A structural analysis of the upper Swift River area, southeast Yukon (105B/3), Part II: The TBMB claims and implications for the regional geology[1]

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ABSTRACT

The TBMB claim group, 4 km southwest of the Dan occurrence in the upper Swift River area of stratiform zinc occurrences, reveals the nature of the host rocks and style of folding. A train of east-southeast-trending, east-northeast-verging, km-scale F_1 overturned anticlines and synclines dominates the area. These folds clearly control the distribution of low metamorphic grade tectonites (in map and vertical cross-sections) and a structural model allows definition of general stratigraphy of the TBMB and BOUND claim areas. A lower, an intermediate, and an upper unit of siliciclastic metasedimentary rocks are separated by two intervening units of base-metal-sulphide-bearing strata (acid to intermediate metavolcanic rock and marble, respectively). Based upon the repetitive F_1 folds (possibly associated with thrust faults) and the similarity of rock types in the TBMB and Dan areas, the authors propose a structural linkage between them.

RÉSUMÉ

Une étude structurale effectuée dans la région de l'indice TBMB, à 4 km au sud-ouest de l'indice Dan, dans la région du cours supérieur de la rivière Swift où se trouvent des indices de zinc stratiformes, a permis d'apporter des éclaircissements quant à la nature du plissement et les roches encaissantes. Un cortège d'anticlinaux et de synclinaux F_2 déversés, d'importance kilométrique, orientés est-sud-est et de vergence est-nord-est prédomine dans la région. Ces plis contrôlent nettement la répartition des tectonites de faible degré de métamorphisme (voir carte et coupes verticales) et un modèle structural permet de définir la stratigraphie générale de la région des indices TBMB et BOUND. Les unités inférieure, intermédiaire et supérieure des roches métasé entaires silicoclastiques sont séparées par deux unités intercalaires de strates renfermant des sulfures de métaux communs (respectivement des roches métavolcaniques acides à intermédiaires et du marbre). La présence de plis F_2 répétitifs (vraisemblablement associés à des failles chevauchantes) et la similarité des types de roches présentes dans les régions de TBMB et de Dan semblent indiquer qu'il existe un lien structural entre celles-ci.

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INTRODUCTION

In the 1940s, prospectors for Hudson Bay Mining and Smelting Co. Ltd. found sphalerite and magnetite in the north-flowing tributaries of the western headwaters of the Swift River; since then at least eight showings have been discovered. Most have mineralogy characteristic of skarn deposits, but this may be a later overprint as a result of syn-tectonic and post-tectonic plutonism. Several aspects of the occurrences suggest possible volcanogenic or exhalative origin, including:

- mineralized horizons traced up to 19 km in strike length; and
- spatial correlation with tuffaceous and volcanic-epiclastic host-rocks.

All mineral showings are in ductile-deformed metamorphic rock. If they are stratiform, resolution of the stratigraphy is of utmost importance in exploration. However this stratigraphy can only be resolved with the aid of detailed structural analysis. Once the structural style is known, it may be possible to predict the location of buried or blind mineralization.

This paper presents the results of detailed geological mapping in the vicinity of the TBMB and BOUND claims (Munson occurrence; Yukon MINFILE 1997, 105B 029). The structures are then compared with those described in a companion study of the Dan occurrence (D'el-Rey Silva et al., Part I; this volume) and their relationship is discussed.

REGIONAL GEOLOGY

The mineralized occurrences lie within late Paleozoic strata of the Yukon-Tanana Terrane (Fig. 1). In this area, four

