of typical intrusion-derived or contact aureole minerals such as titanite, zircon, pyrite, pyrrhotite, andalusite, etc., observed in the heavy minerals panned from the Chuck sample, or as inclusions within the Chuck gold grains, does not lend support to a proximal, intrusive derivation for the gold (Loen, 1994).

Another possible gold source for the Chuck gold grains is nearby, or adjacent, Carlin-type mineralization. Emsbo *et al.* (2006) suggested that the association of gold with specific Tombstone suite intrusions throughout Yukon and Alaska (a continuation of the belt of Tombstone suite intrusions that crops out in the study area) is analogous to the Carlin-type mineralization trend in southwestern USA. This inference is based largely on a similar tectonic regime to that of northern Nevada (Emsbo *et al.*, 2006) where the majority of large Carlin-type gold deposits are hosted in a distal back-arc environment with far-ranging, deep-seated (transpressional?) structures, spatially and temporally associated with magmatism (Hart *et al.*, 2005; Rasmussen *et al.*, 2006; Gabrielse *et al.*, 2006, in press). Carlin-type gold deposits (summarized from Li and Peters, 1998) are commonly found near, but outside, the contact aureole of felsic intrusions and are typically hosted in impure carbonate-argillite strata; however, they may be hosted in intermediate to mafic volcanic rocks or felsic plutonic rocks. These deposits are generally associated with structurally controlled zones of silicification, sericitization, stockwork, and/or brecciation. Gold mineralization is very fine grained (micron scale, or ~0.01 mm), has a range of gold fineness (typically >500), and is disseminated in the host rock with limited associated sulphide minerals, although arsenic-mercury-antimony-bearing minerals are commonly observed. Base metals such as copper are usually not reported with Carlin-type gold; however, copper mineralization has been observed in association with gold at some Carlin-type deposits in China and Nevada (Li and Peters, 1998). The copper measured in the Chuck sample gold grains may be derived from the intermediate to mafic volcanic rocks and remobilized along the same structures that carry Carlin-type fluids. The intensely sericitized, and locally silicified, intermediate to mafic volcanic rocks hosting anomalous copper (-gold) mineralization and the overlying Rabbitkettle Formation limestones are both possible hosts for a Carlin-type deposit. Despite the lack of any associated sulphide minerals with the Chuck sample, and the relatively large gold-grain size compared to those grains of most Carlin-type gold deposits (particularly in the southwestern USA), this option remains a viable possibility for the source of

