GEOLOGY AND ALTERATION OF THE GREW CREEK EPITHERMAL GOLD-SILVER PROSPECT, SOUTH-CENTRAL YUKON

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ABSTRACT

Grew Creek epithermal gold prospect, in south-central Yukon Territory, is adjacent to and southwest of the Robert Campbell Highway, halfway between the communities of Ross River and Faro. The prospect is within the Tintina Trench, which from Late Cretaceous to Tertiary time was a zone of major right lateral movement that juxtaposed Cambrian and Ordovician slates and phyllites of the Pelly-Cassiar Platform (to the southwest) against rocks of the Anvil Allochthon (to the northeast).

Grew Creek rocks are mid-Eocene based on K-Ar dates of basalt of 51.4 ± 1.8 Ma and 50.7 ± 1.8 Ma, and pollen spores in volcaniclastic rock dated at 56 to 46 Ma. Felsic volcanic and volcaniclastic rocks were overlain by a sequence of interbedded coarse clastic sediments, basaltic flows, and basaltic volcaniclastic rock. Late Tertiary uplift and faulting resulted in graben formation and consequent preservation of Eocene rocks in a structurally complex graben bounded to the south by the Grew Creek fault and to the north by the Danger Creek fault.

Mineralization at Grew Creek occurs at the tip of a westwardly pointing wedge of dominantly felsic, crystal lithic lapilli tuff. The zone of precious metal deposition is truncated to the northeast by steeply dipping clastic sediments and to the southwest by the Grew Creek Fault. Gold, electrum, pyrite, and silver selenide were identified in a high grade sample from the discovery outcrop.

Alteration at Grew Creek is both surficial and hydrothermal. Surficial alteration is ubiquitous, pervasive, and characterized by mixed-layer clays and carbonates. Hydrothermal alteration, responsible for the gold-silver mineralization is closely associated with rhyolitic dykes and is of three types: silicic, acid sulphate, and argillic acid sulphate. K-Ar dating of sericite indicates hydrothermal alteration is mid-Eocene (51.5 ± 1.8 Ma and 47.0 ± 1.7 Ma) and synchronous with deposition of the volcanics.

Quartz associated with mineralization at Grew Creek is enriched in heavy oxygen isotopes. A deep magmatic source for the mineralized fluids is one explanation for this enrichment.

INTRODUCTION

The Grew Creek epithermal gold-silver prospect lies near Grew Creek about 1 km west of the Robert Campbell Highway, halfway between the communities of Ross River and Faro in south-central Yukon Territory. The Canyon claim block covering the zone of mineralization is on the western flank of a broad valley which marks the Tintina Trench. This valley was scoured by Pleistocene glacial ice and is extensively covered by till, drumlins and a few small lakes.

Sparse jackpine, spruce, and fir with willow and buckbrush characterize the claim area. Summer weather tends to be cool with daily highs ranging between 15° and 25°C; rainfall is frequent. The Canyon property, owned by Al Carlos of Whitehorse, Yukon Territory, was optioned in 1984 by Hudson Bay Exploration and Development Company Ltd., Toronto, Ontario, who subsequently have conducted an exploration program involving trenching, diamond drilling, geochemical sampling and geophysics.

The Grew Creek discovery is significant as the first reported Tertiary volcanic-hosted epithermal gold showing in the Tintina Trench. This report examines the geology at Grew Creek with special emphasis on the alteration associated with the mineralization.

REGIONAL GEOLOGY

At Grew Creek, epithermal gold-silver mineralization lies within Eocene felsic volcaniclastic rocks in the Tintina Trench. During the Late Cretaceous, major right-lateral movement along the trench caused at least 450 km of displacement (Roddick, 1967; Tempelman-Kluit, 1979). In the Grew Creek area, this resulted in the juxtaposition of the Pelly-Cassiar Platform against rocks of the Anvil Allochthon.

The area southwest of Grew Creek consists of rocks of the Pelly-Cassiar Platform, early Paleozoic pale green phyllite, argillite, and laminated chert of the Kechika Group (Fig. 1, Unit 1). The area northeast of the Tintina Fault zone adjacent to Grew Creek is part

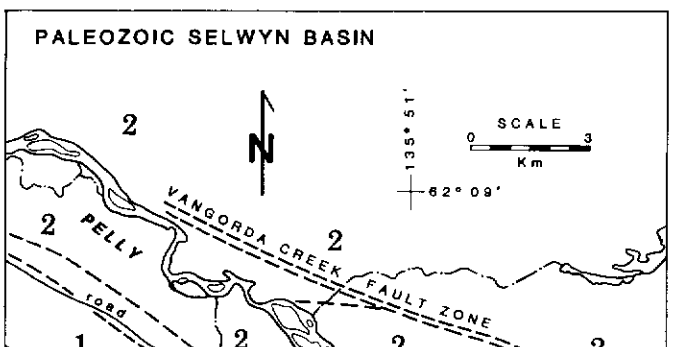


Figure 1. Grew Creek regional geological setting. 1 = unit 1, early Paleozoic Pelly-Cassiar Platform phyllite and chert. 2 = unit 2, Anvil Allochthon metabasalt and marble. 3 = unit 3, Eocene volcanic, volcaniclastic, and fluvial clastics. Grew Creek is marked as Au-Ag occurrence.

of the Anvil Allochthon (Fig. 1, Unit 2), which represent eugeoclinal equivalents of the Selwyn Fold Belt that were thrust northeastward during the Mesozoic (Tempelman-Kluit, 1979; Gordey, 1983).

Balsaltic to rhyolitic volcanism during the Eocene produced the rocks hosting the Grew Creek prospect. The graben created in the Tintina Fault zone during the late Miocene or Pliocene (Tempelman-Kluit, 1980) provided the complex structural setting at Grew Creek. Thus, the Eocene volcanic, volcaniclastic, and fluvial clastic sequence at Grew Creek (Fig. 1, Unit 3) is preserved in a graben sandwiched between these major tectonic elements.

LOCAL GEOLOGY

The Grew Creek prospect area, adjacent to the southwestern margin of the Tintina Trench, is cut by five major northwesterly trending fault zones (Fig. 1). Significant strike-slip and dip-slip motion may have occurred along these steeply dipping faults (Tempelman-Kluit, 1972). Interpretation of the geology at Grew Creek is hampered by very poor exposure and extensive fault disruption. The only good outcrop of the Eocene rocks is along Grew and Rat Creeks and at the discovery outcrop (Fig. 3). Nevertheless, three distinct lithologic units were recognized. They are numbered from oldest to youngest in Figures 1 to 3, and are described in detail below.

Unit 1

Phyllite, argillite, and chert (Fig. 3: PHYL), early Paleozoic in age (Roddick, 1961), form tan weathered outcrop in large cliffs and canyons southwest of the Grew Creek fault. Phyllite is pale green or grey, argillite is dark grey, and chert is grey and laminated.