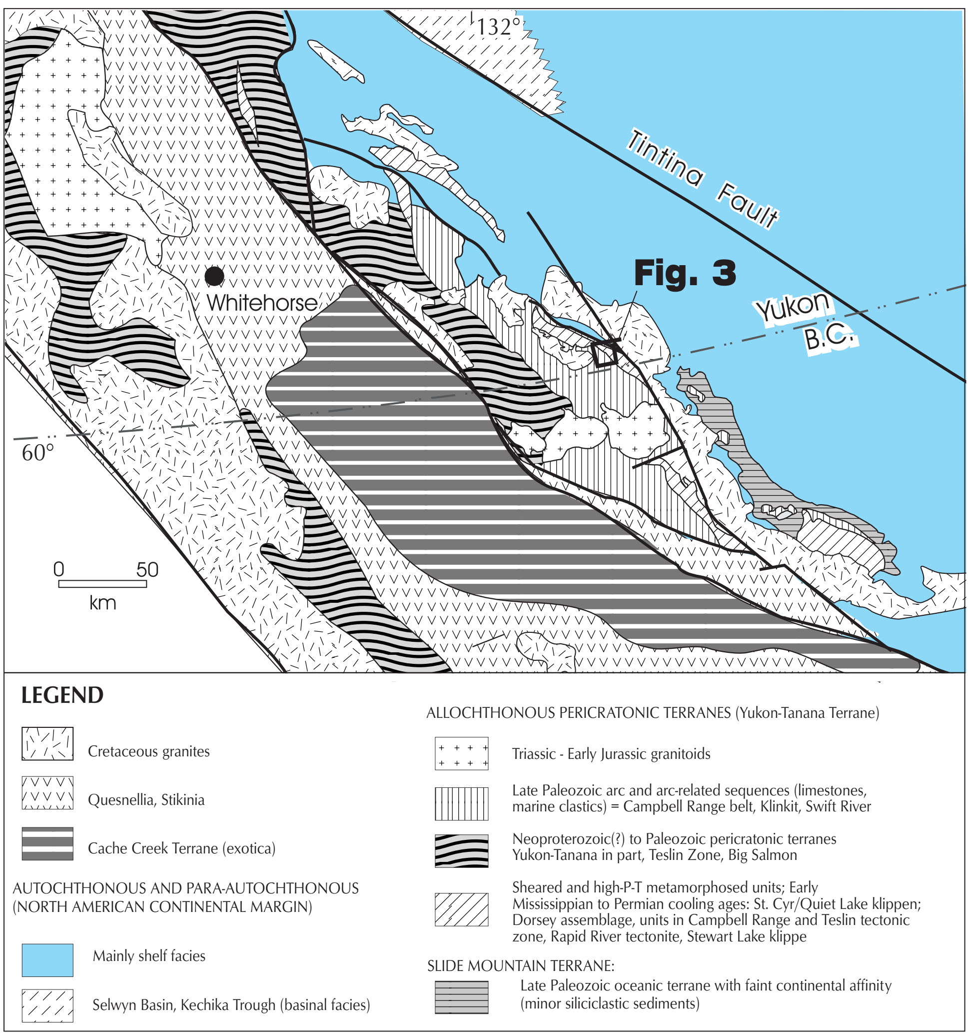


Figure 1. *Generalized terrane map for northern British Columbia and southern Yukon (enlarged from Nelson* et al.*, 2000). The Swift River district lies at the northeast edge of allochthonous pericratonic terranes, generally referred to as Yukon-Tanana Terrane.*

lithostratigraphic assemblages have been recognized (Stevens and Harms, 1996, 2000; Roots et al., 2000; Fig. 2): Swift River, Klinkit, Dorsey and Rum Creek assemblages. The northern group of showings (including Dan, Lucy, and Atom; see Fig 3) are located along the regional trend of the Ram Creek assemblage. Roots & Heaman (in press) determined that at least some of the interleaved metavolcanic and siliciclastic rocks of the Ram Creek assemblage are older than 340 Ma. In contrast, the southern group of showings (includes the BOUND and TBMB claims) are included in the Dorsey assemblage by Stevens and Harms (2000). The Dorsey assemblage contains a thin, persistent felsic meta-tuff horizon dated 365 Ma (Roots and Heaman, in press) and is regionally more deformed than the neighbouring Ram Creek (to the north) and Swift River (to the south) assemblages. A resistant diorite, believed of early Jurassic age, occupies the contact between the Dorsey and Ram Creek assemblages in this area. Therefore the structural relationship is equivocal here, although in northern British Columbia the Dorsey assemblage overrides the Ram Creek assemblage on a mid-Permian thrust (Nelson et al., 1998).

The Ram Creek assemblage near the Dan occurrence includes mafic to intermediate metavolcanic rocks and discontinuous quartzite, marble and calc-silicate rock. Dorsey assemblage consists of mafic gneiss structurally overlain by muscovite± biotite schist, quartzite and minor marble. About 10 km east of the TBMB these rocks yielded P-T estimates ranging from 609-732° C and at least 7.7 kbar (Stevens, 1996). In contrast the Ram Creek assemblage, although strongly foliated and sheared, contains some primary depositional features and exhibits retrograde lower greenschist facies metamorphism.

GEOLOGY OF THE TBMB CLAIM AREA

The north-facing alpine cirque of the TBMB (Fig. 4) is underlain by meta-siliciclastic rocks (layered sericite-quartz schist, quartzite, minor phyllite) with m- to dm-scale intercalation of laminated meta-sandstone, meta-siltstone and metavolcanic rock, calc-silicate schist and banded white to pinkish yellow marble. Plane-table mapping and structural interpretation were required in order to separate these rocks into stratigraphic units.

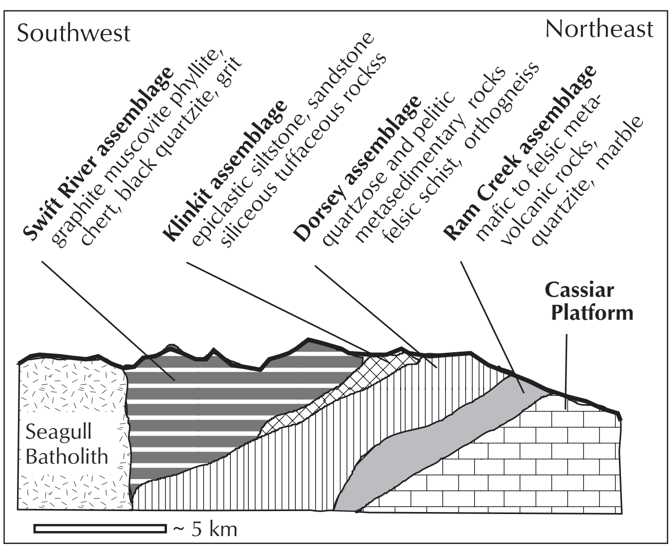


Figure 2. Schematic cross-section of lithotectonic units in the Swift River district, as described by Stevens and Harms (1996). The Dan occurrence lies within Ram Creek assemblage; the TBMB and BOUND claims lie to the southwest, in the area shown here as Dorsey and Klinkit assemblage.

