The geology of placer gold deposits in the Indian River area, west-central Yukon

Grant W. Lowey
Yukon Geology Program

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ABSTRACT

Placer gold deposits in the Indian River area, west-central Yukon, are grouped into five classes based on thickness, grain size, composition, age, process, landform and exposure. The placers vary from 1.5-16 m in thickness and consist of slightly muddy, sandy gravel that is dominated by either vein quartz clasts, or igneous and metamorphic clasts. The gravel was deposited on floodplains, now preserved as terraces and creek and river valley fills, that range from Pliocene(?) to Holocene in age. The formation of the placers is related to a hierarchy of physical scales: at the *lithofacies* scale (m's), bed roughness determined sites of gold deposition; at the *element* scale (10's of m's), gravel bars were preferentially enriched in gold; at the *reach* scale (100's of m's), stream gradient was an important factor; at the *system* scale (100's of km's), braided river environments transported large amounts of gold; and at the *sequence* scale (1,000's of km^2), economic placers formed in the White Channel Gravel unit in downstream parts of the Indian River drainage, and in upstream parts of the drainage in the unit herein referred to as the Local Creek Gravel.

RÉSUMÉ

Les gîtes d'or placériens de la région de la rivière Indian, dans la partie centrale ouest du Yukon, sont regroupés en cinq classes en fonction de l'épaisseur, de la granulométrie, de la composition, de l'âge, des formes de terrain et de l'exposition. L'épaisseur des gîtes placériens varie de 1,5 à 16 m et ils consistent en gravier sablonneux légèrement boueux dans lequel prédominent des clastes de quartz filonien ou des clastes ignés ou métamorphiques. Le gravier s'est déposé dans des plaines inondables aujourd'hui conservées sous forme de terrasses et de vallées de ruisseaux et de rivières dont l'âge varie du Pliocène(?) à l'Holocène. La formation des placers est reliée à une hiérarchie d'échelles physiques: à l'échelle du *lithofaciès* (de l'ordre du mètre), la rugosité du fond détermine les emplacements de dépôt de l'or; à l'échelle de *l'élément* (dizaine de mètres), des barres de gravier ont été enrichies en or de manière préférentielle; à l'échelle du *tronçon* (centaine de mètres), la pente du cours d'eau était un facteur important; à l'échelle du *réseau* (centaine de kilomètres), les cours d'eau anastomosés transportaient de grandes quantités d'or et à l'échelle de la *séquence* (milliers de kilomètres carrés), des placers rentables se sont formés dans les graviers de l'unité de White Channel dans les parties aval du bassin de la rivière Indian et dans les parties amont du bassin dans les graviers de l'unité ici désignée de Local Creek.

INTRODUCTION

The Indian River area, located south of Dawson City in west-central Yukon (Fig. 1), forms the northeast corner of the Stewart River map sheet (115 O&N). The main gold bearing streams are the Indian River, Quartz Creek, Montana Creek, Eureka Creek, Sulphur Creek, Dominion Creek, Gold Run Creek and Caribou Creek (Fig. 2). The Indian River drainage is the southernmost limit of the world-famous Klondike gold fields.

The first payable gold from the Klondike was mined in 1894 at Quartz Creek by William “Billy” Redford (Coutts, 1980). Despite continuous mining for over 100 years, the Indian River drainage has recently been the most important placer area in the Yukon, accounting for nearly 44% of the placer gold production during 1995-97 (Mining Inspection Division, 1998).

One of the most important conclusions following the Placer Mine Panel Discussion which was held in Whitehorse in November, 1997 as part of the Yukon Geoscience Forum, is that we know a lot about placers at the local, or outcrop scale and at the regional, or glacial limits scale, but we know very little about placers at the intermediate, or drainage basin scale. This study represents the first systematic and detailed investigation of placers in the Indian River drainage. Its purpose is to describe the placers, interpret their formation, and apply this information to placer exploration and mining.

BEDROCK GEOLOGY

Although dated, Bostock’s (1942) map provides the most complete coverage of the bedrock geology in the Indian River area. More recent mapping was done by Debicki (1985) and Mortensen (1990, 1996) north of the Indian River, and by Lowey (1982, 1983, 1985) and Lowey and Hills (1988) south of the river. Knight et al. (1994) investigated major and minor trace element compositions of lode and placer gold from the Klondike, and concluded that the placer gold is detrital in origin and was derived from quartz veins present in the bedrock. Rushton et al. (1993) showed that the quartz veins are part of a mesothermal vein system.

