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GEOCHRONOLOGY OF ROCKS AND POLYPHASE DEFORMATION, BEARSKIN (MUDDY) AND TATSAMENIE LAKES DISTRICT, NORTHWESTERN BRITISH COLUMBIA (104K/8, 1)

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KEYWORDS: Geochronology, zircon, U-Pb dating, Tatsamenie, Sam Creek, Icy Pass.

INTRODUCTION

This report presents the preliminary results of a series of zircon dates on the supracrustral and intrusive rocks between Bearskin (Muddy) Lake and Tatsamenie Lake in northwestern British Columbia. These dates are used in conjunction with a geological map to develop a hypothesis for the sequence of polyphase rock deformation in this area.

Although the dates in this paper are preliminary, only one may change significantly with the results of further analysis which is in progress.

The project area is located approximately 140 kilometres west of Dease Lake (Figure 1-12-1). During 1988, 1989 and 1990 detailed 1:5000 and 1:10 000-scale maps were completed across an area extending from the north side of Bearskin (Muddy) Lake to the north shore of Tatsamenie Lake. These maps form a portion of a Ph.D. project by Oliver and are available in an open file format (Oliver, 1993). Map coverage of this and related areas at a 1:50 000 scale has recently been completed by Bradford and Brown (1993, this volume).

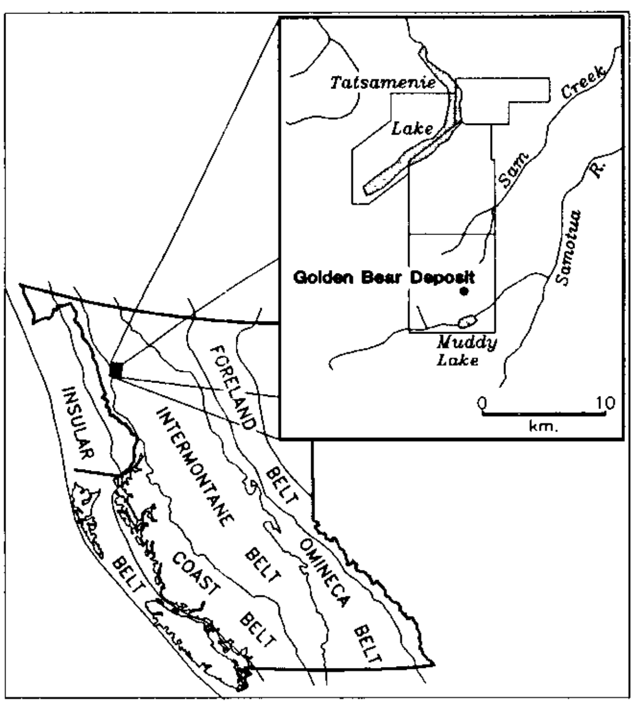

Figure 1-12-1. Location of the Tatsamenie Lake - Muddy (Bearskin) Lake map area within the tectonic framework of the Canadian Cordillera. The position of four 1:10 000-scale detailed Open File geological maps (Oliver, 1993) is also shown.

PREVIOUS WORK

The general stratigraphic and structural relationships of the upper Paleozoic and Mesozoic rocks in the Tatsamenie Lake area were first documented by Souther (1971). The first paleontological confirmation of the Early Permian age of the limestones and other carbonate rocks on the north side of Tatsamenie Lake was made by Monger and Ross (1977).

The study area has been the focus of reconnaissance exploration programs for base and precious metals conducted intermittently since the 1960s. The geology of porphyry copper-molybdenum and gold occurrences in the northwestern parts of the map area was described by Holbek (1976) and Cukor and Sevensma (1971). Precious metals reconnaissance programs conducted by Chevron Minerals Limited during the early 1980s culminated in the discovery and development of the Golden Bear gold deposit. The results of these field programs are documented in a series of assessment reports (Brown and Walton, 1983; Shaw, 1984 and others). Stratigraphic and structural characteristics of the Golden Bear mine area have been described by Schroeter (1987) and Oliver and Hodgson (1989). Geological relationships in the northern half of the study area have been outlined by Oliver and Hodgson (1990).

U-Pb GEOCHRONOLOGICAL METHODS

Zircons are separated from finely crushed 20 to 40 kilogram rock samples using a wet shaking table, heavy liquids and magnetic separator. The concentrates are split into magnetic (M) and nonmagnetic (NM) fractions and hand picked to 100 per cent purity as required. Concordance is improved by air abrasion techniques (Krogh, 1982). Chemical dissolution and mass spectrometery follow the procedures of Krogh (1973). A mixed ^{205}Pb-^{233}U-^{235}U spike is used (Parrish and Krogh, 1987; Roddick *et al.*, 1987). Uranium-lead date errors are obtained by individually propagating all calibration and measurement uncertainties through the entire date calculation and summing the individual contributions to the total variance (Nines, 1980). The isotopic composition of initial common lead is based on the Stacey and Kramers (1975) common lead growth curve. The decay constants are those recommended by the IUGS Subcommis-

TABLE 1-12-1
U-Pb ZIRCON DATA FROM SAMPLES IN THE MUDDY (BEARSKIN) AND TATSAMENIE LAKE AREAS

Fraction:[1,2] Magnetic & size split	wt mg	U^3 ppm	Pb^3 ppm	^{208}Pb %	$^{206}Pb/^{204}Pb$ Measured[4]	$^{206}Pb/^{238}U$ ratio±%1σ Date±2σ	$^{207}Pb/^{235}U$ ratio±%1σ Date±2σ	$^{207}Pb/^{206}Pb$ ratio±%1σ Date±2σ
ID 2	**Felsic pyroclastic**				Lat 58° 18'18" Long 132° 26'12"			
a NM2A/3°abr	0.21	94.4	5.46	16.69	319	0.04879(0.342)	0.3544(0.662)	0.05268(0.501)
-94+74μ						307.1±2.0	308.0±3.5	315.1±23
b M2A/1°abr	0.3	41.4	2.05	11.60	943	0.04808(.120)	0.3499(.336)	0.05279(.295)4
-94+74μ						302.7±0.7	304.7±1.8	319.7±13.5
c M2A/1°abr	0.1	126	7.01	16.96	289	0.04692(.186)	0.3361(.889)	0.05196(.797)
-74+44μ						295.6±1.1	294.2±4.5	283.7±36.9
d M2A/1°abr	0.41	124	6.42	13.04	1147	0.04871(.363)	0.3540(.405)	0.05270(.124)
-74+44μ						306.6±2.2	307.7±2.1	316.0±5.7
ID 5	**Felsic pyroclastic**				Lat 58° 15'24" Long 132° 21'15"			
a NM2A/1°abr	0.23	80.1	4.41	15.48	360	0.04779(.336)	0.3438(.573)	0.05218(.406)
-74μ						300.9±2.0	300.0±3.0	293.3±18.6
b NM2A/1°abr	0.1	49.6	2.94	17.58	206	0.04903(.202)	0.3622(.878)	0.05357(.779)
-74+44μ						308.6±1.2	313.8±4.7	353.0±36
c M2A/1°abr	0.24	89.7	7.96	29.14	95	0.04930(.785)	0.3576(2.62)	0.05261(2.18)
-74+44μ						310.2±4.8	310.4±14	312±103
d M1.5A/3°abr	0.62	79.8	3.98	11.54	2132	0.04842(.407)	0.3534(.422)	0.05294(.090)
-74+44μ						304.8±2.4	307.3±2.2	326.2±4.1
89-254	**Granodiorite**				Lat 58° 21'30" Long 132° 18'00"			
a NM2A/1°abr	0.9	302	11.1	7.94	2431	0.03706(.065)	0.2678(.110)	0.05242(.066)
+104μ						234.6±0.3	240.9±0.5	303.6±3.0
b NM2A/1°abr	0.1	631	32.2	22.52	140	0.03459(.448)	0.2493(1.58)	0.05228(1.29)
-104+74μ						219.2±1.9	226.0±6.4	297.5±60
c NM2A/1°abr	0.3	154	5.49	9.07	921	0.03484(.061)	0.2447(.216)	0.05095(.182)
-74+44μ						220.8±0.3	222.3±0.9	238.4±8.4
d M2A/1°abr	1.01	355	12.1	8.07	14180	0.03475(.393)	0.2424(.394)	0.05060(.016)
+74μ						220.2±1.7	220.4±1.6	222.5±0.8
190-HD	**Hornblende diorite**				Lat 58° 22'15" Long 132° 11'30"			
a NM2A/1°abr	0.2	286	18.3	29.17	86.5	0.03393(.739)	0.2420(2.60)	0.05172(2.15)
-104+74μ						215.1±3.1	220.0±10.3	273±102
b NM2A/1°abr	0.4	81.7	2.92	10.53	872	0.03457(.133)	0.2550(.307)	0.05351(.249)
-74+44μ						219.1±0.6	230.7±1.3	350.4±11.3
c M2A/1°abr	0.10	448	18.1	16.42	271	0.03353(.452)	0.2502(1.19)	0.05412(873)
-74μ						212.6±1.9	226.7±4.8	376±40

Notes: Analyses by J. Gabites, 1992, in the geochronology laboratory, Department of Geological Sciences, U.B.C..
IUGS conventional decay constants (Steiger and Jäger, 1977) are: $^{238}U\lambda=1.55125x10^{-10}a^{-1}$, $^{235}U\lambda=9.8485x10^{-10}a^{-1}$, $^{238}U/^{235}U=137.88$ atom ratio.

1. Column one gives the label used in the Figures.
2. Zircon fractions are labelled according to magnetic susceptibility and size. NM = non magnetic at given amperes on magnetic separator, M = magnetic. Side slope is given in degrees. Abr = air abraded. The - indicates zircons are smaller than the stated mesh (in microns), + crystals are larger than the stated mesh.
3. U and Pb concentrations in mineral are corrected for blank U and Pb. Isotopic composition of laboratory Pb blank is 206:207:208:204 = 18.16:15.614:38.283:1.00, based on ongoing analyses of total procedural blanks of 37 ± 5 pg (Pb) and 6 ± 0.5 pg (U).
4. Initial common Pb is assumed to be Stacey and Kramers (1975) model Pb of the age of the $^{207}Pb/^{206}Pb$ date for each fraction.

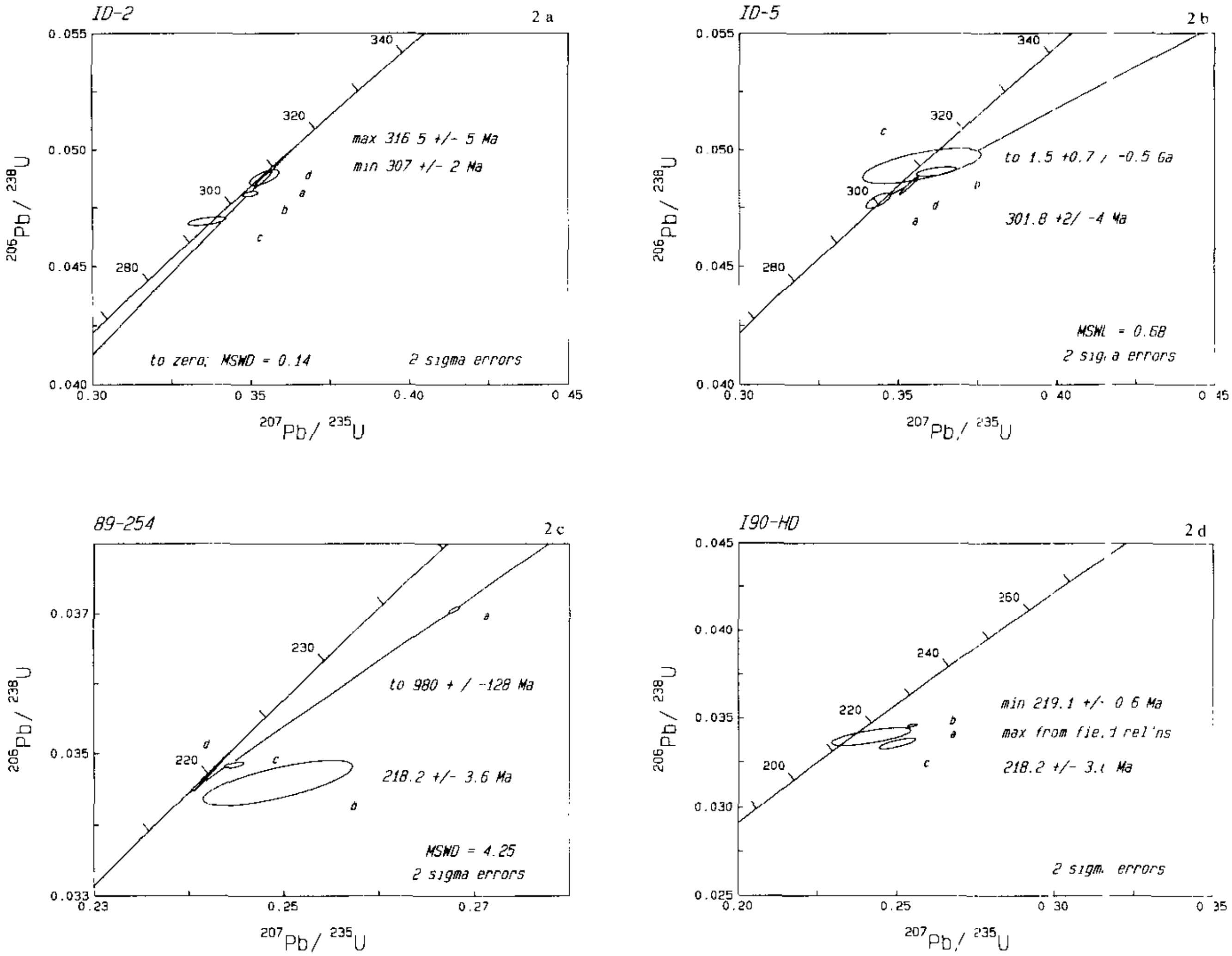

Figure 1-12-2. U-Pb concordia diagram for felsic rocks north of Tatsamenie Lake (Figure 1-12-2a, sample ID-2), for felsic rocks north of Sam Creek (Figure 1-12-2b, sample ID-5), for granodiorite of the Sam batholith (Figure 1-12-2b, sample 89-254, and for the Icy Pass porphyry, (1-12-2d, sample I90-HD).

sion on Geochronology (Steiger and Jäger, 1977). Concordia intercepts are based on the York (1969) regression and Ludwig (1980) error algorithm. Errors reported for the raw U-Pb data are one sigma; those for final dates and shown on concordia plots are two sigma (95% confidence limits).

The analytical results for zircon from four rock samples are summarized on Table 1-12-1 and depicted graphically on Figure 1-12-2 (a-d). Sample locations are shown on Figure 1-12-3.

SAMPLE CHARACTERISTICS AND INTERPRETATION OF U-Pb DATA

TATSAMENIE LAKE FELSIC VOLCANICS (SAMPLE ID-2)

Sample ID-2 was taken from the massive, poorly bedded felsic volcanic rocks which structurally overlie the carbonate rocks exposed on the northwest shore of Tatsamenie Lake. Felsic flows and ash tuffs are the likely protolith. These rocks are strongly deformed and in thin section are observed to be composed of weakly compositionally layered and recrystallized quartz, with lesser feldspar lamellae, and a weak, micaceous, slightly crenulated foliation. The zircons separated from this rock are clear, colourless, doubly terminated prisms. Their aspect ratios are typically 1:1.5 to 3. Fluid inclusions and apatite lathes are visible in some crystals; where possible crystals containing inclusions were not used in the analysis.

The four fractions analyzed all plot close to concordia (Figure 1-12-2a). Two fractions (b and c) have lost lead. There is no indication of inherited zircon in this sample. The lower limit on the age of this sample, 307±2 Ma, is given by the mean of the $^{206}Pb/^{238}U$ dates from the two most concordant fractions (a and d). These analyses are least affected by analytical error in the determination of ^{204}Pb. The sample cannot be older than the $^{207}Pb/^{206}Pb$ from the most concordant fraction; thus the upper limit on the age of

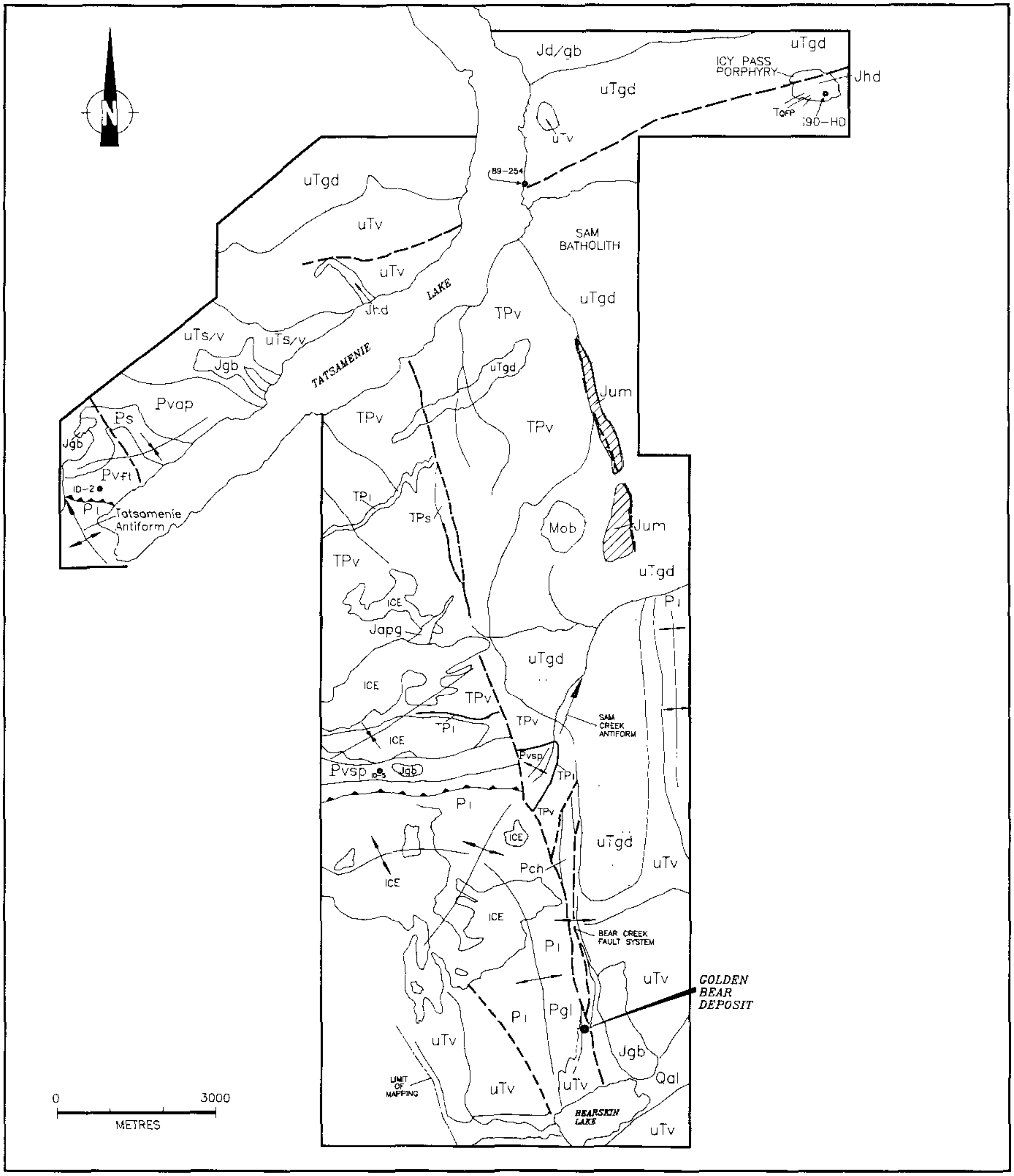

Figure 1-12-3. Inferred lithological and structural relationships for rocks in the Muddy (Bearskin) Lake - Tatsamenie Lake map area. *See* facing page for legend to map.

INTRUSIVE ROCKS

EARLY TERTIARY

Tqfp	Quartz feldspar porphyritic dikes, Sloko equivalent (?).

MIDDLE TO EARLY JURRASIC(?)

Jgb	Massive hornblende pyroxene gabbros.
Japg	Potassium feldspar rich, aplitic dikes.
Jhd	Hornblende diorite.
Jum	Magnetite clinopyroxenite, Alaskan-type ultramafic rocks.

UPPER TRIASSIC

uTgd	Weakly foliated hornblende biotite granodiorites to diorites.

STRATIFIED ROCKS

QUATERNARY

Qal	Unconsolidated sediments.

MIOCENE (?)

Mob	Olivine basalt flows.

UPPER TRIASSIC -- STUHINI GROUP

uTv	Undifferentiated volcanic rocks
uTs	Undifferentiated sedimentary rocks

TRIASSIC TO PERMIAN (ROCKS OF POORLY CONSTRAINED STRATIGRAPHIC AGE)

TPv	Undifferentiated volcanic rocks
TPs	Undifferentiated sedimentary rocks, (TPl limestone.

LOWER PERMIAN -- STIKINE ASSEMBLAGE

Pl	Buff to grey; massive to thin-bedded limestone.
Pch	Chert and strongly silicified dolomites.

PENNSYLVANNIAN

Pvft	Felsic volcanic dust and ash tuffs.
Ps	Undifferentiated clastic and carbonate rocks.
Pvap	Strongly actinolite porphyroblastic mafic volcanic rocks.
PvsP	Siliceous phyllites of volcanic origin.

this rock is given by the mean of the $^{207}Pb/^{206}Pb$ dates for fractions (a) and (d) at 316.5±5 Ma. Field relationships do not provide further constraints on the age of this volcanic rock.

Sam Creek Felsic Volcanics (Sample ID-5)

This sample was selected from a felsic volcanic rock exposed immediately north of Sam Creek. These rocks differ macroscopically from those exposed on the north side of Tatsamenie Lake only in the slight increase in the percentage of mafic mineral phases and more intensely developed phyllitic cleavage. They are interpreted to be fine-grained, poorly stratified felsic pyroclastics.

The zircons separated from this sample are clear, colourless to light tan euhedral prisms with aspect rations of 1:2 to 3. Clear fluid inclusions and apatite laths are visible in about 20 per cent of the crystals. No inherited cores are visible.

The four fractions analyzed cluster near concordia (Figure 1-12-2b) between 300 and 310 Ma, similar to sample ID-2. The zircons in ID-5 clearly contain an inherited zircon component and appear not to have lost lead. The best estimate of the age of the rock is given by the lower intercept of a least squares regression at 301.8+2/−4 Ma. The average age of the inherited lead is 1.5±0.7 Ga. Errors are increased slightly by including fraction (c) with a large error ellipse, but the date is not changed.

Sam Batholith, Granodiorite (Sample 89-254)

A weakly foliated to unfoliated granodiorite extends across the eastern edge of the map area. The intrusion cuts rocks as young as the Upper Triassic Stuhini Group. The batholith is cut by albite dikes which have given a K-Ar whole-rock age of 171±6 Ma (Hewgill, 1985), and by elongate, clinopyroxene-rich, Alaskan-type ultramafic bodies of indeterminate age.

The zircons separated from this sample were almost all broken fragments of clear, colourless, stubby euhedral crystals. Three of the four fractions analyzed define a chord with a lower intercept of 218±3.6 Ma (Figure 1-12-2c). Inherited lead is indicated with an average age of 0.98 Ga. The fourth fraction has a large error ellipse and low $^{206}Pb/^{204}Pb$ ratio. The zircons in this fraction have probably suffered lead loss and contain inherited old lead. Additional fractions from this sample are presently being analysed to improve these age constraints.

Icy Pass Diorite (Sample 190-HD)

The sample is taken from one of the larger porphyry copper-molybdenum and gold occurrences in the northwestern part of the map area. Away from the main hydrothermal alteration zone, these rocks are medium-grained hornblende and plagioclase-phyric diorites. They are foliated only along their contact margins and are cut by quartz-feldspar-porphyritic dikes and rhyolite dikes. The dike rocks are probably equivalent to, or younger than, Sloko-type intrusions.

The zircons separated from sample 190-HD are clear, colourless, euhedral, stubby prismatic crystals. Approximately half of the crystals were broken and a small proportion contain clear fluid inclusions or apatite laths. No inherited cores were present. The three fractions analyzed thus far are discordant and form a cluster such that a least squares regression is not possible (Figure 1-12-2d). The discordance of the three fractions suggests the presence of an inherited zircon component. It is unusual for three discordant fractions with different sizes and magnetic susceptibilities to cluster in this way.

The data set is insufficient to establish a precise emplacement age for the body, and analysis of additional zircon fractions is now in progress. A maximum age limit for the rock is established by field relations. The hornblende diorite intrudes the Sam batholith which we have dated at 218.0±3.6 Ma.

STRATIGRAPHIC AND STRUCTURAL OVERVIEW, AND U-Pb CONSTRAINTS ON ROCK DISTRIBUTION AND DEFORMATION

Schematic structural and stratigraphic relations of Palaeozoic and Mesozoic rocks in the Tatsamenie Lake area are shown on Figure 1-12-3. This figure is simplified from the detailed map of Oliver (1993). Detailed characteristics of the stratigraphy in the area are discussed by Bradford and Brown (1993). Several significant geological features are shown on this figure and assist in the interpretation of zircon data.

- The distribution of felsic rocks is asymmetric across the deformed carbonate rocks which form the core of the Tatsamenie antiform. Felsic rocks are exposed on the northern and eastern limits of the deformed limestone suite. They do not appear to crop out on the western limb of the antiform. On the western side the felsic rocks are commonly truncated by north-trending faults.
- A minimum of two major folding events deform the rocks in the study area. One of these map-scale structures is the Tatsamenie antiform. This and related early folds are characterized by north-trending axial surfaces and tight, upright to weakly east-overturned limbs. This antiform is deformed across broad, upright, northeast-plunging antiform-synform pairs. The interaction of these two fold styles produces well-defined Type II interference patterns (Ramsay, 1967).
- The Sam Creek antiform is faulted and offset by apparent right-lateral motion on a north-trending fault which forms part of the north-trending Bear fault system.

Geochronological data, summarized in Table 1-12-1, place important constraints on interpretations of volcanic stratigraphy and the timing of rock deformation in this area. Geological interpretations integrating these and other age data with field relationships lead to the following conclusions:

- Felsic rocks structurally above Early Permian carbonate rocks are dated at 301.8+2/−4 Ma to 316.5±5 Ma. In this map area, the presence of felsic volcanic rocks overlying limestones was first documented by Oliver and Hodgson (1990). The Early Permian age of the carbonate rocks, which structurally underlie the felsic rocks, initially documented by Monger and Ross (1977) has recently been confirmed by Bradford and Brown (1993).

We believe that the older felsic rocks have been emplaced on top of the Permian section through the action of a south-verging thrust fault. We correlate the felsic package with the felsic volcanic sequence that stratigraphically underlies the Permian limestones regionally, as has been described in the Scud River area by (Brown and Gunning, 1989).

- Geochronological constraints on the timing of the formation of the north-trending Tatsamenie antiform and of the development of overthrust rock sequences are limited. We believe that there is a close relationship between thrusting and the development of tight north-trending major folds such as the Tatsamenie antiform. Souther (1971) used field relationships to infer the presence of a deformational event older than the Middle Triassic, which he termed the Tahltanian orogeny. Brown *et al.* (1992) also inferred an Early Triassic deformational event using observations relating to changes in the intensity of rock fabric, metamorphic grade and truncation of early rock fabrics . The data of this report suggest that formation of the Tatsamenie antiform and the emplacement of overthrust rock sequences is compatible with this Permo-Triassic deformational event.
- The Sam batholith has been dated at 218.2±3.6 Ma. In the region of Sam Creek, this intrusive stock appears to be deflected across the axial surface of a northeast-trending antiform. Deformation of this intrusive body suggests that open, upright fold structures with northeast-trending axial surfaces were initiated later than 218 Ma.
- The Sam Creek antiform is cut by a north-trending fault zone, part of the Bear fault zone. Whole-rock sericite K-Ar dates on hydrothermal alteration envelopes are 205±7 Ma to 179±6 Ma (Schroeter, 1987). These dates may place an upper limit on the timing of the development of northeast-trending structures such as the Sam Creek antiform.

The timing of this event significantly pre-dates Middle Cretaceous folding which affects rocks on the western edge of the Bowser Basin (Evenchick, 1991). It is better correlated to an Early Jurassic deformation which has been documented in the Sulphurets area (Henderson *et al.*, 1992). Brown and Grieg (1990) have documented an undeformed latest Late Triassic to Early Jurassic unconformity in the Stikine River - Yehiniko Lake area. This post-Stuhini Group, pre-Early Jurassic deformational event may also have affected the Tatsamenie Lake area.

- The Sam Creek antiform deforms both the early Tatsamenie antiform and its overthrust sequence. This thrust surface probably had a west-verging orientation prior to its rotation into south-verging positions across structures like the Sam Creek antiform.
- The fault, locally termed the Limestone Creek fault, which defines the western edge of the carbonate strat-

igraphy due north and west of Muddy Lake (Figure 1-12-3) has not been significantly deflected by the southern continuation of the Sam Creek antiform. As is the case for the Bear fault, movement across this fault post-dates the formation of the antiform.

- The presence of pre-Permian felsic rocks north of Tatsamenie Lake and north of Sam Creek raises interesting questions concerning the age of the mafic volcanic rocks between these two points. The exact thickness of the pre-Permian volcanic section is difficult to define solely on the basis of field relationships. This rock package has some similarity to Pennsylvanian volcanic rocks mapped by Nelson and Payne (1984) in the Tulsequah area. The resolution of the age of this suite, and the position of other detachment or unconformable surfaces, requires age constraints based on either isotopic or paleontological data.

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TATSHENSHINI PROJECT, NORTHWESTERN BRITISH COLUMBIA (114P/11, 12, 13, 14; 114O/9, 10, 14, 15 & 16)

PART A: OVERVIEW

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(Contribution to the Corporate Resource Inventory Initiative)

KEYWORDS: Regional geology, Tatshenshini River, Alsek River, St. Elias Mountains, Alexander Terrane, Wrangellia Terrane, Chugach Terrane, mineral potential, metallogeny, Windy Craggy, volcanogenic massive sulphide, lithogeochemistry, stratigraphy, structure, Border Ranges fault, Denali fault, Tats Creek fault, Debris fault, Tarr Inlet suture, Tats group, skarn, hydrothermal alteration.

INTRODUCTION

The Tatshenshini-Alsek area in the extreme northwestern corner of British Columbia (Figure 1-13-1) is renowned for both its rugged wilderness and its endowment of mineral resources, including the world-class Windy Craggy copper-cobalt deposit. The Tatshenshini project is part of an integrated resource planning initiative that will lead to a management plan for the area that is in the best interests of the people of British Columbia. An important part of this process is an accurate assessment of the area's mineral potential. Such assessments rely principally on geological data which are collected in the course of field-based mapping studies. As published geological maps are not sufficiently detailed to permit these assessments, geological mapping in the Tatshenshini-Alsek area was initiated in mid-1992 as part of the provincial Corporate Resource Inventory Initiative (CRII).

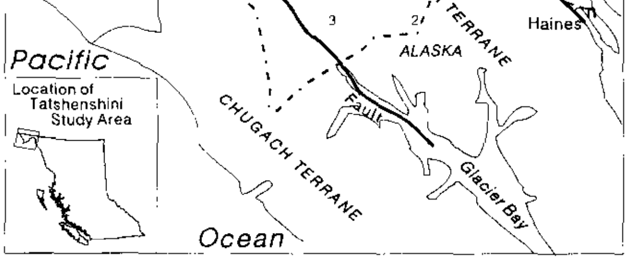

Figure 1-13-1. Location of the study area and major geologic elements. Areas covered by 1992 mapping are shaded. Locations of some significant new mineral occurrences are shown by the solid triangles.

Mapping in 1992 was conducted during the first of two anticipated field seasons over the 18-month life of the project. This report is a brief accounting of the first field season. Part A is an overview of project statistics, some of the highlights and an introduction to components of the study which are critical to accurate determination of mineral potential. These components include:

- geological setting of mineral occurrences (Part B)
- structural and metamorphic affects on the distribution of different metal-bearing rock suites (Part C)
- the latest data from newly discovered or undocumented mineral occurrences within the map area as well as updated information on previously known occurrences both within and outside the map area (Part D).

General location and place name information (Figure 1-13-1 and Figure 1-13-2) that is used in Parts B through D is included in this overview (Part A).

OBJECTIVES

The primary objectives of the Tatshenshini project are to inventory all known mineral occurrences within the Tatshenshini-Alsek area, and to compile geological and mineral occurrence databases from which the mineral potential of the area can be evaluated.

Geological objectives include delineation of areas underlain by Upper Triassic Tats group stratigraphy which hosts the Windy Craggy deposit, and testing the applicability of the Windy Craggy deposit model to newly discovered copper occurrences (*see* Part D). These tasks are complicated by the effects of several tectonic episodes (*see* Part C) which have shuffled and folded the stratigraphic succession and modified the fabric and mineralogy of the rocks through deformation and metamorphism. Essential prerequisites for the accurate definition of mineral potential "tracts" include an understanding of the age and compositional ranges of individual rock packages. Timing and severity of tectonic episodes are also important because these events also affect the distribution of mineral deposits. Nonmetallic contributions to the mineral potential include thin coal seams preserved in relatively small, Early Tertiary sedimentary basins developed along major faults, and gypsum within older sediments (Paleozoic to Triassic?; Campbell and Dodds, 1983a), both in the eastern part of the map area.

ACCOMPLISHMENTS

Mapping reported on here covers parts of nine 1:50 000 map sheets (Figure 1-13-1), an area equivalent to six full

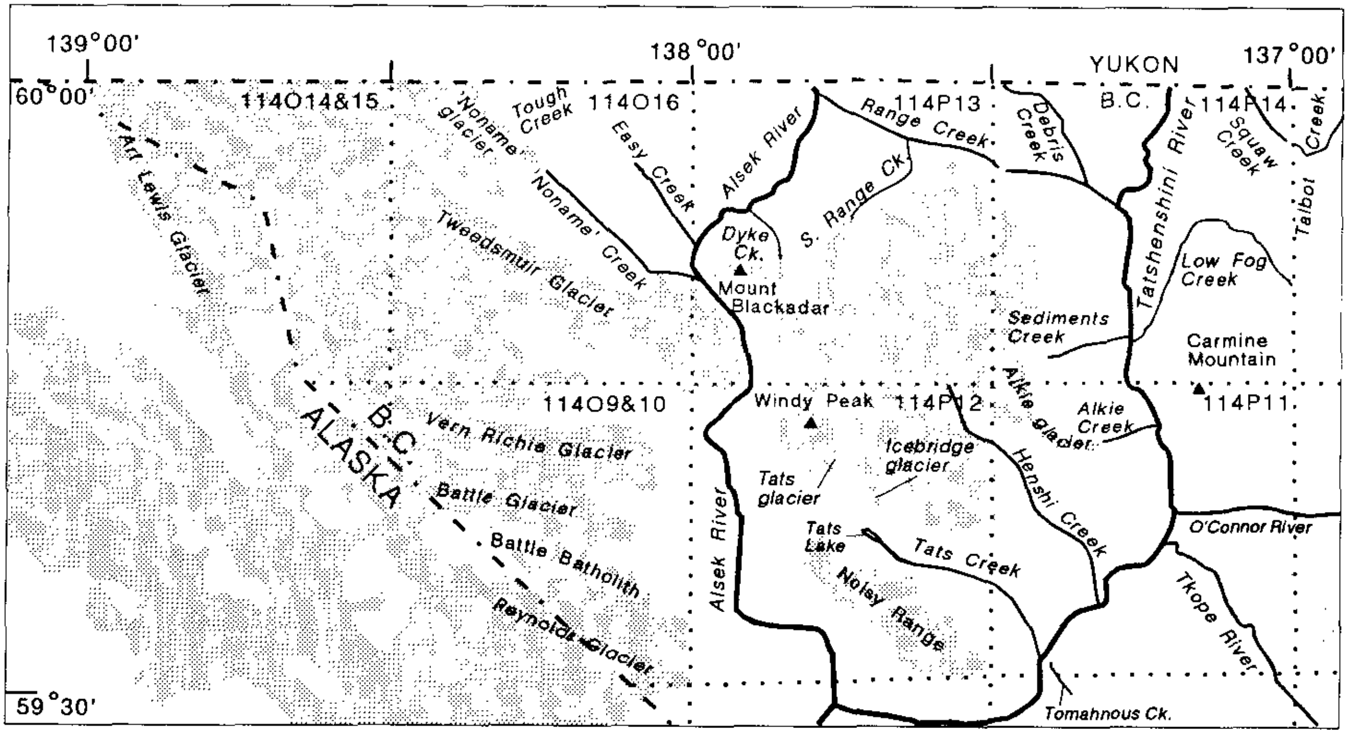

Figure 1-13-2. Geographic location names refered to in Parts A to D of this report that are within the area mapped in 1992.

sheets, or approximately 482 000 hectares. It was mapped in sufficient detail to warrant publication at 1:50 000 scale. At this scale, we are able to outline previously undefined rock units which are now known to cover large portions of the area. Nearly 300 samples collected from various rock units will, when analyses are complete, provide a basis for evaluating the mineral potential of the units. No such "baseline" regional geochemical data previously existed.

During the course of mapping, several significant, previously unknown copper showings were discovered (*see* Part D). Isolated occurrences of anomalous concentrations of other metals, particularly lead, silver and gold were also identified. Samples from these occurrences are in the process of being analysed. Currently available, but incomplete analytical results are tabulated in Part D.

Discovery of some 20 new fossil localities has added significantly to an understanding of the stratigraphy of the area. More than 60 samples are presently being analysed for microfossils. This will help us to further refine the geological history of the area as more fossil ages are determined.

Preliminary mineral potential findings, based mainly upon geological observations and initial geochemical data, have been submitted to the Commission on Resources and the Environment (CORE) to aid in land-use decisions.

LOCATION, ACCESS AND PHYSIOGRAPHY

The study area covers that part of British Columbia west of, and including, a corridor 10 kilometres wide along the Haines Highway. This comprises a triangular area occupied by the rugged St. Elias Mountains and drained by the Tatshenshini and Alsek rivers. It is bounded to the south and west by Alaska and to the north by Yukon Territory. We report here on observations from the northern half of this area (Figure 1-13-1).

The paved Haines Highway, which links Haines Junction, Yukon Territory, with Haines, Alaska, provides year-round access to the eastern part of the area. Several loose-surface roads in varying condition extend west from the highway. A maintained gravel road provides access to placer mining operations in the northern Squaw Range, but requires fording the Tatshenshini River at Dalton Post, Yukon. Abandoned bulldozer-trails extend up Chuck Creek to the O'Connor River gypsum occurrence just east of the study area, up the Parton River to the headwaters of Low Fog Creek, and up Goldrun and Talbot creeks.

The area is most readily accessible by air. A 1000-metre gravel airstrip at the exploration camp of Geddes Resources Limited will accommodate a DC-3 aircraft and provides access to the north-central area. Tats, Low Fog and Range lakes are all large enough for float planes to land and take off. The nearest centres for supplies and services are: Whitehorse, Yukon, some 190 kilometres east-northeast; Atlin, British Columbia, about 225 kilometres to the east; and Haines, Alaska, 135 kilometres to the southeast. Helicopters are the most effective means of transportation within the study area and are available for charter in Atlin, Whitehorse and Haines Junction.

A diversity of biogeoclimatic zones characterizes the Alsek-Tatshenshini area. These result from the interplay of interior and Arctic climates which give way to a coastal influence both to the south and west. Glaciers are small and relatively uncommon in the east, but in the west they cover over 80 per cent of the area and exert a major influence on the weather. In this western area the permanent snow line extends down to 1000 metres elevation. Low overcast and persistent precipitation are typical weather conditions. Snow is common at any time of the year at higher elevations, with winter accumulations in excess of 10 metres. Cornice build-up on the northern sides of ridge crests is common, and failure of cornices throughout the early summer makes work on north slopes hazardous.

Two major north-south valleys transect the Alsek Ranges, and a third separates the western Alsek Ranges from the Icefield Ranges. From east to west the valleys are occupied by the upper Tatshenshini, lower Tatshenshini and Alsek rivers. Willows and boreal and black spruce occupy the Tatshenshini valley and impede travel on foot. Major tributaries of this river are forested mainly by poplar, alpine birch and juniper and are more easily travelled. Much of the Alsek Valley is recently deglaciated and barren of vegetation, but the lower reaches are forested.

PREVIOUS WORK

Work in the Tatshenshini-Alsek area has been hampered by poor access, generally inclement weather and, prior to an aerial photogrammetric survey in 1979, a lack of accurate topographic base maps. The first prospectors entered the area around 1898 in search of placer gold and discovered lode silver-gold showings in the Rainy Hollow area, leading to intermittent copper production between 1908 and 1922. Coarse gold was found along Squaw Creek in 1927 (James, 1928, p. C110) where placer operations have continued to the present.

Earliest geological mapping in the project area focused mainly on the areas surrounding the Windy Craggy deposit following its discovery by J.J. McDougall in 1958, then agent for the Ventures-Falconbridge group (Downing and McDougall, 1991). Exploration at Windy Craggy proceeded intermittently until the 1980s when underground development and detailed mapping (*e.g.*, Prince, 1983) led to the delineation of a deposit containing nearly 300 million tonnes of massive sulphide (Geddes Resources, 1992). Geological mapping of the East Arm Glacier area in the mid-1970s by Swiss Aluminum Mining Company of Canada Ltd. (Scheilly *et al.*, 1976) focused on locating the source of massive sulphide boulders near the toe of the glacier. Subsequent drilling by St. Joe Canada Inc. proved the existence of a massive sulphide lens beneath 340 metres of ice (Brisco, 1987).

Earliest regional mapping was conducted by the Geological Survey of Canada during Operation St. Elias in 1974 (Campbell and Eisbacher, 1974; Campbell and Dodds, 1979, 1983a, b) which relied heavily on application of aerial reconnaissance mapping. More detailed follow-up mapping in subsequent years by Dodds covered parts of map sheets 114P/9, 11, 13, 14 and 15 (Campbell and Dodds, 1983a) and 114P/10 and 12 (Dodds, 1988). British Columbia Geological Survey Branch studies in the area include investigations by MacIntyre (1983, 1984, 1986), MacIntyre and Schroeter (1985) and Peter (1989) and focused mainly on mineral occurrences. An extended investigation of the Windy Craggy volcanogenic massive sulphide deposit (114P/12) by MacIntyre (1983, 1986) addressed its regional stratigraphic and structural setting, and the geochemistry of enclosing basalts. Isotopic age controls in the area (Dodds and Campbell, 1988; Jacobsen *et al.*, 1980) are mainly based on K-Ar isotopic techniques for dating minerals in plutonic rocks.

TECTONIC SETTING

Much of the Canadian Cordillera is an amalgamation of large, commonly unrelated geologic provinces or terranes that may have originated far from their present location and subsequently collided and accreted to the margin of ancestral North America (Coney *et al.*, 198). The Alexander Terrane is one of the largest of these terranes. It is composed largely of platformal and basinal rocks and underlies over 95 per cent of the central map area, extending hundreds of kilometres to the north and south (Berg *et al.*, 1978). Submarine volcanic and sedimentary rocks, interpreted to be fragments of Wrangellia Terrane underlie several tens of square kilometres in the northeastern map area. An even smaller area is underlain by clastic rocks alternatively interpreted to be part of the Chugach Terrane (Wheeler *et al.* 1991) or Wrangellia (Campbell and Dodds, 1983a, b). These rocks are exposed in an irregular strip along the Alaska border, extending less than 2 kilometres into British Columbia at the latitude of the map area. Our mapping in this border area confirmed a highly variable belt of rocks with uncertain terrane affinities. Resolution of this terrane problem is not possible on the basis of current data. Overall, however, the rocks most closely resemble the Tarr Inlet suture zone (Brew and Morrell, 197) which may contain fragments of both the Chugach and Wrangellia terranes.

Faults that apparently separate terranes include the Duke River fault east of the Alexander Terrane (also known as the Denali fault, of which it is a splay), and the Hubbard (or Art Lewis, of Plafker *et al.*, 1976)- Border Ranges fault system west of the Alexander Terrane. Our mapping raises some questions about the nature and location of these terrane-bounding(?) structures. Resolution of these tectonic problems is important because the regional distribution of geologic provinces must be considered when defining tracts of high and low mineral potential.

PROJECT PROCEDURE

Key steps in the mineral potential evaluation process are identification of the distribution of rock packages or "tracts" with distinct geological features, their stratigraphic setting and age, their geochemical profile and tectonic events that may have modified both the rock characteristics and their potential for economic mineralization. Where such data are unavailable, sparse or obsolete, they are gathered principally by field-based geological mapping and collection of samples for laboratory analysis. Mineral potential maps can then be constructed by integration of all sources of data (*e.g.*, rock distribution, geochemistry, fossil ages).

Key steps in a geological mapping program are: compilation of existing data, identification of limitations in existing data, establishing objectives for the collection of new data, optimized collection of field data, collection of samples for laboratory analysis aimed at meeting specific objectives, data analysis and synthesis, and production of maps and reports.

At the beginning of the project, 2 months were spent compiling all available pertinent data onto 1:50 000-scale topographic base maps which would form a starting point for field studies. Over 320 person-days were spent collecting field data in the Tatshenshini-Alsek area during a 2-month period commencing July 4. Initial orientation surveys were conducted along the Haines Highway with a four-person crew. Heavy snowpack precluded fieldwork in the western area until mid-July, at which time an eight-person mapping crew was moved into the centrally located Geddes Resources Limited exploration camp. In early August, the field crew was reduced to four geologists who used mainly short traverses or spot checks in combination with "vantage-point mapping". Mapping and geochemical sampling, generally at a more detailed scale, were also undertaken around significant showings in the region. Lithogeochemical sample coverage and mineral occurrence inventory resulting from this first phase of the project extend beyond the area reported on here.

Fieldwork was supported by an on-site helicopter. Traverses were conducted in accessible areas where critical geological relationships could be established using daily helicopter set-outs and pick-ups. Only four field days were lost due to inclement weather or mechanical problems. In July and August most of the area was also covered by a companion Regional Geochemical Survey (RGS) program which focused on collection of stream sediment and water samples for multi-element analysis (Jackaman, 1993, this volume).

Completion of 1992 Tatshenshini project objectives within the allotted time frame required regional map coverage at a rate of three to six times that of a standard 1:50 000 geological mapping program in similar terrain. This was in part made possible through the increase in mapping efficiency resulting from use of an on-site helicopter, but was also accomplished by limiting mapping in widespread, homogeneous rock units (such as intrusions) to a few representative spot checks. Mapping within such rock units is not, therefore, commensurate with Geological Survey Branch 1:50 000 mapping standards.

Expected Results

Fundamental to fulfilling the objectives of the project is production of 1:50 000 geological maps which represent an integration of all existing data. These will be augmented by geochemical and fossil data as they continue to become available. Complete geochemical results are not available at the time of writing, however, available assay results from samples collected within the Upper Triassic assemblage and elsewhere (reported in Part D) serve to highlight the mineral potential of these rocks. Assay data from this project will eventually be complemented by regional stream-sediment geochemical data collected as part of the companion RGS program. Together they will form the basis for geochemical characterization of mineral potential tracts.

Major oxide and rare-earth element (REE) analyses of specific volcanic units are pending. When available they will assist in the interpretation of the tectonic environment of volcanism. Such chemical analyses may help to constrain the answers to many geological questions which bear on the distribution of, and relationships between, similar rock packages. For example, are probable Upper Triassic pillow basalts enclosing massive sulphide lenses in the placer-rich Squaw Creek valley chemically related to pillow basalts that host the Windy Craggy deposit? Are poorly understood metabasites west of the Alsek River chemically distinct from undeformed and dated basalts to the east? In what tectonic environment did they form? Given the environment of formation, what types of mineral deposits might be expected? Do chemical differences or similarities support the notion of an intervening major tectonic contact or terrane boundary?

OUTPUT PLANNED

Initial products arising from the Tatshenshini-Alsek project include this report (Parts A to D) and a 1:50 000-scale Open File map series featuring the geology and lithogeochemistry of the area described in this report. These will be accompanied at a later date by Open File mineral potential maps of the same area.

Rare-earth element, and fossil and isotopic age data, will be released in the form of government or external publications as data are compiled and interpreted.