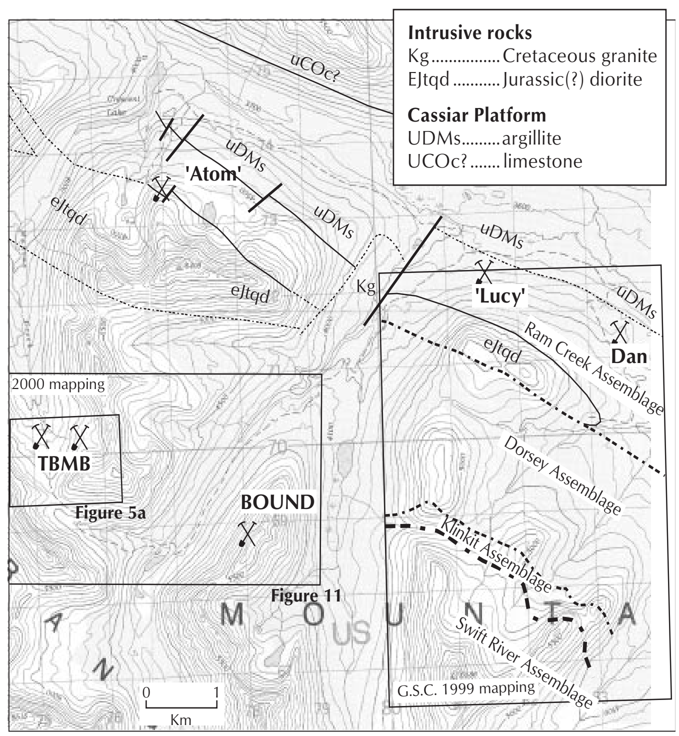


Figure 3. Topographic map (NTS 105B/3) of the upper Swift River area indicating the spatial relationship of showings mentioned in the text. Some contacts are shown from regional mapping by Stevens and Harms (2000); faults are heavy dashed lines.

Figure 4: *An east-facing view of the TBMB area, which is mostly underlain by micaceous siliciclastic rocks. The light-coloured marble exposed on the ridge crest at right is in the hinge of the Northern anticline. Trench C (see Figs. 5a and 11) is indicated by the arrow.*

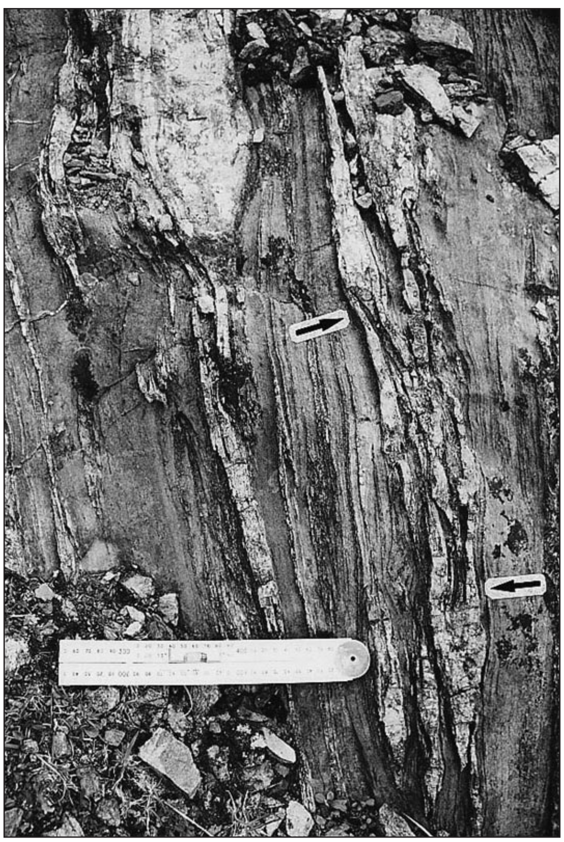


Figure 6. *Interleaved layers showing several F_1 folds (the arrows point to F_1 fold hinges) in light grey marble and light brown metapelites. Attitudes at this location are: B_1 = 060/141°, and $S_0//S_1$ = 214°/70°. Instrument at bottom left is 10 cm long.*

FIELD METHODS

Detailed geological mapping and structural analyses were carried out in an area about 1500 by 1000 m. Figure 5a is based upon 1:2000-scale mapping and shows the location of 59 rock exposures, numbered for reference. These include natural outcrops protruding from rubble as well as three mineral exploration trenches. Using surveying tape and compass, some exposures were mapped in detail (1:100- and 1:200-scale). In addition, a ridge spur about 3 km east of the TBMB (includes the 'BOUND' claim; see Fig. 3) was also investigated.

SUMMARY OF STRUCTURES

All the rocks in the area are polydeformed. The deformation events (D_1-D_3) are similar in scale and style to those of the Dan area (D'el-Rey Silva et al., Part I; this volume). In summary, D_1 developed a pervasive, layer-parallel foliation (S_1) that is axial planar to generally isoclinal F_1 folds from cm- to m-scale (Fig. 6). These structures were affected by a D_2 event, which developed F_2 folds and the axial plane foliation S_2, although S_0/S_1 and S_2 remain sub-parallel in most parts of the area. In several localities the superposition of F_2 on F_1 folds was observed. In detail, it is manifest by a co-axial interference pattern at cm- to dm-scale. Both S_1 and S_2 are defined by sericite, biotite and some chlorite, as well as flattened quartz and carbonate grains. As a consequence, the D_1-D_2 deformation developed a set of greenschist-facies tectonites characterized by an east-southeast-trending