Unit 2

Metabasalt forms large, green cliffs (Fig. 2). Thin sections show this unit to be schistose and composed of dark green, very fine grained chlorite and carbonate (60%), swirls and clots of feldspars (35%), and anhedral quartz (5%). Marble occurs throughout the metabasalt as white cliffs of cream and pale grey medium-grained massive recrystallized limestone.

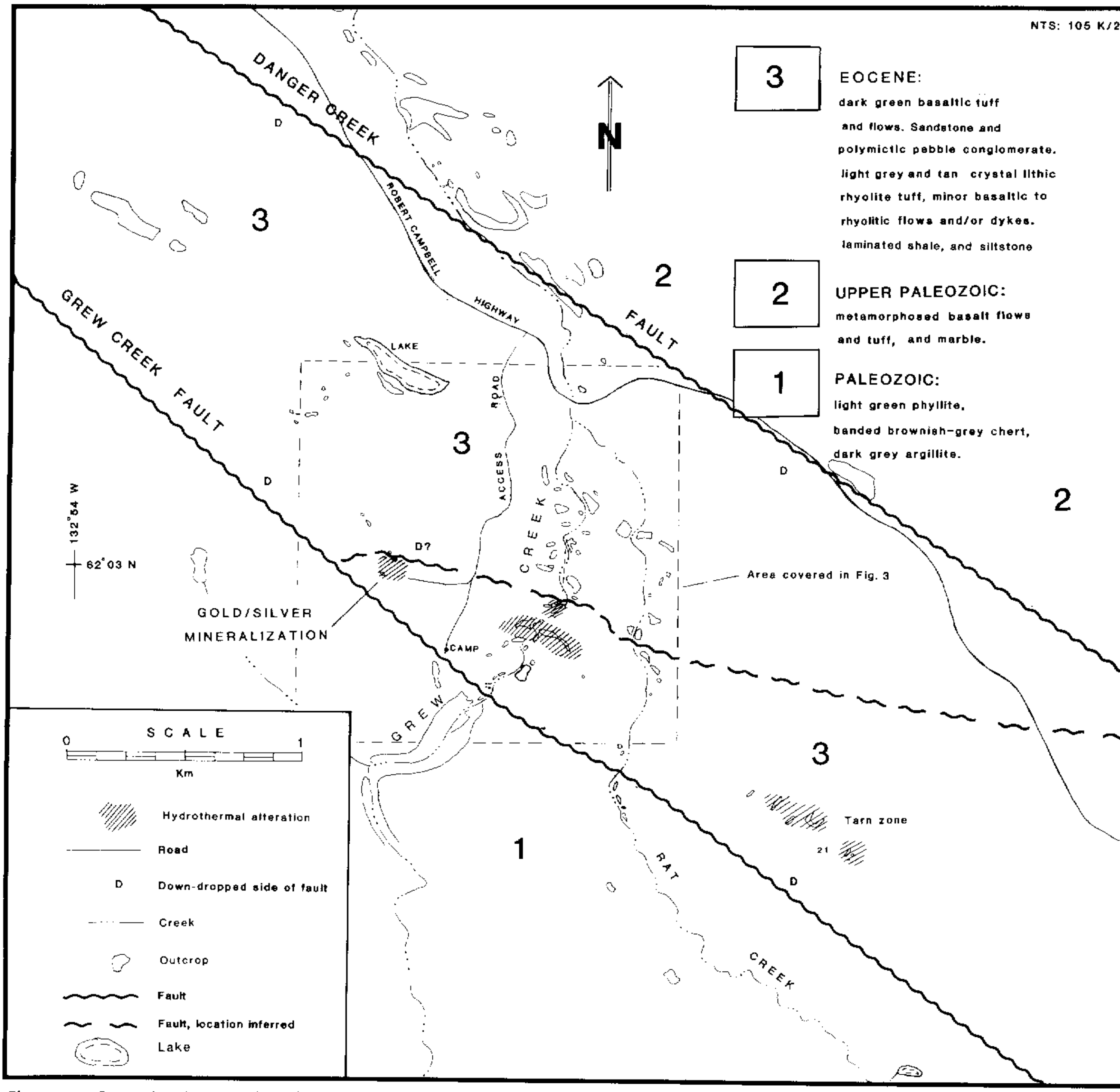


Figure 2. Grew Creek general geology.

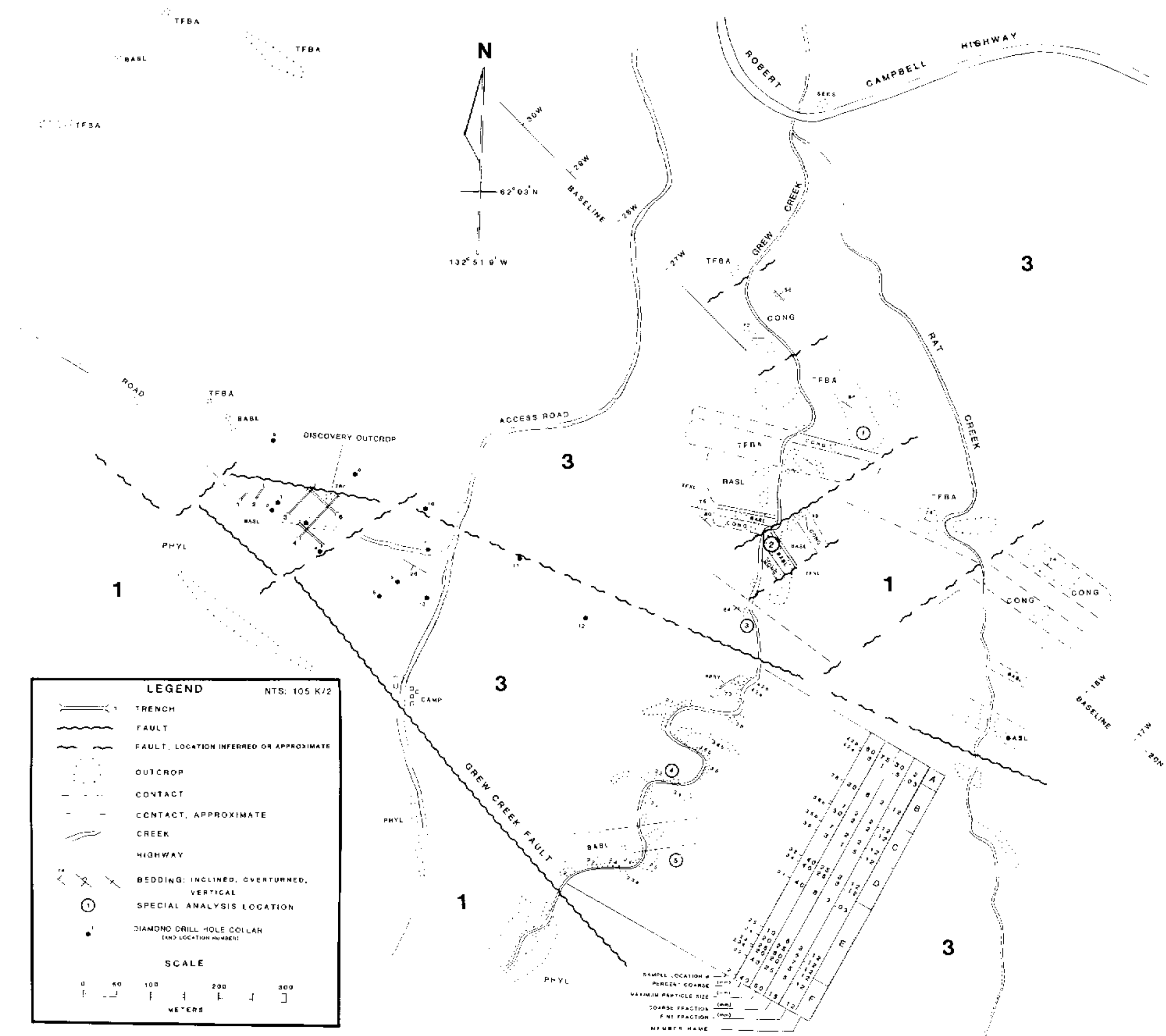
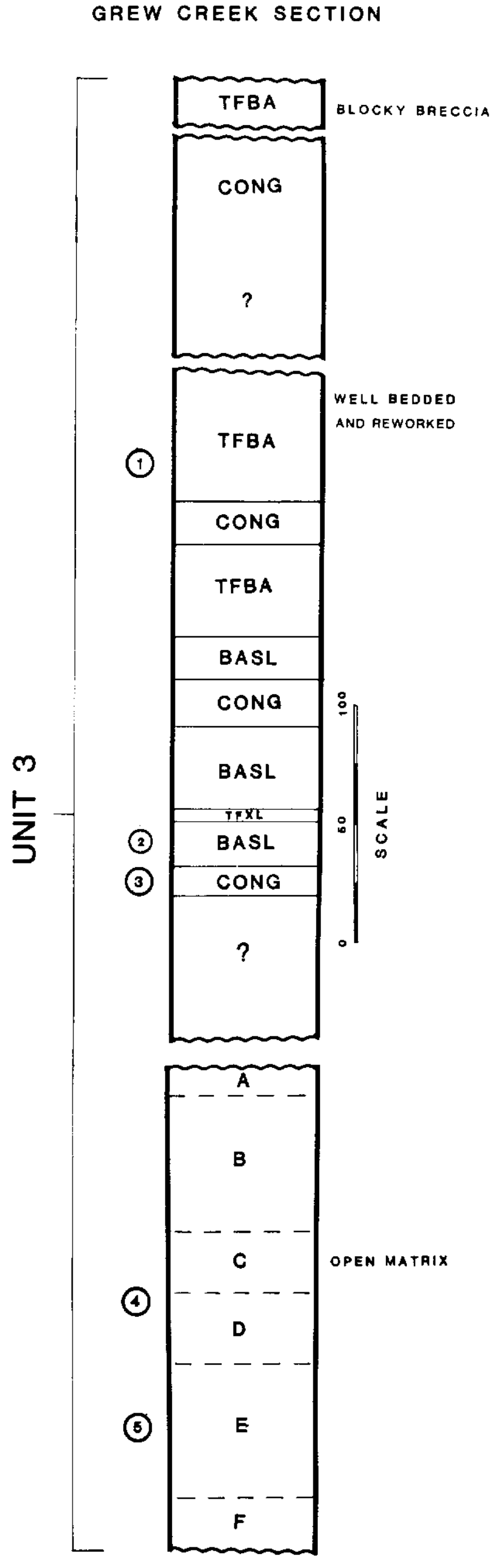


Figure 3. Sample and drill hole location map of the Grew Creek area. Circled numbers indicate special analysis was performed on samples from that location as follows: **1)** Sample D-52, basalt bomb in a well-bedded tuff. Prominent epidote alteration. Whole-rock K-Ar date: 51.4 ± 1.8Ma. **2)** Sample D-6, porphyritic basalt (BASL). Whole-rock K-Ar date: 50.7 ± 1.8Ma. **3)** Sample D-43, poorly sorted conglomerate (CONG) clast lithology listed in Table 1. **4)** Sample D-32, TFXL, Unit 3, Member C, strong sericitic alteration. Whole-rock K-Ar date: 51.5 ± 1.8Ma. **5)** Sample D-25c, crystal lithic lapilli tuff (TFXL), Unit 3, Member B, strong sericitic alteration. Whole-rock K-Ar date: 36.0Ma (± 1.3Ma).

DRILL HOLE INFORMATION:

HOLE NUMBER	ANGLE	DIRECTION	DEPTH
1	-50°	az = 045°	103.6m
2	-50°	045°	96.6m
3	-50°	225°	137.8m
4	-50°	225°	112.5m
5	-50°	045°	125.0m
6	-50°	045°	122.2m
7	-50°	045°	111.2m
8	-50°	225°	136.8m
9	-50°	225°	144.2m
10	-50°	225°	177.4m
11	-50°	225°	164.6m
12	-60°	225°	142.0m
13	-50°	225°	137.8m



Unit 3

This unit has been divided as illustrated in Figure 4. It consists of Ecocene rocks in a graben defined by the Grew Creek fault to the southwest, and the Danger Creek fault to the northeast (Figs. 2 and 3). Figure 4 is a cross-section through the Eocene volcanic and sedimentary sequence of Unit 3 at Grew Creek. Subdivisions within this unit are described below.

Crystal lithic lapilli tuff (Fig. 3, TFXL) is the dominant lithology in Unit 3. This tuff is pale grey and weathers recessively to a pale yellow-tan. Good exposures are restricted to the walls of Grew Creek. Grain size is variable and texture is clast supported. Clasts consist of felsic volcanics and variable amounts of subrounded to angular locally derived shale, and phyllite. Some fragments show weakly developed flow banding. Thin sections of felsic fragments show most feldspar crystals pervasively altered to green, white, and grey clays. Quartz occurs both as scattered subrounded "eyes" and as angular fragments. Patches of carbonate and opaque minerals also are common.

Grain size variations in the exposure of tuff along Grew Creek are documented in Figure 3. Grain size tends to be bimodal with a fine fraction of about 0.1 mm (coarse ash) and a coarse fraction of 2 to 6 mm (small lapilli). Six distinct depositional events are evident based on normally graded variations in the maximum particle size and the coarse fraction of the lapilli and blocks. Fragments up to 75 cm in diameter occur, indicating that the volcanic activity may have been proximal and explosive. Changes in grain size over short distances suggest at least a moderately dipping sequence striking easterly. However, the nearest structural data from core near the discovery outcrop about 300 m to the northwest (Fig. 3) indicates gently dipping bedding at that location. A sericitically altered sample (Fig. 3: outcrop 32) yielded a whole rock K-Ar date of 51.5 $\pm$ 1.8 Ma (Table 5).

Porphyritic rhyolite (Fig. 3: PPRY) forms small reddish brown weathering outcrops that probably represent dykes within the felsic volcaniclastic rocks. Rhyolite is also found in drill core as green flow-like units up to 2 m thick. It is a competent grey rock with a trachytic texture. A thin section shows the rock to consist of 40% euhedral, sub-parallel plagioclase phenocrysts to 4 mm in size, and 5% altered relict opaque minerals within a very fine-grained to aphanitic matrix (55%) rich in opaques, clay, and K-feldspar.