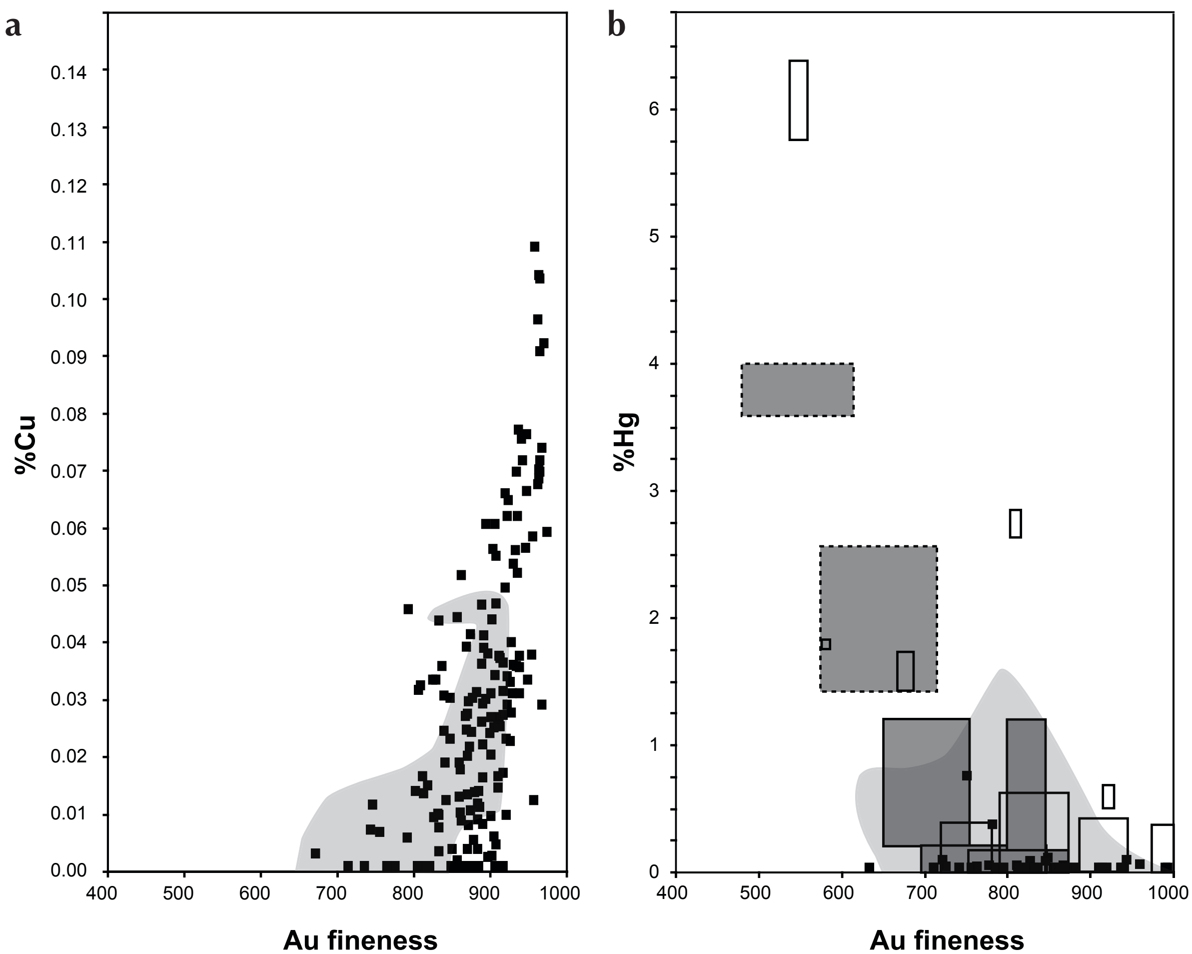

Figure 6. (a) *Plot of copper content vs. gold fineness for intrusion-related gold and the Chuck placer gold sample. The compositional field of intrusion-related gold from the Stewart River map area (Dumula and Mortensen, 2002) is indicated by the pale grey underlay, and compositions exhibited by the Chuck sample are indicated by small black squares;* ***(b)*** *plot of mercury content vs. gold fineness for orogenic and intrusion-related gold, and the isolated placer gold samples. Compositional fields of Archean greenstone-hosted orogenic gold in the Yellowknife Greenstone Belt, Slave craton are indicated by unfilled black outlines (data from Armstrong and Gochnauer, 2000; Gochnauer, unpublished data, 2001), compositional fields for Mesozoic orogenic gold from Yukon are indicated by dark grey boxes (dashed fields are inferred from a few data points; data from Knight* et al.*, 1999b), compositions of intrusion-related gold from the Stewart River map area are indicated by the pale grey underlay (Dumula and Mortensen, 2002), and the compositions exhibited by isolated samples of placer gold are indicated by small black squares.*

the placer gold due to the many other similarities listed above. At this time, the lack of access to compositional data for gold from Carlin-type mineralization does not allow for a compositional comparison with the Chuck sample.

Eastern portion of drainage

Studies of placer gold deposits have documented the presence of quartz and commonly pyrite, as well as other sulphide or silicate inclusions in gold grains sourced from orogenic veins (e.g., Loen, 1994; Knight *et al.*, 1999b). Sulphide inclusions (e.g., pyrite, chalcopyrite and galena; Loen, 1994) are common in gold grains sourced from intrusion-related deposits. Therefore, it is plausible that gold associated with tetrahedrite-bearing sulphide veins could contain inclusions of tetrahedrite, and possible galena, sphalerite and Cu-sulphides from the base-metal veins that they postdate. However, it should also be noted that the size and abundance of inclusions tends to decrease with increasing transport distance due to the effects of 'hammering' of the gold grains (Mortensen *et al.*, 2005). The lack of mineral inclusions (sulphide, silicate, or carbonate) in the isolated samples of gold grains, as viewed under the EMP, does not discount the possibility of a distal, intrusion-related source, especially for isolated samples collected from the South Nahanni River (Fig. 2). A more proximal, vein-derived source as described above can not be discounted by the absence of inclusions, particularly if the small size of the grains and the relatively flat or spherical nature of some of the grains are as a result of increased transport distances rather than primary features of the lode gold source (Mortensen *et al.*, 2005). Figure 6b demonstrates that gold compositions of the isolated samples in the study area overlap with placer gold compositions in the Stewart River map area that have an intrusion-related lode source (Dumula and Mortensen, 2002), although the absence of copper in most of the grains from the isolated samples (Fig. 5d) is inconsistent with the range of low copper concentrations observed in the Stewart River placer gold (Fig. 6a). Several mineral occurrences with anomalous gold concentrations are present in the study area. These are typically adjacent to granitoid intrusions (Fig. 2; as documented in NORMIN). The isolated samples, however, are not spatially associated with granitoid intrusions, nor are they from tributaries that currently drain valleys containing granitoid intrusions, with the exception of samples 86-JPW- 276S and -279S located on the South Nahanni River. These two samples do not have Cailleux flatness indices indicative of the great distances of travel in a fluvial system (i.e., >12 for more than 100 km travel; Youngson and Craw, 1999) necessary for these samples to have been sourced from intrusion-related mineralization (Fig. 5c). Unfortunately, the lack of compositional data for gold from the tetrahedrite-bearing veins in the study area does not allow for a similar compositional comparison.