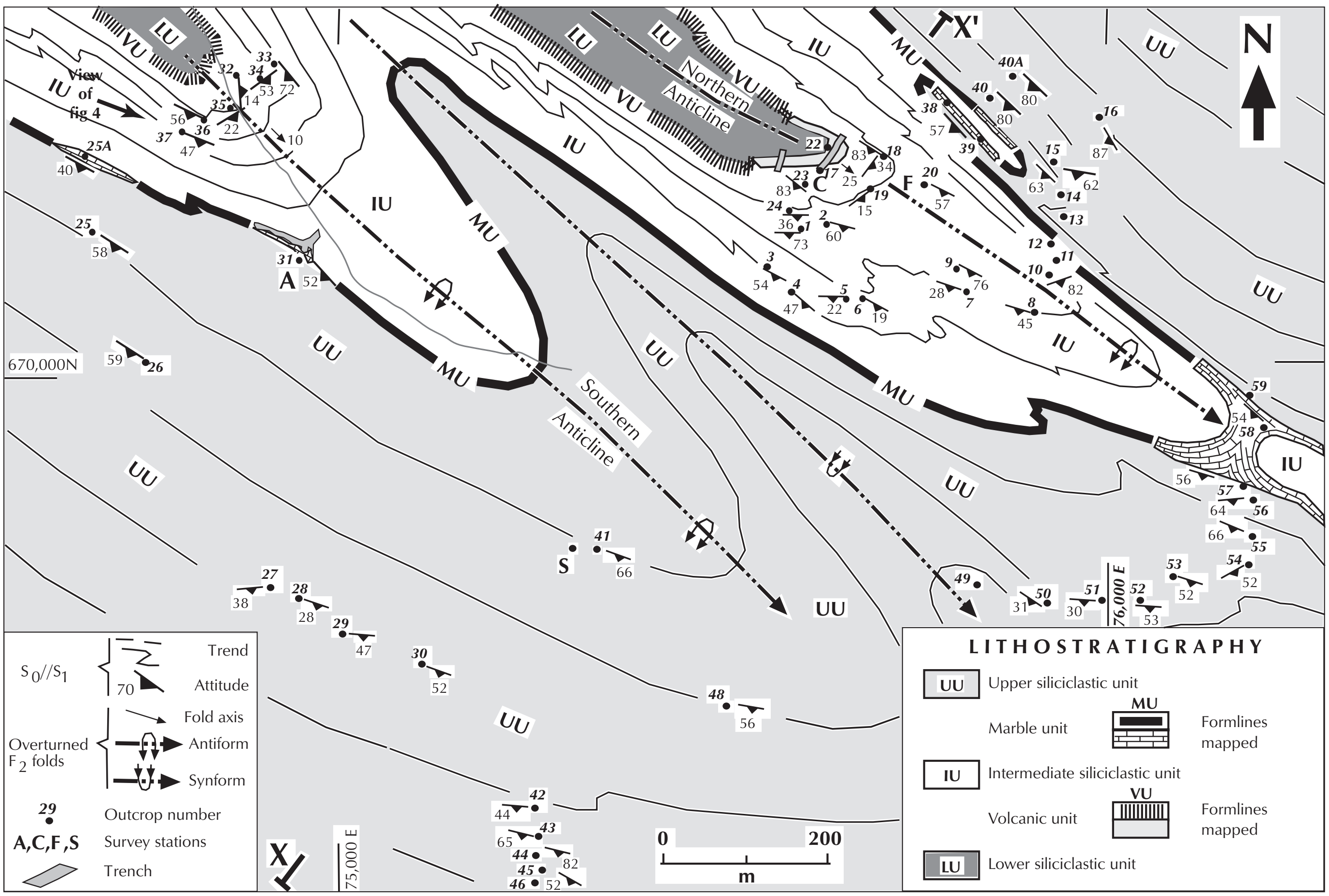


Figure 5a. *Summary lithostructural map of the TBMB area with outcrops numbered. Thin lines within units are formlines, drawn along S_0/S_1 structural trends and using the marble and metavolcanic layers as markers. The D_2 and D_3 structures are omitted for clarity. Letters A and C indicate survey stations with nearby exploration trenches.*