The Indian River area is underlain by mainly Paleozoic metasedimentary (i.e., Kondike Schist and Nasina Assemblage) and meta-igneous rocks belonging to the Yukon-Tanana Terrane (Mortensen, 1996). Minor amounts of altered ultramafic rocks occur locally and are assigned to the Slide Mountain Terrane. According to Mortensen (1996), these two pre-accretionary units were juxtaposed by regional-scale thrust faulting in Early Mesozoic time. The gold-bearing quartz veins were emplaced in the earliest Cretaceous (Rushton et al., 1993), and the area was then unconformably overlain by post-accretionary sedimentary and volcanic rocks in mid- to late Cretaceous time. Lowey and Hills (1988) assigned the sedimentary rocks, in part, to the Tantalus Formation, and Lowey et al. (1986) assigned the volcanic rocks, in part, to the Carmacks Group.

SURFICIAL GEOLOGY

Bostock (1966) and Hughes et al. (1969) provide a regional framework for the surficial geology and glacial history of the Indian River area. Only very restricted surficial mapping (e.g., Morison et al., 1998) has been carried out in the area, although further mapping is planned as part of a proposed NATMAP project (L. Jackson, pers. com., 1998). Limited information on the type of surficial geology units present in the area can be obtained from the Dawson map sheet (located immediately to the north of the Stewart River map sheet) which was mapped by Vernon and Hughes (1966) and more recently by Duk-Rodkin (1996).

The Indian River area, thought to be a mature, subdued landscape by Miocene time, underwent a period of uplift and erosion in the Pliocene (Tempelman-Kluit, 1980). The area was not covered by glacial ice during the pre-Reid (latest Pliocene in age) or later glaciations. However, glacial outwash (i.e., the Klondike Gravel) was deposited on high-level terraces along the Indian River

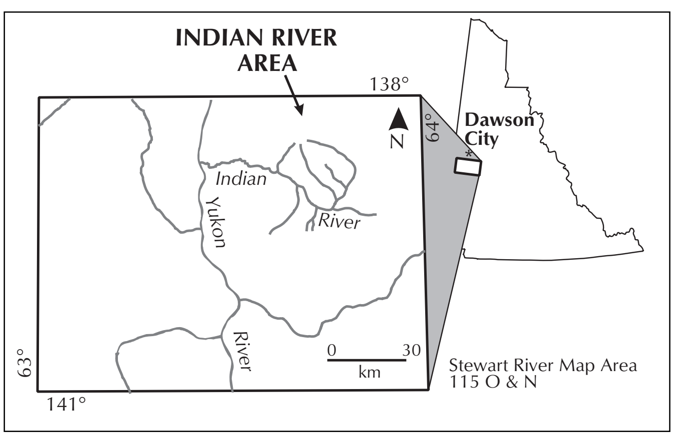

Figure 1. *Location map of the Indian River area, west-central Yukon.*

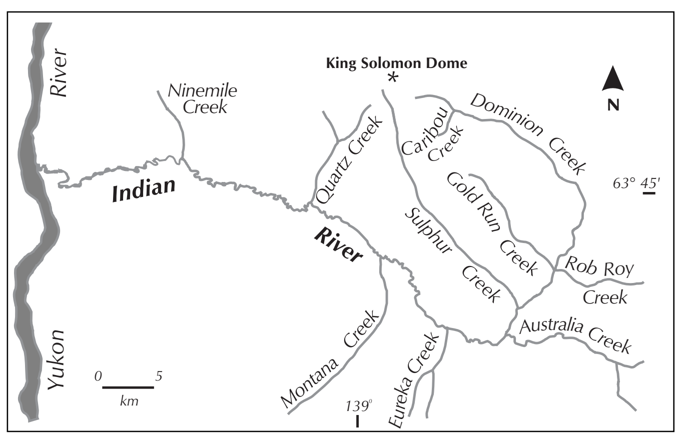

Figure 2. *Main placer gold-bearing streams in the Indian River area.*

(Hughes et al., 1969). Duk-Rodkin (1996) has mapped some of the placer deposits as slope complexes (map unit Cx).

METHODS

This study is based on field work and preliminary laboratory analyses. Field work involved visits to 20 active placer mines and 10 inactive placer mines from June to September, 1997. During these visits, outcrop profiles of the deposits were constructed according to the method outlined by Miall (1996), and representative samples were collected. Ongoing laboratory work includes determining the grain size distribution and clast lithology of gravel samples, palynological analysis of fine-grained sand and silt samples, and radiometric age dating of tephra and organic samples. Outcrop profiles are tentatively correlated by lithocorrelation (cf. Schoch, 1989) which will be confirmed by chronocorrelation once radiometric age dates are available.

PLACER GEOLOGY

McConnell's (1905) paper on the Klondike gold fields includes the most comprehensive description available of placers in the Indian River drainage, and he was the first to correctly interpret the origin of the placer gold. The report by Gleeson (1970) provides a description of the type and distribution of heavy minerals present in the placers, as well as regional trends in gold fineness. A synopsis (including descriptions of gravel mined and gold recovered) of placer mines in the area can be found in the Mining Inspection Division (1998) report, as well as in earlier placer industry reports (Indian and Northern Affairs Canada).

DESCRIPTION OF PLACER DEPOSITS

The placer deposits can be grouped into five classes (Fig. 3) on the basis of thickness, grain size, composition, age, dominant sedimentary process (e.g., fluvial, mass wasting, weathering, etc.), type of landform (e.g., terrace, valley, etc.), and exposure (e.g., exposed on the surface, buried, or exhumed).

Placer Deposit 1 occurs along Quartz Creek, where it forms high-level terraces (Fig. 4). The terraces consist of approximately 16 m of slightly muddy, sandy gravel that is dominated by vein quartz clasts (Fig. 5). The gravel is interpreted to be Pliocene(?) in age, and represents paleofloodplain deposits of a braided stream. It is assigned to the White Channel Gravel unit which forms the prominent terraces on Bonanza and Hunker creeks (McConnell, 1905, 1907; Lowey, 1998).