Another possibility for the origin of the isolated gold grains is a glacially transported, distal source from Archean greenstone gold deposits in the Precambrian shield (Spirito *et al.*, 1988; Jefferson and Spirito, 2003). Gold grains transported by southwest-flowing continental ice sheets would be deposited within glacial till as poorly concentrated and poorly sorted, relatively large and/or irregular grains displaying crystalline outlines and low degrees of flattening due to their initial glacial transport in host rock clasts. Striations, grooves, crush marks and folded grain edges would also be common (Herail *et al.*, 1989). It is also possible, however, for gold grains with a nearby lode source to have some, or all, of these features (Loen, 1994; Youngson and Craw, 1999). Most gold grains from the isolated samples have relatively low Cailleux flatness values and range in morphology from delicate with relict crystallinity, to partially or entirely flattened and rounded grains, to almost spherical grains. These grains also display much more complex surficial textures, such as scratch and smear marks, dents, and more frequently folded grain margins than the Chuck sample. All of these observations are consistent with glacially transported material.

Gold compositions of the isolated samples in the study area are compared with available data for multiple Archean greenstone-hosted orogenic gold deposits in the Yellowknife greenstone belt (YGB), Slave craton, NWT (Armstrong and Gochnauer, 2000; Gochnauer, unpublished data, 2001; Fig 6b). Results of EMP analyses of gold, silver and mercury for *in situ* gold from the Archean deposits indicate that gold fineness and mercury concentration form several distinct compositional fields (Fig. 6b); gold fineness typically ranges from 720 to 1000 and mercury is typically <0.5%, although a couple of individual deposits of lower gold fineness (500 to 750) have anomalously high mercury concentrations (Gochnauer, unpublished data, 2001). Copper was not measured for the YGB lode gold. The lack of mercury in several of the YGB deposits, with the exception of two grains from the isolated samples, combined with an overlapping range of gold fineness (Fig. 6b), allows for a viable Archean-derived and glacially transported model for the placer gold. Although Yukon orogenic gold has not been proposed as a possible lode source, compositional fields of several lode gold deposits in the Klondike region, Yukon (Knight *et al.*, 1999b) also overlap with many of the placer gold grain compositions (Fig. 6b). This compositional overlap with orogenic gold from the Klondike indicates that the same, or a similar, Mesozoic mineralizing event could also be regarded as a possible lode gold source for the isolated placer gold samples. Ultimately, whether there are one or more sources of gold for the isolated placer gold occurrences, the lack of a statistically valid population for each sample does not allow us to make any inferences as to the original gold source(s), aside from describing compositional similarities or dissimilarities between the placer gold and gold from specific lodes.

FUTURE WORK

Further imaging of gold grains using the back-scattered electron detector (BSE) will be carried out on the polished grain mounts in order to document the nature and thicknesses of high gold-fineness rims and any mineral inclusions that were not obvious under the EMP. The identification of particular sulphide, sulphate, or silicate mineral phases or combinations thereof will be important in addressing the possible lode gold sources, particularly with respect to Carlin-type gold for the Chuck sample and glacially transported Archean greenstone-derived gold for the isolated samples. Additional analyses on the grains will include laser ablation inductively coupled plasma mass spectrometry methods to determine trace-element signatures by measuring lower concentrations of copper and mercury, and trace amounts of other elements such as arsenic, bismuth, tellurium, antimony, chromium, arsenic, tungsten, rubidium, strontium, tin, barium, etc. (e.g., Outridge *et al*., 1998). This compositional data, combined with a statistical Kernal Density estimation (KDE) of shape and trace element composition, will accurately define specific populations within a sample group. This, in turn, will allow stronger inferences as to the distance of travel the grains have undergone and the most prospective lode gold deposit-type(s) (e.g., intrusion-related, Carlin-type, Archean greenstone, etc.) for the placer gold in the South Nahanni River watershed. The more detailed work will be particularly useful for the Chuck sample. This work is expected to take place early in 2007.

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