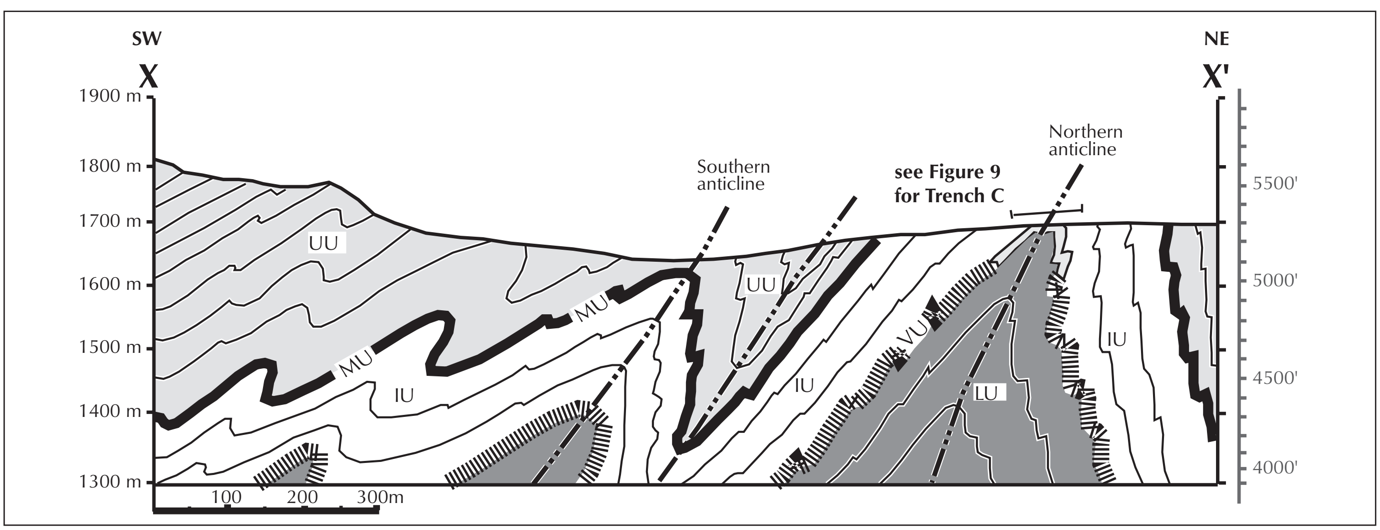
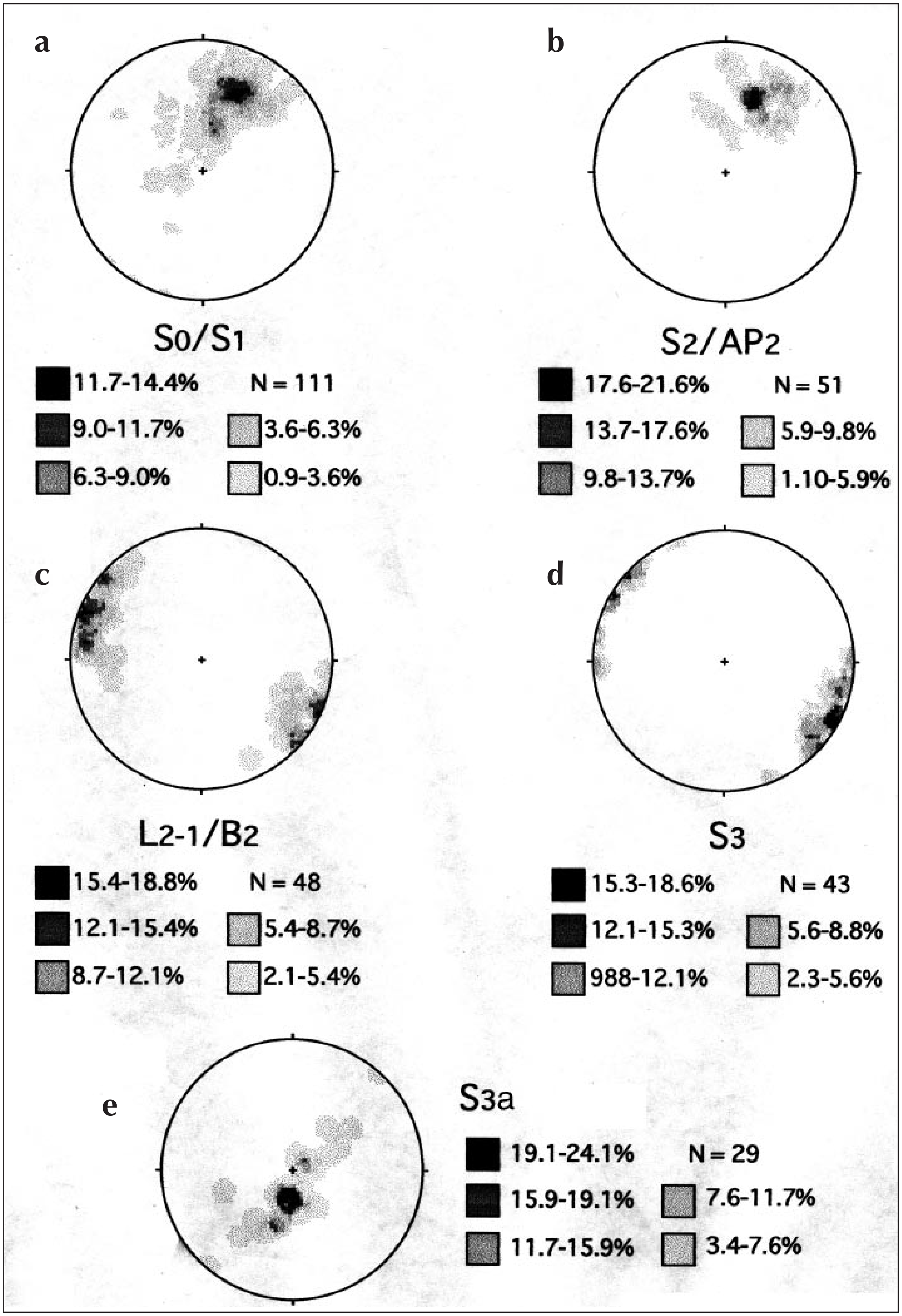


Figure 5b. *Summary vertical section across the TBMB area, based on the demonstration of the Southern and Northern anticlines, with an inferred intervening syncline. Two other kilometre-scale F_2 folds have been interpreted along the normal limb of the Southern anticline. F_1 folds have been omitted, basically for a reason of scale, but they have been noticed in several outcrops. Details in text.*

Figure 7. *Density stereograms of D_2 and D_3 structures in the lower hemisphere of Schmidt-Lambert net. (a) Poles to compositional layering and foliation defined by planar minerals; (b) poles to D_2 penetrative foliation and axial planes of minor folds; (c) intersection lineation of S_1 and S_2 and second phase fold axes (B_2); (d) poles to third phase axial plane foliation; (e) poles to spaced cleavage.*



