Placer geology and prospective exploration targets of Sixtymile River area, west-central Yukon

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ABSTRACT

Sixtymile River alluvial deposits can be subdivided into four main types, on the basis of age and physiographic setting. These are pre-Reid and older; interglacial (prior to the McConnell glacial episode); modern (Holocene); and technogenic. All deposit types are placer-gold-bearing, and historically the most placer gold has been produced from modern (Holocene) deposits, followed by pre-Reid and older, interglacial, and finally, technogenic deposits.

Prospective placer gold exploration targets still exist and include 1) pre-Reid and older buried abandoned channels; 2) interglacial buried and/or abandoned alluvial terraces; 3) modern (Holocene) alluvial channels and gulches; and 4) technogenic deposits. Various exploration techniques can be used to evaluate these targets including airphoto interpretation, seismic and ground-penetrating radar surveys, electrical resistivity and magnetometer surveys, auger and reverse circulation drilling, and bulk sampling.

RÉSUMÉ

Les dépôts alluviaux de la région de Sixtymile se répartissent selon l'âge et le cadre physiographique en quatre grands groupes principaux. Ceux-ci sont d'âge pré-Reid et plus anciennes; des dépôts alluviaux interglaciaires (antérieur à l'époque glaciaire de McConnell); des dépôts alluviaux contemporains (Holocène); et des dépôts résultant du développement technologique. Tous ces types de dépôts contiennent de l'or placerien, et historiquement la plupart de l'or placerien était produit des dépôts contemporains (Holocène), suivit par les dépôts pré-Reid, et plus anciennes, les dépôts interglaciaires, et finallement, ceux résultant du développement technologique.

Plusieurs prometteuses cibles d'exploration à la recherche de placers peuvent être identifiées dans le bassin de la rivière Sixtymile et regroupées en quatre principaux cadres de dépôt : 1) chenaux abandonnés enfouis pré-Reid et plus anciennes; 2) terrasses alluviales enfouies et abandonnées; 3) chenaux et ravins alluviaux contemporains; et 4) dépôts résultant du développement technologique. Diverses méthodes d'exploration de ces cibles peuvent être utilisées dont l'interprétation de photographies aériennes, les levés sismiques et au géoradar, les levés de résistivité électrique et magnétométriques ainsi que le forage à la tarière suivi d'un échantillonnage en vrac.

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RATIONALE OF STUDY

The Sixtymile River and several of its tributaries have been the focus of placer gold mining since 1892, pre-dating the Klondike Gold Rush which began with the discovery of gold on Bonanza (then Rabbit) Creek in August, 1896. Active mining in the area has been more or less continuous since then, and several of the creeks have been mined up to four times, with increasingly larger and more efficient equipment.

This study builds upon the work of previous researchers and is intended to fulfill two purposes: to supplement previous understanding of the paleogeography and Quaternary history of the Sixtymile River area; and to focus on the detailed placer geology for the purposes of broadening placer gold exploration and current placer mining efforts.

LOCATION

The Sixtymile River is located in the unglaciated, west-central Yukon, and it is one of the major left limit tributaries of the Yukon River (Fig. 1, see facing page). Its headwaters are located in Alaska, and from there it flows east-northeast and finally southeasterly to join the Yukon River at the abandoned site of Ogilvie. Placer mining has mainly been confined to the Canadian side of the Sixtymile River, which includes major tributaries: Bedrock Creek, Miller Creek, Glacier Creek, Big Gold Creek, Little Gold Creek, California Creek, Fifty Mile Creek, Matson Creek and Ten Mile Creek.

PREVIOUS WORK

The glacial limits in this area were first mapped by O.L. Hughes (1968), later compiled by Hughes *et al.* (1969) and subsequently re-mapped by Duk-Rodkin (1996).

A 1:250 000-scale surficial map of the northern parts (NTS 116B/C) of the drainage was completed by Duk-Rodkin (1999), and the surficial geology of the southern part of the study area was mapped at 1:50 000 scale by Jackson (2005).

R.L. Hughes studied the evolution and origin of the placer-gold-bearing gravel of the Miller Creek and Sixtymile River drainages (Hughes, 1986; Hughes *et al.*, 1986). More recently, the placer geology of the drainage was studied by Lowey (2000, 2004).

FIELD AND LABORATORY METHODOLOGY

Twenty-five sections were visited and described within the study area between 2000 and 2003. Mining operations provided excellent exposures of pay gravel and overburden, which enabled the stratigraphic relationships between different units to be ascertained. Sections were described with emphasis on physical sedimentary features, including grain size, bed thickness, gravel fabric, primary sedimentary structures, lithology and rounding of clasts. Cryogenic features such as ice-wedge casts and cryoturbation of sediments were also noted and described when present. Samples were collected for grain-size, heavy mineral and radiocarbon analyses.

Forty-five bulk sediment samples of between 3 and 4 kg each were collected. Selected samples were panned on site to document any presence of gold, while most samples were collected for grain-size and heavy mineral analysis following the methodology of Folk (1974). Grain-size samples were dried, split and sieved through #4, #10, #18, #35, #60, #120 and #230 US Standard mesh screens. Each fraction was collected and weighed (Fig. 2), and the minus #230 mesh screen material was then analysed by hydrometer for the sand, silt and clay ratio.

Hand-panned concentrates of the heavy minerals from several samples were derived from the combined #18 to #120 mesh fractions. Gold, when present, was separated from the other heavy minerals and both fractions were air-dried. Selected gold and other heavy mineral grains were analysed by PetraScience Consultants Inc. (Vancouver, BC) using a scanning electron microscope (SEM) and electron microprobe.

Figure 2. *Gravel samples were dried and sieved through a series of US Standard mesh screens to determine matrix grain-size distribution.*

Six organic samples were collected for ^{14}C dating. Wood was sampled wherever possible to avoid any root contamination, which may occur while bulk-sampling organic-rich soil samples. Since some samples were likely to be close to, or beyond the age of radiocarbon-dating methods, Accelerated Mass Spectrometer (AMS) analyses were completed.

