GEOLOGY AND MINERALIZATION, BEARSKIN (MUDDY) AND TATSAMENIE LAKE DISTRICT (SOUTH HALF), NORTHWESTERN BRITISH COLUMBIA (104K)

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KEYWORDS: Economic geology, Stikine terrane, Golden Bear, gold, ore controls, structural geology, stratigraphy

INTRODUCTION

The Muddy Lake–Golden Bear project was initiated in 1988 to examine in detail the structural and stratigraphic setting of a sequence of gold occurrences and deposits between Tatsamenie Lake and Muddy Lake, 137 kilometres west of Dease Lake. Upper Paleozoic rocks in this area host several gold occurrences and one developing mine, the Golden Bear property.

The project area, outlined in Figure 2-11-1, covers approximately 150 square kilometres, in an area where relief varies from 940 to 2200 metres. Excellent outcrop exposures are present in much of this region, but permanent snow, ice and felsenmeer limit on the higher plateaus. Detailed field mapping, at a scale of 1:5000, was completed over approximately one half of the project area, extending from Muddy Lake to Sam Creek. Additional data on the style and controls on mineralization have been obtained from underground mapping and sampling in the Golden Bear mine. Work during the 1988 field season has refined the regional stratigraphic column and clarified the structure on both regional and mine scales.

This report emphasizes selected results of surface and underground mapping, but does not include analytical data from samples collected. Results of mapping over the north half of the project area will be presented in a subsequent report, following the 1989 field season.

PREVIOUS WORK

Earliest reports on the regional geology of the map area are recorded by Kerr (1930), covering the Taku district northwest

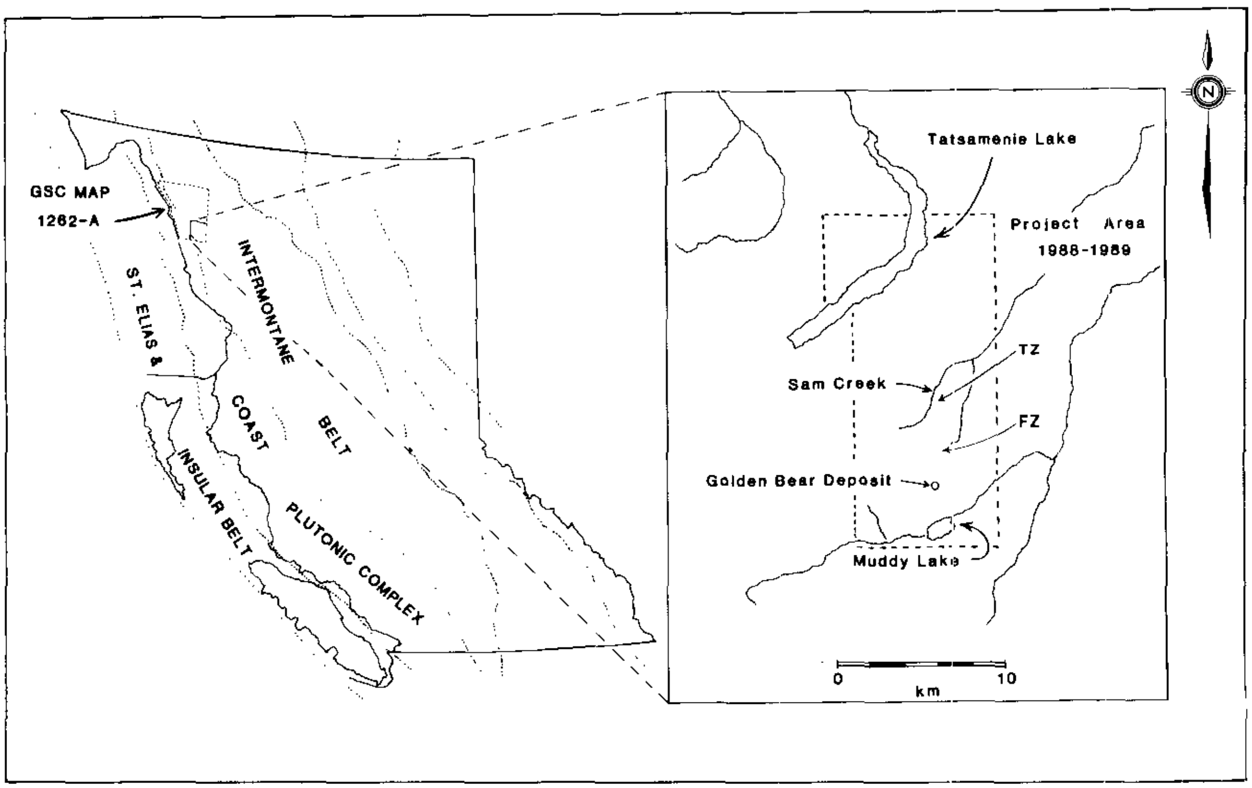

Figure 2-11-1. Location of the Tatsamenie–Muddy Lake project within the tectonic framework of the northwestern Canadian Cordillera. Location of Fleece (FZ) and Totem (TZ) mineralized zones.

British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1988, Paper 1989-1.

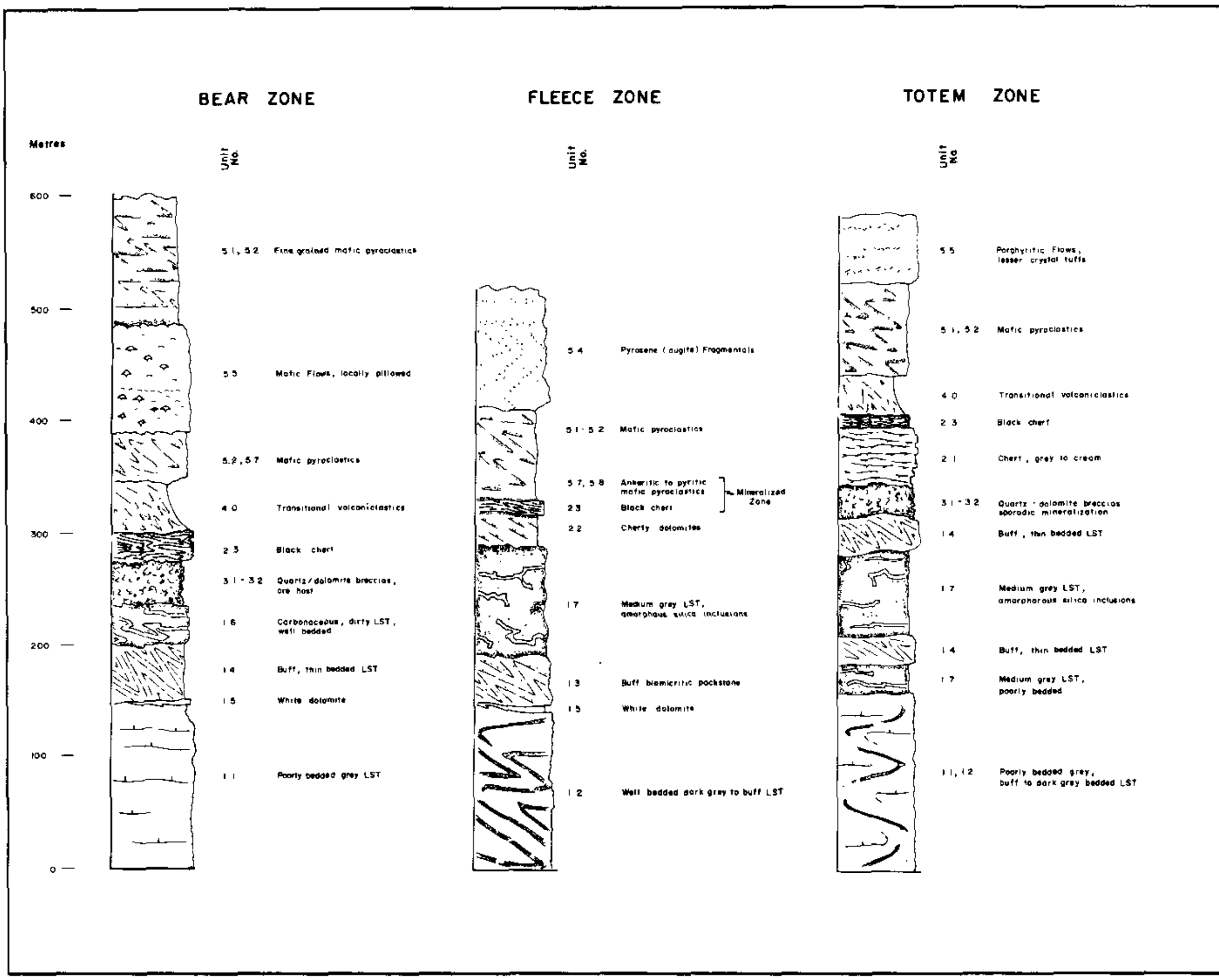

Figure 2-11-2. Stratigraphic sections through Bear, Fleece and Totem mineralized zones, Golden Bear property. Refer to Table 2-11-1 for identification of numbered lithologic units.

of the project area and Cockfield (1926) in the area to the northeast. The geological map and accompanying report produced by Souther (1971) is the principal source of regional data. Stratigraphy within the Tatsamenie Lake area has been briefly examined by Monger (1970). This area, and the Golden Bear deposit, were examined and sampled by Schroeter (1985, 1986, 1987) over a 3-year period during the earlier exploration phases. His reports contain the only published data on isotopic dating of alteration, timing of igneous emplacement, and whole-rock chemical analyses within the study area.

Much of the technical database for the region between Tatsamenie and Muddy Lake, and for the Golden Bear deposit, has been developed by geologists of Chevron Canada Resources Ltd. and its joint venture partner at that time, North American Metals Corporation. The results of surface geological mapping and drill-core data for this region are thoroughly documented in a summary report by Wober and Shannon (1985).

REGIONAL GEOLOGY

The area is underlain by an assemblage of Upper Paleozoic limestones and cherts conformably overlain by pre-Upper Triassic volcaniclastic sediments formed in a back-arc environment. This assemblage forms part of the larger Stikine terrane now located on the northern limit of the Stikine Arc. In the Stikine Arc, strongly deformed supracrustal rocks, and belts of younger intrusions, trend northeast across the north-northwesterly grain of the Cordillera. Stratigraphy within the project area correlates closely with the type-section proposed by Monger (1977) for the Stikine assemblage, but the base of this stratigraphic column, comprising Mississippian and older strata, is not exposed in the project area.

Structures formed during three main deformational periods: the Middle Triassic and earlier, the Late Jurassic, and the Early Tertiary (Souther, 1971). Early folds are typically tight, upright antiforms and synforms with north-trending axial surfaces, and locally sheared to rootless intraforma-

Table of Formations

Pleistocene and Recent

11.0 Glacial and Fluvial Deposits

INTRUSIVE LITHOLOGIES

Jurassic (?) and Younger

10.0 Diabase Dykes

9.0 Felsic Intrusives

- 9.1 Porphyritic Felsic Dykes

8.0 Gabbro

- 8.1 Foliated Gabbro
- 8.2 Unfoliated Gabbro

7.0 *Granodiorite*

- 7.1 Foliated Granodiorite - dioritic marginal phases
- 7.2 Pegmatitic Granodiorite

SUPRACRUSTAL LITHOLOGIES

Pre Upper Triassic

6.0 Clastics

- 6.1 Argillites and Interbedded Siltstones
- 6.2 Argillites and Interbedded Volcaniclastics

5.0 Mafic Volcanics

- 5.1 Mafic Ash Falls - lesser interbedded epiclastics
- 5.2 Mafic Lapilli Pyroclastics - lesser crystal tuffs
- 5.3 *Mafic Agglomerates*
- 5.4 Pyroxene Fragmentals
- 5.5 Mafic Flows - locally pillowed
- 5.6 Feldspar Porphyritic Flows
- 5.7 Ankeritic Pyroclastics - fuchsite, quartz and carbonate alteration
- 5.8 Pyritic Tuffs - disseminated pyrite greater than 3%
- 5.9 Amphibolitic Gneiss - mafic volcanic protolith
- 5.10 Chlorite Schist

4.0 Transitional Volcaniclastics and Clastics

- 4.1 Ankeritic Phyllites - lesser silica rich interbeds
- 4.2 *Sericitic Volcaniclastics - weakly calcareous*, chlorite subordinate to sericite

3.0 Fault Breccias - Age of Brecciation Indeterminate

- 3.1 QDx - quartz dolomite breccias, silica rich protolith
- 3.2 DQx - dolomite quartz breccias, carbonate protolith
- 3.3 QSDx - heterolithic breccias, sericitic fragments
- 3.4 QRb - ribbon banded quartz veins

Permian and Older

2.0 Silicate Facies

- 2.1 Chert - ribbon banded, light to medium grey
- 2.2 Cherty Dolomites - pink dolomite, grey chert interbeds
- 2.3 Black Chert - lesser fine-grained black clastics
- 2.4 *Siliceous Intrabiomicritic Limestones*

1.0 Carbonate Facies

- 1.1 LST - grey to cream, thick bedded
- 1.2 LST - *interbedded buff to dark grey carbonate beds*
- 1.3 LST - buff biomicritic packstones, poorly bedded
- 1.4 LST - buff, thin bedded, micritic
- 1.5 LST - clean white to pearl-grey dolostone
- 1.6 LST - carbonaceous, dark grey, well bedded, lesser black chert interbeds
- 1.7 LST - dark to medium grey, amorphous black chert inclusions

Table 2-11-1. Table of Formations.

tional isoclines. The development of broader, northwest-trending open folds is the result of continued east-west shortening during the Jurassic. The onset of extensional deformation during the mid-Tertiary is recorded in a series of normal fault structures which penetrate the youngest Tertiary rocks (Souther, 1971). The principal focus of this study is the documentation of the deformational history of the area.

PROPERTY GEOLOGY: SUPRACRUSTAL LITHOLOGIES

Details of stratigraphy in the Muddy Lake area, and across the mineralized zones, are outlined on three stratigraphic columns (Figure 2-11-2 and Table 2-11-1). The rocks in these columns correspond only to Units 3 and 4 of Souther's regional map and are all pre-Upper Triassic or older. Stratigraphic ages are based on the paleontologic data of Monger and Ross (1971). Limited isotopic age data for some of the intrusive rocks and alteration minerals are reported by Schroeter (1987).

PERMIAN AND OLDER

1.0 Carbonate Facies

A thick, poorly bedded grey to cream limestone (1.1), prominent in the southern half of the map area, occurs at the base of the carbonate succession. This unit is not exposed to the north where its stratigraphic position appears to be occupied by a well-bedded, buff to dark grey limestone exceeding 100 metres in true thickness (1.2). None of the limestones appear to be extensively dolomitized, quartz-injected or otherwise altered, except near major fault zones. Faulting and folding have resulted in considerable thickening, perhaps by a factor of two or more, of the limestone stratigraphic section (Figures 2-11-3 and 2-11-6).

Buff-weathering, ankeritic limestones (1.3 and 1.4) form prominent stratigraphic markers on the property. Both of these units contain significant crinoidal debris but only one is well bedded (1.4). The contact between buff-weathering limestones and overlying carbonaceous limestones is often marked by a thin, pearl-grey to cream-coloured, clean limestone less than 10 metres thick (1.5).

A dark grey carbonaceous limestone, containing black chert interbeds (1.7), forms the uppermost unit of the carbonate sequence. A lateral facies equivalent of this unit contains distinctive, irregular, black chert inclusions (1.6) and forms the protolith of one of the breccia types in the mineralized zone (3.2). The lack of well-defined bedding within this unit makes it difficult to estimate its true thickness but it appears to range from 50 metres to greater than 100 metres thick.

2.0 Silicate Facies

Quartz-rich chemical sedimentary rocks are abundant in the northern half of the map area. Unit 2.1 is pale grey, cream to buff-weathering, moderately recrystallized, typically well-bedded, clean chert. Ribbon layering, 2 to 5 centimetres thick, is weakly developed and no sulphides were noted. In several localities a black, dirty chert (2.3) occurs at the

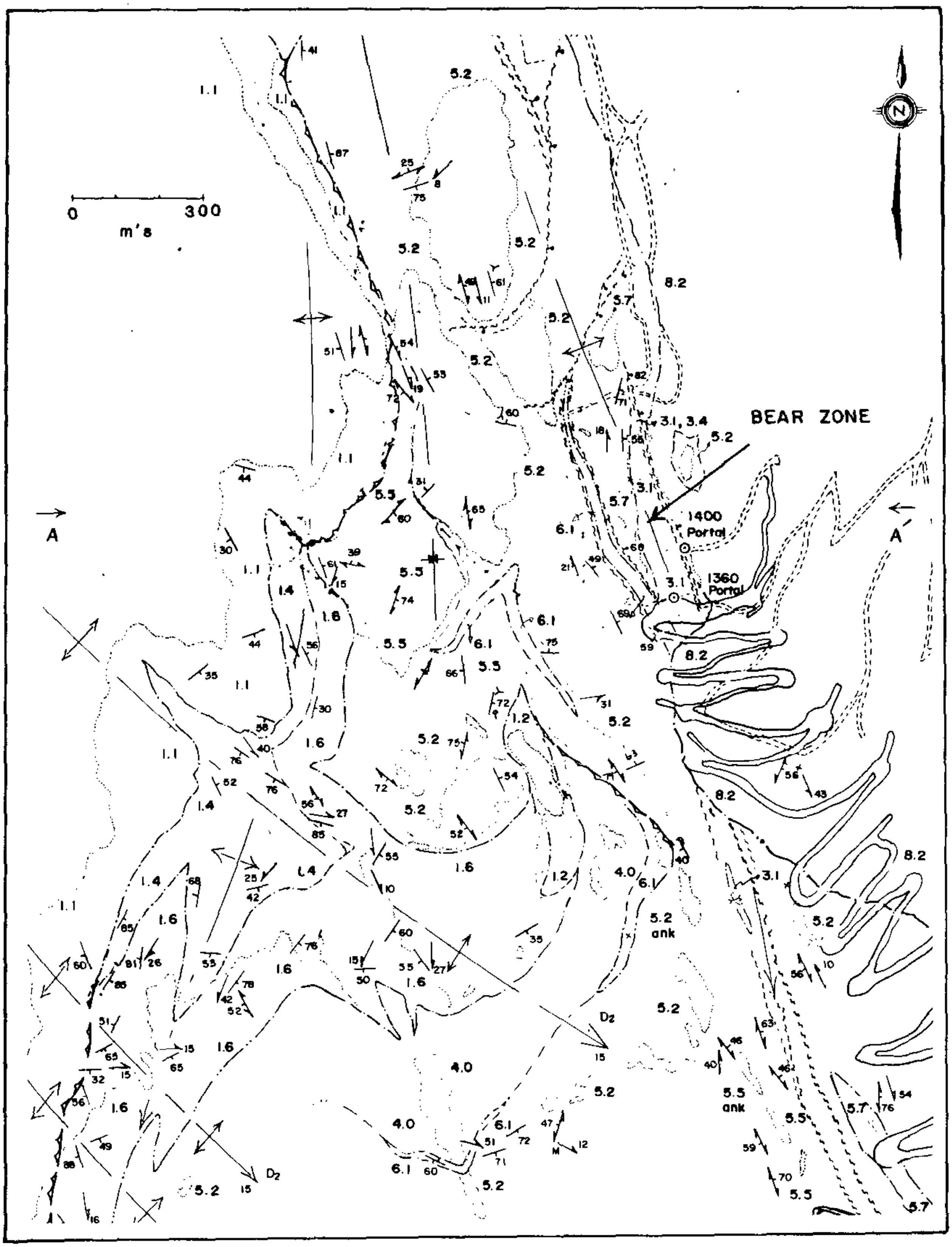

Figure 2-11-3. General surface geological relationships within the immediate vicinity of the Golden Bear deposit. Gold mineralization is developed within steep east-dipping faults which, on this section, are truncated by the large landslide slips forming a fault contact with Unit 8.2. Refer to Table 2-11-1 for identification of numbered lithologic units.

conformable contact between the carbonate and overlying volcanic-dominated successions. The unit is thin, less than 25 metres true thickness, and locally contains a significant proportion of fine-grained black clastic material. Within the Fleece zone this lithology may host ore. Pink cherty dolomites (2.2) and siliceous intrabiomicritic limestones (2.4) occur locally within this cherty sequence.

PRE-UPPER TRIASSIC

3.0 Fault Breccia

Spectacular breccias, dominantly within a limestone/dolomite or chert host, are localized near the Bear fault. The breccia zones range up to 40 metres wide and are a significant ore host. The host limestone is extensively dolomitized and silicified but pyrite is sparse, less than 3 per cent. Protoliths for these breccias may be recognized from the breccia fragments (3.1 and 3.2). Heterolithic breccias (3.3) are predominant immediately adjacent to contacts between limestone and volcanic rocks and contain volcanic fragments completely replaced by sericite. Schroeter (1987) has dated this alteration at 204 Ma. Weakly ribbon-banded quartz veins (3.4) occur locally in the breccias but are not widespread.

4.0 Transitional Volcaniclastic and Clastic Rocks

Two submembers of this unit are recognized: ankeritic phyllites (4.1) and sericitic volcaniclastics (4.2). These lithologies are best exposed in the northern part of the map area in the canyon of Sam Creek. Their strike continuity is interrupted by large-scale faults and fold structures. Unit 4.1 becomes progressively more siliceous near its exposed base and may locally be transitional to the underlying silicate facies of chemical sedimentary rocks. The strong sericite development within the sericitic volcaniclastics, Unit 4.2, is unlikely to be hydrothermal in origin. The unit lacks any significant sulphide development, green micas are conspicuously absent and the presence of secondary quartz is not documented.

5.0 Mafic Volcanic Rocks

Ten subunits were mapped in the mafic volcanic sequence on the property. Units 5.1 to 5.3 are a mafic pyroclastic assemblage ranging from ash tuffs (5.1), through lapilli tuffs (5.2) to agglomerates (5.3). These rocks are typically monolithologic and, except near major fault zones, unaltered. Interbeds within Unit 5.2 are characteristic of well-preserved feldspar crystal tuffs. Feldspars may be weakly sericitized and chlorite may pseudomorph amphiboles.

The base of Unit 5.4 is defined by an abrupt increase in the pyroxene content, principally augite. Small pyroxene phenocrysts, both within angular fragments and in the matrix, may exceed 30 per cent of the rock volume. Amphiboles coexist with pyroxene and olivine is absent in Unit 5.4, indicating this rock is not an ultramafite.

Mafic flow sequences (5.5) are common in the map area; however, pillowed flows were only identified in a small area approximately 200 metres southwest of the Bear zone 1360 portal. Plagioclase-porphyritic flows, containing 20 to 40 per cent phenocrysts, were mapped as a separate unit (5.6). Phenocrysts locally exceeded 1.5 centimetres in length.

Ankeritic mafic tuffs (5.7) and pyritic tuffs (5.8) are altered facies of the volcanic sequence associated with mineralization and faults. Quartz-ankerite veins and veinlets are locally developed in envelopes 20 to 40 metres wide around fault zones. Carbonate exceeds quartz within veins and also in pervasively altered rock, which typically contains no more than 5 to 10 per cent quartz. Similar alteration is common in ankeritic mafic volcanic rocks near their contacts with limestones and dolomites, but is unrelated to mineralization.

The most pyritic mafic volcanic rocks in the area are exposed underground in the Bear zone. In these exposures, pyrite, generally less than 5 per cent, occurs as uniform disseminations, slightly coarser aggregates and along hairline fractures. Pyritic tuffs are the principal hostrock for mineralization in the Golden Bear deposit.

Amphibolitic gneiss (5.9) is developed where mafic rocks have been altered in the aureole, 75 to 100 metres wide, around large granodiorite intrusions. The gneiss is characterized by alternating layers rich in feldspar and amphibole, 5 to 15 centimetres thick. The layering is locally cut by small, sometimes pegmatitic, felsic intrusions. Chlorite schists (5.10) may also be related to intrusive contacts but are more clearly related to fault zones. In most cases the protolith of the chlorite schist appears to be pyroxene fragmental rocks of Unit 5.4.

6.0 Clastic Rocks

Two units are identified within this division: well-bedded argillites and siltstones (6.1), and a thin overlying sequence of fine-grained interbedded mafic pyroclastics and lesser black clastic rocks (6.2). The combined thickness of these units is less than 100 metres. They are intruded by a large gabbro sill. In the Holocene, bedding-parallel slips in the

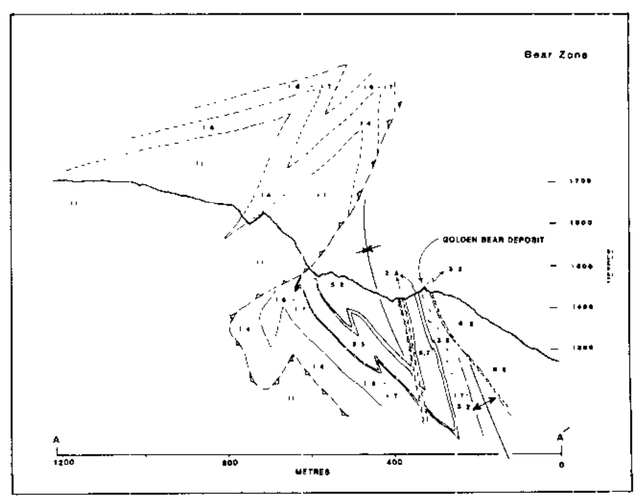

Figure 2-11-4. Geological cross-section, looking north, through the Golden Bear deposit above the 1400-metre portal. Contacts are down-plunge projections of surface data defined in Figure 2-11-3. Numbered lithologic units are identified in Table 2-11-1.

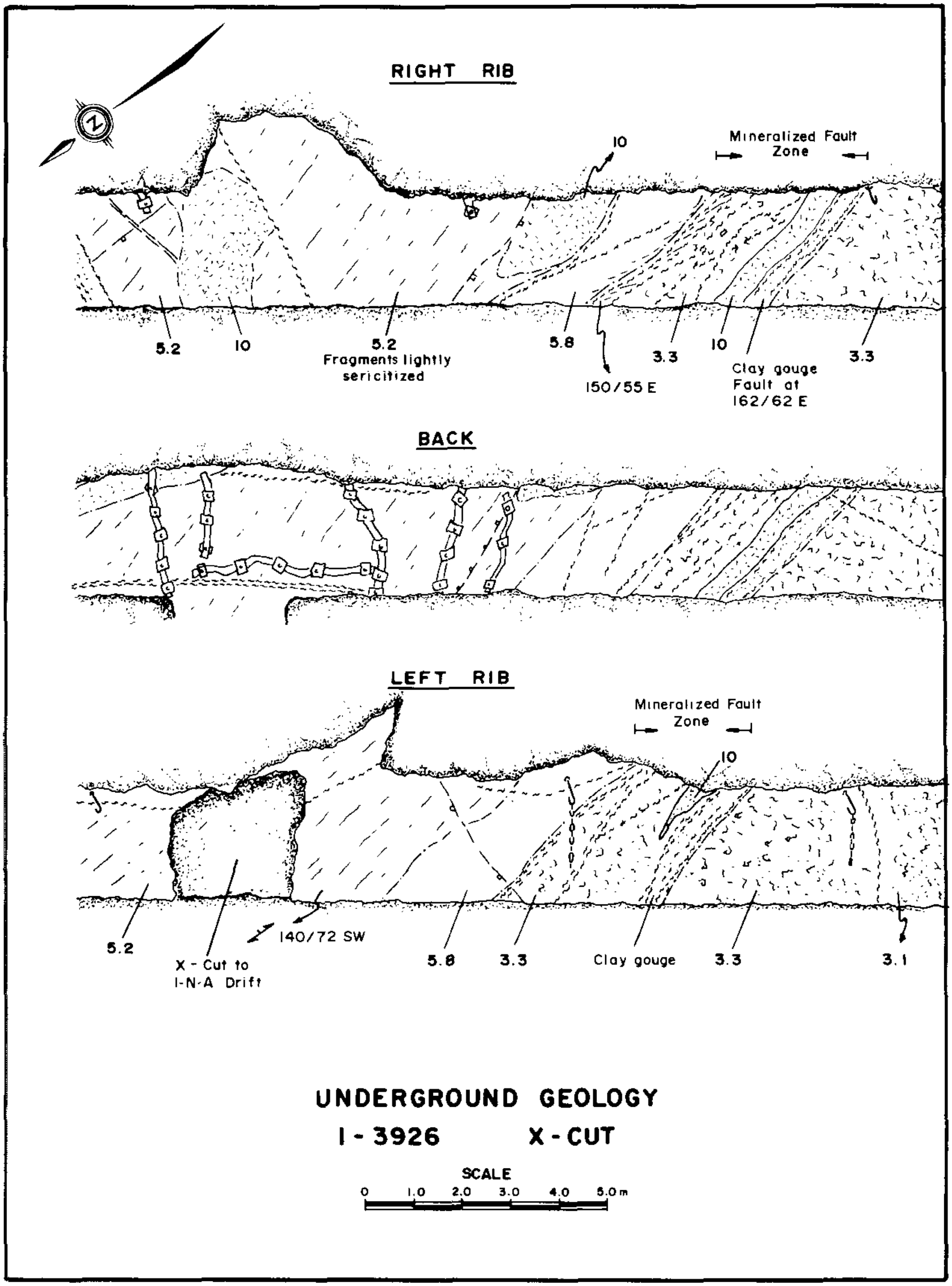

Figure 2-11-5. Underground geological plan, through the I-3926 crosscut, Golden Bear deposit. Strongest mineralization is developed between the fault contacts of a pyritic tuff (Unit 5.8) and extensive quartz dolomite and heterolithic breccia (Units 3.3 and 3.1). Numbered lithologic units are identified in Table 2-11-1.

clastic sediments resulted in a large mass of gabbro sliding downslope as a major rock avalanche which now covers the hangingwall of the deposit.

PROPERTY GEOLOGY: INTRUSIVE LITHOLOGIES

JURASSIC AND YOUNGER

7.0 GRANODIORITE

Unit 7.0 is a medium-grained granodiorite characterized by the presence of potassic feldspars, free quartz and a light colour index, less than 25. It forms a large intrusive body exposed in the northeast half of the project area. Locally this granodiorite is foliated (7.1) and the fabric is similar to that recognized in the surrounding rocks. Marginal phases of this body are often dioritic and in places are cut by coarse-grained felsic pegmatites (7.2).

8.0 GABBRO

Unfoliated gabbroic intrusions (8.1) are typically coarse grained, amphibole rich and may show poorly developed igneous layering. Gabbros are foliated (8.2) adjacent to major faults.

9.0 FELSIC INTRUSIVES

Porphyritic felsic dykes (9.1) were noted infrequently during surface mapping. Small sodic feldspar laths are randomly orientated within a reddish buff fine-grained matrix. Felsic dykes carry ore-grade mineralization in the Fleece zone (Wober and Shannon, 1985) but are not a significant ore host. Quartz phenocrysts are reported from the felsic dykes in this zone.

10.0 DIABASE DYKES

Dark green, fine-grained diabase dykes (10.0) cut all other lithologies and are discordant to faults within the main ore zone. Postmineralization dykes are most common within extensional fractures in the main deposit and are rarely noted on surface outside of this zone.

STRUCTURE OF MINERALIZED ZONES

BEAR ZONE

The geological setting of the Bear deposit is illustrated in Figures 2-11-3 and 2-11-4. The hostrocks are deformed into large chevron folds with steeply orientated southwest-dipping axial surfaces and moderate (20 to 25 degree) southerly plunges. The chevron folds are parasitic on a regional south-plunging antiform and are refolded about northeast-dipping axial planes. The second generation of folds is characterized by rounded hinge regions. The interference patterns produced by the interaction of the two fold systems are transitional between Type I and II patterns. Doubly plunging hinge lines are common within some of the finer marker beds in the limestone succession, but southerly plunges dominate.

The contact between limestone and volcanic rocks is conformable in the central part of the map area (Figure 2-11-3) but is discordant elsewhere as a result of a bedding-transgressive thrust which places the oldest limestone units directly against younger volcanics. This thrust is best defined on the cross-section (Figure 2-11-4) drawn through the Bear main zone. All contacts on this section are interpreted from down-plunge projections from surface.

The ductile style of deformation in rocks immediately adjacent to the deposit is in marked contrast to brittle deformation which characterizes the Bear fault zone. A temporal discontinuity in deformational episodes is clearly suggested. The fault zone is controlled by steep east-dipping, north-striking, late normal faults. The extensive brecciation associated with these faults obliterates all previous rock fabrics and interpretation of fault movements is difficult. Within 500 to 800 metres of the Bear fault system, planar rock fabrics have been rotated from north-northeast strikes into a northerly alignment with the fault. This structural pattern, and the isotopic age data from alteration, suggest that the Bear fault is an old, repeatedly activated fault system in which the last deformational event has been brittle and extensional. The last major failure on this plane is recent, less than 2000 years ago. It resulted in a subsequent landslide slip of a large gabbroic intrusive mass in the immediate hangingwall of the ore zone in some parts of the mine. Apparent offsets across this plane are significant as stratigraphy and structure are not easily correlated across this fault.

The Golden Bear deposit is under active mining development and is estimated to contain 625 390 tonnes diluted geological reserves grading 18.63 grams gold per tonne (L.E. Titely, personal communication, 1988). The orebody is metallurgically complex and contains submicron-sized gold particles within a sulphide and silicate matrix (Wober and Shannon, 1985). A significant proportion of the mineralization is contained in a gouge zone, 2 to 6 metres wide, within a fault splay of the main Bear fault. Mineralization gradually weakens away from this structure, in the quartz-dolomite breccias in the footwall, and in the pyritic tuffs on the hangingwall contact. Ore-grade mineralization may exceed 9 metres in width. Postmineralization diabasic dykes were emplaced within, subparallel and locally discordant, to the fault system. The mineralized zone is not characterized by well-defined vein structures or free quartz and there is little vein material present. Macroscopic indicators of alteration are assemblages of ankerite, fuchsite, pyrite and quartz in the hangingwall mafic fragmental rocks and pervasive dolomitization and brecciation of limestone protoliths in the footwall. Alteration diminishes rapidly away from fault structures and is typically weak within 25 metres of mineralization. Contact relationships and general structural features of one of the mineralized areas in the mine are illustrated in Figure 2-11-5.

FLEECE ZONE

The Fleece Bowl mineralized zone contains drill-indicated reserves of 415 000 tonnes of 8.15 grams gold per tonne (Wober and Shannon, 1985) and remains open down the plunge of the regional structure. Mineralization is localized at the intersection of a major fault, identified locally as the

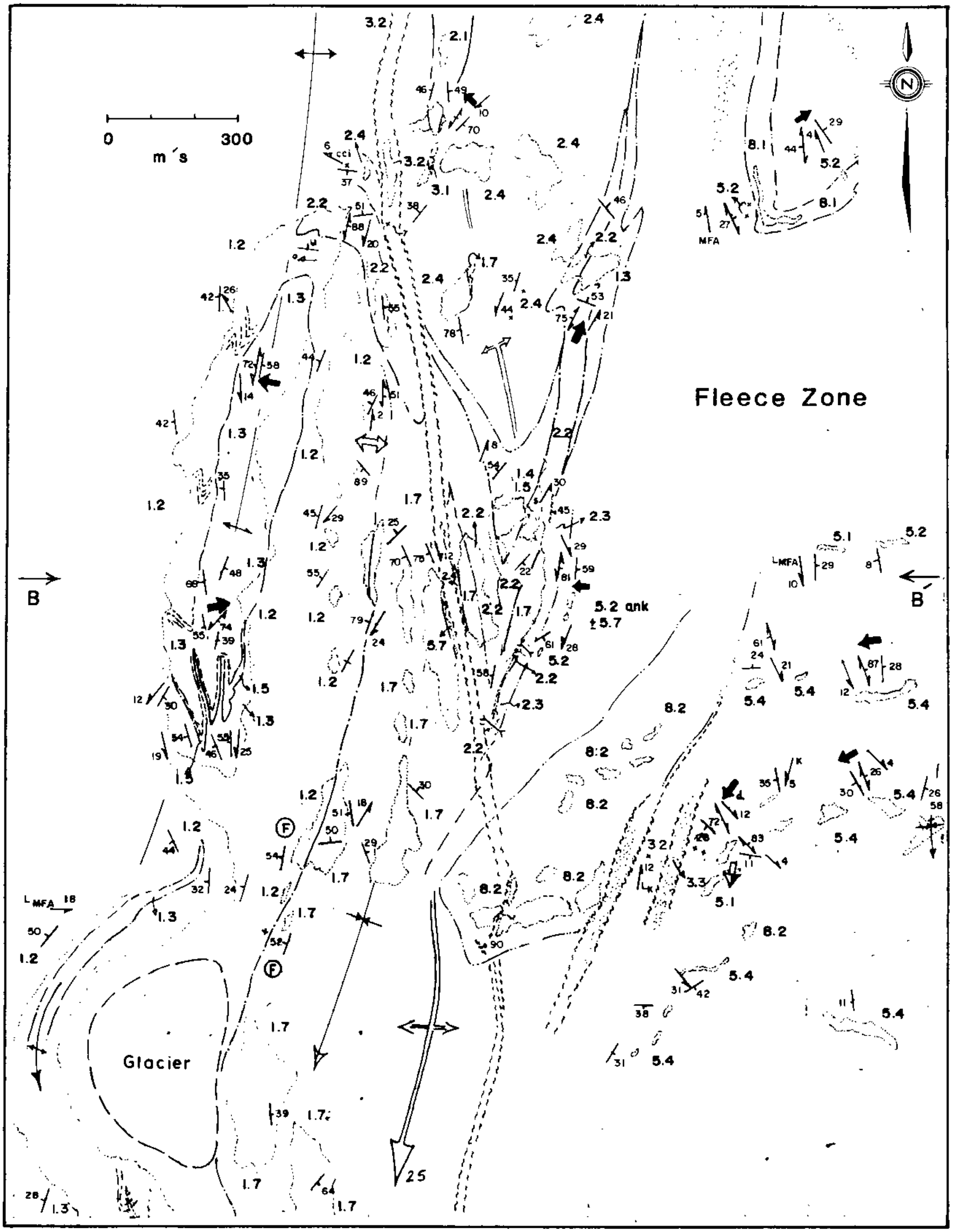

Figure 2-11-6. Surface geology, Fleece zone. Mineralization is confined to the faulted west limb of a south-plunging antiform, one of a series tight, upright chevron folds. Refer to Table 2-11-1 for identification of numbered lithologic units and to Figure 2-11-1 for the approximate location of this zone.

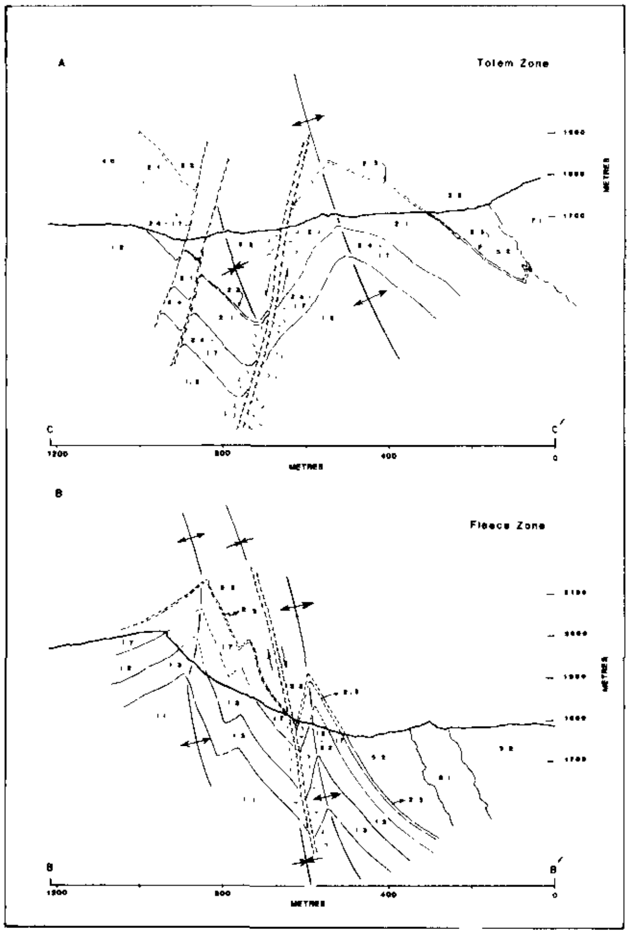

Figure 2-11-7. Geological cross-sections through the Totem zone (7a) and the Fleece zone (7b), looking north. The two sections are separated by 1500 metres of strike, with only limited divergence of hinge lines between these two points. Refer to Table 2-11-1 for identification of numbered lithologic units.

West Wall fault, with the contact of the black chert and argillaceous siltstone unit with the volcanic rocks (Figures 2-11-6 and 2-11-7b). The fault is part of the main Bear fault system and is localized on the western limb of an extremely tight anticline. A sequence of tight fold structures is clearly exposed in the cliffs overlooking the Fleece zone. These structurally repeat the carbonate stratigraphy in the footwall to mineralization. Hinge lines of these folds are traceable for up to 4 kilometres along strike, through all three mineralized zones. Individual hinge lines are well defined by changes in cleavage vergence, structural facing and abrupt changes in bedding attitude.

The Black fault (Wober and Shannon, 1985; Schroeter, 1986) appears most likely to follow the black chert horizon forming the eastern limb of the main antiform which is localized over the Fleece zone. Although this limb may be slightly faulted, unlike the western limb, it is only weakly mineralized. Plunge directions within the Fleece zone are south at 20 to 25 degrees. It is yet to be determined if mineralization also rakes in this direction. This zone differs slightly from the main Bear zone primarily in the weak development or absence of well-defined quartz-dolomite breccias (Figure 2-11-2). Mafic pyroclastic rocks in the stratigraphic footwall of the zone carry a similar alteration assemblage to that noted underground in the Bear zone, with widespread ankerite development, lesser fuchsite, moderate quartz-carbonate veinlets and weak pyritization (5 per cent).

TOTEM SILICA ZONE

The Totem silica zone occurs at the northern limit of mapping. The main feature of the area is an extensive zone of quartz-rich rocks with a strike length of 1800 metres and a maximum width of 300 metres. The zone was initially interpreted as a silica cap to an epithermal system; more recent observations suggest the quartz within this zone is a primary or a very early diagenetic chert: (1) the rock locally displays well-defined bedding features and may be weakly ribbon-banded; (2) it appears to follow a specific stratigraphic horizon; (3) it has been affected by early folds and has well-developed penetrative planar and linear fabrics, unlike the younger breccias of the Bear zone; and (4) structural facings and bedding dips change from west to east across the zone, suggesting an antiformal structure. The fold may be doubly plunging; at its southern limit the antiform plunges toward the Fleece zone, but in the northern part of the Totem zone some lineation measurements indicate steep northerly plunges.

Folds in the area of the Totem zone are slightly more open than those in the Fleece zone and their western limbs are truncated and offset by the main fault system. Surface data suggest the main mineralized structure has been rotated from a steep easterly dip in the area of the Bear deposit, to a steep westerly dip in the area of the Totem zone (Figures 2-11-7a and 2-11-8).

Anomalous gold values are often present along the intersection of the main fault system with the contact of chert and mafic volcanic rocks and are associated with angular, coarse-grained dolomite and chert breccias which are irregularly developed along it. This structural zone and its unique deformational style crosses the Sam Creek drainage and continues north towards Tatsamenie Lake.

DISCUSSION: IMPLICATIONS FOR EXPLORATION

Other gold deposits are likely to be found by exploration in areas within the northwestern Cordillera having a tectonic and stratigraphic framework similar to the Muddy Lake district. The field data summarized in this report suggest the following points should be considered in exploration:

(1) Fault systems, such as the Bear fault and related zones, are likely to be persistent deep-rooted structures. The apparent rotation of rock fabrics into parallelism with these faults suggests late brittle movement may have been localized in pre-existing deformational zones.

(2) Surface expression of the fault systems is often poorly defined. However, as they are located within broader deformational zones, often with anomalous strikes relative to the regional structural grain, they can be identified by careful surface mapping.

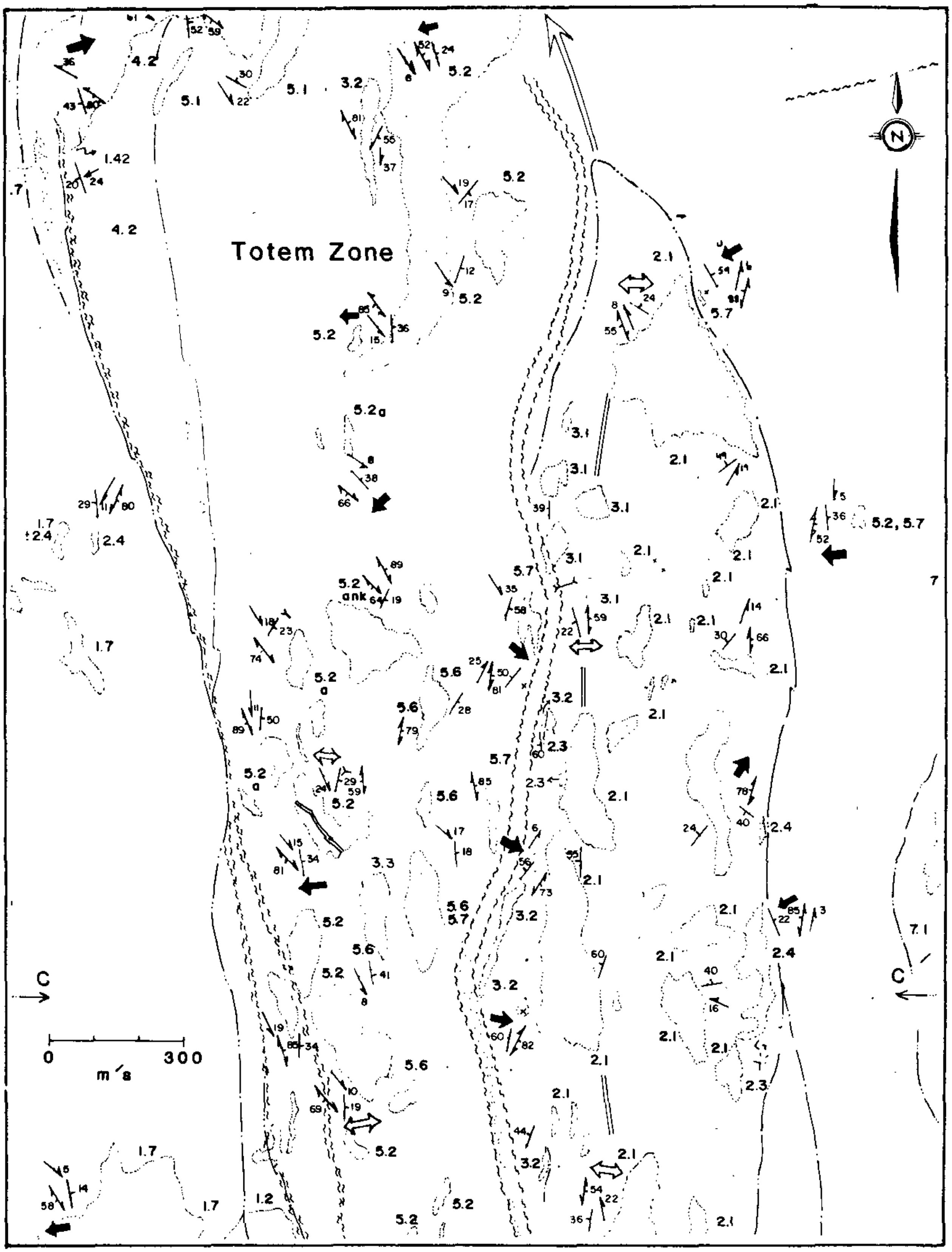

Figure 2-11-8. Surface geology, Totem zone. The zone contains anomalous gold values along the strike of the main fault system, near the volcanic-chert contact which localizes this structure. Numbered lithologic units are identified in Table 2-11-1 and the approximate location of the Totem zone is shown in Figure 2-11-1.

(3) The characteristic alteration assemblages, ankeritic carbonates, silica, fuchsite and lesser sulphides, are common to many gold-producing systems and are a prominent feature of these deposits. Ankeritization, with weak silicification of mafic volcanics along their conformable contacts with limestone, is common throughout this area and is typically not auriferous. Recognition of the differing alteration styles and their structural settings is important.

(4) Gold mineralization within the study area is discordant to stratigraphy but clearly occurs preferentially along zones of contrasting competency, specifically chert-dolomite-volcanic contacts. These contacts may be extensively deformed and the style of deformation should be recognized in order to efficiently direct subsurface exploration.

(5) No strong relationship between high-level intrusions and gold mineralization has been noted in this area.

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