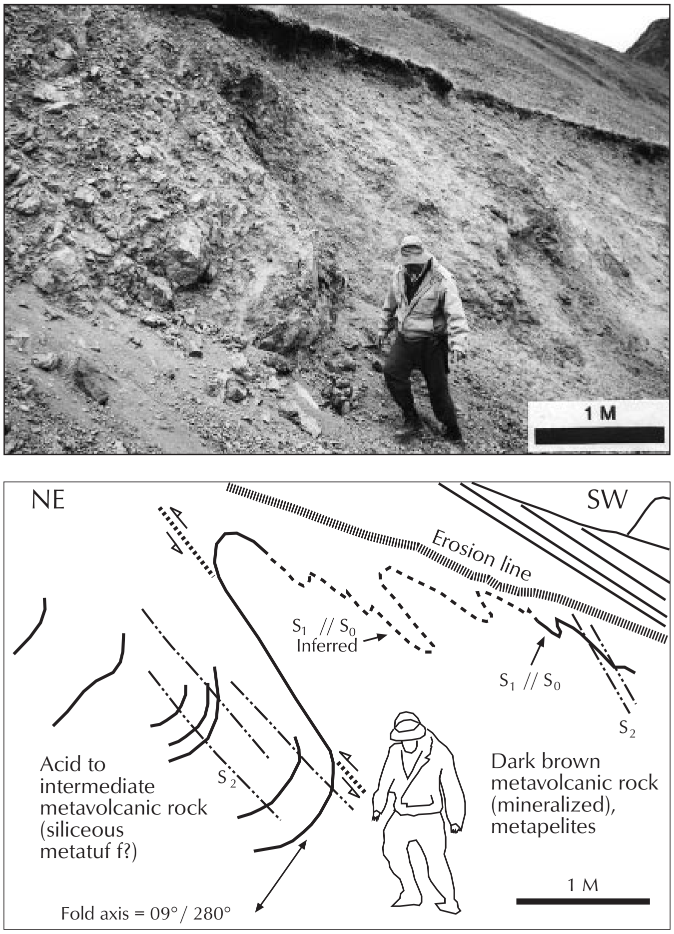


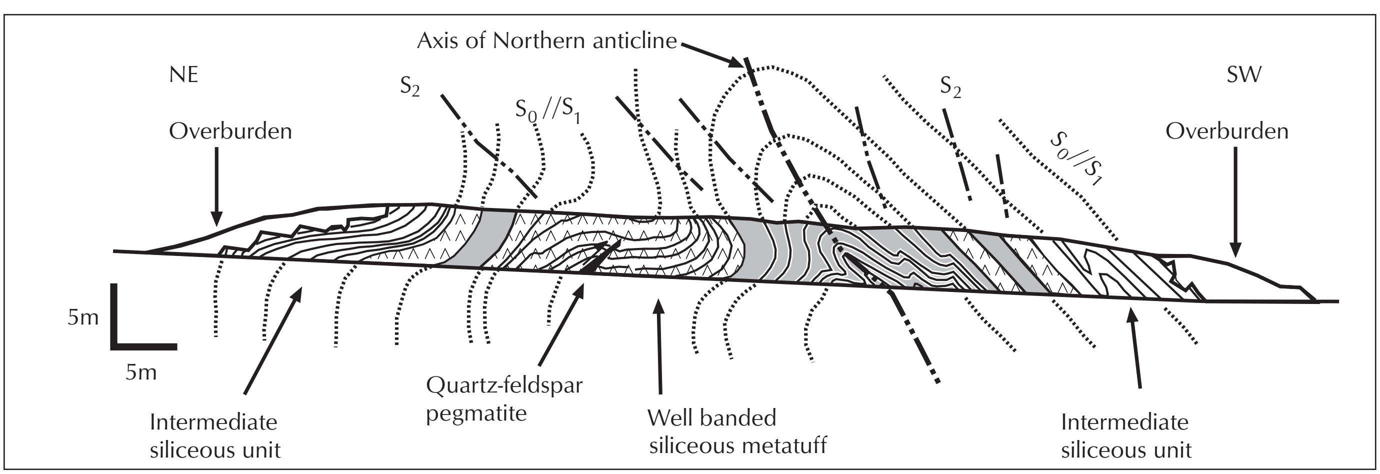
***Figure 8.** Wall of exploration trench near station C, revealing folded micaceous quartzite and metapelite. Despite the advanced stage of physical weathering, structural analysis resolved F_2 folds (up to 10-m-scale) with asymmetric geometry and overturned limbs, possibly associated with south-dipping thrust faults. The attitudes of S_1//S_0 and S_2 measured in the limb of the southernmost fold are respectively 215°/42° and 210°/52°. The axis of the major fold is 09°/280°.*

penetrative and anisotropy of $S_0/S_1/S_2$ planes. These planes dip southerly at moderate to high angles.

The structures of the first two events define a sub-horizontal, north-northeast-trending maximum compressive stress, with a sub-horizontal intermediate stress parallel to the east-southeast-trending fold axis of the F_1 and F_2 folds (Fig. 7 and stereonets in D'el-Rey Silva et al., Part I; this volume). The D_3 event is characterized by open to tight, generally <1-m-scale, kink-style F_3 folds, and by a penetrative foliation (S_3) that dips steeply and cross cuts $S_0/S_1/S_2$ planes. These D_3 structures are the plane of intermediate stress (commonly to west-northwest; Fig. 7d); another set of fractures, planes and spaced cleavage (S_{3a}, Fig. 7e) dips shallowly and generally northward and defines the plane of minimal compressive stress. As a whole, the D_1-D_3 evolution appears to be progressive, and suggests a single tectonic cycle.

Two localities of continuous exposure, as well as the spatial relationship between the S_2 foliation with the S_0/S_1 planes, and asymmetry of m- to dm-scale parasitic F_2 folds, demonstrate the existence of two larger F_2 anticlines. These are termed Northern and Southern anticlines in Figure 5. The upright limbs of these F_2 folds dip 30° to 55° south-southwest, whereas the overturned limbs dip between 70° to 85° south-southwest. Definition of these major folds permit inference of an intervening overturned F_2 syncline, shown in the vertical cross section (Fig. 4b). These structures are described in detail as follows.

***Figure 9.** Sketch of the eastern wall of the trench near C (Figure 8 is from slightly left of centre), illustrating the sequence of mineralized metavolcanic layers (shaded).*



THE NORTHERN ANTICLINE

The Northern anticline, nearly 1 km wide, is defined in the northeastern part of the area. South of the trace of the axial plane, outcrops 3 to 9 systematically display S_2 dipping more steeply south than S_0/S_1, thus defining the normal limb. In outcrops 10 through 16 north of the axial trace, S_2 dips less than S_0/S_1, and defines the shorter limb. The hinge is well exposed along a 70-m-long, northeast-trending trench close to survey station C (Fig. 8 and 9).

From outcrop 16 the overturned limb is exposed on the ridge crest that forms the northern limit of mapping. This outcrop consists of east-southeast-trending, sub-vertical siliciclastic rocks. Eastward, the ridge crest turns to the south and trends across the strike of different rock units (outcrops 59 to 52). The hinge of the Northern anticline (see Fig. 5a) passes through the 120-m-wide marble unit (outcrops 59, 58 and 57). The hinge is preserved by the ridge topography; on the east-facing slope this marble unit extends as two separate limbs.