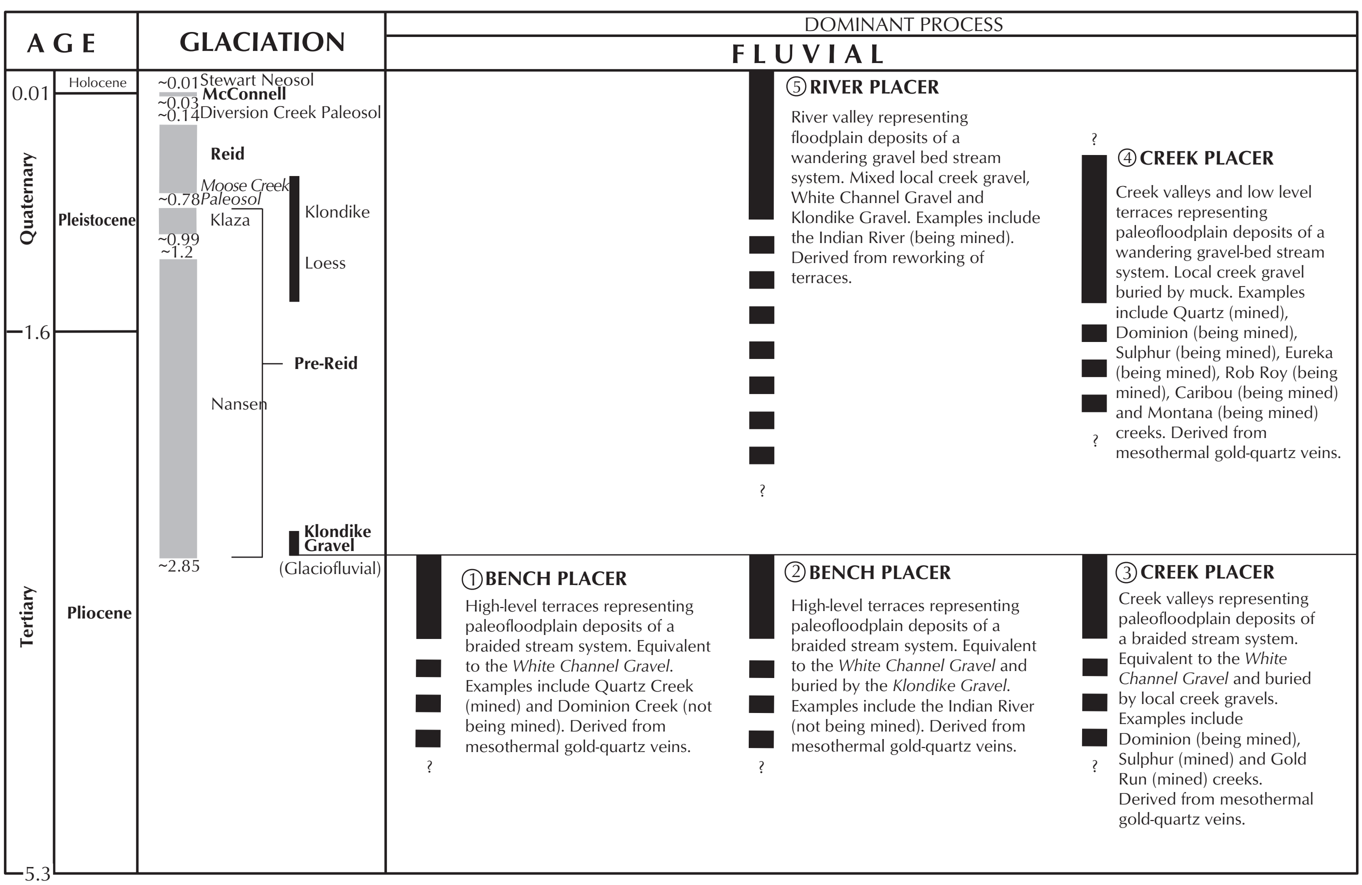

Figure 3. *Classification of placer deposits in the Indian River area.*

Placer Deposit 2 occurs along the Indian River, where it forms high-level terraces (Fig. 6). The terraces consist of approximately 16 m of slightly muddy, sandy gravel that is dominated by vein quartz clasts (Fig. 7). The gravel is also interpreted as Pliocene(?), and represents paleofloodplain deposits of a braided stream. It too is assigned to the White Channel Gravel unit. The White Channel Gravel of this deposit type is buried by the Klondike Gravel which is composed of vein quartz, igneous, metamorphic, and sedimentary clasts, and represents glacial outwash (Hughes et al.,1969).

Placer Deposit 3 occurs along the lower part of Dominion, Sulphur and Gold Run creeks, where it forms the fill of the creek valleys (Fig. 8). The creek valley fill consists of approximately 5 m of slightly muddy, sandy gravel that is dominated by vein quartz clasts (Fig. 9). The gravel is interpreted to be Pliocene(?) in age, and represents paleofloodplain deposits of a creek. It is also assigned to the White Channel Gravel unit. The White Channel Gravel of this deposit type is buried by local creek gravel which is dominated by igneous and metamorphic clasts.

Placer Deposit 4 occurs along Montana, Eureka and Caribou creeks, and along the upper part of Sulphur, Gold Run and Dominion creeks, where it forms the fill of the creek valleys (Fig. 10). The creek valley fill consists of approximately 2 m of slightly muddy, sandy gravel that is dominated by igneous and metamorphic clasts (Fig. 11). The gravel is interpreted to be Pliestocene(?) in age, and represents paleofloodplain deposits of a creek. It is assigned to the Local Creek Gravel unit.

Placer Deposit 5 occurs along the Indian River, where it forms the fill of the present day river (Fig. 12). The river fill consists of approximately 1.5 m of slightly muddy, sandy gravel that is

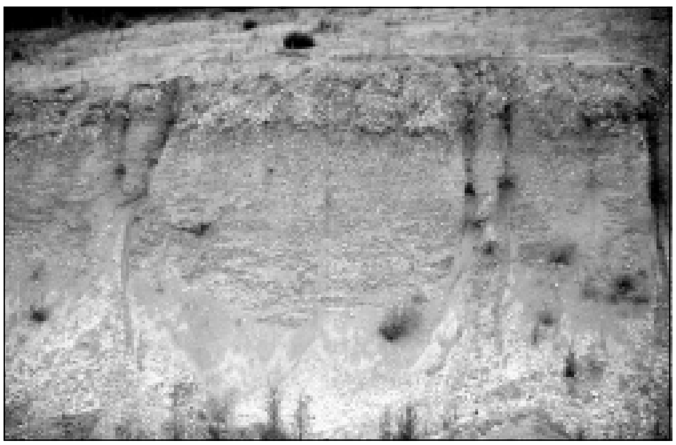

Figure 4. *Photograph of gravel exposed on terraces along Quartz Creek.*

Figure 6. *Photograph of gravel exposed on terraces along the Indian River.*

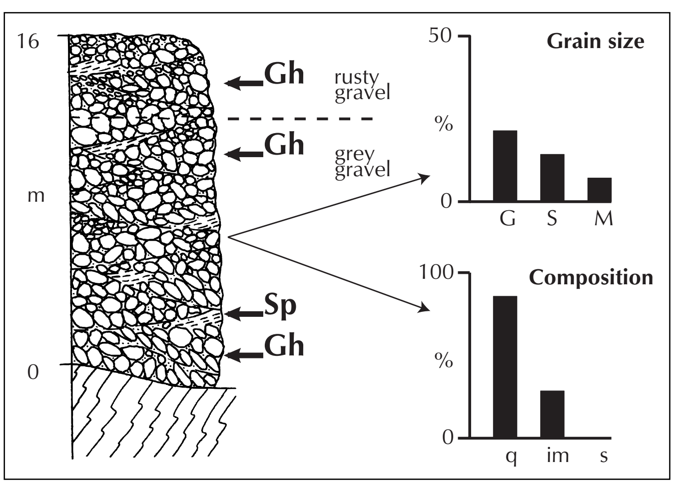

Figure 5. *General stratigraphic section of Placer Deposit 1 and typical grain size distribution and composition of gravel.*

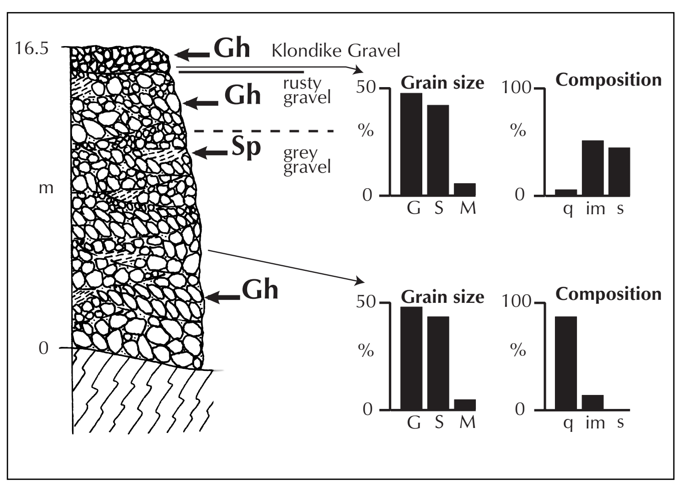

Figure 7. *General stratigraphic section of Placer Deposit 2 and typical grain size distribution and composition of gravel.*

Gh*=horizontally bedded gravel*	***G****=gravel*	***M****=mud*	***im****=igneous and metamorphic clasts*
Sp*=planar bedded sand*	***S****=sand*	***q****=quartz vein clast*	***s****=sedimentary clasts*

characterized by a mixed lithology of vein quartz, igneous, metamorphic, and sedimentary clasts (Fig. 13). Most of the vein quartz clasts were derived from the White Channel Gravel, whereas the sedimentary clasts were derived from reworking of the Klondike Gravel. Both units are exposed in high-level terraces along the river. The gravel is interpreted to be Holocene in age, and represents paleofloodplain deposits of a wandering gravel-bed river. It is assigned to the Mixed Gravel unit.

FORMATION OF PLACER DEPOSITS

All of the placer deposits are fluvial in origin, and a very important concept in fluvial sedimentology is that different depositional processes operate at different physical scales (Miall, 1996). A five-fold hierarchy of physical scales — from the outcrop (the smallest size) to the entire drainage area (the largest size) — can be recognized in placer deposits of the Indian River drainage (Fig. 14).

The lithofacies scale is metres in size (and days in duration) and represents beds classified on the basis of grain size, texture, and sedimentary structures. Typical lithofacies present are Gh (i.e., gravel that is horizontally bedded), Gp (i.e., gravel that is planar bedded) and Sp (i.e., sand that is planar bedded). At this scale, the important processes forming placers are entrainment sorting, dispersive sorting, suspension sorting (Slingerland, 1984) and bed roughness (Day and Fletcher, 1991). The bed roughness, or unevenness of the gravel pavement, is probably

Figure 8. *Photograph of gravel exposed in a placer mine pit on Dominion Creek.*

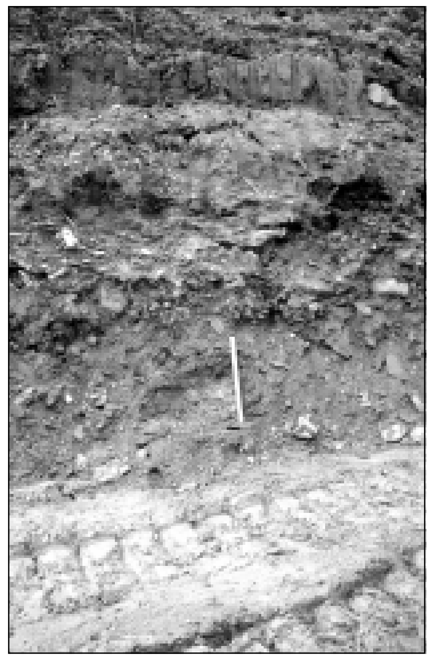

Figure 10. *Photograph of gravel exposed in a placer mine pit on Caribou Creek.*

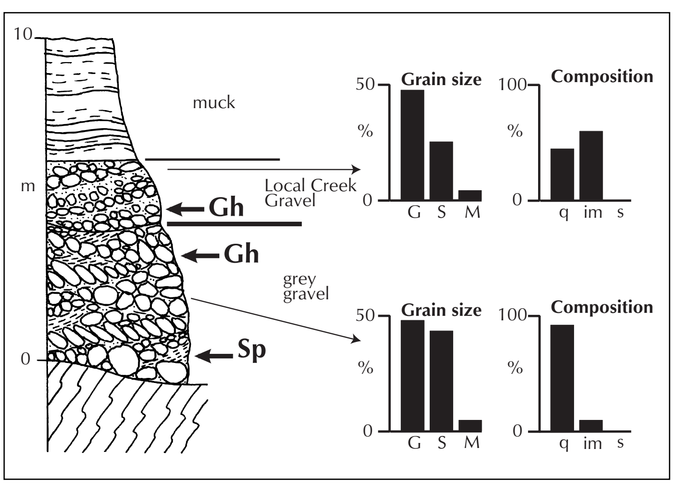

Figure 9. *General stratigraphic section of Placer Deposit 3 and typical grain size distribution and composition of gravel.*

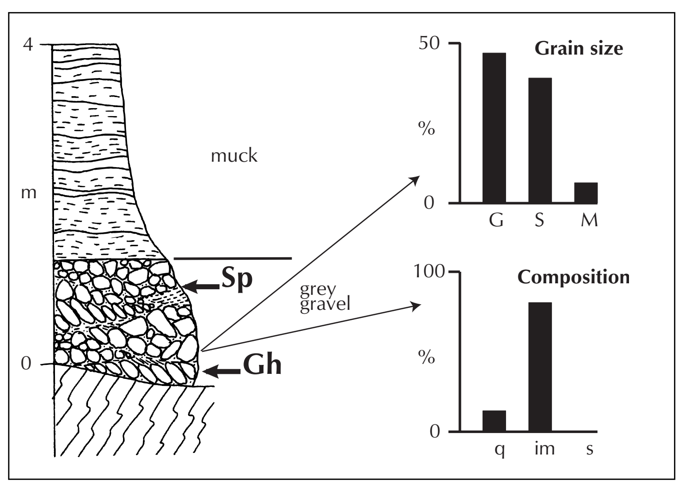

Figure 11. *General stratigraphic section of Placer Deposit 4 and typical grain size distribution and composition of gravel.*

Gh=*horizontally bedded gravel*	***G***=*gravel*	***M***=*mud*	***im***=*igneous and metamorphic clasts*
Sp=*planar bedded sand*	***S***=*sand*	***q***=*quartz vein clast*	***s***=*sedimentary clasts*

the most important process because this acts like a sluice to trap the gold. Hence, gravel lithofacies, particularly Gh, are preferentially enriched in gold relative to sand lithofacies.

The element scale is 10's of metres in size (and years in duration) and represents an assemblage of lithofacies. Typical elements are GB (i.e., gravel bars), SB (i.e., sand bars), and CH (i.e., channel fill deposits). At this scale the important process forming placers is the accumulation of gravel beds (i.e., lithofacies Gh) into gravel bars (i.e., element GB). Hence, gravel bars become enriched in gold relative to sand bars because the gravel bars are made up of the gold-bearing gravel beds.

Figure 12. *Photograph of gravel exposed in a placer mine pit on the Indian River.*

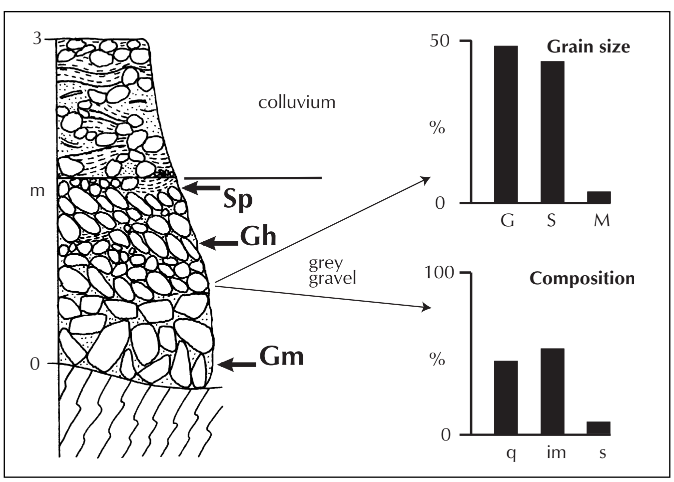

Figure 13. *General stratigraphic section of Placer Deposit 5 and typical grain size distribution and composition of gravel.*

Gh=*horizontally bedded gravel*	***q***=*quartz vein clast*
Sp=*planar bedded sand*	***im***=*igneous and metamorphic clasts*
G=*gravel*	***s***=*sedimentary clasts*
S=*sand*	
M=*mud*	

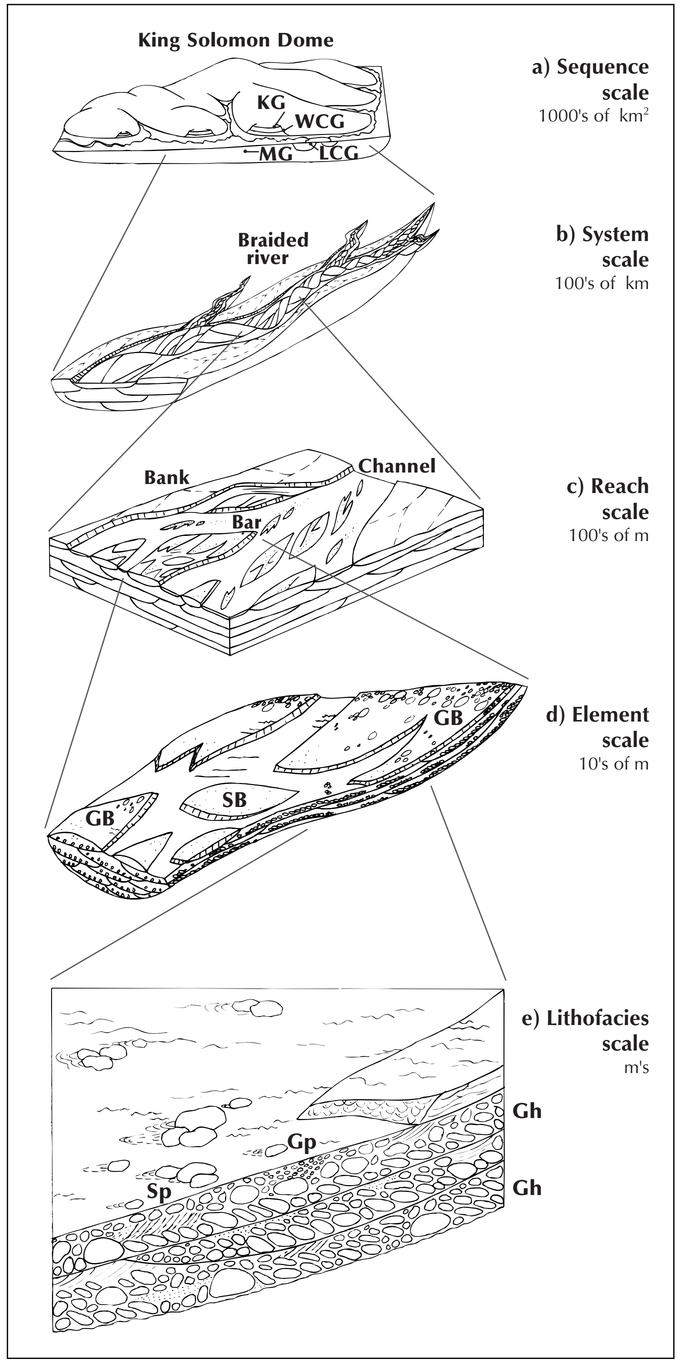

Figure 14. *Fivefold hierarchy of physical scales related to formation of placer deposits:* ***a)*** *sequence scale (the Indian River drainage looking north towards King Solomon Dome);* ***b)*** *system scale;* ***c)*** *reach scale;* ***d)*** *element scale;* ***e)*** *lithofacies scale.*

KG=*Klondike gravel*	***SB***=*sand bar*
WCG=*White Channel gravel*	***Gh***=*horizontally bedded gravel*
LCG=*local creek gravel*	***Gp***=*planar bedded gravel*
MG=*mixed gravel*	***Sp***=*planar bedded sand*
GB=*gravel bar*	

The reach scale is 100's of metres in size (and 10's of years in duration) and represents a continuous length of a stream channel (including the bars, smaller channels and banks). At this scale, the important processes forming placers are stream junctions (Mosley and Schumm, 1977) and the gradient of the stream (Hester, 1970). The stream gradient, or slope of the stream channel, is probably the most important factor because this controls the velocity of the stream flow, and the velocity of the stream flow determines the transportation, and deposition of the alluvium and the gold. Generally, the lower the stream gradient, the greater the potential for deposition of gold (Hester, 1970).

The system scale is 100's of kilometres in size (and 100's of years in duration) and represents a sedimentary environment, such as a river or alluvial fan. The braided river environment (characterized by many channels separated by small bars or islands, and coarse-grained alluvium) deposited most of the placers in the Indian River drainage.

The sequence scale is 1000's of square kilometres in size (and 1000's of years in duration) and represents mappable stratigraphic units (i.e., formations or members) made up of one or more sedimentary environments. Of the four gravel units recognized in the Indian River drainage, the White Channel Gravel, Local Creek Gravel, and Mixed Gravel formed economical placers. Note that Placer Deposits 1, 2 and 3 all belong to the same stratigraphic unit (i.e., the White Channel Gravel), but the deposits differ according to landform (e.g., terrace or creek valley) and expression (e.g., exposed on the surface or buried by the Klondike Gravel or Local Creek Gravel).

APPLICATION TO EXPLORATION AND MINING

The hierarchy concept of physical scales has important implications regarding placer exploration and mining. For example, the lithofacies scale should be considered during exploration, particularly when panning grab samples and drill cuttings because coarse-grained sediments (i.e., lithofacies Gh) trap more gold. Generally, this scale is too small to take into account when mining (i.e., an entire lithofacies or bed would be mined).

The element scale should be considered during exploration, particularly when evaluating drill results because gravel bars (element GB), especially the upstream ends of the bars, are preferentially enriched in gold relative to sand bars (element SB). Generally, this scale also is too small to take into account when mining.

The reach scale should be considered during exploration and when mining because lower steam gradients have greater potential for placer gold deposition. Detailed drill spacing may reveal the original gradient of the stream channel, and this information can be used to identify blocks of ground that contain potentially higher concentrations of gold.

The system scale should be taken into account during exploration because only coarse-grained fluvial deposits carry economic concentrations of gold. Generally, this scale is too large to take into account when mining (i.e., only a part of a system or sedimentary environment would be mined).

The sequence scale should be considered during exploration because only certain stratigraphic units are gold-bearing, such as the White Channel Gravel (which tends to form in the lower part of the Indian River drainage), and the Local Creek Gravel (which tends to form in the upper part of the drainage). Generally, this scale is also too large to take into account when mining.

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