Geology and U-Pb zircon geochronology of upper Dorsey assemblage near the TBMB claims, upper Swift River area, southern Yukon

Charlie Roots[1]
Geological Survey of Canada

Tim Liverton
Rhyoflow Ltd.[2]

Larry Heaman
Department of Earth and Atmospheric Sciences, University of Alberta[3]

Roots. C., Liverton, T. and Heaman, L., 2003. Geology and U-Pb zircon geochronology of upper Dorsey assemblage near the TBMB claims, upper Swift River area, southern Yukon. *In:* Yukon Exploration and Geology 2002, D.S. Emond and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 199-212.

ABSTRACT

Meta-sandstone, siltstone and phyllite, with marble and intermediate-to-felsic tuffaceous horizons, host the Munson (TBMB) and Mod zinc-lead occurrences, about 7 km southwest of the Dan and Crescent properties. These host rocks are part of the Late Devonian Dorsey assemblage. Complexities resulting from isoclinal folding and faulting inhibit direct correlation of strata from one ridge exposure to another. The strata are overlain by dark meta-siltstone of the mid-Mississippian Swift River succession. Although faulted, the lack of a strong lithologic contrast between the units suggests only minor dislocation.

Pre-Jurassic and Cretaceous granites and a diorite sill intrude the Dorsey rocks. Chloritic tuffaceous layers host showings of pyrrhotite, chalcopyrite and sphalerite; carbonate pods contain sphalerite + galena ± pyrrhotite; and quartz-feldspar meta-tuff layers are pyritic.

U-Pb zircon age results for leucosome from a nearby exposure of lower Dorsey rocks indicate an approximate crystallization age of 373 Ma, and about 358 Ma for a granitic dyke in the upper Dorsey assemblage, bracketing the age of deposition of this Yukon-Tanana Terrane assemblage.

RÉSUMÉ

Le grès, le siltstone et le phyllade métamorphisés, avec marbre et horizons tufacés intermédiaires à felsiques, contiennent les indices (Zn-Pb) de Munson (TBMB) et de Mod à environ 7 km au sud-ouest des indices de Dan et de Crescent. Ces roches encaissantes font parties de la série de Dorsey du Dévonien tardif. La complexité due à un plissement isoclinal et à une fracturation empêche d'établir une corrélation directe d'une crête exposée à l'autre. Ces strates sont recouvertent par le siltstone métamorphisé foncé de la succession de Swift River du Mississippien moyen. Même si ce contact semble être une faille, l'absence d'un contraste nettement lithologique entre les unités font supposer une dislocation mineure.

Des granites et un filon-couche de diorite préjurassiques et crétacés injectent les roches de Dorsey. Les couches tufacées chloritiques logent des indices de pyrrhotite, de chalcopyrite et de sphalérite; les masses carbonatés contiennent sphalérite + galène ± pyrrhotite; et les couches de tuf métamorphisé à quartz-feldspath sont pyriteuses.

Les résultats de datations U-Pb sur le zircon d'un mobilisat migmatitique provenant de la partie inférieure de la série de Dorsey indique un âge de cristallisation approximatif de 373 Ma, et d'environ 358 Ma pour un filon granitique dans la partie supérieure de la série de Dorsey. Ces âges délimitent la période de déposition de cette série du terrane de Yukon-Tanana.

[1]*croots@gov.yk.ca*

[2]*Box 393, Watson Lake, Yukon, Canada Y0B 1C0*

[3]*Edmonton, Alberta, Canada T6G 2E3*

INTRODUCTION

Yukon-Tanana Terrane is a composite of continentally derived strata overlain by volcanic arc successions and intruded by granitic rocks of characteristic Mississippian age. Most areas are polydeformed, and only recently have several Late Paleozoic stratigraphic successions been differentiated as a result of new mapping and isotopic dates. Better understanding of these rocks (e.g., Nelson et al., 2000) and new maps of their distribution can focus exploration for stratabound mineral deposits to favourable stratigraphy (including correlative units separated by faulting and at different metamorphic grade).

The southern prong of the Yukon-Tanana Terrane extends south of the Yukon-BC border near the hamlet of Swift River. There it broadly comprises three tectono-stratigraphic units. These are Neoproterozoic (?) to Paleozoic pericratonic terranes (namely Big Salmon Complex and Ram Creek assemblage); late Paleozoic arc and basin successions (Klinkit and Swift River groups); and sheared, highly metamorphosed Mississippian to Permian? units (Dorsey assemblage; see Fig. 1). In the Dorsey assemblage (Stevens and Harms, 1996; Roots et al., 2000) are several occurrences of felsic schist (e.g., Nelson, 1997, 2000), the age of which (Roots and Heaman, 2001) is similar to felsic rocks that host significant volcanogenic massive sulphide occurrences in Yukon-Tanana Terrane near Finlayson Lake (e.g., Murphy, 1998).

This paper describes the stratigraphic setting of the felsic tuffaceous rocks of Dorsey assemblage where they are best exposed near stratiform Zn-Pb occurrences that include Crescent (Atom) and Dan (Yukon MINFILE 2001, 105B 026 and 027; Bremner and Liverton, 1991a,b; D'el-Rey Silva, et al., 2001a). Although these and nearby showings are clearly skarn-related, the felsic rocks are more abundant than previously recognized, and abundant pyrite is associated with them. Furthermore, previous cursory examination of these rocks has led to the suggestion that they may be a structurally emplaced slice of a younger unit, such as Klinkit Group (Roots et al., 2000) or Ram Creek assemblage (D'el-Rey Silva et al., 2001b). The work described here refutes these earlier notions.

The regional mapping project for which this study is a part included geochronology research in order to place constraints on the probable oldest and youngest age of sedimentation. The appendix describes further attempts to isotopically date the Dorsey assemblage.

REGIONAL TECTONIC FRAMEWORK

Rocks of the Yukon-Tanana Terrane were deformed in pre-Mississippian and mid-Permian time (Mortensen, 1992; Murphy and Piercey, 1999), then pushed north- and eastward over the miogeoclinal sedimentary apron of ancestral North America (e.g., Snyder et al., 2002), beginning in Middle Jurassic time. The Yukon-Tanana Terrane is therefore a relatively thin carapace of strongly deformed, dismembered and admixed stratigraphic sequences or assemblages (see Colpron and the Yukon-Tanana Working Group, 2001 for assemblage summary), and their continuity is further offset by major transcurrent faults, such as Tintina (Fig. 1).

In southern Yukon, Yukon-Tanana Terrane includes the Dorsey assemblage and overlapping Swift River group. Near the head of Swift River in southern Yukon and also near the head of the Cottonwood River in northern British Columbia, the Dorsey assemblage can be divided into a lower part that contains abundant sill-like bodies of metabasite, and an upper part, which does not. The lower part consists of amphibolite and garnet amphibolite interlayered (interbedded?) with metatuffs, fine-grained quartzite, biotite-muscovite + graphite schist, quartzofeldspathic schist (metamorphosed chert, argillite and orthoquartzite, respectively), and marble. The upper part consists of thinly layered impure quartzite with biotite-muscovite partings (meta-argillite); thin bedded limestone and calc-silicate rock; dark grey meta-chert; and interlayered chlorite + muscovite + garnet schist and quartz-muscovite schist that represent intermediate to felsic tuff protoliths (J. Nelson, pers. comm., 2001). A quartz-eye metarhyolite from the upper Dorsey assemblage near Munson Lake yielded a U-Pb age of 355 ± 2.7 Ma (Late Devonian; Roots and Heaman, 2001).

The Swift River group exhibits two depositional themes: hemipelagic, deep-water sedimentation resulting in thick successions of dark-coloured chert and argillite; and sporadic siliciclastic influx, represented by quartzite/phyllite sequences near its base, and local units of quartz wacke, grit, argillite and phyllite, particularly near its top (J. Nelson, pers. comm., 2001). This succession is unconformably overlain by the Screw Creek Limestone of late Mississippian to early Pennsylvanian age.

In the Swift River area these units are also thermally metamorphosed by diorite of probable Jurassic age and the Cretaceous Seagull Batholith.

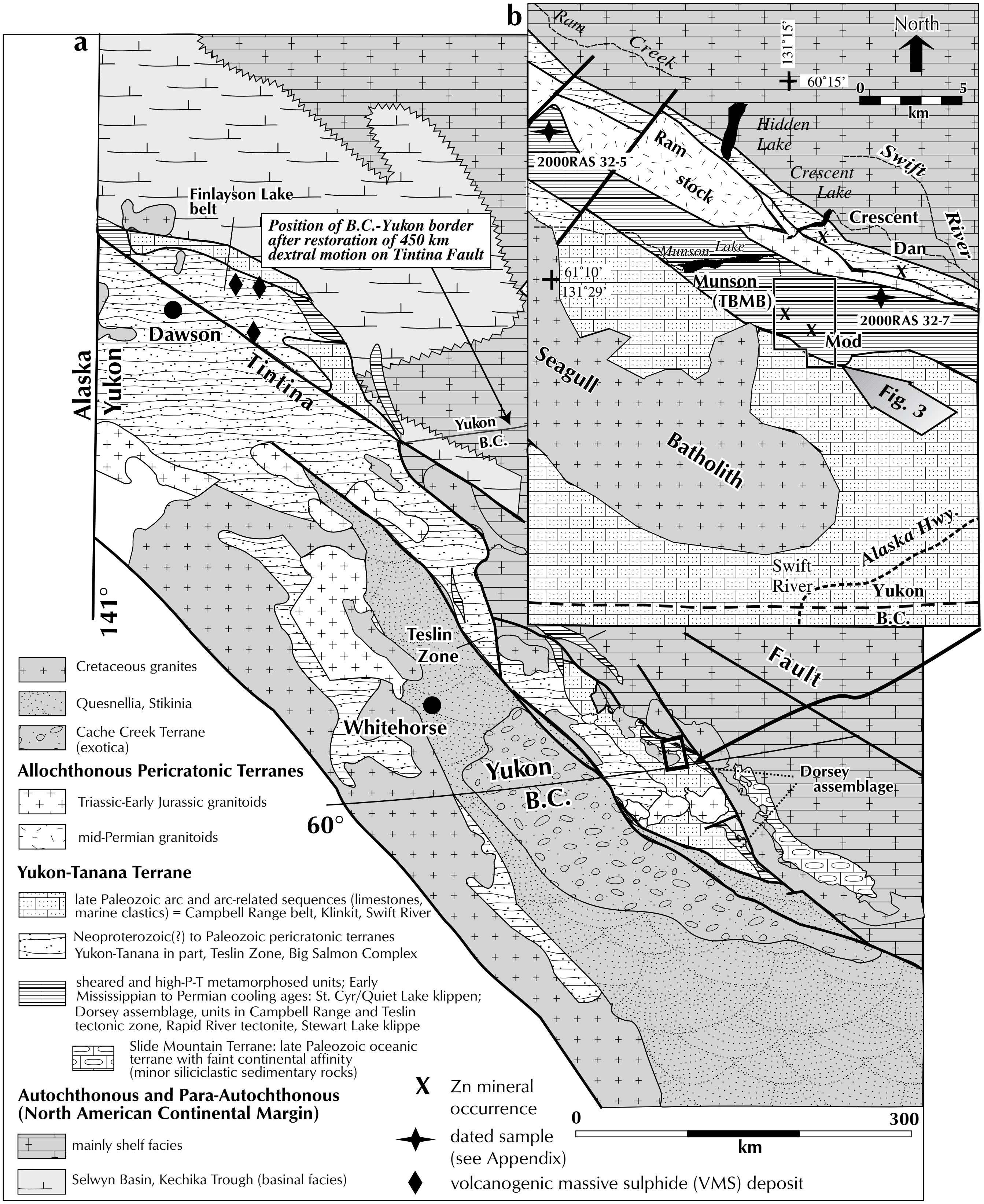

***Figure 1. (a)** Tectonic elements in Yukon-Tanana Terrane of southern Yukon and northern British Columbia (modified from Nelson et al., 2000). **(b)** Distribution of main geological units, and location of the principal Zn occurrences, isotopically dated igneous samples (see Appendix), and the study area (Fig. 3).*

GEOLOGY OF THE TBMB AREA

ACCESS AND PREVIOUS WORK

The current study area lies 15 km north of the hamlet of Swift River, Yukon. It is accessed by 4-wheel drive vehicle on an upgraded bulldozer track that extends 7 km south and west from a former exploration camp (for the Dan-Crescent mineralization) at the end of a 37-km-long gravel road leaving the Alaska Highway at km 1162. It is an area of steep-sided mountain ridges (Fig. 2) separated by alpine valleys.

Showings of magnetite and pyrrhotite with sphalerite and galena were discovered in 1946 by prospectors working for Hudson Bay Mining and Smelting Company, Limited. Now known as Bom, Munson (TBMB) and Mod occurrences (Yukon MINFILE 2001, 105B 028, 029 and 031), they were drilled in 1947 and 1969, and have been periodically restaked and trenched since.

Poole et al. (1960) included this area in a broad map unit (Dorsey Group) during reconnaissance mapping; the rocks were later subdivided by Abbott (1981), and named the Dorsey and Swift River assemblages based on assumed provenance and differing metamorphic grade by Stevens and Harms (1996, 2000). The current study extends the structural study of the TBMB occurrence by D'el-Rey Silva et al. (2001b) to adjacent ridges and provides a more regional perspective.

PRESENT WORK

Ridges surrounding the TBMB occurrence provide excellent exposure of layered rocks (hereafter referred to as the 'TBMB succession') and their contact with overlying Swift River strata.

Foot-traverses by Liverton and Roots covered all ridges and most prominent outcrops in the area (Fig. 3; features mentioned in the text are located by UTM coordinates, based upon NAD 83, Zone 9 grid system). The first two authors also measured two transects of continuous across-strike exposure on adjacent ridge crests (referred to as 'TBMB' and 'East' ridges), using a 60-m tape to survey the lithologic variety of the layered rocks. As a result of deformation strata thickness is not primary,

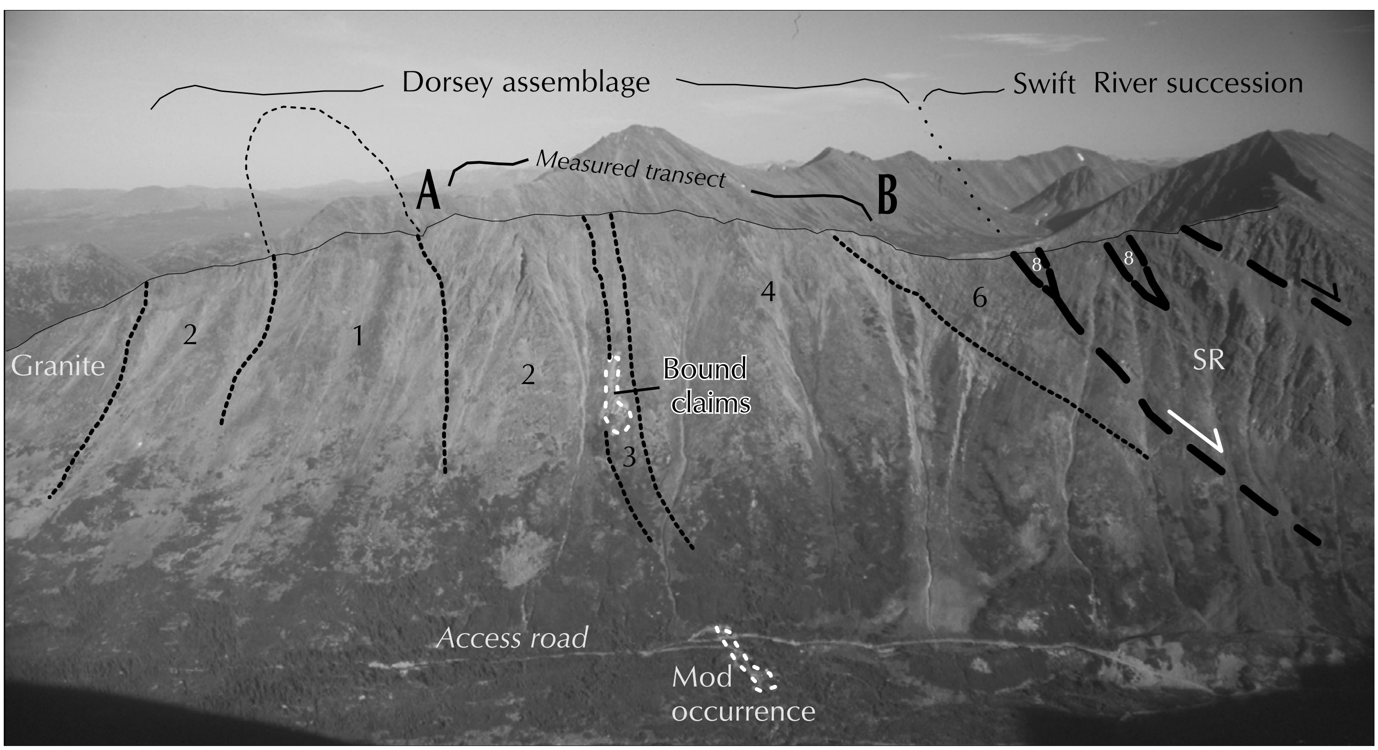

Figure 2. *Looking southeast at the profile of East ridge (field of view: 2 km) indicating units described in text and in the legend of Figure 3.*

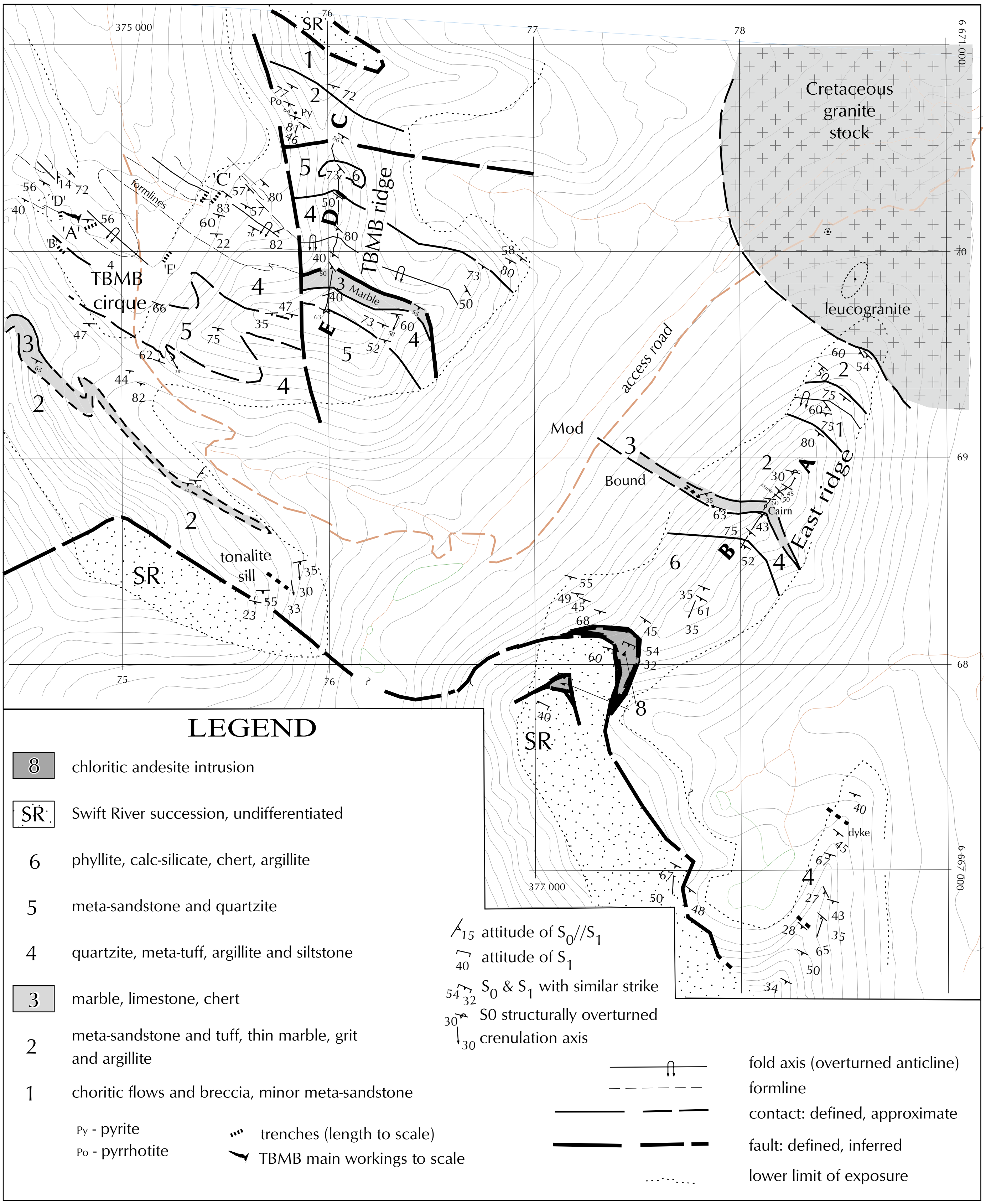

Figure 3. *Sketch geological map of the study area surrounding the TBMB mineral occurrence.*

geological contacts are transposed parallel to tectonic foliation, and this foliation obliterates primary depositional textures. Six numbered lithological units are described here.

Unit 1: Mafic flows and breccias.

The structurally lowest unit (north end of the generally south-dipping succession) consists of dark green to grey, massive or thickly layered, amphibole-chlorite ± quartz-biotite schist, interlayered with brown meta-sandstone. The only primary volcanic structures are calcite clots in one layer, which may originally have been amygdules. Most layers contain hornblende crystals retrograded to chlorite. At the north end of East ridge, decimetre-scale brown psammite and gritty layers with chloritic matrix interspersed with mafic layers indicate that the latter were probably extrusive flows and breccias.

Unit 2: Mixed meta-volcanic and sedimentary rocks

Metre-scale layering is plainly observed from a distance in this light brown to greenish weathering unit but these contacts are difficult to discern in outcrop. The lower part (unit 2a) is dominated by meta-sandstone, meta-siltstone and thin black argillite layers, with at least two horizons of quartz-feldspar schist. The upper part (unit 2b) includes grey and brown meta-sandstone with laminated chlorite schist (probably mafic meta-tuff), thin layers of grey quartzite and beds of limestone up to 2 m thick.

Thin sections of the schist reveal isolated euhedral quartz and feldspar phenocrysts, some exhibiting embayments. The authors therefore conclude that the schist was a felsic meta-tuff.

Unit 3: Carbonate and bedded meta-chert

Marble, limestone and minor dolostone form a prominent white band 30-50 m wide, extending eastward from TBMB ridge. Its base is not exposed (the argillite is sheared immediately below, suggesting a fault) and most of the band is coarse-grained white marble. The upper third of the unit is thin- to medium-bedded limestone in which vague columnar structures are locally discerned.

This marble contains no evidence of multiple tight folds, and the previous interpretation by D'el-Rey Silva et al. (2001b) of its thickness resulting from folding of a thin limestone bed mapped in the TBMB cirque to the west, is rejected.

The limestone band described above ends abruptly west of TBMB ridge (Fig. 4). Another band of white carbonate is exposed on the ridge 1 km to the southwest. These two outcrops are interpreted as the same unit, separated by a north-northwest trending, steeply east-dipping fault. The

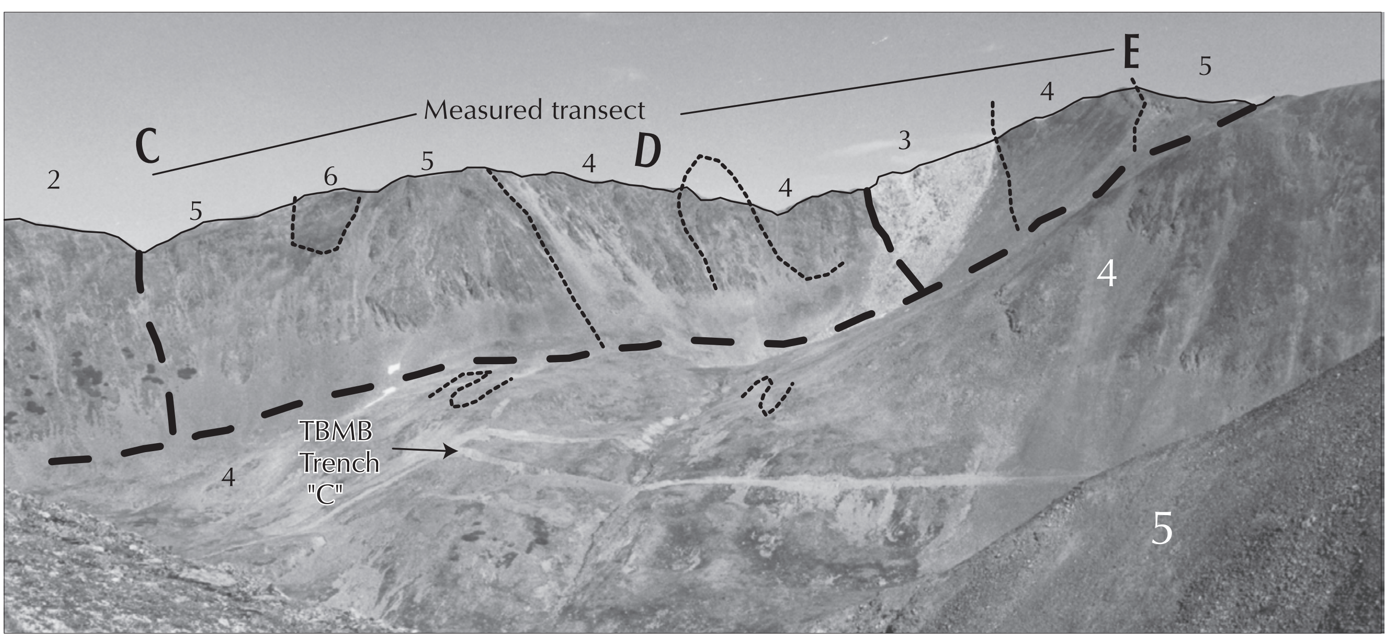

Figure 4. *Looking eastward at profile of mid-section of TBMB ridge, indicating units and structures described in the text and in the legend of Figure 3. The measured transect is 760 m long.*

existence of this fault is indicated by a shallow ditch on the spur south of TBMB ridge (UTM 375890E, 6669885N), which is an abrupt lithologic break between greenish psammite (unit 4) and grey phyllite/quartzite (unit 5).

The prominent white carbonate band is not present on the crest of East ridge, but is exposed midway down the western slope (the 'Bound' showing, Figs. 2, 3). Following the tectonic layering to the ridge crest suggests the white limestone undergoes a transition to light brown-weathering, medium-bedded chert, which comprises a 30-m section of the ridge crest, including the cairn on the highest point. This could be a lateral facies transition, or the chert may have replaced part of the carbonate through diagenesis, regional or contact metamorphism — exposure is insufficient to determine.

Unit 4: Quartzite, felsic meta-tuff and fine-grained metasedimentary rocks

Grey-white quartzite, metre-thick beds of coarse quartz-feldspar augen schist, thin beds of green and purple meta-chert, dark grey argillite and meta-siltstone comprise an upper mixed unit in the TBMB succession. On East ridge the quartzite has maroon (hematitic) stains parallel to foliation. At the south end of TBMB ridge quartzite and carbonaceous metasiltstone enclose a quartz-feldspar schist layer at least 10 m thick, as well as a 2-m thick grey marble and thinner calc-silicate layers.

Unit 5: Meta-sandstone and quartzite

This unit, dominated by brown siliclastic layers without argillite, tuff or carbonate interbeds, underlies the southwest spur of the TBMB ridge, and is also identified at the north end of the same transect. Some metre-thick layers of white-weathering medium-bedded meta-chert are present, and in the west where deformation is slightly less pervasive, intraclasts near the top allow determination of upright bedding. In other places ptygmatic folding and quartz boudinage indicate the futility of applying such observations to large areas.

Unit 6: Calc-silicate rock and phyllite

The uppermost unit of the TBMB succession is defined from its exposure on East ridge, directly beneath the dark cliffs of Swift River strata. The long saddle contains only sparse outcrops of grey phyllite, with lesser green-yellow calc-silicate rock and dark argillite. North of the transect on TBMB ridge, a knob of pyritic black argillite is correlated with this unit. This unit is present beyond this area: it was described below the Swift River strata, 7 km east of the TBMB (see Roots et al., 2000).

Swift River Group

Dark-weathering siltstone and argillite borders the study area on the south (Fig. 3) and these rocks extend southward around the Seagull Batholith. These strata are less deformed and metamorphosed than the underlying TBMB succession and are regionally described by Nelson (2001). Although this extensive unit has not been directly dated, it predates late Mississippian-early Pennsylvanian limestone, and appears to be younger than mid-Mississippian, since it lacks the ca. ~340 Ma intrusions ubiquitous in Yukon-Tanana Terrane.

At the south end of the East ridge the lowest Swift River rocks are dark grey siliceous and phyllitic argillite. Centimetre-thick sandy intervals exhibit size grading and cross-stratification, indicating upright beds. Higher in the succession are layers of fine-grained brown quartzite several metres thick. On the ridge southwest of TBMB cirque, the lowest rock of Swift River Group is jet-black argillite with sandy intervals.

Unit 8

On East ridge, at the base of the Swift River Group, and also as a fault-bounded outcrop about 50 m stratigraphically above the base, is a black, dense, slightly magnetic, fine-grained andesite with slickensides. No features were found to indicate whether this rock was intrusive or a flow. The sheared zones are probably related to the competency contrast between the Dorsey and Swift River rocks during Jurassic deformation. The unfoliated nature of the andesite suggests its Jurassic or Cretaceous age.

Intrusive rocks

A sub-circular granitic stock underlies the northeast corner of the study area (Fig. 3), but other intrusions are too small to show on the map.

Pink to grey, medium-grained, unfoliated granite is exposed at the north end of East ridge and in a stream canyon below the access road. Although undated, its mineralogy and geochemistry (Liverton, 1992) indicate it is a satellite plug of the Seagull Batholith (mid-Cretaceous; nearest exposure is 5.5 km south). Granitic dykes within Swift River rocks on East ridge (e.g., at UTM 375572E, 6685593N) are likely apophyses of this intrusion.

A foliated tonalite sill near the southwest edge of the study area (at UTM 75858E, 6668510N) and a larger plug north of the area on TBMB ridge (close to the Verley (STQ) showing; Yukon MINFILE 2001, 105B 078) have similar texture and mineralogy to the meta-plutonic rock that yielded a Late Devonian (358 Ma) U-Pb zircon date (see Appendix).

Dark green, fine-grained andesite dykes less than a metre wide crosscut the TBMB succession on both East and TBMB ridges. Their age is unknown but in composition they resemble the andesite within the Swift River strata (unit 8).

STRUCTURE

The TBMB succession exhibits a strong planar tectonic fabric. Rootless near-isoclinal fold hinges are common in thinly banded rocks. Regional metamorphism is upper-chlorite to lower-amphibolite grade with garnet and secondary hornblende developed in rocks of appropriate composition. The S_1 layering dips moderately to steeply southwest, and lineations measured on prismatic secondary minerals and minor fold axes plunge south.

Isoclinal, metre-wavelength F_1 folds are refolded by more open, mountain-scale F_2 folds that are overturned to the northeast (D'el-Rey Silva et al., 2001b). Several outcrops (e.g., around UTM 375600E, 6670200N) exhibit mesoscopic chevron folds with inter-limb angles of ~25-30° (Fig. 5), which is considerably less than the 'lock-up' angle for brittle deformation. Such folding suggests the presence of high-strain zones within the F_2 structures, likely within the axes of these folds. F_2 axial traces plunge south and major antiforms were deduced from repetition of tectono-stratigraphic units.

D'el-Rey Silva et al. (2001b) measured minor structures in the TBMB cirque and extrapolated the derived antiforms eastward. The transect along the TBMB Ridge shows that the thick marble there is not the result of tight isoclinal folds of the thinner carbonate layers mapped around the TBMB cirque — it is a separate carbonate unit with contrasting lithological units above and below. Furthermore on East ridge the lack of repetitive stratigraphy suggests that the large antiform proposed in D'el-Rey Silva et al. (2001b) does not exist. Instead the authors of the current study infer the structural style to be cascading northerly verging folds with attenuated limbs similar to those described by D'el-Rey Silva et al. (2001b) in the TBMB cirque.

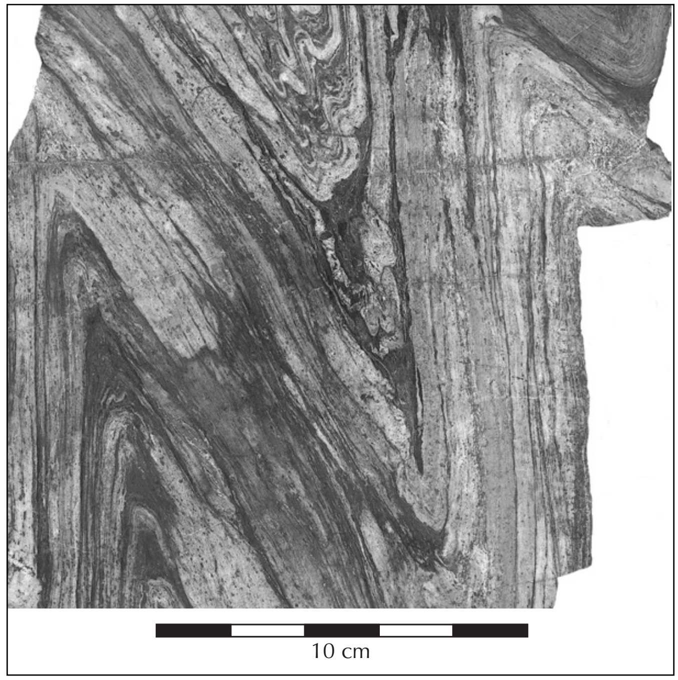

Figure 5. *Sawn slab of green-grey meta-siltstone collected from talus of unit 4, about 500 m southeast of the TBMB trench 'C'. Light-coloured minerals are quartz, feldspar and ?diopside; dark patches contain hornblende and magnetite.*

MINERALIZATION

Regionally the TBMB, Mod occurrences and Bound showing are aligned with the northwest-trending foliation, however each has distinctive mineralogy:

(i) At the Bound showing, sphalerite and euhedral magnetite replace portions of a marble lens;

(ii) At the Mod (Bom) occurrence, bands of massive pyrrhotite, sphalerite and galena up to 15 cm thick lie within chlorite and amphibole-rich layers of Unit 2;

(iii) The highest economic grade showing, of the TBMB is at trench 'A' where coarse-grained sphalerite and galena are abundant along the irregular contact of a massive white marble and siliceous metasedimentary rocks (unit 4). In places, chlorite and actinolite form veins and stringers within the marble.

(iv) Sphalerite occurs in mafic rocks in the antiform core exposed at trench 'C', and pyrrhotite and chalcopyrite are disseminated in mafic layers in trench 'E'.

(v) Disseminated pyrrhotite and sphalerite occur in chloritic metavolcanic rocks (unit 1) immediately north of the TBMB ridge transect.

DISCUSSION

1. CORRELATION AND PALEO-ENVIRONMENT OF UPPER DORSEY ASSEMBLAGE

The authors conclude that the TBMB succession is part of the Dorsey assemblage, despite its lower state of strain and greater lithological variety when compared to other Dorsey exposures. It is of higher metamorphic grade than Ram Creek assemblage to the north, and contains felsic metavolcanic rock, a lithology notably absent in the Klinkit Group. Furthermore, felsic tuff and foliated granitic intrusions along strike with the TBMB succession are older (ca. 357 Ma (upper Devonian); Roots and Heaman, 2001; sample 32-7 in appendix) than Ram Creek assemblage (mid-Mississippian: 349 ± 1.1 Ma felsic volcanic unit 1 km west of Hidden Lake, U-Pb zircon date by J.K. Mortensen, pers. comm., 2002; and a ca. 342 Ma intrusion, Roots and Heaman, 2001). All Klinkit Group ages are late Mississippian or younger.

The TBMB succession, however, has greater lithologic variety and preserved layering than most exposures of the Dorsey assemblage. Only one other locality, about 24 km southeast of the hamlet of Swift River, is known. That 200-m thick exposure is described by Nelson (2001, p. 62): "above the highest grits, a thin and highly variable upper Dorsey assemblage — garnetiferous and magnetite-bearing green biotite-sericite-chlorite schist, quartzite, amphibolite, black phyllite and quartz-sericite schist — passes into monotonous black chert and phyllite/argillite of the lower Swift River..." These metaclastic sedimentary rocks likely correlate with the TBMB succession.

The TBMB succession appears to represent distal products of bi-modal volcanism — pyroclastic flows or settling from the water column — interbedded with quartz sandstone, siltstone, mudstone and chert. The thin limestone and chert beds suggest a deep-water depositional environment. A possible tectonic setting for the TBMB succession would be the sedimentary apron at the base of a seamount or volcanic island. The variety of source material and alternation of sediment types suggest deposition as a deep-sea fan below a submarine canyon from a rapidly eroding source area. The lack of large clasts and presence of fine sediment suggest a position near the limit of the fan. Alternation of sediment types is well documented surrounding volcanic arc islands in Indonesia (e.g., Mitchell and Reading, 1971).

2. THE CONTACT BETWEEN THE DORSEY AND SWIFT RIVER ROCKS

This boundary between the Dorsey and Swift River rocks is visible on the west side of East ridge (Fig. 2), but is difficult to observe at close range among the low cliffs. It was not specifically studied, but the authors present several observations.

i) The Dorsey layering is generally more steeply dipping than the Swift River strata on East ridge. On the ridge crest the contact is a metre-thick band of strongly cleaved rock at the top of relatively incompetent unit 6, overlain by 10 m of andesite (unit 8; considered intrusive) overlain by argillite.

ii) On the ridge southwest of TBMB, gently south-dipping Swift River black argillite directly overlies steeply foliated calc-silicate and psammitic rocks, which the authors interpret as an overturned limb of unit 2.

iii) Toward its top the Dorsey assemblage becomes finer grained and increasingly carbonaceous, suggesting waning volcanism and erosion of the Dorsey arc. There is no great lithologic distinction between these and overlying Swift River strata, which was deposited in a basin without volcanic input. Regionally the authors have determined that these units are in correct stratigraphic sequence: a major thrust fault bringing older over younger is not present here.

Regionally the contact between these two units is a fault wherever it is exposed. South of the hamlet of Swift River, Nelson (2001) noted that the contact was sheared and the shear bands and minor faults dip more steeply than the overall foliation. A top-to-the southwest, normal shear sense was determined from thin section by Nelson (2001) and is locally found in outcrop (M. de Keijzer, pers. comm., 1999). Near the TBMB, the contact is sheared but no small-scale indicators reveal the primary sense of motion. Nevertheless, the planar nature of the shear — slicing across the tightly folded underlying TBMB succession — clearly indicates these units came in contact relatively late in the tectonic history. It is possible that Swift River strata were detached during regional uplift resulting from Jurassic or Cretaceous intrusions. The down-to-the-southwest slip (noted by Roots et al., 2000 and Nelson, 2001) is in the range of hundreds of metres, rather than kilometres, displacement.

3. ZN-PB-CU-AG METALLOGENY

The two 'trends' of zinc-dominated sulphide mineralization (Dan-Crescent, and Munson-Mod; Fig. 1) differ in metamorphic grade but not in style.

In the northern trend, trenches at the Dan occurrence exhibit discordant massive sphalerite and pyrrhotite with garnet and/or pyroxene and retrograde actinolite-chlorite adjacent to marble; and immediately south in the same area, pyrrhotite ± chalcopyrite occur in acid to intermediate tuffs. At the 'Lucy' prospect, 1050 m to the west-northwest along the regional trend, concordant pyrrhotite-chalcopyrite is present in finely banded actinolite-chlorite rock, adjacent to coarse euhedral magnetite. Finely laminated actinolite-chlorite with fine-grained red sphalerite is present ~50 m north (on the opposite side of the marble horizon intersected in drilling). Further west-northwest along the regional trend, the 'Gossan Hill' showing consists of massive sphalerite and discordant coarse magnetite; and the Atom occurrence consists of coarse massive sphalerite associated with ferroactinolite and hedenbergite. This northern trend, therefore, shows many features of contact metasomatic mineralization (Bremner and Liverton, 1991a,b).

The southern 'trend' of TBMB-Mod-Bound also shows mineralogy consistent with skarn origin. The Mod occurrence consists of pyrrhotite and sphalerite in mafic tuffaceous rocks; while the Bound and TBMB showings lie at the contact of carbonate with chlorite/amphibolite rock, similar to the Dan occurrence. Galena and pyrrhotite collected from three of these occurrences were analysed for lead isotopes and clearly demonstrate broadly mid-Triassic to mid-Jurassic model ages (Mortensen and Gabites, 2002). The 400-m-thick diorite and gabbro sill of inferred Jurassic age that lies between the Dan and TBMB occurrences is the most likely cause of the mineralization.

With the exception of disseminated pyrrhotite and sphalerite north of the TBMB ridge transect, no new indications of mineralization were discovered during this study.

CONCLUSIONS

i) The southern trend of Zn-Pb occurrences lie within rocks of Dorsey assemblage, in contrast to Ram Creek assemblage, which hosts the northern trend.

ii) Abundant felsic and mafic volcanic rocks are present in uppermost Dorsey assemblage.

iii) Dorsey assemblage is overlain by Swift River succession, but the fault is probably a relatively late feature (Jurassic or Cretaceous)

ACKNOWLEDGEMENTS

This report represents years of prospecting interest by the second author and an attempt by the first author to extract from the emerging regional picture some elements useful at the claim-group scale. Luiz D'el-Rey Silva greatly assisted in elucidation of structure and recognition of its polydeformed nature. The contribution of analytical work by Geospec consultants, arranged by Bob Thompson of the Geological Survey of Canada, has been essential to advancement of the regional geology.

Enthusiastic logistical support of Hardy Hibbing and Saïd Secerbegovic are gratefully appreciated. Comments by J. Nelson and a careful review by Lee Pigage clarified the paper.

REFERENCES

Abbott, J.G., 1981. Geology of the Seagull tin district. *In:* Yukon Geology and Exploration 1979-80, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 32-44.

Bremner, T. and Liverton, T. 1991a. Crescent. *In:* Yukon Exploration, Part C, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 25-26.

Bremner, T. and Liverton, T. 1991b. Dan. *In:* Yukon Exploration, Part C, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 27-30.

Colpron, M. and the Yuko-Tanana Working Group, 2001. Ancient Pacific Margin – An update on stratigraphic comparison of potential volcanogenic massive sulphide-hosting successions of Yukon-Tanana Terrane, northern British Columbia and Yukon. *In:* Yukon Exploration and Geology 2000. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada., p. 97-110.

D'el-Rey Silva, L.J.H., Liverton, T., Paradis, S and Roots, C.F., 2001a. A structural analysis of the upper Swift River area, southeast Yukon, (105B/3), Part I: Dan zinc occurrence and implications for sulphide mineralization. *In:* Yukon Exploration and Geology 2000, D.S. Emond and L. H. Weston (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 289-299.

D'el-Rey Silva, L.J.H., Liverton, T., Roots, C.F. and Paradis, S., 2001b. A structural analysis of the upper Swift River area, southeast Yukon, (105B/3), Part II: The TBMB claims and implications for the regional geology. *In:* Yukon Exploration and Geology 2000, D.S. Emond and L. H. Weston (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 301-310.

Liverton, T. 1992. Tectonics and metallogeny of the Thirtymile Range, Yukon Territory, Canada. Ph.D. thesis, Royal Holloway, University of London.

Mitchell, A.H.G. and Reading, H.G. 1971. Evolution of island arcs. Journal of Geology, vol. 79, p. 253-284.

Mortensen, J.K., 1992. Pre-mid-Mesozoic tectonic evolution of the Yukon-Tanana Terrane, Yukon and Alaska. Tectonics, vol. 11, p. 836-853.

Mortensen, J.K. and Gabites, J.E. 2002. Lead isotopic constraints in the metallogeny of southern Wolf Lake, southeastern Teslin and northern Jennings River map area, Yukon and British Columbia: Preliminary results. *In:* Yukon Exploration and Geology 2001. D.S. Emond, L.H. Weston and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 179-188.

Murphy, D.C., 1998. Stratigraphic framework for syngenetic mineral occurrences, Yukon-Tanana Terrane south of Finlayson Lake: a progress report. *In:* Yukon Exploration and Geology 1997, C.F. Roots (ed.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 51-58.

Murphy, D.C. and Piercey, S.J., 1999. Finlayson Project: Geological evolution of Yukon-Tanana Terrane and its relationship to the Campbell Range belt, northern Wolverine Lake map area, southeastern Yukon. *In:* Yukon Exploration and Geology 1998, D.S. Emond and C.F. Roots (eds.), Exploration and Geological Division, Yukon Region, Indian and Northern Affairs Canada, p. 47-62.

Nelson, J.L., 1997. Last seen heading south: extensions of the Yukon-Tanana Terrane into northern British Columbia. *In:* Geological Fieldwork 1996, British Columbia Ministry of Employment and Investment, Geological Survey Branch, Paper 1997-1, p. 145-156.

Nelson, J.L., 2000. Ancient Pacific Margins Part VI: Still heading south: Potential VMS hosts in the eastern Dorsey Terrane, Jennings River (104O/1; 7,8,9,10). *In:* Geological Fieldwork, 1999, British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Survey Branch, Paper 2000-1, p. 107-120.

Nelson, J.L. 2001. Geology of north-central Jennings River map area 104-O/14E and 15, British Columbia. *In:* Geological Fieldwork, 2000; British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Survey Branch, Paper 2001-1, p. 55-66.

Nelson, J.L., Mihalynuk, M.G., Murphy, D.C., Colpron, M., Roots, C.F., Mortensen, J.K. and Freidman, R.M., 2000. Ancient Pacific Margin: A preliminary comparison of potential VMS-hosting successions of the Yukon-Tanana Terrane, from Finlayson Lake district to northern British Columbia. *In:* Yukon Exploration and Geology 1999, D.S. Emond and L.H. Weston (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 79-86.

Poole, W.H., Roddick, J.A. and Green, L.H., 1960. Geology, Wolf Lake, Yukon Territory. Geological Survey of Canada, Map 10-1960, uncoloured, 1:253 440-scale map, with marginal notes.

Roots, C.F. and Heaman, L., 2001. Mississippian U-Pb dates from Dorsey Terrane assemblages in the upper Swift River area, southern Yukon Territory. *In:* Geological Survey of Canada, Current Research 2001-A1, 9 p.

Roots, C.F., de Keijzer, M. and Nelson, J.L., 2000. Wolf Lake project: Revision mapping of Dorsey Terrane assemblages in the upper Swift River area, southern Yukon and northern BC. *In:* Yukon Exploration and Geology 1999, D.S. Emond and L.H. Weston (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 115-125.

Ross, G.M. and Harms, T.A., 1998. Detrital zircon geochronology of sequence 'C' grits, Dorsey Terrane (Thirtymile Range, southern Yukon): provenance and stratigraphic correlation. *In:* Radiogenic and Isotopic Studies: Report 11, Geological Survey of Canada, Current Research 1998F, p. 107-115.

Ross, G.M. and Parrish, R.R., 1991. Detrital zircon geochronology of metasedimentary rocks from the southern Omineca Belt, Canadian Cordillera. Canadian Journal of Earth Sciences, vol. 28, p. 1254-1270.

Snyder, D.B., Clowes, R.M., Cook, F.A., Erdmer, P., Evenchick, C.A., van der Velden, A.J. and Hall, K.W., 2002. Proterozoic prism arrest suspect terranes: Insights into the Ancient Cordilleran Margin from seismic reflection data. GSA Today, Geological Society of America, vol. 12, no. 10, p. 4-9.

Stevens, R.A. 1996. Dorsey Assemblage: pre-mid-Permian high temperature and pressure metamorphic rocks in the Dorsey Range, southern Yukon Territory. *In:* Lithoprobe report No. 56. SNORCLE and Cordilleran Tectonics Workshop, p. 70-75.

Stevens, R.A. and Harms, T.A., 1996. Geology in the vicinity of the Dorsey Range, southern Yukon Territory and northern British Columbia, scale 1:50 000. *In:* Lithoprobe report No. 56. SNORCLE and Cordilleran Tectonics Workshop, p. 222-225.

Stevens, R.A. and Harms, T.A., 2000. Bedrock geology of the Dorsey Range, southern Yukon Territory and northern British Columbia. Geological Survey of Canada, Open File 3926, 1:100 000-scale map.

Yukon MINFILE 2001. Wolf Lake – 105B. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada.

APPENDIX
U-PB ZIRCON DATES FROM IGNEOUS ROCKS IN DORSEY ASSEMBLAGE

Determination of the age of the oldest and youngest rocks in polydeformed assemblage is a fundamental step in their tectonic reconstruction. The Dorsey assemblage is considered among the oldest elements of the Yukon-Tanana Terrane in southern Yukon. A felsic tuff from upper Dorsey assemblage is 355.6 ± 2.7 Ma in the Swift River area (Roots and Heaman, 2001); and a 355 Ma intrusion into lowest Dorsey assemblage in the Cottonwood River area (R. Friedman, pers. comm., 1999; in Nelson, 2000), further indicates the Late Devonian / Early Mississippian age of this unit. The samples reported here were attempts to discover if some Dorsey strata (e.g., the TBMB succession) are younger than this, and to find out whether significantly older rocks were present in lower Dorsey assemblage. Locations of the two samples (one east, the other west, of the TBMB area) are shown on Figure 1. Although the samples contained only poor quality zircon and did not yield tightly constrained dates, they confirm the age of Dorsey assemblage.

SAMPLE 2000RAS 32-5 - LEUCOSOME

High-pressure and -temperature mineral assemblages in the lower Dorsey assemblage were recognized by Stevens (1996) 23 km northwest (along regional trend) of the TBMB area. There the floor of a north-facing cirque, presumed to have been vacated by ice in the last century, spectacularly exposes quartz + biotite + feldspar + muscovite + horneblende ± garnet + actinolite schist and gneiss. Dispersed through these dark, migmatitic rocks are cream-coloured quartz-feldspar boudins, veins and rootless fold hinges. One of the largest of these anastomosing leucosome veinlets was sampled in hopes of finding isotopically dateable minerals.

Table 1. Description and location information for igneous samples in Table 2.

Zircon fraction	Description*	Location data
2000RAS 32-5: Leucosome of high-grade lower Dorsey Assemblage		
1	21 zircon crystals; equant, transparent with inclusions, non-magnetic	Yellow-white feldspathic melt segregation (1 m wide), west side of central gully at front of upper level of north-facing cirque at 5100′ elevation, 7 km northwest of outlet of Munson Lake; UTM: 366500E, 6679250N (NAD 27) in northwest 105 B/3 map area.
2	52 zircon crystals; slim prisms with 4-6:1 length:width, colourless, transparent, non-magnetic	
2000RAS 32-7: Meta-tonalite dyke in upper Dorsey Assemblage		
1	Single large prismatic zircon crystal; 2:1 length:width, colourless, nearly transparent; no chemistry	Foliated intrusion, 4 m x 100 m exposure on north slope of large hill at 5125′; 6.25 km southeast of outlet of Crescent Lake; UTM: 380900E, 6669091N (NAD 27) in east-central 105 B/3 map area.
2	11 poor zircon; prism fragments with 1:1 length:width, brown, transparent, magnetic, 1° tilt	
*Note: 1° is the angle of tilt of the Fanz isodynamic separator.		

This sample contained a moderate amount of tan to colourless, generally poor-quality zircon. The zircon population is complex with abundant crystals displaying visible core/overgrowth relationships. The majority of the zircon crystals are small resorbed tan prisms (<60 microns) with thin colourless tips, abundant fractures and associated turbidity (alteration?). A small proportion of colourless subhedral to euhedral prisms with no visible evidence of cores, fractures or alteration, were also recovered. The first two multi-grain fractions from this sample consisted of (#1) 21 equant colourless best quality grains and (#2) 52 narrow long colourless prismatic grains (Table 1). Crystals with visible cores were avoided during grain selection.

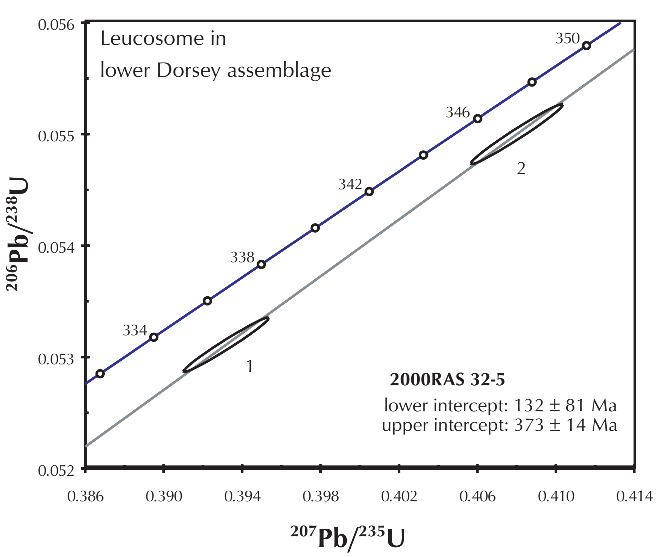

Figure 6. Concordia plot with 2-sigma error estimates for two zircon fractions of Dorsey leucosome.

The U-Pb results for these two multi-grain zircon fractions are listed in Table 2 and displayed in the concordia diagram (Fig. 6). Both fractions had similar chemistry with moderate uranium content (558-586 ppm) and slightly low Th/U (0.16-0.18). Although the analyses are slightly discordant, they have similar $^{207}Pb/^{206}Pb$ ages of 358.1 and 362.6 Ma, hinting at a Devonian crystallization age. A reference line constructed to pass through these two analyses yields an upper intercept age of 373 ± 14 Ma, which is interpreted as an approximate estimate for the crystallization age of this gneiss.

Discussion

The leucosome is presumed to be siliceous partial melt released during peak metamorphism (estimated 609-732°C and 7.7 to 14.1 kbar from mineral assemblages in nearby siliceous rock; Stevens, 1996) from the intermediate-to-mafic refractory parent. The 373 Ma date confirms conviction that the migmatitic rocks are older than the upper Dorsey assemblage of metasedimentary origin.

SAMPLE 2000RAS 32-7 – META-TONALITE DYKE

This strongly foliated plutonic rock intrudes psammite and garnet-bearing schist correlated with the TBMB succession in upper Dorsey assemblage. It outcrops over a 4-m-wide and about 100-m-long area on a north-facing slope,

Table 2. *Uranium-lead analytical data for igneous samples in Dorsey assemblage.*

Zircon fraction	Weight (μg)	U (ppm)	Th (ppm)	Pb (ppm)	Th/U	TCPb (pg)	^{206}Pb/^{204}Pb	^{206}Pb/^{238}U	^{207}Pb/^{235}U	^{207}Pb/^{206}Pb	^{206}Pb/^{238}U	^{207}Pb/^{235}U	^{207}Pb/^{206}Pb	% Disc
2000RAS 32-5														
1	16	585.6	90.7	29.9	0.16	8	3859	0.05311 ± 10	0.3932 ± 9	0.05369 ± 5	333.6 ± 0.6	336.7 ± 0.6	358.1 ± 2.1	7.0
2	35	558.3	100.5	30.0	0.18	23	2969	0.05500 ± 11	0.4080 ± 10	0.05380 ± 5	345.2 ± 0.7	347.4 ± 0.7	362.6 ± 2.2	4.9
2000RAS 32-7														
1	4	110	52	27	0.48	10	624	0.21589 ± 44	2.6864 ± 83	0.09025 ± 20	1260.1 ± 2.3	1324.7 ± 2.3	1430.8 ± 4.1	13.1
2	10	1155	204	56	0.18	7	4878	0.04991 ± 10	0.3694 ± 8	0.05368 ± 5	314.0 ± 0.6	319.2 ± 0.6	357.5 ± 1.9	12.5

about 300 m south of the previously dated felsic tuff (sample 99RAS 31-1; Roots and Heaman, 2001). In two outcrops the compositional boundary between tonalite and schist obliquely crosscuts the strong tectonic layering, indicating the intrusive relationship.

The rock is medium grained, with about 25% clear quartz prominent among the white feldspar and oriented hornblende. Primary minerals are entirely recrystallized.

A moderate zircon yield was recovered from the crushed and separated sample. The majority of zircon crystals are light tan and generally of poor quality with numerous fractures and turbid zones. Most are small (<80 microns) and dominantly resorbed subhedral prisms. A large number of grains display visible core/overgrowth relationships with the more obvious examples having turbid brown cores. A smaller number of the zircon crystals are colourless, transparent subhedral to euhedral prisms (generally 3:1 length:width ratios), and a very small proportion of tiny slender needles were also recovered.

Two zircon fractions were selected from this sample (Table 1) and U-Pb results are presented in Table 2. Fraction #1 was a large resorbed single grain interpreted to be a xenocryst, and it has a Mesoproterozoic ^{207}Pb/^{206}Pb age of 1431 Ma. Fraction #2, consisting of 11 light brown prisms and fragments, had a much higher uranium content (1155 ppm), lower Th/U (0.18) and a much younger ^{207}Pb/^{206}Pb age of 358 Ma. Because one fraction is a xenocryst, portrayal on a concordia diagram is not meaningful. The light brown prisms selected for fraction #2 are interpreted to be primary igneous crystals and, taking into consideration the slight discordance (12.5%), the best estimate for the minimum emplacement age is 358 Ma.

Discussion

The best estimate for the age of the orthogneiss is very close to that of the more precisely dated felsic tuff nearby. If the actual date is younger by a few million years, it would suggest that the sedimentary succession underwent rapid burial and was cannibalized by rising granitic magma in the roots of the volcanic arc.

The xenocryst date of 1.4 Ga coincides with a minor fraction of detrital zircon ages from Dorsey grits — only one of the twenty grains analysed by Ross and Harms (1998) was similar. The Dorsey sedimentary rocks are considered continentally derived, based upon the preponderance of zircons whose ultimate source was the western Canadian Shield (1.7-2.0, and 2.5-3.3 Ga;) and those ca. 1.4 Ga were considered to reflect local source areas (Ross and Parrish, 1991). The supposition of a local source is reinforced by the presence of this xenocryst, presumably gleaned from underlying crystalline rock, in intrusions of the Dorsey assemblage.