The marble layer is exposed along the overturned limb of the Northern anticline as

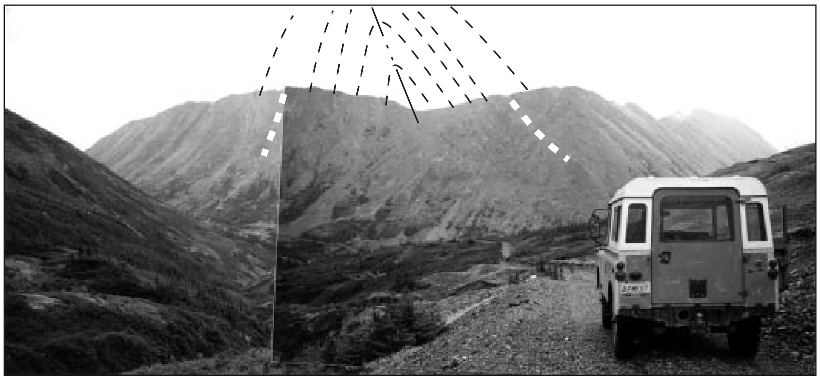


Figure 10. *An eastward view of the spur containing the BOUND claims. The dashed white line marks the approximate position of the discontinuous marble layer. The general structure is interpreted as the continuation of the Northern anticline.*

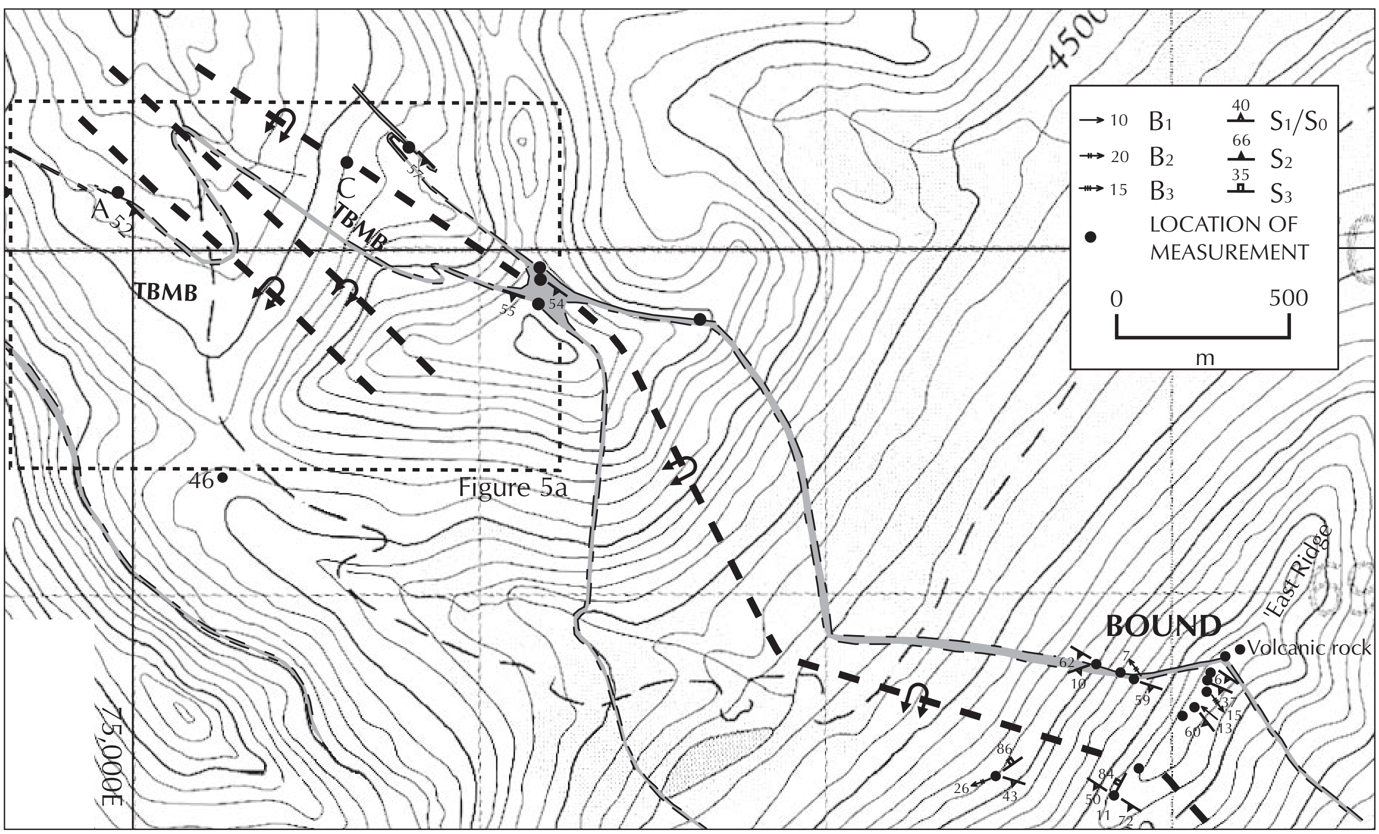


Figure 11. *Simplified map of the area enclosing the TBMB and BOUND claims. The marble layer (shaded) indicates the position of the F_2 folds. Bends in the marble layer in valleys reflect use of the "rule of V's" for dipping planar structures (Ragan, 1985).*

well, particularly to the east of trench C. Outcrops 38 and 39 contain beautiful examples of isoclinal F_1 folds (Fig. 6). The angular relationships between the S_2 foliation and the previous planar structures reveal a 10-m-scale anticline-syncline pair (outcrops 38 and 39) that are parasite folds on the overturned limb of the Northern anticline.