Volcaniclastic sediments form thin distinctive beds found only in drill core. They are matrix-supported, poorly lithified black volcaniclastic debris flows or lahars that contain fragments of altered and silicified felsic volcanics in a soft carbon-rich muddy matrix. These rocks are interbedded with felsic volcanic flows, mudstone, and sandstone, and are spatially associated with the conglomerate and sandstone described below.

Conglomerate and sandstone (Fig. 3: CONG) occur as isolated small outcrops along Grew Creek that are steeply dipping and poorly lithified. They are pale grey, clast-supported, have a cleanly washed appearance, and are variably sorted with normal and reversely graded bedding with frequent channel scours, and occasional carbonized plant debris. Cementing is largely carbonate. Clast lithology is in Table 1.

Figure 4. Grew Creek section. Circled numbers indicate special analysis was performed on samples from that location as follows: **1)** Sample D-52, basalt bomb in a well-bedded tuff. Prominent epidote alteration. Whole-rock K-Ar date: 51.4 $\pm$ 1.8Ma. **2)** Sample D-6, porphyritic basalt (BASL). Whole-rock K-Ar date: 50.7 $\pm$ 1.8Ma. **3)** Sample D-43, poorly sorted conglomerate (CONG) clast lithology listed in Table 1. **4)** Sample D-32, TFXL, Unit 3, Member C, strong sericitic alteration. Whole-rock K-Ar date: 51.5 $\pm$ 1.8Ma. **5)** Sample D-25c, crystal lithic lapilli tuff (TFXL), Unit 3, Member B, strong sericitic alteration. Whole-rock K-Ar date: 36.0Ma $\pm$ 1.3Ma.

TABLE 1
Clast description from conglomerate in Unit 3 (CONG; from outcrop 43, special sample location 3; Figs. 3 and 4).

45%	thinly laminated dark-grey muscovite-quartz schist with frequent limonite stained patches and streaks.
16%	pale green, laminated (0.5 mm layers) muscovite-feldspar-quartz schist with limonite stained spots.
15%	white (vein?) quartz.
13%	crumbly pale grey volcanic clasts (TFXL).
6%	pale-green to pale-grey medium-grained sucrosic muscovite-feldspar schist.
3%	banded black and grey carbonaceous chert.
2%	equigranular coarse-grained (0.5 to 1 mm in diameter) quartzite.

The altered felsic volcanic fragments indicate felsic tuff (Fig. 3, TFXL) from the same unit as a probable source. This suggests the conglomerate and associated basalt post-date the felsic rocks. However, one small bed of felsic crystal tuff with vesicular fragments does occur upsection adjacent to a basalt flow.

Porphyritic basalt (Figs. 3 and 4, BASL) occurs throughout the map area as flows conformable to bedding and as dykes and/or sills. It forms prominent outcrops, commonly cliffs, and is brown weathering. The matrix is grey and fine-grained. Plagioclase (An_{95}) occurs as anhedral phenocrysts up to 3mm in diameter and as smaller euhedral crystals. Thin sections show the rock consists of 50% plagioclase, 20% opaques, 20% indeterminant matrix altered to carbonate, 5% relict oxyhornblende, and 5% relict olivine. A weakly altered sample (Fig. 3: Outcrop 6) yielded a whole rock K-Ar date of 50.7 ± 1.8 Ma (Table 5). Whole rock chemical analyses, shown in Table 2, indicate a relatively unaltered and subalkaline (de Rosen-Spence, 1976), high to very high K (Gill, 1981), tholeiitic basalt (Miyashiro, 1974).

Basaltic volcaniclastics (Figs. 3 and 4, TFBA) are throughout the map area. They are dark green, extremely variable rocks, breccias, and ash to block tuff with variable amounts of rock fragments, mostly shale and dark coloured volcanic clasts. Rocks include well-bedded, reworked tuff deposits with sub-rounded sand-sized quartz grains, massive, chaotic, clast-supported, extremely angular breccia dominated by schist and shale fragments, and medium-green, vesicular basalt flows with small carbonate and quartz amygdules and drusy cavities. Mineral assemblage and major element abundance (Table 2) of a bomb in the well-bedded member of TFBA (Figs. 3 and 4, Special Sample Location 1) is almost identical to that of a basalt flow (Fig. 3: Special Sample Location 2). This suggests a similar magmatic source and the probability of periodic basaltic volcanism during rapid sedimentation of the felsic volcanic pile. A K-Ar date of 51.4 ± 1.8 Ma was obtained from this bomb (Table 5).

Muddy sediments (Fig. 3: SEDS) occur north of the highway as scattered exposures along Grew Creek. They are grey to pale purple weathering rocks consisting of interbedded conglomerate, sandstone, mudstone, and shale. The conglomerate is very poorly sorted with a clay or silt matrix. Conglomerate beds include numerous channel scours filled with silt. The bedded sediments range from arkosic, well-sorted fine-grained sandstone up to 30 cm thick with variable amounts of plant debris, to thinly bedded, fissile, micaceous, carbonaceous and silty shale. These rocks are separated from the rest of the Eocene sequence by a gap of several hundred meters that obscures any relationship with the Grew Creek section and precludes their inclusion in Figure 4.

ALTERATION

Analytical methods

Both general and detailed studies of alteration were done. Ninety-four sample locations in Unit 3 (Fig. 3) were examined by X-ray diffraction on oriented water mounts (Carroll, 1970). This data was compared to standard runs of minerals of known composition using the same preparation technique, and to tabulated X-ray diffraction data (Joint Committee on Powder Diffraction Standards, 1980). All mineral assemblages in Table 3, Figure 5, and in the text are listed in order of decreasing diffraction peak intensity. Peak intensity was used as a qualitative measure of relative

TABLE 2
Chemical compositions (oxides, weight %)[1], actual and normalized for basaltic rocks from Grew Creek, Yukon. Samples D52 (basaltic bomb, TFBA) and D6 (porphyritic basalt, BASL) are from Unit 3 (Fig. 3).

	— Sample D52 —		— Sample D6 —	
	Composition	Normalized	Composition	Normalized
SiO_2	47.34	49.05	47.88	50.62
TiO_2	2.42	2.51	2.26	2.39
Al_2O_3	16.10	16.68	16.13	17.05
Fe_2O_3	3.92	4.06	3.76	3.98
FeO	6.25	6.48	6.43	6.80
MgO	5.02	5.20	3.94	4.17
CaO	7.75	10.10	7.64	8.08
Na_2O	3.38	3.50	3.84	4.06
K_2O	1.32	1.37	1.94	2.05
P_2O_5	0.52	0.54	0.63	0.67
MnO	0.50	0.52	0.13	0.14
LOI	2.59		4.34	
TOTAL	99.82	100.01	98.92	100.01

1. Weight % oxides calculated by Midland Earth Science Associates, Conway House, Conway Street, Long Eaton, Nottingham, U.K.
LOI = loss on ignition.

amounts of each phase present. Surficial and hydrothermal alteration types were identified, as described below.

Surficial alteration

Warm subtropical conditions that existed during the Eocene (Hopkins, 1974; Rouse, 1977; Wolfe, 1978), in conjunction with heavy rainfall (over 1,800 mm/year, Rouse, pers. comm., 1986), the high permeability of the host rock, and a fluvial sedimentary environment contributed to a deep weathering profile at Grew Creek. Pleistocene glaciation and erosional processes removed most exposures of the Eocene rocks. Only exposures along Grew Creek and isolated outcrops elsewhere remain (Fig. 3).

Felsic volcanic rock in outcrop is friable. Feldspar crystals are altered to a waxy white and grey material and the matrix to a grey material with a resinous lustre. The characteristic alteration assemblage consists of mixed-layer smectite/illite + quartz + various feldspars + iron rich carbonates. These alteration minerals are attributed to surficial weathering processes.

Surficial alteration is superimposed on all hydrothermal alteration facies. Althought surficial alteration can be pervasive and intense, it lacks acid sulphates and the abundant secondary K-feldspar characteristic of the hydrothermal alteration discussed below.

Hydrothermal alteration

Areas of intense hydrothermal alteration are shown by diagonal hatching in Figure 2. Hydrothermal alteration is subdivided into the following facies based on mineralogy: silicic, acid sulphate, and argillic acid sulphate.

Silicic alteration, represented in the felsic lapilli tuff of Unit 2 (Fig. 3) forms resistent, rounded knobs in outcrop. Original pyroclastic textures are obscured and altered rocks are a darker grey compared to unsilicified specimens. The mineral assemblage is dominated by quartz ± K-feldspar ± mixed-layer smectite/illite ± albite ± Fe-rich carbonate. This assemblage is associated closely with anomalously high precious metal values and gold-silver-rich chalcedonic quartz plus K-feldspar veins up to several cm thick.

Acid sulphate alteration occurs along Grew Creek in several places near altered felsic dykes. The presence of an acid sulphate mineral, jarosite or alunite, as determined by X-ray diffraction, distinguished this facies.

Argillic acid sulphate alteration, recognized only in trenches and core because weathers recessively, is characterized by crumbly rock that is pale grey or white when dry. Strong alteration totally obliterates original textures. The associated mineral assemblage is dominated by smectite ± mixed-layer smectite/illite, + carbonate ± jarosite ± alunite ± sericite ± kaolinite ± K-feldspar (primary?) ± plagioclase (primary?) ± iron-oxides ± quartz (partly primary?). Either one or the other of the acid

TABLE 3

Detailed lithological and alteration features of Trench 4 from 0 to 84 meters. (Fig. 3)

METERS	LITHOLOGY[1]	QUARTZ %[2]	CLAY %[2]	VEIN[3] STRIKE/DIP	AU[4]	AG[4]	AS[4] PPM	HG[4] PPB	ALTERATION[5]
1	TFXL								
2	TFXL								
3	TFXL	50							
4	TFXL	20							QZ ML OR si
5	TFXL		20			2			
6	TFXL		30						
7	TFXL	40							
8	TFXL	40							
9	TFXL	40							
10	TFXL		20		1	2	500	220	
11	ROTN		20						ML sm ms il or
12	ROTN		20						
13	TFXL	70			1	1	300	115	
14	TFXL	70			1	2	210	200	
15	ROTN		20	093/--	1	1	30	110	
16	ROTN		20						QZ ML fs
17	TFXL	70							QZ ML OR ca si al
18.5	TFXL	70			1	1	90	300	
19	ANDS								
20	ANDS								
21	ANDS								
22.5	ROTN		30		—	1	33	220	
23.5	TFXL	10	10		1	1	85	330	ML fs qz ka
24.3	TFXL	20							
25.2	TFXL	70			1	1	240	120	ML AB ka
26	TFXL	10			1	1	330	155	
27	TFXL	10			2	2	190	360	QZ ml or ca
28	TFXL	10							
29	TFXL	10							
30	TFXL	10							
31	TFXL	10							
32.3	TFXL	10							
33	ROTN		20						
34	ROTN		20						
35	ROTN		20		1	2	75	295	
36	TFXL	40							
36.5	ROTN				1	1	100	500	QZ ml or pl ca si
38	TFXL	40			1	2	62	295	
39	TFXL	40							
40	TFXL								
41	TFXL								
42	TFXL								
43	TFXL	20			—	2	115	160	
44	TFXL	20			—	1	90	60	
45	TFXL	20					100	125	
46	TFXL	20			1	1	170	110	
47	TFXL	20							
48	TFXL	20			1	1	200	650	
49	TFXL	20							
50	TFXL	20							QZ OR al ja ca
51	TFXL	70							
52	TFXL	70							
53	TFXL	70			1	2			
54	TFXL	70		280/66	$	$			
55	TFXL	70			$	$			
56	TFXL	70		150/90	$	$			QZ OR ja al ml si cb
57	TFXL	70			$	$			
58	TFXL	70			$	$			

TABLE 3 (cont.)

METERS	LITHOLOGY[1]	QUARTZ%[2]	CLAY%[2]	VEIN[3] STRIKE/DIP	AU[4]	AG[4]	AS[4] PPM	HG[4] PPB	ALTERATION[5]
59	TFXL	70			$	$			
60	TFXL	70			$	$			
61	TFXL	70			$	$			
62	TFXL	70			$	$			
63	TFXL	70		140/90	$	$			
64	TFXL	70			$	$			
65	TFXL	70		084/83	$	$			
66	TFXL	70		154/90	$	$			
67	TFXL	70			$	$			
68	TFXL	70			$	$			
69	TFXL	70			1	1	300	120	QZ OR al ja ca si
70	TFXL	70							
71	TFXL	70							
72	TFXL	70			1	1	100	110	
73	TFXL	70							
74	TFXL	70			1	2	270	140	
75	TFXL	70							
76	TFXL	70							
77	TFXL	70			1	2	150	240	
78	TFXL	70							
79	TFXL	20			1	1	75	60	
80	TFXL	20			1	2	140	310	
81	TFXL	20							
82	TFXL	20							
83	TFXL	20							
84	TFXL	20							
85	TFXL	20							

1. LITHOLOGY: TFXL = rhyolitic, crysal lithic lapilli tuff; ROTN = totally disaggregated rock material, probably TFXL. BASL = porphyritic basalt. See unit descriptions in text for complete description.
2. QUARTZ% = estimated total percentage of secondary quartz present. CLAY% = estimated total percentage of clay minerals present.
3. VEIN STRIKE/DIP = the strike and dip (to the right of strike direction) of major chalcedonic quartz and quartz-feldspar veins.
4. Au, Ag: - = not detected, much less than 2g/tonne; 1 = less than 2g/tonne; 2 = 2-7g/tonne; 3 = less than 7g/tonne; $ = high values (pers. comm., Hudson Bay geologists) but no data available); black space = no data available.
5. Alteration is coded so that upper case indicates dominant phases, lower case indicates relatively smaller quantities as determined by weaker XRD peaks. QZ = quartz, ML = Mixed-layer clays dominated by smectite and illite, OR = K-feldspar, CA = calcite, SI = siderite, AL = alunite, JA = jarosite, CB = carbonate.

Trench strikes 045° (azimuth) and is inclined -5° in this direction. O meters is at 1334.00N, 2804.00E on property grid (Fig. 3).

sulphates is always present in this facies. Anomalous concentrations of heavy metals also occur with these assemblages.

Dykes are a feature common to all zones where increased alteration is evident in outcrop. This increased alteration may reflect local hydrothermal effects from the emplacement of hot dyke material into the porous lithic tuff. On the other hand, the emplacement of the impermeable dyke material may restrict and channel the flow of groundwater along the dyke margins, causing increased alteration associated with the locally higher flux of water.

Intense hydrothermal alteration occurs between Outcrop 25 and 31 within and proximal to the basalt dyke (Fig. 3). The basalt is completely altered to a cream, brown, and green spotted clay at one place (Fig. 3, Outcrop 25) that masks the original texture and mineralogy of the rock. K-feldspar and albite are the dominant alteration phases in some exposures. Kaolinite and epidote are also present in the altered basaltic material.

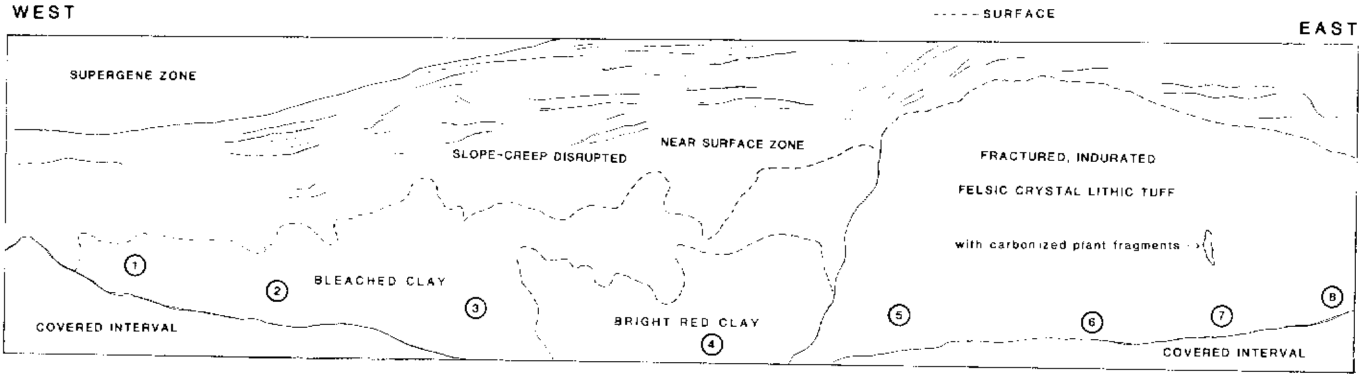
At the discovery outcrop (Fig. 3), the largest silicic alteration zone has an assemblage of quartz, K-feldspar and precious metals. Jarosite, alunite, and Fe-rich carbonate occur as a later episode of veining around brecciated fragments of strongly silicified tuff. Steeply dipping, commonly brecciated, chalcedonic quartz and K-feldspar veins with very strong precious metal values are prominent in this zone. Immediately adjacent to this silicic alteration, a rhyolite dyke is intensely altered to a soft, friable smectite.

Outcrop 42 (Fig. 3) has minor alunite in an otherwise dominantly surficial assemblage. This acid sulphate occurrence is adjacent to a porphyritic rhyolite dyke with extensive pervasive alteration and minor disseminated pyrite. The dyke crosses Outcrop 37 (Fig. 3) near the acid sulphate and silicic alteration found in Outcrop 36b; it is too small to show at the scale of Figure 3.

Trench 4 alteration

A detailed analysis of part of a wall in Trench 4 is shown in Figure 5. This part of the trench provided clean exposure of the different facies of alteration associated with the mineralization. Samples were taken to represent each visually and texturally distinct alteration type. Silicic alteration represented by Samples 5, 6, 7, and 8 is dominated by quartz and K-feldspar. Mineralization also appears to be favoured in this zone, although the correlation based on these few samples is erratic and may be affected by cross-cutting quartz-feldspar-precious metal rich veins. There is an abrupt change in Samples 2, 3, and 4 which represent a zone of pervasive argillic acid sulphate alteration characterized by a mixed-layer illite/smectite and a diverse assemblage that includes the sulphates jarosite and alunite. A hematite stained zone of the argillic acid sulphate facies appears to be associated with the margin of the silicic facies. This juxtaposition of argillic and silicic facies is repeated seven times along Trench 4. Detailed features of Trench 4 are reported in Table 3.

TRENCH 4 X-SECTION (0 TO 8m)



XRD RESULTS:

①	②	③	④	⑤	⑥	⑦	⑧
ML	ML	ML	ML	QZ	QZ	QZ	QZ
MS (illitic)	PL	JAROSITE	CA	ML	ML	ML	ML
KA	AB	CA	QZ	KF	KF	DO	KF
PL	JAROSITE	DO	PL	IL	CA	PL	AB
CL	SIDERITE	KF	KF		PL		CA
QZ	MS	PL	CL				DO
	IL	MS					
	ALUNITE	IL					
	QZ	CL					
		KA					
		ALUNITE?					

Silicified rock fragments in a clay matrix with limonite stains and carbon streaks

Total clay alteration. Limonite stains and carbon streaks.

Hematite stained clay rich zone.

Fractured and silicified rock fragments. Limonite, hematite? and manganese? stained patches. Bleached patches of intense alteration. Hematite stained veinlets.

Silicified rock with patches of clay alteration. Limonite, Fe-carbonate, and alunite in veins and fractures. Large carbonized plant fragments.

←——ACID LEACHED ZONE——→ ARGILLIC ACID SULPHATE ALTERATION

←—TRANSITIONAL ZONE—→

←—FE-OXIDE DEPOSITION—→

←——SILICIFIED ZONE——→ SILICIC ALTERATION

POTASSIUM DEPOSITION

GEOCHEMICAL ANALYSIS:

	①	②	③	④	⑤	⑥	⑦	⑧
Se: (ppm)	0.1	0.1	0.4	0.3	0.5	0.2	0.1	0.1
Au:*	1	1.	1.	–	1.	3.	–	1.
Ag:*	1.	2.	2	1.	1.	2.	1.	1.
As: (ppm)	73.	173	540.	70.	550.	300.	310.	360.
Hg: (ppb)	95.	225.	316.	225.	185.	110.	85.	95.
Te: (ppm)	.01	.01	.01	.01	.01	.65	.03	.01

*Au, Ag: – : <.2 grams/tonne
1 : <2 grams/tonne
2 : 2-7 grams/tonne
3 : >7 grams/tonne

SCALE: Sample locations are 1 meter apart

EXPLANATION

AB: albite
CA: calcite
CL: chlorite
DO: fe-rich dolomite
KA: kaolinite
ML: mixed-layer clays mostly smectites
MS: muscovite
KF: K-feldspar
PL: plagioclase
QZ: quartz
—— contact
- - - gradational or poorly defined contact
① etc. sample location

Figure 5. Detailed analyses of part of Trench 4 (Fig. 3) at Grew Creek representing hydrothermal alteration associated with mineralization.

MINERALIZATION

High-grade gold-silver mineralization occurs in the discovery outcrop, adjacent trenches and drill holes. It is associated with the silicic alteration; chalcedonic quartz and K-feldspar veins in silicified material contain the highest values of precious metals.

Gold, electrum, pyrite, and silver selenide, occur as disseminated specks in and adjacent to quartz-potassium feldspar veins. Figure 6 is a backscattered electron photomicrograph of a sample from the discovery outcrop (Fig. 3: Outcrop 76c) showing two grains of gold (white colour), one located in a vein hosted by crystal tuff (TFXL) and the other in an iron-oxide and alunite vein (distinguished by a paler grey shade, Fig. 6). The host rock has been strongly silicified and has patches of K-feldspar. The pale grey mesh-like network in Figure 6 indicates areas of higher iron content. Gold in the iron-oxide and alunite vein (Fig. 6) may represent an inclusion from the silicified wall rock because all other precious metal grains were found in the silicic host.

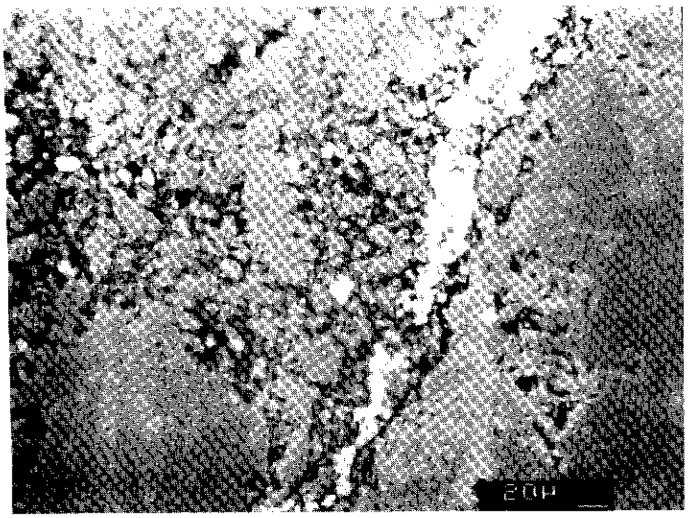


Figure 6. Scanning electron micrograph of gold associated with silicic alteration at Grew Creek (Fig. 3, discovery outcrop). Pale vein hosting one of the gold grains consists of iron oxides and alunite.

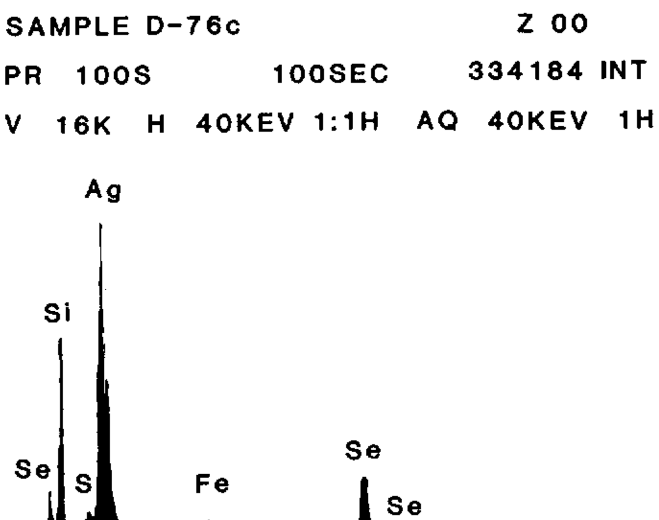


Figure 7. Energy dispersive spectrograph of a silver selenide mineral in the discovery outcrop (Fig. 3) at Grew Creek. Iron and sulphur may indicate pyrite in which case the silver-selenium peaks may represent haumannite, Ag_2Se or aguilarite, Ag_4SeS. The silica peak reflects the silicic alteration associated with mineralization in the discovery outcrop (Fig. 3).

The occurrence of precious metals with different gangue phases may indicate repeated mineralization events. The association of silica with mineralization and prominent vein layering suggests episodic deposition from the same hydrothermal fluid. The high gold and silver content of the argillic facies (Fig. 6) may represent remobilization of metals during a later stage acid leaching of the silicified rock.

Silver selenide is defined by Figure 7 which shows a graph of the energy dispersive spectrum for a grain in Sample 76c (Fig. 3). Peaks corresponding to characteristic energy levels for silver, selenium, sulphur, and iron are labelled in Figure 7. The iron and sulphur may indicate a separate pyritic phase. If so, a silver selenide such as haumannite, Ag_2Se, or aguilarite, Ag_4SeS is indicated. Assays for selenium in Trench 4 are shown in Figure 5; values are not unusual relative to other precious metal deposits (Boyle, 1979).

The proximal location of the two alteration facies in Trench 4 (Fig. 5: silicic with the K-feldspar, argillic with the alunite and jarosite) indicates two incompatible pH conditions — a low pH assemblage superimposed upon a near neutral pH regime. A possible explanation for this association involves the evolution of carbon dioxide and hydrogen sulphide from a rising solution which results in a rise in the pH of the residual solution that causes precipitation of silica, feldspar, gold, silver, silver selenide, and iron sulphide. Carbon dioxide and hydrogen sulphide react under oxidizing surface conditions to form strong acids, and these leach the host rock adjacent to the silicified zone, leaving clays and other phases such as alunite and jarosite that are stable under such acid conditions (Rose, et al., 1979).

OXYGEN ISOTOPES

Analyses of four quartz-carbonate vein samples for stable heavy oxygen isotopes are in Table 4.

TABLE 4
Oxygen isotope results from Grew Creek, Yukon.

SAMPLE NO.	MINERAL	$\delta^{18}O$ (SMOW)[1]
10-1-95	quartz	6.8
10-2-95	carbonate	6.9
10-1-143	quartz	5.5
10-2-143	carbonate	11.0
10-1-152	quartz	5.6
10-2-152	carbonate	11.0
12-1-119	quartz	2.1
12-2-119	carbonate	7.7

1. All analyses by K. Mullenbachs, University of Alberta, Edmonton, Alta.

Laboratory results shows $\delta^{18}O$ values ranging between 2.1 and 7.7 for quartz and between 5.6 and 11 for carbonate. A comparison of these values with results obtained in other similar systems described as epithermal (Nesbitt, et al., 1986) show the Grew Creek veins to be considerably enriched in $\delta^{18}O$. This enrichment is intermediate between the values often seen in epithermal deposits ($\delta^{18}O$ = -5 to +2 per mil) and those found in mesothermal deposits ($\delta^{18}O$ = +15 to +18 per mil).

Heavy isotope enrichment of a brine is commonly a result of one of three main processes: 1) a primary magmatic source for the brine in which the isotopic composition is in equilibrium with an ^{18}O enriched magma, 2) an isotopic exchange with an extremely enriched sedimentary host rock, and 3) extensive reaction with a moderately enriched host rock under conditions of low water/rock ratios. Any combination of these factors may be operating in a geothermal system.

The most probable explanation for the heavy isotope enrichment at Grew Creek is a primary magmatic source for the ore-forming fluids. This seems especially reasonable in view of the position of Grew Creek in a zone of deep crustal fracturing and major associated intrusive activity. However, other factors may be important. The Grew Creek deposit lies very close to metasediments of Unit 1 and these types of rocks are highly enriched in heavy oxygen isotopes (Taylor, 1974). However, it does not seem likely that there would be a significant exchange of oxygen occurring with this highly indurated rock. Epithermal systems regionally associated with clastic carbonates tend to have relatively enriched ^{18}O values (Taylor, 1974; White, 1974). About 1.5 km to the north, the nearest limestone crops out just across the Danger Creek Fault (Fig. 1). Extensive faulting that has occurred since the Eocene increases the possibility that blocks of ^{18}O-rich limestone may be near Grew Creek, and may have reacted with heated circulating groundwater.

The relatively high porosities of the tuffaceous rock that hosts the deposit and adjacent sandstones indicate a probable high water/rock ratio in the geothermal system, precluding extensive isotopic exchanges with a moderately enriched rhyolitic host rock.

The large difference in $\delta^{18}O$ values between the quartz and carbonate in the veins reflects disequilibrium conditions. Cross cutting relations show the carbonate deposition was clearly a later event. $\delta^{18}O$ enhancement in the carbonate may be due to the easier exchange of heavy oxygen isotopes with the carbonate relative to the quartz.

AGE DATING

Potassium-argon

Five specimens from Unit 3 were chosen for whole-rock age dating. Results are in Table 5. Samples 6 and 52 date whole rocks, but Samples 25c and 32 date strong sericitic alteration. Sample 21 shows only partial sericitic alteration. Field locations are in Figures 2, 3, and 4. Detailed descriptions of analysed samples are in Duke (1986).

Palynology

Two samples from Diamond Drill Hole 9 (Fig. 3) at 32.5 m (mudstone) and 115.5 m (TFXL) contained 11 varieties of palynomorphs listed in Table 6. A middle Eocene assemblage, estimated as representing 56 to 46 Ma was found. The following combination of palynomorphs was the diagnostic criteria (Glen E. Rouse, pers. comm., 1986): *Pistillipollenites macgregorii* (late Paleocene to mid-Eocene), *Tilia vescipites* (early to late Eocene), *Fusiformisporites - B* (mid to late Eocene), *Tetracellaesporites - 1* (restricted to mid-Eocene), and over 10 specimens of *Granatisporites cotalus* (which peaks in the mid-Eocene).

The plant material examined was very heavily carbonized, indicating that it was subjected to temperatures of at least 270°C and probably over 300°C (Rouse, pers. comm., 1986).

TABLE 5

Potassium-argon data for volcanic rocks from Grew Creek area, south-central Yukon

Sample number	Location lat(°N)	long(°W)	Rock unit and rock name	% K (±) (n = 2)	$^{40}Ar^*$ / $^{40}Ar_{total}$ [2]	$^{40}Ar^*$ 10^{-5} cm^3 STP/g [2]	Apparent age (Ma)[3]	Time[4]
D-25c	62.05	132.87	Lapilli tuff breccia, unit 3 (TFXL)	2.23 0.02	0.653	3.152	36.0 ± 1.3	Eocene-Oligocene border
D-21	62.05	132.87	Felsic tuff, unit 3 (TFXL), sericitized	4.62 0.03	0.925	8.552	47.0 ± 1.7	Eocene
D-32	62.05	132.87	Felsic lapilli tuff, unit 3 (TFXL), sericitized	4.29 0.03	0.856	8.705	51.5 ± 1.8	Eocene
D-6	62.05	132.87	Basalt flow, unit 3 (BASL)	1.73 0.00	0.709	3.458	50.7 ± 1.8	Eocene
D-52	62.05	132.87	Basaltic bomb, unit 3 (TFBA), epidotized	1.16 0.01	0.911	2.350	51.4 ± 1.8	Eocene

1. Argon analyses are by J. Harakal and potassium analyses are by K. Scott: all analyses were done at the Geochronology Laboratory, The University of British Columbia.
2. Ar^* indicates radiogenic argon.
3. Constants used are from Steiger and Jager (1977): $\lambda_e = 0.581 \times 10^{-10} yr^{-1}$; $\lambda = 4.962 \times 10^{-10} yr^{-1}$; $^{40}K/K = 1.167 \times 10^{-4}$.
4. Time designation is from Harland et al. (1982).

TABLE 6

Palynology[1] of Grew Creek samples from Drill Hole 9 (Fig. 3), 32.5m (mudstone), and 115.5m (crystal lithic lapilli tuff).

NAME	AGE RANGE
Spores and pollen	
Pistillipollenites macgregorii	late Paleocene to mid-Eocene
Tilia vescipites	early to late Eocene
Fungal spores	
Circulosporites - 1	mid-Eocene
Tetracellaesporites - 1	mid-Eocene
Fusiformisporites - B	mid to late Eocene
Disporisporites sp.	early to mid-Eocene
Granatisporites cotalus	peak in mid-Eocene
Pesavis	late Paleocene to late Eocene
Recycled	
Cicatricosisporites cf. hughesii	Albian to Maastrichtian
cf. Palaeoperidinum pyrophorum	Upper Cretaceous to Paleocene
Triporopollenites mullensis	Paleocene

1: All analyses by Glen E. Rouse, Department of Geological Sciences, The University of British Columbia, Vancouver, B.C.

CONCLUSIONS

Rocks preserved in a graben in Tintina Trench at Grew Creek are part of a sequence that represent proximal explosive felsic volcanism followed by interspersed rapid fluvial sedimentation and basaltic volcanism. K-Ar dates on unaltered whole rocks agree closely with palynology and indicate an age of mid-Eocene.

K-Ar whole rock dates on sericitically altered samples suggest hydrothermal alteration occurred from the time of deposition and may have contined at least until the end of the Eocene. Hydrothermal alteration appears to be spatially related to rhyolite dykes. Gold and silver mineralization is found with silicic and argillic alteration associated with a rhyolite dyke and acid sulphate minerals. It is characterized by multiple episodes of precious metal-rich chalcedonic quartz veining and brecciation of the felsic tuff host. Mineralization at the discovery outcrop is offset by faults that probably formed during creation of Tintina Trench in late Miocene or Pliocene. This suggests the mineralization pre-dates that event. Heavy oxygen isotopes in chalcedonic quartz veins suggest a deep, hot, magmatic source for the mineralized fluid.

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