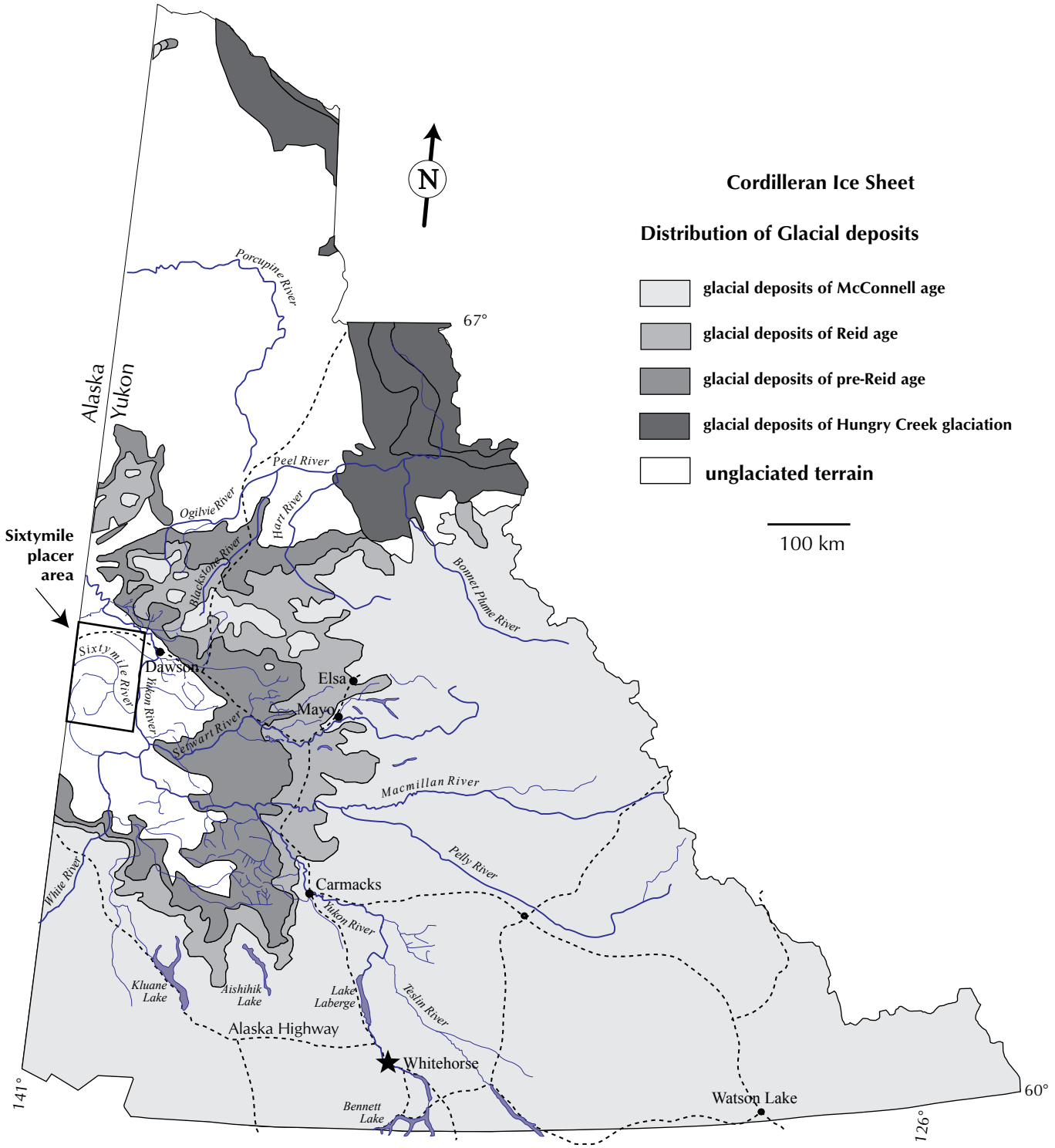


Figure 1. *Glacial limits in Yukon showing location of Sixtymile placer area (glacial limits after Duk-Rodkin, 1999).*

MINING HISTORY

The Sixtymile River area has been mined for placer gold since well before the discovery of gold in the Klondike in 1896. In 1877, while prospecting along the Yukon River, Arthur Harper and Jack McQuesten reported 'good prospects' on bars of the lower Sixtymile River (Wright, 1976). McQuesten himself reportedly made $6 to $8 per day on several bars (at $20.65/ounce). These bars were worked to a small extent by members of the Schwatka expedition in 1883 (Wright, 1976).

Glacier creek was extensively hand-mined for years following the discovery of gold on it in 1883. Prospecting first occurred on Miller Creek in 1887, but no significant activity was recorded until 1892, when considerable mining was reported on Glacier, Miller, and to a lesser extent on Bedrock and Big Gold creeks. By 1895, 350 miners were reportedly working in the Sixtymile area (Wright, 1976). Activity temporarily dwindled when gold was discovered on Bonanza Creek in 1896.

Beginning in 1912, the Northern American Transportation and Trading Company dredged for a few years on Miller Creek. The dredge was subsequently acquired by Holbrook Dredging Company in 1929, and in 1937 was converted from steam to diesel power, operating until 1941 on the Sixtymile River (Debicki, 1983).

In the late 1930s, prospect drilling was conducted by North American Mines, Inc. on the ground at the mouth of Glacier Creek and at the confluence of Big Gold Creek and Sixtymile River. From 1949 to 1959, Yukon Placer Mining Company was operating on Yukon Exploration Company's property on Big Gold, at the mouth of Glacier Creek. They used a 3.5-cubic-foot (0.099 m^3) bucket-line diesel-electric dredge (built by Yukon Exploration Company in 1947) and an open-cut bulldozer-sluicing plant (Debicki, 1983).

In the 1950s and 1960s, several small operators including James Lynch, Miller Creek Placers and Glacier Creek Placers mined on Miller, Glacier, Bedrock and Big Gold creeks as well as the left limit of Sixtymile River (LeBarge and Coates, 2005).

Companies and individuals active in the 1970s and 1980s included Sixtymile Enterprises, Brisebois Brothers Construction Ltd., Cogasa Mining Corporation, Fell Hawk Placers, W. Hakonson, Chuck and Lynn McDougall, Territorial Gold Placers, Oak Bay Manor, Granges Exploration and Tri-Kay Placers. In the 1980s, underground mining was conducted on Miller Creek by Chumar Placers, Dublin Gulch Mining and Klondike Underground Mining Ltd. (LeBarge and Coates, 2005).

In the 1990s, active operators included K-1 Mining & Services, Fell-Hawk Mining, D & P Mining Exploration Ltd., S. Prohaszka, Coulee Resources Ltd., Eldorado Placers Ltd., Aardvark Placers, 6077 Yukon Ltd., Graham Ventures, Walter Yaremcio, Brisbois Brothers Construction Ltd., Hawker/Tri-Kay Properties, Goldmark Minerals, No Name Resources, G. Fowler, M. Orbanski and J.M. Mining Ltd. (Mining Inspection Division, 2003).

Since 2000, mining has been conducted by F. and K. Hawker, J.M. Mining, W. Yaremcio, Gordon Hagen, Tim Coles, Northway Mining, Brisbois Brothers Construction Ltd., Dredgemaster Gold, Maurice Alexander, S. Prohaszka, Midas Rex Mining, Powers and Long, J. Ganter, K-1 Mining and Eldorado Placers (LeBarge and Coates, 2005).

MINING VOLUMES

Between 1998 and 2002, 13 placer mining operations (Fig. 3) were active on the Sixtymile River and its tributaries (Mining Inspection Division, 2003). Although data is incomplete, Table 1 is a compilation of available information of the amount of sediment stripped and sluiced during that period.

PLACER GOLD PRODUCTION

Table 2 shows the recorded placer gold production from available sources. This production can be considered minimum amounts, as gold is sometimes not reported in royalties and pre-1978 information is anecdotal in nature.

Figure 3. *Frank and Karen Hawker's placer mine in the Sixtymile River valley, 2001.*

Table 1. *Minimum amount of material stripped and sluiced, Sixtymile area, 1998-2002.*

Drainage	Stripped, cubic yards (m^3)	Sluiced, cubic yards (m^3)
Sixtymile	2,706,614 (2 069 355)	949,551 (725 983)
Miller	130,926 (100 100)	63,773 (48 758)
Big Gold	356,793 (272 787)	52,768 (40 344)
Glacier	468,519 (358 208)	137,378 (105 033)
Little Gold	12,460 (9526)	3327 (2543)
Totals	**3,675,311 (2 809 977)**	**1,206,796 (922 661)**

Table 2. *Recorded placer gold production, Sixtymile area.*

Creek	Tributary of	Recorded production, crude ounces (g)		
		1892-1977	1978-2005	1892-2005
Sixtymile	Yukon	8152 (253 556)	227,964 (7 090 478)	236,116 (7 344 034)
Miller	Sixtymile	47,525 (1 478 194)	49,876 (1 551 318)	97,401 (3 029 512)
Glacier	Big Gold	34,365 (1 068 872)	16,462 (512 026)	50,827 (1 580 897)
Big Gold	Sixtymile	31,098 (967 257)	2637 (82 020)	33,735 (1 049 277)
Little Gold	Big Gold	3775 (117 416)	5066 (157 570)	8841 (274 986)
Bedrock	Sixtymile	4393 (136 638)	3796 (118 067)	8189 (254 706)
Fifty Mile	Sixtymile	0	105 (3266)	105 (3266)
Matson		0	24,385 (758 459)	24,385 (758 459)
Ten Mile		0	30,261 (941 223)	30,261 (941 223)
Totals		**129,308 (4 021 931)**	**360,554 (11 214 491)**	**489,862 (15 236 422)**

GENERAL SETTING

BEDROCK GEOLOGY

Figure 4 is a generalized map of the bedrock geology of the study area, which was mapped by Mortensen (1988, 1990, 1996). The area is underlain by Proterozoic to Mississippian metamorphic rocks of the Yukon-Tanana Terrane; this, in turn, is overlain by mainly flat-lying Cretaceous Tantalus Formation sandstone and pebble conglomerate, and Late Cretaceous Carmacks Group andesitic flows and breccias.

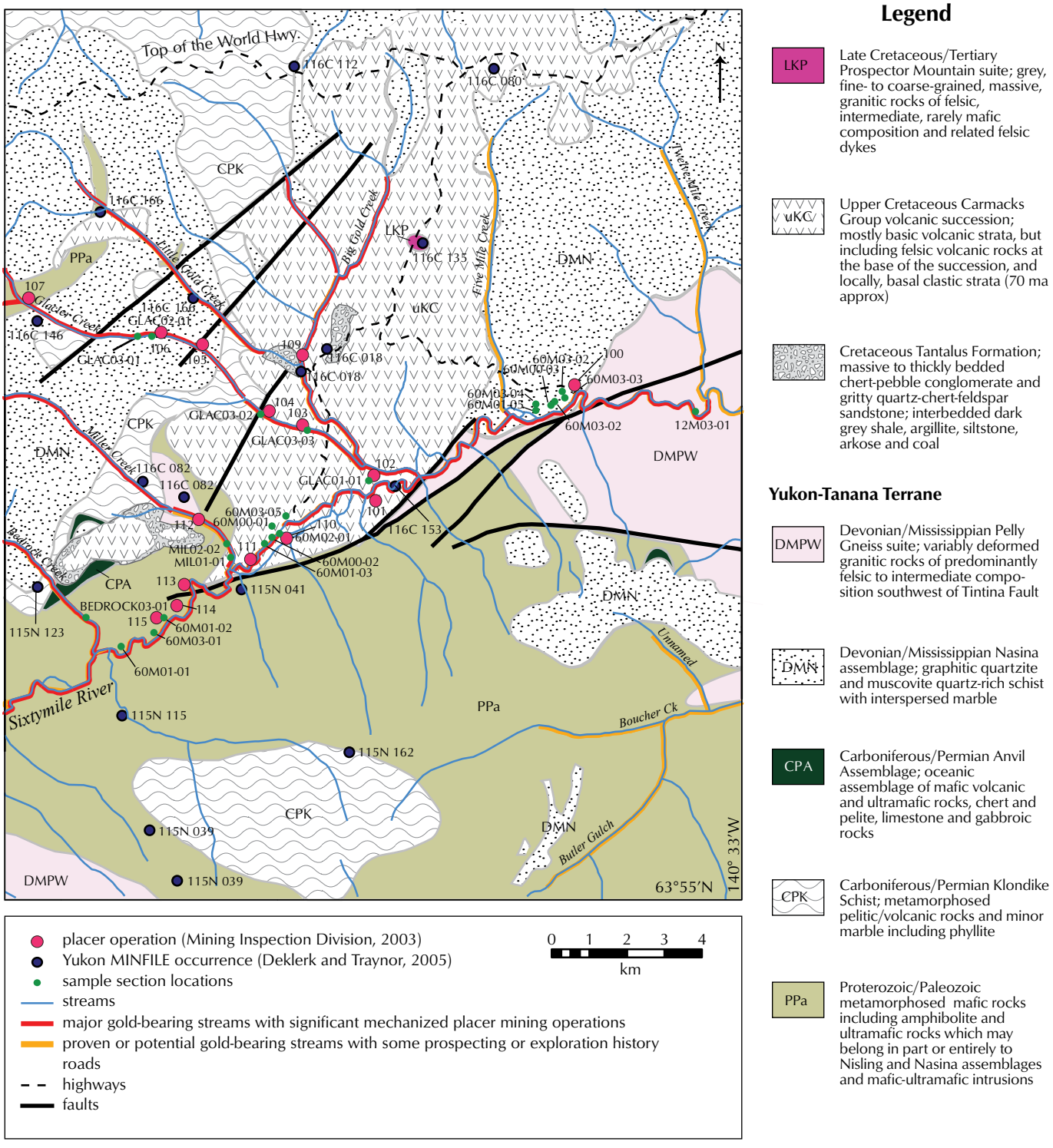
Structurally, the Sixtymile River flows along an asymmetric graben structure which progressively down-drops flat-lying panels of Tantalus Formation and Carmacks Group volcanic rocks to the level of the valley bottom on the north side of the Sixtymile river valley. A set of major northeast-trending faults generally separates this package from dominantly metamorphic rocks of Yukon-Tanana Terrane to the south.

MINERAL DEPOSITS

Several mineral deposits of various types occur in the Sixtymile area (Fig. 4 and Table 3). As documented in the Yukon MINFILE database (Deklerk and Traynor, 2005), veins are the main occurrence type. The veins cut both Tantalus Formation and Carmacks Group rocks and the metamorphic basement rocks; many of them are thought to be epithermal in nature (Glasmacher, 1985, Glasmacher and Friedrich, 1999). Studies of gold compositions in the Sixtymile District by Mortensen *et al.* (2006) suggest that these epithermal veins may not be the main contributors to placer gold in the Sixtymile River and its tributaries. Significant lode gold sources may remain to be discovered in the Sixtymile River area.

QUATERNARY HISTORY AND REGIONAL SURFICIAL GEOLOGY

The Sixtymile River is situated in the dominantly unglaciated western part of the Yukon Plateau (Fig. 1). Previous researchers (Bostock, 1966; Hughes, 1968) had considered the drainage to be unglaciated, however, Duk-Rodkin (1999) described part of the Sixtymile river valley as glaciated during one of the pre-Reid (780K to 2.5 Ma B.P.) glacial events, with a corresponding glacial moraine terminating between left limit tributaries, Twelve Mile Creek and California Creek. Lowey (2004) shows the Sixtymile river drainage to be unglaciated, while Jackson (2005) mapped several glaciofluvial terraces along the Sixtymile river valley, upstream of Bedrock Creek, and on the left limit of Mosquito Creek. Fifty Mile Creek is also mapped with a right-limit glaciofluvial terrace. These are



Legend

LKP — Late Cretaceous/Tertiary Prospector Mountain suite; grey, fine- to coarse-grained, massive, granitic rocks of felsic, intermediate, rarely mafic composition and related felsic dykes

uKC — Upper Cretaceous Carmacks Group volcanic succession; mostly basic volcanic strata, but including felsic volcanic rocks at the base of the succession, and locally, basal clastic strata (70 ma approx)

Cretaceous Tantalus Formation; massive to thickly bedded chert-pebble conglomerate and gritty quartz-chert-feldspar sandstone; interbedded dark grey shale, argillite, siltstone, arkose and coal

Yukon-Tanana Terrane

DMPW — Devonian/Mississippian Pelly Gneiss suite; variably deformed granitic rocks of predominantly felsic to intermediate composition southwest of Tintina Fault

DMN — Devonian/Mississippian Nasina assemblage; graphitic quartzite and muscovite quartz-rich schist with interspersed marble

CPA — Carboniferous/Permian Anvil Assemblage; oceanic assemblage of mafic volcanic and ultramafic rocks, chert and pelite, limestone and gabbroic rocks

CPK — Carboniferous/Permian Klondike Schist; metamorphosed pelitic/volcanic rocks and minor marble including phyllite

PPa — Proterozoic/Paleozoic metamorphosed mafic rocks including amphibolite and ultramafic rocks which may belong in part or entirely to Nisling and Nasina assemblages and mafic-ultramafic intrusions

Figure 4. *Sixtymile area placer mining operations, measured section locations and generalized geology (modified after Gordey and Makepeace, 2003 and Mortensen, 1996).*

Table 3. *Mineral deposits, Sixtymile River area.*

MINFILE number	Name	Status	Class	Commodity
115N 039	Golden Crag; Judy; Lerner	open pit past producer	vein	lead; silver, gold
115N 040	Connaught; Mosquito Creek	open pit past producer	vein	lead; silver, gold
115N 041	Per	drilled prospect	disseminated; stockwork; vein	gold; lead; silver; zinc
115N 115	The	unknown	unknown	unknown
115N 123	Bedrock	showing	igneous-contact; vein	silver, copper, gold
115N 162	Peak	showing	syngenetic	unknown
116C 018	Hungry; Kostem; Lgc; Pine; Rod	drilled prospect	coal	gold
116C 019	Boundary Lake; Devils Canyon; Gold Flake	showing	vein	lead; silver; zinc
116C 020	Alaska	anomaly	unknown	unknown
116C 080	Hamburger; Tony	unknown	unknown	unknown
116C 082	Elsie; Klonx; Marv	anomaly	unknown	mercury; tungsten
116C 112	Pub	showing	sedimentary; stratiform	zinc, copper, lead
116C 133	Baldy	showing	unknown	copper; lead; silver; zinc
116C 135	Be; Cholach; Guch; Jem	showing	vein	lead; silver
116C 146	Birch; Cedar	anomaly	unknown	gold; zinc
116C 153	Glasmacher; Lcg	showing	epithermal; replacement	gold
116C 158	Big Gold; Chels	unknown	breccia; vein	unknown
116C 166	Little Gold	anomaly	vein	unknown

interpreted by Jackson (2005), and Nelson and Jackson (2002) to be related to local pre-Reid alpine glaciations.

The subsequent Reid (311±32 ka to *ca*. 80 ka; Alloway *et al*., 2005) Cordilleran ice sheet did not advance into the region, but was likely contemporaneous with local alpine glaciation, as documented by geomorphic features described in the Fifty Mile Creek drainage by Lowey (2000, 2004). Periglacial weathering and increasing base-levels caused aggradation in the period leading up to the maximum glacial extent, and later, incision with decreasing base-levels during glacial retreat.

The McConnell (27-10 ka; Mathews *et al*., 1990) glaciation brought wind-blown silt (loess) into the area on katabatic winds. This blanketed existing sediments and bedrock surfaces, and through erosion, accumulated into the lower parts of the Sixtymile River valley.

STRATIGRAPHY AND SEDIMENTOLOGY

Table 4 displays the location and elevation of stratigraphic sections measured and sampled in the Sixtymile area drainages.

DESCRIPTION AND INTERPRETATION OF STRATIGRAPHIC SECTIONS

Although some evidence exists for glaciofluvial sediment in the Sixtymile drainage basin (Jackson, 2005), all stratigraphic sections examined in this study are interpreted to be fluvial in origin. On the basis of age and physiographic setting, four types of alluvium can be described: modern (Holocene); interglacial (prior to the McConnell glacial episode); pre-Reid and older; and technogenic deposits. Although all of these types of alluvium are placer-gold bearing, there are broad differences between them in size and grade. Radiocarbon dates are shown in Table 5.

Table 4. *Stratigraphic sections from Sixtymile River area (plotted on Figure 4).*

		Latitude			Longitude			Elevation	
Section	**Creek**	**°**	**min**	**sec**	**°**	**min**	**sec**	**feet**	**metres**
60M00-01	Sixtymile River	64	0	6	140	46	16	2262	689
60M00-02	Sixtymile River	63	59	53	140	45	59	2224	678
60M00-03	Sixtymile River	64	2	21.1	140	38	2.5	2100	640
60M01-01	Sixtymile River	63	57	51	140	51	33.7	2335	712
60M01-02	Sixtymile River	63	58	31.8	140	49	22.4	2322	708
60M01-03	Sixtymile River	63	59	42.2	140	46	35.3	2270	692
60M01-04	Sixtymile River	64	2	11.6	140	39	57.7	2100	640
GLAC01-01	Glacier Creek	64	1	13.2	140	44	29.6	2279	695
MIL01-01	Miller Creek	63	59	30	140	47	48	2290	698
60M02-01	Sixtymile River	63	59	57	140	46	25.8	2270	692
60M02-02	Sixtymile River	64	2	19.8	140	38	33	2130	649
GLAC02-01	Glacier Creek	64	2	34.2	140	51	26.6	2753	839
MIL02-01	Miller Creek	63	59	38.5	140	47	48.7	2287	697
MIL02-02	Miller Creek	63	59	48.7	140	48	13.2	2334	711
10M03-01	10 Mile Creek	63	30	51	140	0	38	1750	533
12M03-01	12 Mile Creek	64	2	37.5	140	33	12.3	2080	634
BEDROCK03-01	Bedrock Creek	63	58	38	140	52	56.1	2446	746
GLAC03-01	Glacier Creek	64	2	24.9	140	51	59.1	2763	842
GLAC03-02	Glacier Creek	64	1	45.3	140	47	45.6	2418	737
GLAC03-03	Glacier Creek	64	1	34.5	140	45	29.2	2330	710
60M03-01	Sixtymile River	63	58	28.4	140	49	13.8	2314	705
60M03-02	Sixtymile River	64	2	28.5	140	37	20.4	2063	629
60M03-03	Sixtymile River	64	2	31.3	140	37	29.7	2148	655
60M03-04	Sixtymile River	64	2	9	140	39	47	2096	639
60M03-05	Sixtymile River	64	0	6.2	140	45	44.4	2557	779

Table 5. *Radiocarbon dates for Sixtymile area drainages.*

Original sample number	Beta sample number	Section - unit	Drainage	14C date in years (AMS)	Mining operation
60M003-04	Beta 165202	60M00-03-04	Sixtymile	4520 ± 40 BP	Hakonson
60M00-1	Beta 165203	60M00-01-02	Sixtymile	45 420 ± 1100 BP	Hawker bench
60M01-04	Beta 165204	60M01-04-01	Sixtymile	9380 ± 40 BP	Hakonson
60M01-02-05	Beta 165205	60M01-02-05	Sixtymile	1290 ± 40 BP	Sandberg
WL03-76	Beta 189861	60M03-04-04	Sixtymile	2430 ± 40 BP	Hakonson peat
WL03-80-2	Beta 189862	60M03-05-02	Sixtymile	>50 030 BP	Hawker bench

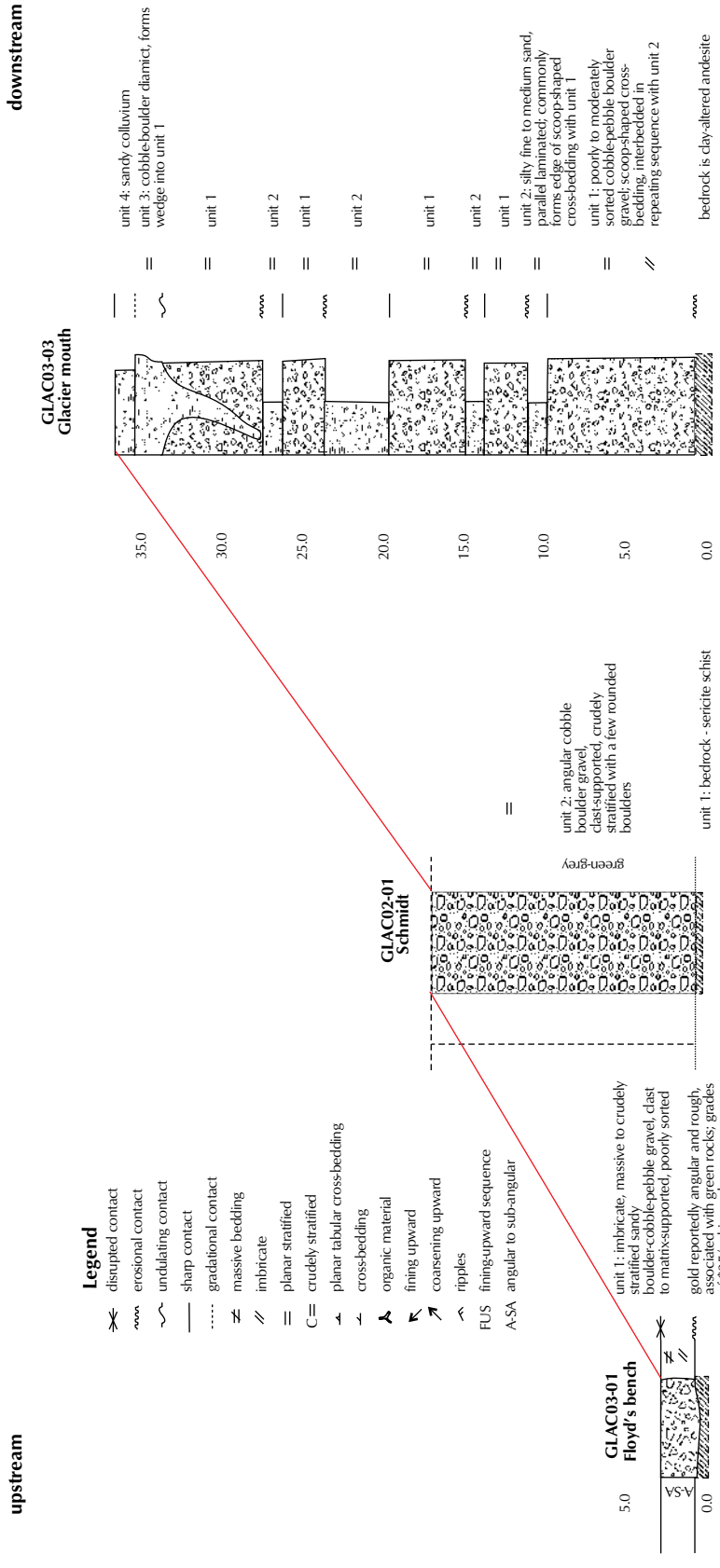


Figure 5. *Pre-Reid and older correlation, Glacier Creek valley.*

PRE-REID AND OLDER DEPOSITS

Pre-Reid and older deposits are represented by intermediate- to high-level terrace gravels exposed along the lower reaches of Glacier and Miller creeks. In upstream reaches, these terraces form incised abandoned channels, which run parallel to the modern channel. Figure 5 displays the stratigraphic correlation of measured sections GLAC03-01, GLAC02-01 and GLAC03-03. Sediments in these sections consist mainly of poorly sorted, angular, massive to crudely stratified, cobble-boulder gravel, which is interbedded with planar-laminated fine to medium sand (Fig. 6). This sequence represents a period of alluvial fan deposition under periglacial climatic conditions, which would be consistent with the onset of one of the pre-Reid glacial events. Further evidence of a periglacial environment is provided by the presence of a large ice-cast sand/gravel wedge at the top of measured section GLAC03-03 (Fig. 5), as well as the absence of any organic material.

These abandoned channels contain significant placer gold and have been mined extensively, including underground mining which was conducted on the left limit of Miller Creek. The highest gold grades are found at the gravel/bedrock contact and this deposit type ranks second (to modern or Holocene deposits) in the amount of placer gold produced in the Sixtymile River drainage.

INTERGLACIAL (PRE-MCCONNELL) DEPOSITS

Interglacial alluvial deposits in the Sixtymile River drainage are found on left-limit, low- to intermediate-level terraces. They consist mainly of massive to crudely stratified, quartz-rich, cobble-pebble gravel, overlain in varying combinations by rusty planar-stratified pebble-cobble gravel, and ice-rich to ice-poor silt and macro-organic materials (Figs. 7 and 8). The crudely stratified gravel represents a time of braided river sedimentation in the Sixtymile River drainage, while the planar-stratified gravel represents a transition to a wandering gravel-bed river system. Silt represents abandonment of the channel, and subsequent growth of macro-organic materials, which were further buried by aeolian sediments and infiltrated by permafrost ground ice.

Figure 6. *Periglacial pre-Reid and older age gravel, at the mouth of Glacier Creek, measured section GLAC03-03, approximately 30 m in height.*

Figure 7. *Interglacial alluvial terrace gravel, measured section 60M00-01, at Frank and Karen Hawker's placer mine. Note in-situ tree stump (AMS radiocarbon dated at 45 420 ± 1100 years B.P. – Beta 165203).*

Figure 8. *Interglacial alluvial terrace, measured section 60M03-05. Note ice-cast sand/gravel wedge at the contact between massive gravel and well stratified gravel units (adjacent to shovel). This is coincident with the transition from a braided to a wandering gravel-bed stream environment.*

Radiocarbon dates of 45 420 ± 1100 BP (Beta 165203) from section 60M00-01, and >50 030 BP (Beta 189862) from section 60M03-05 (Table 5) indicate that these deposits are at least as old as the pre-McConnell interglacial.

Figure 9 shows stratigraphic correlations of measured sections in these deposits, which include 60M00-01, 60M03-05, GLAC01-01, 60M03-03 and 12M03-01.

These deposits have been mined on the left limit of Sixtymile River between Glacier and Miller creeks. Placer gold grades are highest at the gravel/bedrock contact, although this deposit type ranks lowest in the relative amount of placer gold historically produced.

MODERN (HOLOCENE) ALLUVIAL DEPOSITS

Modern (Holocene) alluvial deposits in the Sixtymile River drainage basin occur along the present flood plain, on low terraces and within gulches. In the main valley of Sixtymile River, deposits consist of varying combinations of massive to crudely stratified pebble-cobble gravel, planar-, cross- and epsilon-stratified pebble-cobble gravel, medium to fine sand, and silt. Crudely stratified and massive gravel represent fluvial channel lag deposits, while the planar-, cross- and epsilon-stratified gravel represent point bar and channel bar sequences. Sand is typically deposited on bar tops and silt is the result of overbank flood deposition. These are fining-upward sequences characteristic of a meandering river system. Contemporaneous gulch deposits of Sixtymile River tributaries are represented by poorly sorted, locally-derived angular gravel.

Figure 10 displays the stratigraphic correlations of Sixtymile River upstream of Glacier Creek, and includes measured sections 60M01-01, 60M01-02 (Fig. 11) and 60M03-01. A modern (Holocene) age is indicated by a radiocarbon date of 1290 years B.P. (Beta 165205). Figure 12 displays the stratigraphic correlations of Sixtymile River downstream of Five Mile Creek, and includes measured sections 60M01-04, 60M03-04, 60M02-02, 60M00-03 and 60M03-02. Three radiocarbon dates (Beta 165204 – 9350 years B.P.; Beta 189861 – 2420 years B.P.; and Beta 165202 – 4520 years B.P.) indicate that this sequence is also Holocene in age. Measured sections from Sixtymile River tributaries Ten Mile, Miller and Bedrock creeks (10M03-01, MIL01-01, MIL02-02 and BEDROCK03-01; W. LeBarge, unpublished data) have similar stratigraphy and are also interpreted to be Holocene in age.

Figure 11. *Measured section 60M01-02, modern (Holocene) alluvial gravel and silt on Sixtymile River, Don Sandberg's placer mine.*

Placer gold occurs in all modern (Holocene) alluvial deposits studied but has mainly been mined in the valleys of Glacier, Miller, Big Gold, Little Gold and Bedrock creeks and Sixtymile River, making this deposit type the highest placer-gold producer. Gold grades are generally highest at the gravel/bedrock contact, but economic values commonly extend a metre or more into bedrock.

TECHNOGENIC DEPOSITS

Technogenic deposits can be described as alluvial deposits which have been subjected to some component of human disturbance, and include both actual tailings from previous mining activity, and remnant undisturbed placer-gold-bearing sediments which have been buried by tailings, or

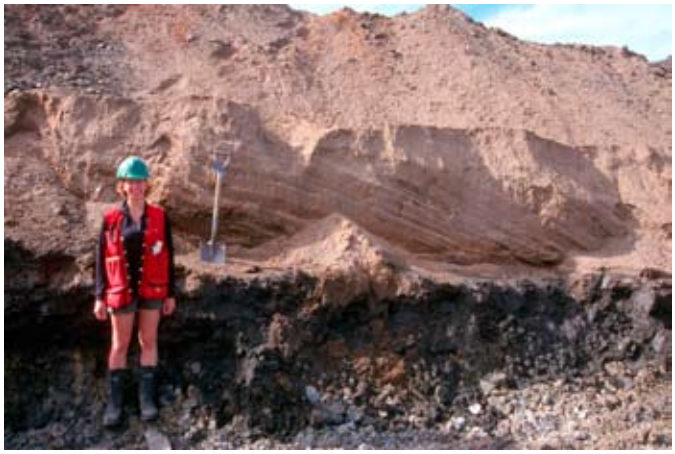


Figure 13. *Technogenic deposit, measured section 60M01-03. Typical dredge tailings with planar-tabular-stratified sandy gravel over mud and bedrock. Fractured bedrock here contains economic gold values.*

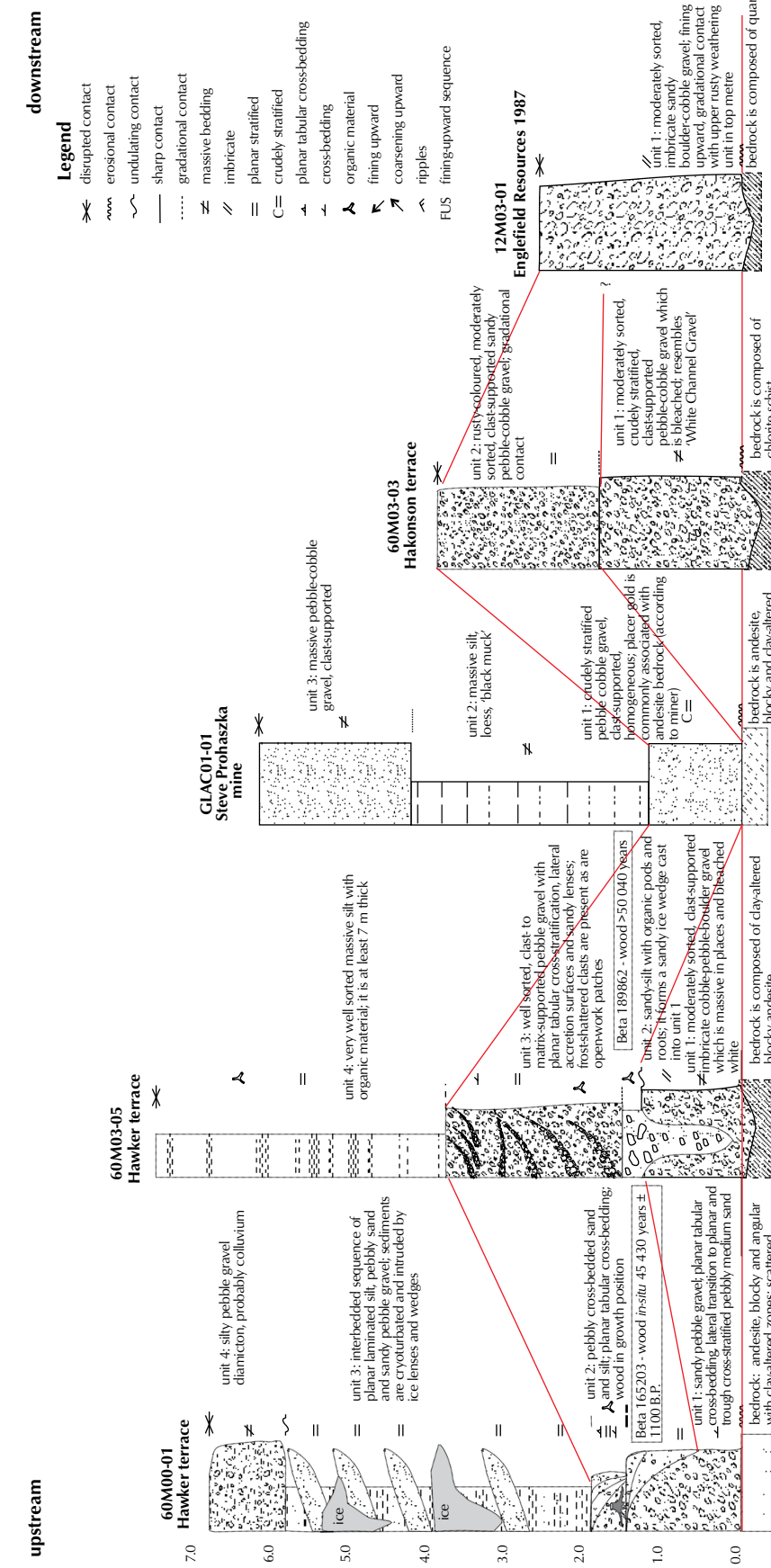


Figure 9. *Interglacial (pre-McConnell) correlation Sixtymile river valley.*

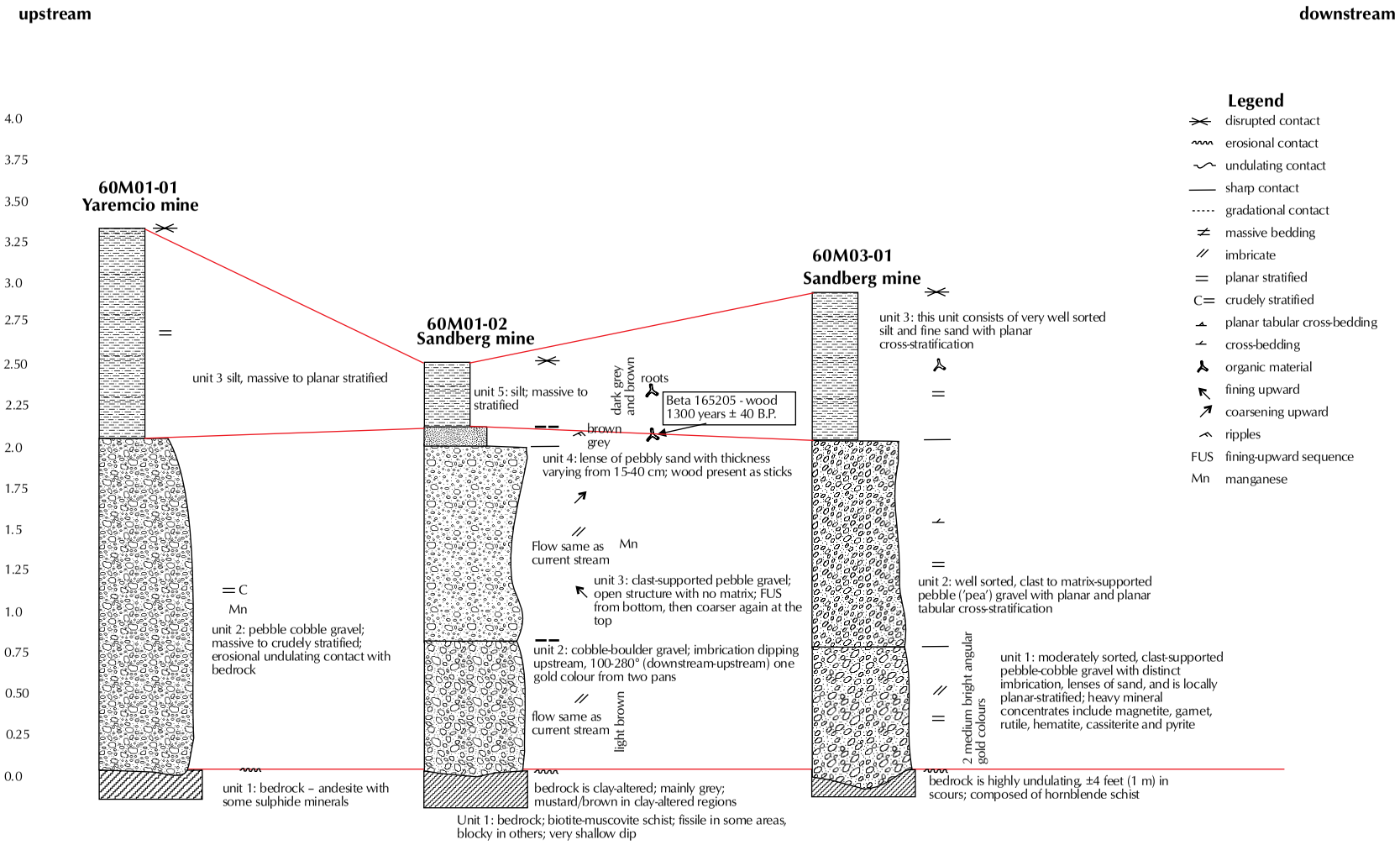


Figure 10. *Modern (Holocene) correlation Sixtymile River upstream of Glacier Creek.*

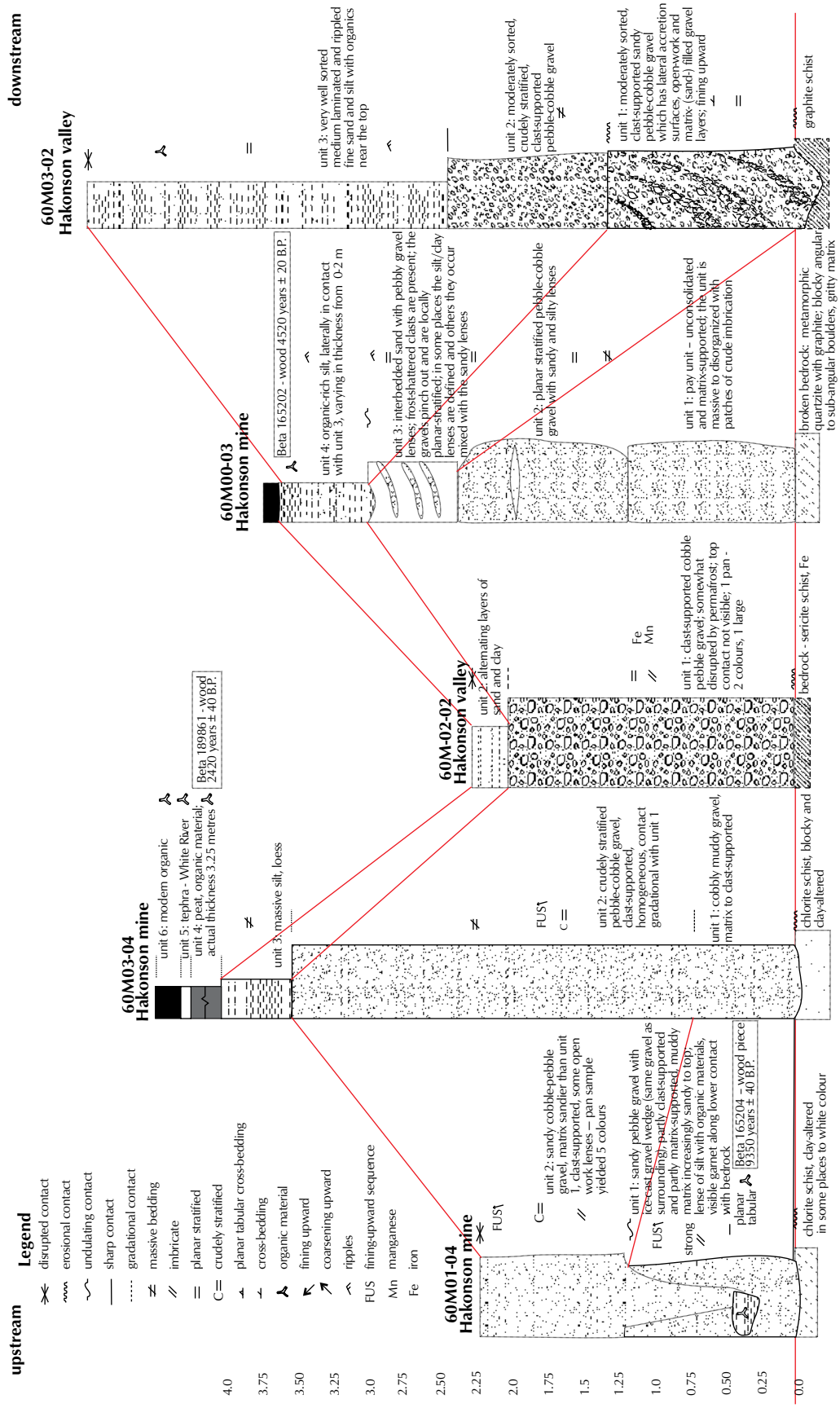


Figure 12. *Modern (Holocene) correlation, Sixtymile River downstream of Five Mile Creek.*

covered by man-made structures or objects. Such deposits mainly lie within the confines of the modern floodplains of Sixtymile River and its tributaries. Sediments generally consist of various combinations of fractured bedrock with localized pockets and reefs of crudely to well stratified pebble-cobble gravel (virgin gravel), overlain by well sorted clay and silt (fine tailings), and well sorted planar-tabular-stratified pebbly gravel and sand (coarse tailings). These sediments are found in measured sections 60M01-03 (Fig. 13), 60M00-02, 60M02-01, MIL02-01 and GLAC03-02.

These deposits commonly contain rich values of placer gold but are generally small in extent, with the best gold grades found in berms and pockets of virgin gravel, and the lowest gold grades found in dredge tailings. Fractured bedrock commonly contains economic values of placer gold extending one or more metres from the former gravel contact. This deposit type ranks third highest in the amount of gold produced relative to the other deposit types described in this study.

DISCUSSION AND INTERPRETATION OF PALEOGEOGRAPHIC HISTORY

Based on the stratigraphic sections studied and the regional surficial geology, a paleogeographic history of the Sixtymile drainage basin can be reconstructed.

Prior to the onset of Pleistocene glaciations, the Sixtymile River area was a stable plateau which was subjected to a long period of slow erosion, which formed pediment surfaces on the upper slopes. Jackson (2005) mapped these as P^{T}.

The onset of the first of the pre-Reid glaciations resulted in an increase in physical weathering and erosion of bedrock, and a dramatic increase in stream base-levels. In drainage basins which lacked local alpine ice, periglacial conditions during maximum glacial time nonetheless triggered downstream aggradation of gravel in a braided stream depositional environment. As the pre-Reid glaciation waned, the stream channels of Miller, Glacier, and possibly other Sixtymile tributary streams, shifted southwest, resulted in downcutting into bedrock, and abandonment of the former stream deposits as high-level terraces. Ice-cast sand and gravel wedges formed on those surfaces under diminishing periglacial conditions. The end result was the formation of the pre-Reid and older terraces, which are mapped by Jackson (2005) as unit At^{T}. In drainage basins subjected to pre-Reid alpine glaciations, glaciofluvial deposits formed downstream, mapped by Jackson (2005) as units Gt^{PR} and Cx/Gt^{PR}.

Interglacial (pre-McConnell) intermediate-level fluvial gravel terraces aggraded during increased base-levels, caused by either a subsequent pre-Reid glaciation or the later Reid glaciation. Braided stream deposits formed during a period of high sediment availability and stream flow. As stream flow and deposition waned, ice-cast sand and gravel wedges formed on the abandoned gravel surfaces. Better sorting and stable channels developed as the stream morphology evolved from a braided to a wandering gravel bed stream depositional environment. Downcutting of these terraces ensued as the interglacial period progressed. These terraces are mapped by Jackson (2005) as units At^{P} and Af/At^{P}, along with contemporaneous tributary valley alluvial deposits mapped as ACx^{P}.

The McConnell glaciation was likely not proximal enough to affect base-levels, however, it did result in the deposition of loess on slopes and abandoned intermediate-level terraces. As the McConnell glaciation ended, the Klondike plateau was uplifted differentially, resulting in the incision of Sixtymile River into bedrock and the formation of gravel-covered bedrock terraces, which progressively increase in elevation above the modern river level towards the confluence with Yukon River. Stable reworking and slow deposition of alluvial sediments evolved the Sixtymile River into a meandering stream system, resulting in the modern (Holocene) sediments which currently lie within the valley bottom of the Sixtymile River and its tributaries. These are mapped by Jackson (2005) as units Ap, Af and Ax.

Technogenic deposits are human-made deposits formed by mining activity, and these lie mainly within the valley of Sixtymile River in modern-age sediments. Most of them are the result of dredging activity which took place between 1912 and 1959, although some were the result of mechanical mining in subsequent years. These are mapped by Jackson (2005) as unit m.

GOLD AND HEAVY MINERAL CHARACTERISTICS

In the main Sixtymile River valley, placer gold is generally fine-grained and flat, although angular coarse gold and wire gold have also been found. The average size is between 10 mesh and 40 mesh US Standard screen size (2 mm to 0.425 mm). Some of the gold is manganese-

stained, and the fineness (purity out of a possible maximum value of 1000) varies between 810 and 840.

Gold from Miller Creek is reported to have a fineness of 827 to 857, and is commonly rough or angular, and iron and manganese-stained. It generally varies in size between 10 mesh and 60 mesh (2 mm to 0.250 mm).

In Glacier Creek, gold is approximately 20 mesh (0.850 mm) in size, with some fine and granular grains, and some nuggets with dark staining. Gold recovered from the bench gravel is generally coarser grained than that in the creek gravel. Fineness of the gold, based on bulk bullion assays, ranges from 830-860. Recent mining has encountered mercury amalgam along with the gold, presumably from old-timers' tailings (LeBarge and Coates, 2005).

Gold from Little Gold Creek has a fineness of around 850, and has included some nuggets which were described as smooth and spongy with quartz attached, and weighing 2-3 pennyweights (3 g to 4.6 g).

Big Gold Creek gold is generally fine-grained and flat with few nuggets, and has a fineness between 820-840.

Table 6 is compiled from an unpublished report by PetraScience Consultants Inc., and contains scanning electron microscope analyses (SEM) of selected gold grains and other heavy minerals from throughout the Sixtymile River area. All grains of gold were somewhat flat with smooth edges, and some grains contained minor amounts of silver, but most had high gold/silver ratios.

Heavy minerals found throughout the Sixtymile River area include magnetite, hematite, garnet, pyrite, arsenopyrite, galena, barite and scheelite. In addition, cinnabar is found in Miller Creek in the vicinity of Wy gulch. This is one of only two reported occurrences of placer cinnabar in Yukon. Scanning-electron microscope (SEM) analyses also identified zircon and chromite in heavy mineral samples.

FUTURE PLACER GOLD POTENTIAL

Potential placer gold exploration targets ranging from pre-Reid to modern (Holocene) age exist in several stratigraphic settings in the Sixtymile River area. Figure 14 is a schematic cross-valley profile, which illustrates generalized overall stratigraphy and potential placer gold targets. These targets include: 1) pre-Reid and older buried abandoned channels; 2) interglacial (pre-McConnell) buried and/or abandoned alluvial terraces; 3) modern (Holocene) alluvial channels and gulches; and 4) technogenic deposits.

PRE-REID AND OLDER BURIED ABANDONED CHANNELS

This setting is illustrated as exploration target number 1 in Figure 14. Left-limit abandoned channels on both Glacier (measured sections GLAC03-01, GLAC02-01 and GLAC03-03; Figs. 5 and 6) and Miller creeks demonstrate the potential for buried abandoned channels in other drainages such as Bedrock and Little Gold creeks. The left limit of such creeks should be targeted for exploration by

Table 6. *Summary of SEM analyses of gold and heavy minerals in Sixtymile area.*

Sample number	Location	Section number	Observations (SEM)
GLAC99-1	Glacier Creek	GLAC 99-1 McDougall	pure gold, several small grains
2001 Hawker	Sixtymile River	60M01-03 Hawker valley	pure gold, clay in holes
WL03-62	Sixtymile River	60M03-02 Hakonson	dominantly high gold, minor silver (single nugget)
60M mouth	Sixtymile River	60M mouth	dominantly gold, minor mixed gold-silver
SixtyM 002 unit 2	Sixtymile River	60M00-02 Hawker valley	pure gold (no silver observed)
SixtyM 002 unit 3	Sixtymile River	60M00-02 Hawker valley	dominantly gold, trace silver; quartz
SixtyM 003 bedrock	Sixtymile River	60M00-03 Hakonson	dominantly gold, trace silver
SixtyM 003 unit 1	Sixtymile River	60M00-03 Hakonson	gold, other phases – magnetite, barite, pyrite, ?chromite, ?garnet (CaFeAlSi)
SixtyM 003 unit 2A	Sixtymile River	60M00-03 Hakonson	pure gold; barite, zircon, garnet (CaFeAlSiMn)
SixtyM 003 unit 2B	Sixtymile River	60M00-03 Hakonson	gold with trace silver; garnet (FeMnAlSi)
WL03-50	Sixtymile River	60M03-01 Sandberg	gold with trace silver, trace clay

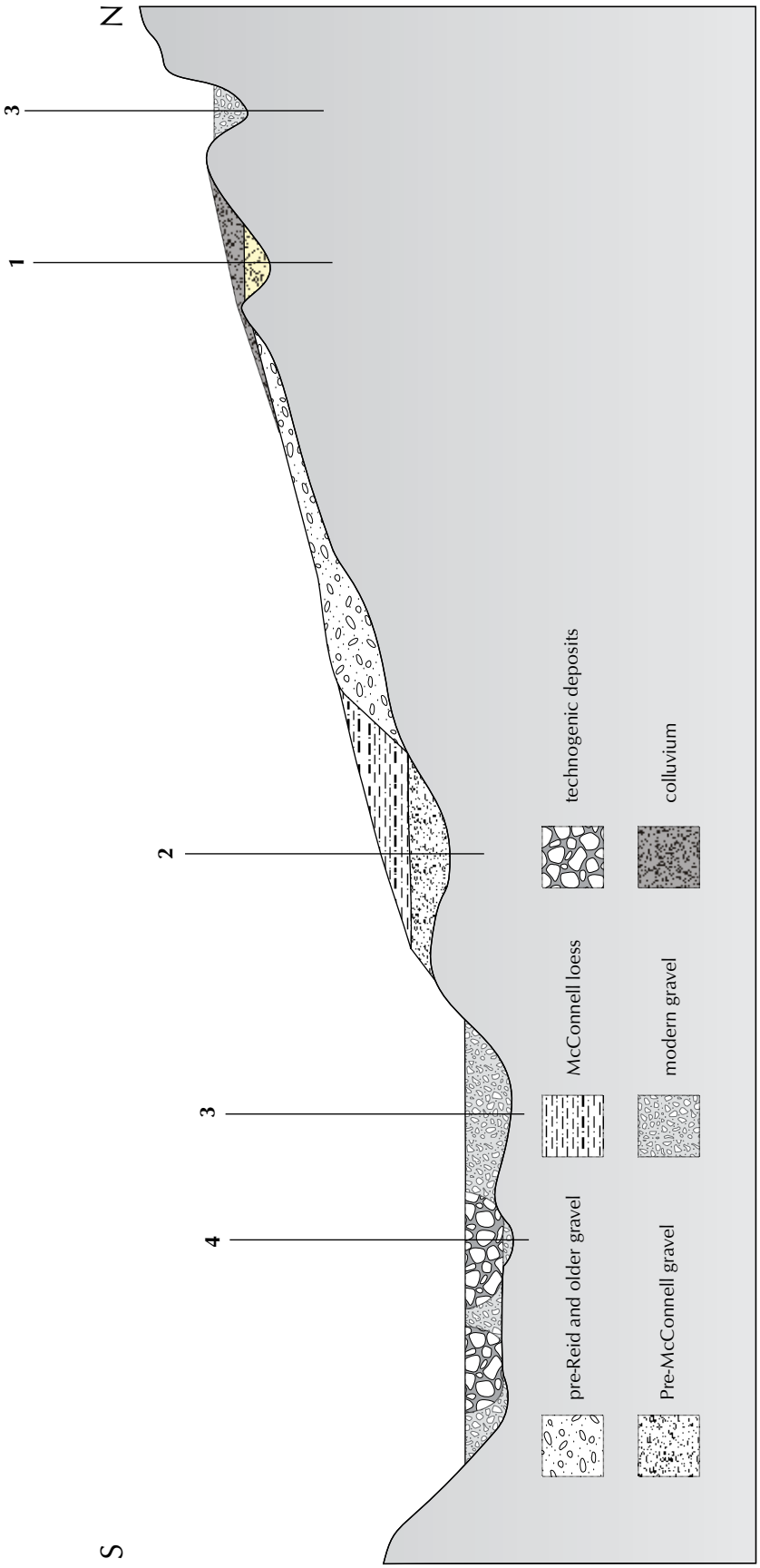


Figure 14. *Schematic cross-valley profile of Sixtymile River, illustrating generalized stratigraphic relationships and exploration targets: 1) pre-Reid buried abandoned channels; 2) interglacial (pre-McConnell) buried and/or abandoned alluvial terraces; 3) modern alluvial channels and gulches; and 4) technogenic deposits.*

methods such as ground-penetrating radar or seismic surveys, followed by test-pitting or drilling.

INTERGLACIAL (PRE-MCCONNELL) BURIED AND/OR ABANDONED ALLUVIAL TERRACES

This setting presents several exploration targets, mainly on the left limit of Sixtymile River, although a similar stratigraphic setting may exist on the right limit of Sixtymile River as well. Measured sections 60M00-01 (Fig. 7) and 60M03-05 (Fig. 8) best illustrate this setting, displayed in Figure 14 as target number 2. These terraces are most obvious towards the mouth of Sixtymile River, otherwise airphoto interpretation, followed by test pitting or drilling, will confirm their presence further upstream.

MODERN (HOLOCENE) ALLUVIAL CHANNELS AND GULCHES

Along the main valley of Sixtymile River, and in many tributary gulches, lie numerous unexplored potential placer targets. These are illustrated in Figure 14 as target number 3. Measured sections describing this type of deposit include 60M01-01, 60M01-02, 60M03-01, 60M01-04, 60M03-04, 60M02-02, 60M00-03 and 60M03-02 (Figs. 10, 11 and 12). The potential of these deposits can be explored by geophysical methods such as ground-penetrating radar or seismic surveys to determine the bedrock profile, and test-pitting or drilling to determine grade and volume.

TECHNOGENIC DEPOSITS

These have been described in measured sections 60M01-03 (Fig. 13), 60M00-02, 60M02-01, MIL02-01 and GLAC03-02. These deposits are shown as target number 4 in Figure 14. Exploration for these types of deposits would involve airphoto interpretation and literature research to determine areas of previous mining activity; and test-pitting or drilling to determine grade and volume of potential remnant placer-gold-bearing zones. Seismic and ground-penetrating radar surveys may help to determine thawed (mined) versus frozen (unmined) ground and the thickness of deposits.

RECOMMENDATIONS FOR FURTHER WORK

A program of detailed (1:25 000-scale or greater) surficial mapping, which includes ground-truthing and sampling of gravel deposits for gold content, is recommended. In addition, the development of a longitudinal profile of Sixtymile River bedrock terraces would be useful in correlating gravel deposits and helping to further reconstruct the paleogeographic history, as well as identifying additional prospective areas for placer gold deposits.

Detailed study of gold particles from known lode sources, as well as from placer deposits, may help us to reconstruct the sedimentary and geological history of Sixtymile River area. By using a combination of SEM, electron microprobe and laser-ablation ICP-MS methods to analyse the shape and composition of gold particles, it may be possible to trace the history of gold particles from lode sources, through intermediate hosts in bedrock and unconsolidated gravel, to present hosts in modern gravels. It may also be possible to use this method to determine the presence of possible undiscovered lode gold sources in the Sixtymile area.

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