THE SOUTHERN ANTICLINE

This is a nearly 500-m-wide structure defined along a succession of outcrops in the northwestern border of the area (numbers 26, 25, 25A, 37, 36, 35, 32, 34, and 33; see Fig. 5a). The fold hinge is outlined by a nearly 200-m-long exposure of >1-m-thick layers of sericite-quartz schist and sericite quartzite along a northeast-flowing creek between outcrops 37 and 33. The layers display well-defined composite banding (S_0/S_1) with several cm- to dm-scale intrafolial F_1 folds. The upright, southern limb of the Southern anticline (defined between outcrops 37 and 26) encloses a layer of marble (outcrop 25A) along strike with a marble layer mapped east-southeast in trench A (outcrop 31).

LITHOSTRATIGRAPHY

The lithostratigraphy of the area was determined after the definition of the Northern and Southern anticlines. It consists of five units (Fig. 5a): Lower, Intermediate and Upper siliciclastic units (respectively LU, IU, UU), separated by metavolcanic and marble units (respectively VU and UM). Tracing the marble marker horizon around the hinge of the Southern anticline and through the intervening syncline, one reaches the hinge of the Northern anticline at the eastern part of the area (outcrop 57; see Fig. 5a). The metavolcanic rocks also turn around the hinge of the Northern anticline, but are structurally lower than the marble. The formlines for the VU unit respect the scale of the folds and the attitudes measured along the normal limb of the Northern anticline (outcrops 3-11 and 17-24). These two marker units permit division of the siliciclastic rocks into three units, as shown in the vertical cross-section (Fig. 5b).

STRUCTURE NEAR THE BOUND CLAIM

The same rock types are present 3 km southeast of the TBMB area, and similar D_1-D_3 structures are evident. The east-southeast-trending layers cross a ridge spur containing a discontinuously exposed marble horizon (Fig. 10). The angular relationships between S_2 and S_0/S_1 along the crest indicate that the southern part of the ridge corresponds to the longer upright limb of an anticline, whereas the northern part of the crest, in which the layers are sub-vertical, corresponds to the shorter limb. The authors interpret this structure as a major overturned F_2 anticline that is the eastern continuation of the Northern anticline (Fig. 11).

CONCLUSIONS

The mapping and structural analysis of the TBMB area has shown that the scattered, isolated outcrops of marble constitute a marker horizon within a coherent stratigraphic succession. Furthermore, the overturned anticline defined by this stratigraphy continues at least 3 km to the east. This detailed work therefore extends the possibility that a general stratigraphy can be worked out, at least on the scale of a single mountain, where distinct marker horizons are present. This is profoundly important to the search for stratiform sulphide mineralization. At the trench near survey station A, 12% Zn has been sampled, and sphalerite is also found in the trench near station C.

There is little doubt that the structures mapped in the TBMB area are related to those of the Dan area; the same deformation phases and structural style are present at both. Clearly the entire region underwent many of the same deformational events.

Could all these rocks have the same protolith? The first and second authors have examined both areas and propose that rocks of the TBMB area are part of the Ram Creek assemblage. The proposition that the Ram Creek assemblage extends as far south as TBMB requires that the belt of Dorsey rocks (Stevens and Harms, 1995; 2000) between the two localities is either not exposed or tightly infolded. The former is more likely, because on the regional scale a south-dipping thrust brings Dorsey assemblage rocks over top of the Ram Creek assemblage. This problem cannot be resolved until the intervening ridge (north of the TBMB and south of the Atom showings) has been examined, and this is planned for 2001.

Another intriguing possibility is that the marble exposed at the TBMB and Bound showings corresponds to the large limestone outcrops about 4 km further east (area shown on Fig 2; illustrated in Fig. 12 of Roots et al., 2000). The marble at the latter locality is thicker (varies from 20 to 50 m) than at the TBMB (2-10 m) and appears to be less deformed; it contains unidentified crinoids and other organic debris, and includes carbonate blocks in darker phyllite near its structural base (Roots et al., 2000). To resolve this, the stratigraphic sequences must be described for both areas, and outcrops flanking the kilometre-wide valley separating this area from the spur containing the BOUND claim warrant careful examination.

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REFERENCES

Bell, A.M., 1981. Vergence: An evaluation. Journal of Structural Geology, vol. 3, p. 197-202.

D'el Rey Silva, L.J., Liverton, T.J., Paradis, S. and Roots, C.F., 2001 (this volume). A structural analysis of the upper Swift River area (105B/3), Yukon, 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, Indian and Northern Affairs Canada, p. 289-299.

Nelson, J.L., Harms, T. and Mortensen, J., 1998. The southeastern Dorsey Terrane: Characteristics and correlations. *In:* Lithoprobe Report no. 57, SNORCLE and Cordilleran Tectonics Workshop, p. 279-288.

Nelson, J.L., 2000. Ancient Pacific Margin 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, B.C. Department of Energy, Mines and Petroleum Resources, Paper 2000-1, p. 107-126.

Nelson, J.L., Mihalynuk, M.G, Murphy, D.C., Colpron, M, Roots, C.F., Mortensen, J.K. and Friedman R.M., 2000. 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, p. 79-86; and *In:* Geological Fieldwork, 1999, British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Survey Branch, Paper 2000-1, p. 19-26.

Ragan, D.M., 1985. Structural Geology: An Introduction to Geometric Techniques. Third edition, Wiley and Sons, New York, 393 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, Indian and Northern Affairs Canada, p. 115-125.

Roots, C.F. and Heaman, L., in press. Mississippian U-Pb dates from Dorsey Terrane assemblages in the upper Swift River Area, southern Yukon. Geological Survey of Canada, Current Research, 2001-A01, 16 p.

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., 1995. Investigations in the Dorsey terrane, Part I: Stratigraphy, structure and metamorphism in the Dorsey Range, southern Yukon Territory and northern British Columbia. *In:* Current Research 1995-A, Geological Survey of Canada, p. 117-127.

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 (map scale 1:100 000).

Yukon MINFILE, 1997. Wolf Lake - 105B. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada.