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GEOLOGY AND MINERAL OCCURRENCES, UPPER CLEARWATER CREEK AREA, MT. HAYES A-6 QUADRANGLE, ALASKA

By

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CONTENTS

FIGURES

TABLES

PLATES

DESCRIPTION OF MAP UNITS

UNCONSOLIDATED DEPOSITS

Spring Deposits

Qcal — CALCRETE DEPOSITS - Gray- to tan-weathering calcium carbonate deposits around cold springs in the southern part of the map area. Crudely layered, cementing talus and rock fragments from surrounding hillslopes. Aprons and domes currently forming around active cold springs, older deposits up to 3 m thick and dissected by modern streams are found in canyons. Locally includes silcrete and concretionary iron nodules, particularly in the northern map area.

Fluvial Deposits

Qaf — ALLUVIAL FAN DEPOSITS - Poorly to moderately sorted gravel, sand, and silt deposited primarily by streams at valley mouths. Proximal parts of fans are frequently composed of unsorted debris-flow deposits. Contains numerous large boulders in discrete zones representing major flood episodes in proximal zones and along former channels. Surface is smooth to slightly irregular and covered by abandoned braided-stream channels.

Qal — STREAM ALLUVIUM - Elongate deposits of pebble-cobble gravel and sand with few to numerous boulders beneath modern floodplains. Generally well-sorted and medium to thick bedded; locally cross-bedded. Estimated thickness is up to 6 m. Surface is smooth, except for low scarps.

Colluvial Deposits

Qc — UNDIFFERENTIATED COLLUVIUM - Heterogeneous mixtures of angular rock fragments, gravel, sand, and silt left on slopes or at the bases of slopes by complex mass-movement processes, including free fall, bouncing, rolling, sliding, snow avalanches, gelifluction, and frost creep. Locally washed by meltwater and slope runoff. Bedding is medium to thick. Estimated thickness is up to 6 m. Surface is generally smooth and follows configuration of underlying bedrock surface.

Qc/d — UNDIFFERENTIATED COLLUVIUM OVERLYING GLACIAL DRIFT - Heterogeneous mixtures of angular rock fragments, gravel, sand, and silt left on slopes or at the bases of slopes by complex mass-movement processes, which overlie mixtures of gravel, sand, and silt deposited directly from glacial ice.

Qcf — FLUVIAL-COLLUVIAL FAN DEPOSITS - Heterogeneous mixtures of angular rock fragments, gravel, sand, and silt deposited at the mouths of steep bedrock canyons and sideslopes primarily by debris flows and during stream floods caused by heavy summer rainfall. Estimated thickness is up to 16 m. Surface is generally smooth, except for shallow, steep-sided channels, and covered by scattered boulders.

Qcl — LANDSLIDE DEPOSITS - Some slides consist of very large, almost intact masses of fractured and disrupted bedrock. Others, particularly in Coal Creek, are very poorly-sorted, large blocks of considerably disrupted, chaotic landslide debris. Surfaces are generally hummocky and in places have low concentric ridges about the toe of the slide.

Qct — TALUS - Unsorted mixtures of angular rock fragments, gravel, sand, and silt deposited at the mouths of bedrock couloirs by snow avalanches, free fall, tumbling, rolling, and sliding. Estimated thickness is up to 16 m. Typically cone or apron-shaped and covered by numerous angular boulders.

Qcr — ROCK-GLACIER DEPOSITS - Heterogeneous mixtures of angular rock fragments, gravel, sand, silt, and ground-ice deposited in cirques and on lower walls of glaciated valleys by the flow of rock glaciers. Perennially frozen where active. Surface is generally furrowed, ridged, and pitted and covered by angular boulders.

Glacial Deposits

Qd — TILL - Heterogeneous mixtures of gravel, sand, and silt deposited directly from glacial ice. May be locally reworked by meltwater, gelifluction, frost creep, and debris flows. Generally massive-bedded, except thin- to thick-bedded where reworked by stream action. Estimated to range in thickness from 3 to more than 20 m.

Qm — MORAINE - Lateral, medial, and end moraines with generally sharp topographic forms along valley sides or bottoms. Mostly composed of coarse rubbly till except in larger valleys, where till has sandy or silty matrix.

STRATIFIED AND METAMORPHIC ROCKS

Ts — SANDSTONE - Brown, coarse-grained feldspathic sandstone beds with some carbonized plant material, mafic volcanic pebble conglomerate, and white chalky kaolinized ash beds. Thin, discontinuous coal beds and yellow-brown shale are also present. Bedding attitude varies from flat lying to broken, contorted, and locally vertical. Unit apparently lies unconformably above adjacent stratigraphy but is involved in numerous slump blocks and landslides within the Coal Creek Valley.

Tc — CONGLOMERATE - Cobble conglomerate with clasts of greenstone, quartz diorite, quartz, and argillite; local thin interbeds of gray, medium- to coarse-grained, moderately consolidated sandstone with some carbonaceous plant material. Unconformably overlies greenstone of the Clearwater terrane (cg) in the northern map area and is present in slumpblocks within Qcl in section 31.

Rock Units of the Maclaren Metamorphic Belt

The Maclaren metamorphic belt is a pro-grade Barrovian-type metamorphic belt (Smith, 1974; Smith and Turner, 1973, 1974), which grades from lower greenschist facies argillite within the map area, through schist of amphibolite facies to the north. The rocks within the belt dip to the north with lower metamorphic grades underlying higher grades; hence the sequence is structurally inverted. The argillite unit (KJa) is thrust over Clearwater terrane rocks in the map area: chlorite tuff and graywacke (ctc and ctg) to the south, and greenstone (cg) to the north. At the head of Eldorado Creek, about 10 mi west in the Healy A-1 Quadrangle, the argillite unit is intruded by an alkali gabbro pluton from which K-Ar dates of 130 $\pm$4 my on biotite and 143 +4 m.y. on hornblende have been reported (Smith and Turner, 1973), thus establishing a minimum depositional age of Late Jurassic-Early Cretaceous for argillites (KJa) of the Maclaren belt.

KJa — ARGILLITE AND GRAYWACKE - Dark gray to black, dark brown weathering, bedded argillite, siltstone, and graywacke with minor conglomerate, carbonaceous limestone, and calcareous siltstone. Fine-grained layers are commonly laminated showing cyclic grading, festooned crossbedding, and load casts. Fine-grained clasts include detrital grains of quartz and plagioclase, chert and shale; common metamorphic minerals are white mica, epidote, graphite, carbonate, and actinolite. Conglomerate clasts include limestone, quartz, argillite, and medium-grained felsic intrusive in a black argillaceous matrix. Unit is distinguished from argillite (ca) lower in section by generally thicker beds, lower metamorphic grade, a greater abundance of coarser grained rocks, and dark brown rather than orange-brown- to tan-weathering outcrops.

Rock units within the Clearwater terrane

The Clearwater terrane is composed of a more or less continuous sequence of greenstone, argillite, limestone, and tuff of Paleozoic and possibly early Mesozoic age. Conodonts recovered from a single outcrop of crinoidal limestone at the base of the sequence (cl, fossil locality B) have been assigned a preliminary age of Silurian to Devonian (Tipper, written communication, 1989). Other fossil evidence from limestones in the lower part of the section (cgl, fossil locality C), suggests the age of the sequence could range from Upper Devonian to Triassic (Harris, written communication, 1989). Thus the evidence at hand is permissive of a middle to Upper Paleozoic age for the entire sequence. The closest known rocks approaching this age are about 150 km northwest near Cantwell, Alaska, where Late(?) Devonian to Mississippian radiolarians and conodonts are reported in a mid-Cretaceous tectonic melange of Mesozoic rocks (Csejtey, 1986, p. 60-63). Other Devonian rocks are located more than 150 km northeast, north of the Denali Fault (Nokleberg, and Aleinikoff, 1985). Kaskawalsh Group rocks, which include Silurian-Devonian(?) and older(?) rocks thought to be an extension of the Alexander terrane of Southeast Alaska, are located about 400 km southeast of the map area in the Wrangell Mountains where they are thought to unconformably underlie the Wrangellia terrane (MacKevett, 1978).

Maclaren metamorphic belt rocks are clearly in thrust fault contact with Clearwater terrane along its northwest boundary. However, contact relationships with the Amphitheater Group basalts along the southeast boundary of the Clearwater terrane are less certain. Field evidence supporting the contention that Clearwater terrane has been thrust over Amphitheater Group rocks includes discontinuous limestone bodies along the southeast border, general structural deformation, and extensive shearing within rocks near the base of the terrane, particularly in the Coal Creek area. Stratigraphic units within both the Amphitheater Group and the Clearwater terrane however, are roughly parallel, with no apparent structural discordance. Thus an alternative explanation for the older ages within lower parts of the Clearwater terrane is that windows through an unconformity beneath generally younger Clearwater terrane (Upper Triassic?) have exposed the Paleozoic coquina and other fossiliferous limestones. The limited rock exposures and continuity of outcrops do not allow a clearcut resolution of the problem at this map scale.

ct — TUFF - Light green to gray-green phyllitic tuff with subordinate chlorite, quartz, plagioclase crystal tuff, massive greenstone flows, graywacke, black to gray-green argillite, finely laminated tan cherty tuff, thin rare beds of flaky pale green tuff, and light to dark gray limestone. Conglomerate of flattened, black shale chips in a green tuff matrix is locally present. This unit is generally weathered to tan, orange, and brown in the vicinity of felsite intrusives. Mineralogy in the contact aureoles includes carbonate, epidote, sericite, $\pm$ talc, actinolite, apatite, ilmenite, and leucoxene. Cross-cutting white quartz and quartz-carbonate veining is common throughout the unit. Chlorite tuff (ctc) is locally present at the top of the unit. The upper portion of the unit contains massive beds (< 1 m thick) of graywacke with subordinate tuff and greenstone flows (ctg). Larger limestone beds in this unit and its members are designated 'ctl'. The basal contact of this unit appears to be transitional with underlying argillite (ca) and marker limestone (cml).

ctc — CHLORITE TUFF - Apple green, fine-grained, schistose tuff. Mineralogy in thin section includes chlorite, quartz, plagioclase, ± epidote, white mica, and carbonate. Found locally at the top of the tuff unit (ct) in thrust contact with overlying argillite (KJa).

ctg — GRAYWACKE AND TUFF - Gray-green, massive, tabular beds (<1 m thick) of fine- to medium-grained graywacke, which forms prominent resistant knobs on the ridges within the map area. The graywacke is composed of subangular detrital grains of quartz, plagioclase, and rock fragments (including volcanic glass, chloritic volcanic rocks, and chert) in a matrix of carbonate and microcrystalline quartz, sericite, epidote, and chlorite. Graded beds indicate the sequence is upright. Strongly foliated tuff is interbedded with the graywacke. Greenstone with actinolite, chlorite, carbonate, epidote, ± clinopyroxene mineralogy; dark gray argillite; and light to dark gray limestone are also present.

ctl — LIMESTONE - Light to dark gray, fine-grained laminated limestone. Pelitic lenses are common. Forms thin, discontinuous pods within tuff (ct) and graywacke (ctg).

cml — MARKER LIMESTONE - Gray, fine-grained, laminated to locally massive limestone. Lenses of pelite and microsparite common. Locally carbonaceous. Abundant calcite-filled crosscutting planar fractures. Forms distinct, resistant outcrops up to 12 m thick near the transitional contact etween the argillite (ca) and tuff (ct) units.

ca — ARGILLITE - Dark gray to black, orange brown to tan weathering, generally fissile argillite; subordinate gray-green tuff, green siltstone, graywacke, and fine-grained green-brown basalt flows, minor pale green chert. White and cream-colored, anastomosing, thin (<5 mm) quartz and calcite veins common, some quartz veins with scheelite. Tuffaceous greenstone bodies, generally lenticular and slightly schistose, and thin (<5 cm) cherty horizons are rare. Light to dark gray, thin bedded, finely laminated argillaceous limestone bodies are common; these are up to several feet in dimension, discontinuous, and more abundant in the upper part of the unit. Locally the unit is structurally disrupted by faulting and isoclinal folding. Blocks of argillaceous limestone and calcarenite up to several feet in dimension are rolled up in local shearing, as are greenstones and tuffaceous greenstone. Generally appears to overlie the upper greenstone unit (cg) conformably, but the contact is locally faulted.

cal — LIMESTONE - Light to dark gray, fine-grained laminated to massive limestone. Occurs as thin, discontinuous, and at some places folded pods within the argillite unit (ca).

cg — GREENSTONE - Dark green-gray and brown-red metabasalt with local chert layers and thin lenticular bodies of siliceous, argillaceous limestone. The siliceous layers often weather in relief. The unit is intruded by numerous mafic sills and dikes and by several quartz diorite bodies north of Coal Creek. Massive agglomerates and pillow basalts are typical of the unit with fine-grained, light-weathering, recrystallized glassy rims on pillows and pillow fragments; hyaloclastic breccia is locally present. Carbonate pods are common around pillows. Small discontinuous layers or bodies of light gray argillaceous limestone (cgl); dark gray argillite (cga); and green, schistose tuff with black argillite chips are typical of the unit. Argillite and limestone seem to be deposited as local occurrences on an irregular surface of extrusive lavas, including flows and tuffaceous debris. Generally appears to be basaltic but andesitic and gabbroic rocks are also present. Gabbronorite and pyroxenite are found as rare float.The unit is generally altered by multiple intrusions of felsite (TKif) in the Coal Creek and Copper Creek areas. Shearing and partial serpentinization are also common in those areas. Quartz-chlorite-epidote alteration is common throughout most of the unit, in varying degree. The greatest amount of alteration appears to be in the Coal Creek and Copper Creek areas. The upper contact of the unit with the overlying argillite (ca) is generally sharp, and appears conformable locally. However, the contact is locally sheared and structurally disrupted. The lower contact with the massive, thick basaltic greenstones of the main part of the Amphitheater Group is possibly faulted and difficult to determine with certainty. On the north side of Coal Creek, the contact is associated with small discontinuous bodies of light gray limestone (cl and cgl).

cga — ARGILLITE - Small discontinuous bodies of dark gray-brown argillite that appear to be deposited as local pods within the greenstone unit (cg).

cgl — LIMESTONE - Small discontinuous bodies of dark gray argillaceous limestone that appear to be deposited as local pods within the greenstone unit (cg). A maximum age of post-Middle Devonian is established for this unit by micro-fossils recovered at fossil locality C that included conodont fragments of post-Ordovician morphotype and ichthyoliths (fish teeth) of post-Middle Devonian morphotype (Harris, written communication, 1989).

cl — LIMESTONE - Medium brownish-gray, fine- to coarse-grained limestone with significant argillaceous and tuffaceous material. The limestone is generally massive, but crude layering is common. Upsection the amount of tuffaceous limestone increases and greenstone and tuffaceous argillite are common. The contact of the limestone and the overlying greenstone unit (cg) apppears to be gradational. However, structural deformation, shear zones, and minor faulting are common. Outcrop on the slope surrounding fossil locality B is a medium brownish-gray, coquina limestone with abundant crinoid stem debris. Significant amounts of argillaceous and tuffaceous material are also present. Conodonts recovered from the crinoid hash have been assigned a preliminary age of Silurian-Devonian (Tipper, written communication, 1989).Small limestone bodies (cgl) mapped at the base of the greenstone unit (cg) in sections 12 - 15 may be stratigraphically equivalent to this unit (cl).

Rock units within the Amphitheater Group

The Amphitheater Group (Smith, 1974) consists of approximately 40,000 feet of weakly metamorphosed basalt, andesite, and tuffaceous rocks with local, impure limestone (Stout, 1976). It is probably correlative with Middle to Late Triassic, rift-related basalt sequences that extend to the east along the south side of the Alaska Range. Only the upper part of the Amphitheater Group is present within the map area.

TRcr LIMESTONE AND SHALE - Dun-weathering, thin- to medium-bedded dark gray, fine-grained limestone, interbedded with black shale and siltstones. Beds are 5 to 30 cm thick, some may be graded. Most rocks are moderately to highly fractured with dark gray calcareous cement in fractures. The bedding is rhythmic, indicating that these rocks may be a turbidity deposit. Fossils from locality A (Monotis Subcircularis and M. Salinaria) suggest an Upper Triassic (Norian) age for this unit (Silberling, written communication, 1969). The areal extent of these rocks is about 1/3 km; they may be in a coherent landslide block that has not moved very far. The entire extent of these rocks is confined to the exposures south of Coal Creek, except for a small cutbank on the north side of the creek, where similar rocks are exposed that are highly fractured and folded. No fossils were found in this cutbank, which would be approximately in the toe of the landslide block, if correlative with the main exposure.

The degree of metamorphism and structural disruption of these carbonates is markedly less than the surrounding Amphitheater basalts and the Clearwater terrane. These rocks may represent a separate structural block, although their age is clearly Upper Triassic and correlates approximately with the age of the Amphitheater Group.

TRab BASALT AND ANDESITE - Dark green, green and maroon, to olive-gray basalt and andesite of the Amphitheater Group (Smith, 1974; Stout, 1976). Blocky to massive weathering, weakly metamorphosed and rarely schistose, the unit is locally fractured and shattered with myriad slickensides. Consists dominantly of subaerial and submarine flows 15 cm to several meters thick, intruded by numerous mafic sills and dikes. Numerous knobby weathering pillow horizons. Amygdaloidal in part. Fine-grained groundmass with medium- to coarse-grained phenocrysts. Mineralogy includes plagioclase, clinopyroxene, magnetite, and palagonite. Much of the plagioclase is altered to sericite, chlorite, and epidote; clinopyroxene to actinolite, epidote, and chlorite. Amygdules filled with quartz, chlorite, calcite, epidote, prehnite, pumpellyite and zeolites. K-Ar date of 142.8 $\pm$ 4.3 m.y.(amphibole) from basalt (TRab) approximately 14 km southeast (Smith, in press) probably represents an age of metamorphism. Late Triassic (late Karnian) fossils from interlayered limestones within these rocks from the Zackley prospect east of the map area (Silberling, 1983) probably date the formation of this unit.

INTRUSIVE ROCKS

TKif FELSITE DIKES AND ASSOCIATED QUARTZ-CARBONATE-LIMONITE ALTERATION - Orange-brown weathering aplitic dikes which intrude all other pre-Cenozoic units in map area. Typically altered in zones up to 2 m wide, and associated with intense quartz - carbonate veining and some quartz - carbonate breccia. Mineralogy includes quartz, sericite, epidote, chlorite, $\pm$ amphibole, $\pm$ pyrite, and zeolites(?). The typical orientation of these dikes is northeast - southwest at a high angle, approximately parallel to the general structural fabric of the map area, though numerous randomly oriented dikes also crop out. Dikes vary from several centimeters to meters thick. Included in this unit are minor dense greyish-greenish white aplite dikes, with minor disseminated pyrite, which are relatively unaltered, and also light grey, aphanitic leuco-quartz diorite dikes.

TKim INTERMEDIATE TO MAFIC DIKES - Intermediate to mafic dikes which intrude KJa and ca units. Medium to dark grey to green, fine-grained to aphanitic, and relatively less altered than other igneous rock units. They are typically porphyritic with hornblende and/or plagioclase phenocrysts up to 1 cm long. Dikes are up to 2 m thick. Whole rock chemical analyses from a hornblende porphyritic dike intruding KJa are shown in Table 2.

TMzqm BIOTITE QUARTZ MONZONITE - Medium-grained, granular, massive plug in KJa at northern boundary of map area. Contains about 20 percent biotite and possible minor hornblende. The plug is intruded by an aplite dike, and contains pyrrhotite near contacts with KJa. K-Ar dates pending.

TMzgd GRANODIORITE - Small plugs intrusive into Amphitheater group argillite unit (ca) in southwestern map area. Rocks are medium grey, fine-grained, granular, and massive. Mineralogy consists of quartz, plagioclase, alkali feldspar, white mica, opaque oxides and apatite. Alteration products include sericite, opaque oxides and carbonate. Unit is distinctive due to the abundance of white mica (approximately 20 modal percent). Age unknown.

MzPzif PYRITIC FELSITE - Small bodies of leucocratic fine- to medium-grained granite(?) which intrude tuffs of the ctg unit. Severely altered, with strained and recrystallized quartz and plagioclase as the only remnant primary minerals with a phaneritic texture. Secondary mineralogy includes abundant sericite and lesser amounts of epidote, chlorite and opaque oxides. Disseminated pyrite within the unit causes characteristic orange weathering surfaces. Contains at least one vein of massive stibnite, approximately 5 cm wide. Fresh surfaces are greyish-white; textures vary from unfoliated to moderately foliated. Age unknown.

MzPzg GRANITE, QUARTZ MONZONITE - Felsic stock with variable foliation and alteration; intrusive into tuffs (ct, ctg) in section 6. Mineralogy consists of quartz, alkali feldspar, plagioclase, trace apatite, ± trace zircon, ± trace titanite; mafic minerals, which are largely to completely altered, included hornblende, and possibly biotite in some samples. Alteration minerals include sericite, chlorite, carbonate, epidote, opaque oxides, and iron oxide staining. Rocks are variable in terms of percent mafic content and texture, but generally are medium- to coarse-grained, with pinkish-orange and green coloration. Porphyritic phases with phenocrysts of hornblende and alkali feldspar are present locally. Altered mafic minerals are commonly flattened out along foliation planes. Foliation tends to increase toward contacts. Whole rock analyses of granite samples 88DNS150 and 88DNS151 are listed in Table 2. Age unknown.

MzPzqd QUARTZ DIORITE, QUARTZ MONZONITE, GRANODIORITE - Medium to dark green-grey, medium- to coarse-grained intrusive rocks, with moderate to severe alteration and deformation. Appears to be in intrusive contact at northwest margin of granite stock in section 6; septa and/or xenoliths of tuff and greenstone from host unit (ct, ctg) are included in the more mafic intrusive. Also intrudes greenstones (cg) as a swarm of small plugs and dikes north of Coal Creek. Similarity of degree of alteration and deformation suggests that rock of this unit may be close in age to granite unit (MzPzg), and probably predates metamorphism. Metamorphism was apparently during Jurassic, based on a K-Ar date from Amphitheater basalt (Smith, in press). Composition consists of quartz (10 - 30%), plagioclase, ± alkali feldspar (up to about 10%), hornblende, opaque oxides, ± apatite, and minor late biotite in some samples. Alteration products make up about 50% of some samples and include epidote, chlorite, sericite, opaque oxides, carbonate and iron oxide staining. Rocks are generally moderately to poorly foliated; mafic mineral content ranges from approximately 25 to 60%. Quartz - epidote veining is common in the unit. Major oxide analyses of quartz diorite sample 88Pe116 are listed in Table 2. Age unknown.

im MAFIC INTRUSIVES - Mafic dikes, sills and plugs intrusive into greenstone unit (cg). Grey, fine- to medium-grained, hypidiomorphic-granular, with no preferred grain shape orientation. Primary mineralogy includes plagioclase laths, ± clinopyroxene, hornblende, opaque oxides, ± minor quartz (<5 percent), and ± apatite. Alteration is moderate to severe, with secondary mineralogy including epidote, chlorite, carbonate, sericite, prehnite, leucoxene, and iron oxide staining. Unit includes minor gabbronorite and pyroxenite, seen as float in southwest portion of map area. A whole rock chemical analysis of gabbro sample 88DNS122 is listed in Table 2.

GEOLOGIC MAP SYMBOLS

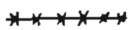
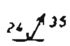
	Contact–solid line where known or inferred, dotted where concealed
	High-angle fault–solid line where known, dashed where inferred, dotted where concealed.
	Thrust fault–solid line where known, dashed where inferred, dotted where concealed. Queries between dashes indicate probable existence. Sawteeth on upper plate.
	Felsic dikes and areas of quartz-carbonate alteration. Small outcrop indicated with single symbol.
	Mafic dikes
q	Quartz - Massive quartz plugs >3 m in diameter or quartz veins >3 m wide.
	Amygdaloidal basalt
	Springs or seeps
	Fossil locality
	Airphoto lineament
	Bedding traces
	Landslide scarp, show direction of movement
	Prospect trench
	Strike and dip of inclined beds
	Strike and dip of inclined beds, plunge of slickensides
	Strike and dip of overturned beds
	Strike and dip of foliation
	Strike and dip of joints
	Strike and dip of cleavage
	Strike of vertical beds
	Strike of vertical jointing

FIGURE 2. CORRELATION OF MAP UNITS

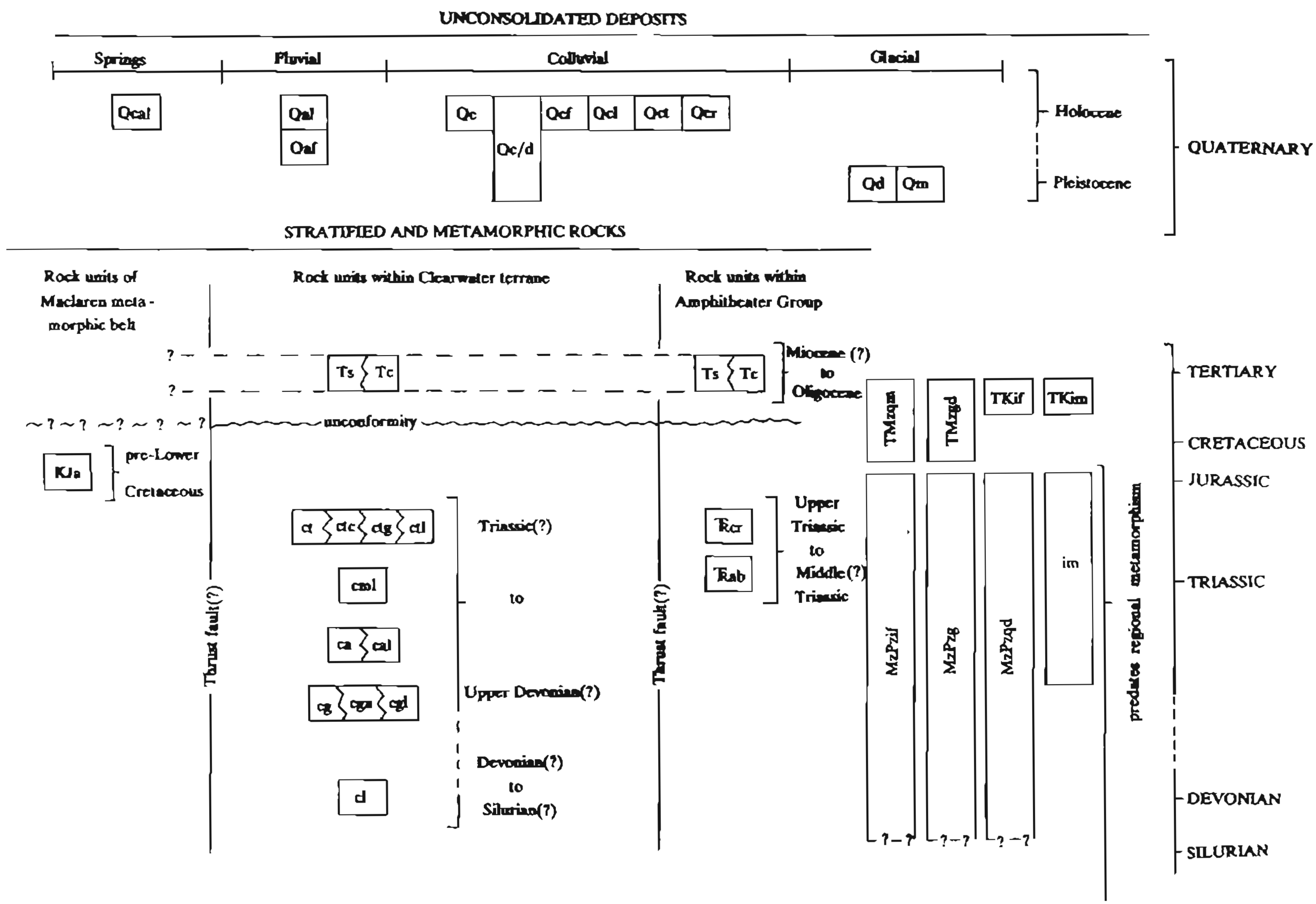


Table 1. Fossil localities.

Locality	Fossils	Stratigraphic Range	Reference
A	Monotis Subcircularis and M. Salinaria	Triassic (Norian)	Silberling, 1969
B	conodonts in crinoid hash	Silurian(?)-Devonian(?)	Tipper, 1989
C	conodont fragments ichthyoliths	Upper Devonian-Triassic	Harris, 1989

Table 2. Major oxide and trace element analyses and CIPW normative calculations, igneous rocks, Clearwater Mountains.

SAMPLE	88DNS104	88DNS122	88DNS150	88DNS151	88Pe116
ROCK	Hb dike	gabbro	granite	granite	qtz diorite
UNIT	TKim	im	MzPzg	MzPzg	MzPzqd
SiO_2	51.91	49.98	71.18	71.68	63.92
Al_2O_3	14.78	13.48	13.63	13.70	15.09
CaO	6.56	10.47	1.14	1.54	4.73
MgO	5.98	5.98	0.58	0.59	2.36
Na_2O	3.10	2.65	3.90	3.75	3.55
K_2O	2.77	0.39	4.62	4.39	1.14
Na_2O+K_2O	5.87	3.04	8.52	8.14	4.69
Fe_2O_3*	9.96	13.20	1.90	1.81	6.15
Fe_2O_3	2.64	4.70	1.57	1.42	2.36
FeO	6.59	7.65	0.30	0.35	3.41
FeO/Fe_2O_3	2.50	1.63	0.19	0.25	1.44
MnO	0.18	0.22	0.05	0.05	0.12
TiO_2	0.61	1.50	0.26	0.25	0.44
P_2O_5	0.29	0.16	0.10	0.09	0.07
Cr_2O_3	0.01	<0.01	<0.01	<0.01	<0.01
LOI	3.00	1.39	1.54	1.31	1.93
SUM	99.30	99.50	99.00	99.30	99.60
Rb	57.00	22.00	172.00	183.00	21.00
Sr	549.00	165.00	103.00	247.00	144.00
Y	26.00	15.00	<10	<10	25.00
Zr	21.00	51.00	112.00	110.00	80.00
Nb	13.00	28.00	<10	11.00	12.00
Ba	683.00	80.00	775.00	802.00	282.00

Fe_2O_3* = Total iron as Fe^{3+}; LOI = Loss on ignition;
All analyses done with XRF by X-Ray Assay Laboratory, Ontario, Canada. Major oxides reported as weight percent; trace elements reported as ppm.

Quartz	0.00	0.00	27.39	29.80	24.12
Corundum	0.00	0.00	5.21	0.20	0.00
Orthoclase	17.16	2.24	26.60	26.51	6.93
Albite	27.50	21.75	32.15	32.42	30.92
Anorthite	19.18	38.96	4.87	7.21	22.54
Diopside	10.61	8.68	0.00	0.00	0.94
Hypersthene	17.53	18.05	1.41	1.50	10.63
Olivine	2.89	2.98	0.00	0.00	0.00
Magnetite	3.21	4.22	0.00	0.00	2.89
Hematite	0.00	0.00	1.71	1.79	0.00
Ilmenite	1.22	2.76	0.38	0.22	0.86
Rutile	0.00	0.00	0.05	0.14	0.00
Apatite	0.70	0.36	0.23	0.21	0.17
SUM	100.00	100.00	100.00	100.00	100.00

Table 3. **Descriptions of mineral occurrences.**

Unless otherwise noted, the mineral occurrence descriptions listed below were compiled from the 1988 field notes of T.E. Smith, G.H. Pessel, D.N. Solie, and K.H. Clautice and from the rock sample analyses listed in Clautice and others, 1988.

1. Au (1880 ppb), Pb(1080 ppm), Zn (5990 ppm)in quartz-carbonate veins brecciating greenstone.

2. >1% Cu in malachite-stained greenstone.

3. Elongate mineralized zone with sporadic occurrences of chalcopyrite azurite, and malachite. Coincides with faulted contact between metavolcanic rocks and pelitic metasediments. Fault zone mostly covered by talus. Exposed copper occurrences are in highly fractured and altered volcanic rock on southeast side of fault (Smith, Trible, and Stein, 1973).

4. Cu (1775 ppm), W (400 ppm) in gray-green, finely-fractured, pyrite-, epidote-, silica-altered rock exposed in small cut-bank above stream, extent unknown. Au (295 ppb) in pyrite-rich sample.

5. Au (460 ppb), chalcopyrite, malachite in 10 cm wide quartz-epidote vein in basalt (Cu-8710 ppm).

6. Au (1500 ppb), Cu (>1%), Ag (85.4 ppm) in high-grade from 3 to 6 m wide folded, hornfelsed limey sediments that can be traced about 30 m below hornblende pyroxene gabbro sill.

7. Au (350-540 ppb) in two samples from a 1 m wide orange-weathering, quartz-carbonate breccia zone that can be traced over 100 m along northeast side of creek at faulted(?) contact between Clearwater terrane units, which include greenstone with argillite and carbonate pods and an overlying hornblende pyroxene gabbro sill. Upstream end of breccia zone intersects northeast-southwest trending, 1-2 m wide zone of orange-weathering, carbonate alteration, which crosses the creek at a local offset in the gabbro sill and trends northeast over the ridge and above the sill for several hundred meters. Abundant fine, silica-filled fractures and in places rhythmically banded silica- and carbonate-filled fractures are typical of the carbonate alteration zone.

8. Au (760 ppb) in massive pyrite float in creek in vicinity of pyritic greenstone.

9. Pyrite-sericite-quartz altered alaskite dike (1 to 2 m wide) with disseminated chalcopyrite and quartz-pyrite-molybdenite veinlets (Blakestad, 1988, and this study).

10. Symmetrical open fracture-filled vein (4 cm wide) of bornite with medial zone of terminated quartz crystals associated with epidote in amygdaloidal basalt found throughout rubble-crop within 1 m of 30 cm wide light green clay (gouge?) zone and 3 m wide argillite pod within non-amygdaloidal basalt (Cu>1%, Ag-36.6 ppm).

11. Small amounts of copper-bearing float occur throughout a rock slide at this locality. Malachite, azurite, chrysocolla, bornite, and chalcocite associated with quartz, calcite, and epidote occur in pods and stringers cutting andesitic to basaltic lava. A traverse above the slide failed to reveal the source (Kaufman, 1964, p.7, no.10).

12. Locality where cupriferous quartz veins 5 to 15 cm wide occupy minor fault zone. Veins contain chalcocite, pyrrhotite, covellite(?) and malachite (Smith, Trible, and Stein, 1973).

13. Au (240 ppb), Ag (28.4 ppm, As (465 ppm), Cu (2690 ppm), and Pb (1960 ppm) in 3 m wide quartz vein.

14. Au (2950 ppb), Sb (>1%) in 5 cm wide antimony vein in 1 m wide zone of clay-altered felsite that can be traced >60 m trending northeast across saddle.

15. As (680 ppm) in quartz veins in argillite.

16. Au (305 ppb) and Ag (22.6 ppm) with chalcopyrite and malachite (>1% Cu) in 5 to 60 cm wide quartz veins in meta-tuff.

17. Mo (322 ppm) and W (175 ppm) in 1.5 cm wide limonite and green-stained fractures within felsite.

18. Scheelite-bearing soil found in two trenches partially excavated into argillite with limonite- and carbonate-altered dike rock and quartz-carbonate veining. Although some argillite and basalt bedrock are evident in the trenches, most trenches appear to have been excavated into glacial drift. Trench walls found partially collapsed in 1988. Float rock in vicinity of trenches of argillite with scheelite-bearing, limonite-stained quartz veins and one small sample of very brecciated argillite with a 3 cm wide vein of massive scheelite. Blakestad (1988a) reports WO_3 to 64.4% in some samples from this area.

19. Float trains of scheelite-bearing rock traced with black light to rubble-crop exposures of scheelite-bearing, carbonate-altered breccia in dark gray limestone in one area and in another area near a local contact between shale and a rusty-colored sandy carbonate rock (Blakestad, 1988a).

20. Pb (>1%), Ag (22 ppm), As (950 ppm), Zn (5190ppm), and Cu (2600 ppm) in thin (2 to 5 cm wide) zone in altered tuff, tuffaceous argillite.

21. Ba (1430 ppm) in quartz veins in argillite.

22. Ba (1310 ppm) in quartz veins in argillite.

23. Malachite in limey argillite float near rusty quartz carbonate breccia (Cu-7030 ppm).

24. Malachite, azurite in silicified felsite (As-705 ppm, Cu-2360 ppm, Hg 281 ppm).

25. Hg (36 ppm), W (80 ppm), As (410 ppm) in orange-stained greenstone in vicinity of pyritic felsite.

26. Malachite stain in 30 cm wide quartz vein (Cu-8890 ppm).

27. Au (170 ppb), As (1925 ppm), Hg (64 ppm) in rusty quartz stockwork in argillite.

28. Large areas of rusty-colored limonite-hematite staining occur in easterly to northeasterly striking folded andesitic to basaltic greenstones with interbedded limestones. A small intrusive body of granodiorite composition cuts the volcanics south of the stained zones. The stained areas that were examined are caused by weathering carbonate zones in andesite, and by ferruginous cement in a brecciated zone. Further prospecting is warranted to investigate the composition of the more inaccessible stained zones (Kaufman, 1964, p. 7, no. 9).

29. Au (260 ppb) in altered tuff.

30. As (3330 ppm), Sb (55 ppm) in rusty calcrete or sinter

31. As (6520 ppm) in rusty, calcareous tufa or calcrete around modern-day cold spring.

32. Cu (1370 ppm), As (345 ppm), Zn (726 ppm) in black gossan material from trench/drill pad.

33. Thin (20 cm wide) zone of malachite-, chalcopyrite-bearing amygdaloidal basalt (Cu >1%, Ag-24.6 ppm).

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