Geological Survey of Canada

CURRENT RESEARCH
2003-A3

Geology of the Atnarko metamorphic complex, southern Tweedsmuir Park, west-central British Columbia

S.A. Israel and L.A. Kennedy

2003

Natural Resources Canada
Ressources naturelles Canada

Canada

CURRENT RESEARCH

ISSN 1701-4387
Catalogue No. M44-2003/A3E-IN
ISBN 0-662-33298-9

Authors' address

***S.A. Israel** (sisrael@eos.ubc.ca)*
***L.A. Kennedy** (lkennedy@eos.ubc.ca)*
Geological Survey of Canada
Department of Earth and Ocean Sciences
University of British Columbia
6339 Stores Road
Vancouver, British Columbia
V6T 1Z4

Publication approved by GSC Pacific, Vancouver

Geology of the Atnarko metamorphic complex, southern Tweedsmuir Park, west-central British Columbia[1]

S.A. Israel and L.A. Kennedy

Israel, S.A. and Kennedy, L.A., 2003: Geology of the Atnarko metamorphic complex, southern Tweedsmuir Park, west-central British Columbia; Geological Survey of Canada, Current Research 2003-A3, 8 p.

Abstract: The southern portion of the Atnarko metamorphic complex is characterized by west-southwest-directed contractional high-strain structures within middle-greenschist- to upper-amphibolite-facies metamorphic rocks and plutonic rocks. Similar rocks in the central and northern portions of the complex are characterized by southwest- and northeast-striking foliations and northwest-verging folds. The ages of structures in the south are not well constrained, but they may be as old as Middle to Late Jurassic, and possibly related to the thrusting of the Intermontane superterrane over the Insular superterrane. The foliations and folds in the central and northern areas of the complex are likely younger than Early Cretaceous, and possibly related to mid-Cretaceous thrusting associated with the East Waddington Thrust Belt.

Résumé : La partie sud du complexe métamorphique d'Atnarko est caractérisée par la présence, au sein de roches métamorphiques du faciès des schistes verts intermédiaire au faciès des amphibolites supérieur et de roches plutoniques, de structures témoignant d'une intense déformation par compression dirigée vers l'ouest–sud-ouest . Dans les parties centrale et nord du complexe, des roches semblables sont caractérisées par des foliations de directions sud-ouest et nord-est ainsi que des plis à vergence nord-ouest. Dans la partie sud du complexe, l'âge des structures n'est pas bien encadré, mais elles pourraient remonter aussi loin qu'au Jurassique moyen ou tardif et il se peut qu'elles soient liées au charriage du superterrane intermontagneux sur le superterrane insulaire. Les foliations et les plis dans les parties centrale et nord du complexe sont probablement postérieures au Crétacé précoce et il est possible que ces structures soient liées au charriage qui s'est produit au Crétacé moyen dans la zone de chevauchement d'East Waddington.

---

[1] Contribution to the Targeted Geoscience Initiative (TGI) 2000–2003.

INTRODUCTION

This paper builds upon 1:20 000 scale bedrock mapping that took place in 2001 (Israel and Kennedy, 2002), as well as earlier mapping by van der Heyden (1990), within southern Tweedsmuir Provincial Park, west-central British Columbia (Fig. 1). The main purpose of this mapping was to unravel the complex structural and metamorphic relationships within the Atnarko metamorphic complex and to place the complex into a regional tectonic framework.

The Atnarko metamorphic complex forms a metamorphic and structural culmination first described by van der Heyden (1990), and is located near the boundary of the Coast and Intermontane belts of the Canadian Cordillera. The Intermontane Belt is represented in this region by the Middle Jurassic Hazelton Group, which forms part of the younger portion of the Upper Paleozoic to Middle Jurassic Stikine Terrane. Hazelton Group volcanic rocks and associated plutonic rocks outcrop extensively northwest of the Complex. Early Cretaceous Monarch volcanic rocks found within the Coast Belt are regionally extensive to the north, west and south of the complex (van der Heyden, 1990, 1991; Rusmore et al., 2000). Large areas east of the complex are covered by the Late Jurassic Hotnarko volcanic rocks, which have been associated with a Late Jurassic magmatic arc (van der Heyden, 1990, 1991). Large volumes of Middle Jurassic to Tertiary plutonic rocks occupy the entire region within and surrounding the complex (van der Heyden, 1990, 1991; Rusmore et al., 2000; Israel and Kennedy, 2002; Hrudey et al., 2002). We divide the Atnarko metamorphic complex into three geographic and structural zones: the Ptarmigan Lake, the Glacier Mountain, and the Pandemonium Pass areas. This paper describes the geology of the Glacier Mountain and Pandemonium Pass areas; the geology of the Ptarmigan Lake area is described in Israel and Kennedy (2002). The Pandemonium Pass area extends from Pandemonium Pass north to the Turner Lake chain, and the Glacier Mountain area includes rocks north of the Turner Lake chain to Echo Lake (Fig. 2).

LITHOLOGY

(?) Early Jurassic volcanic and sedimentary rocks

Volcanic and sedimentary rocks in the southern portion of the map area consist largely of polydeformed and metamorphosed mafic, and rarely felsic, volcanic rocks and associated sedimentary rocks that occur as two northwest-striking units separated by a wide zone of migmatite and gneiss (Fig. 2).

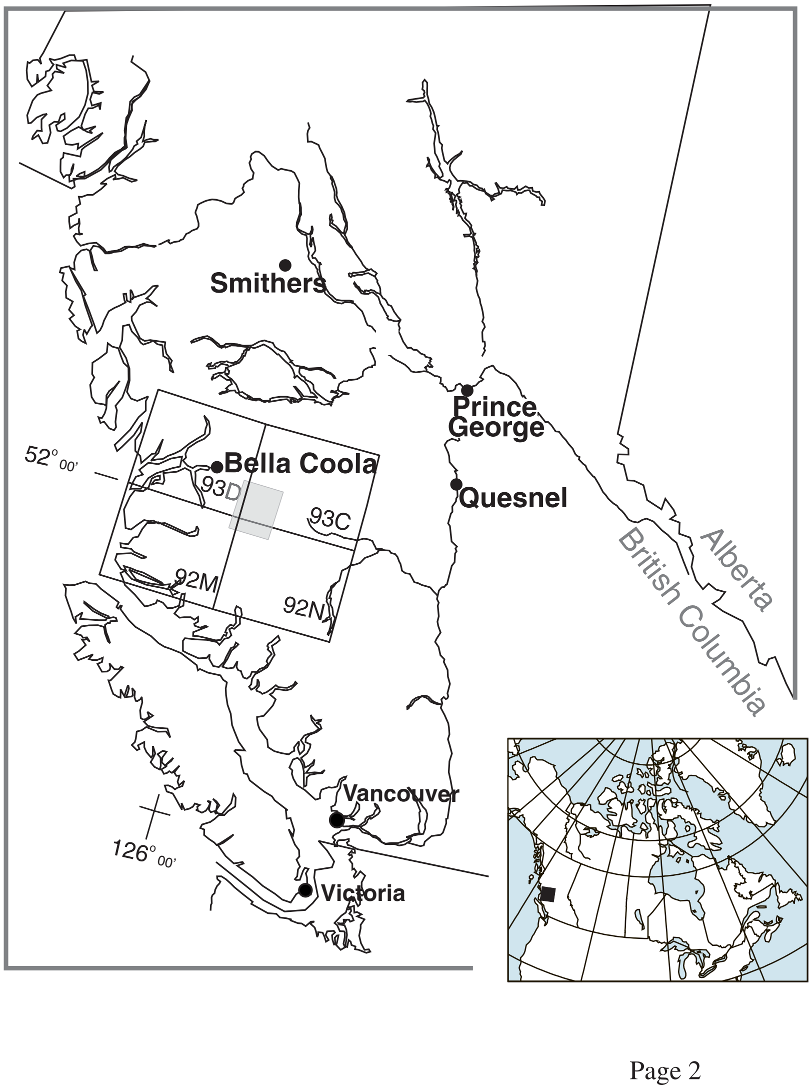

Figure 1.

Location of the study area.

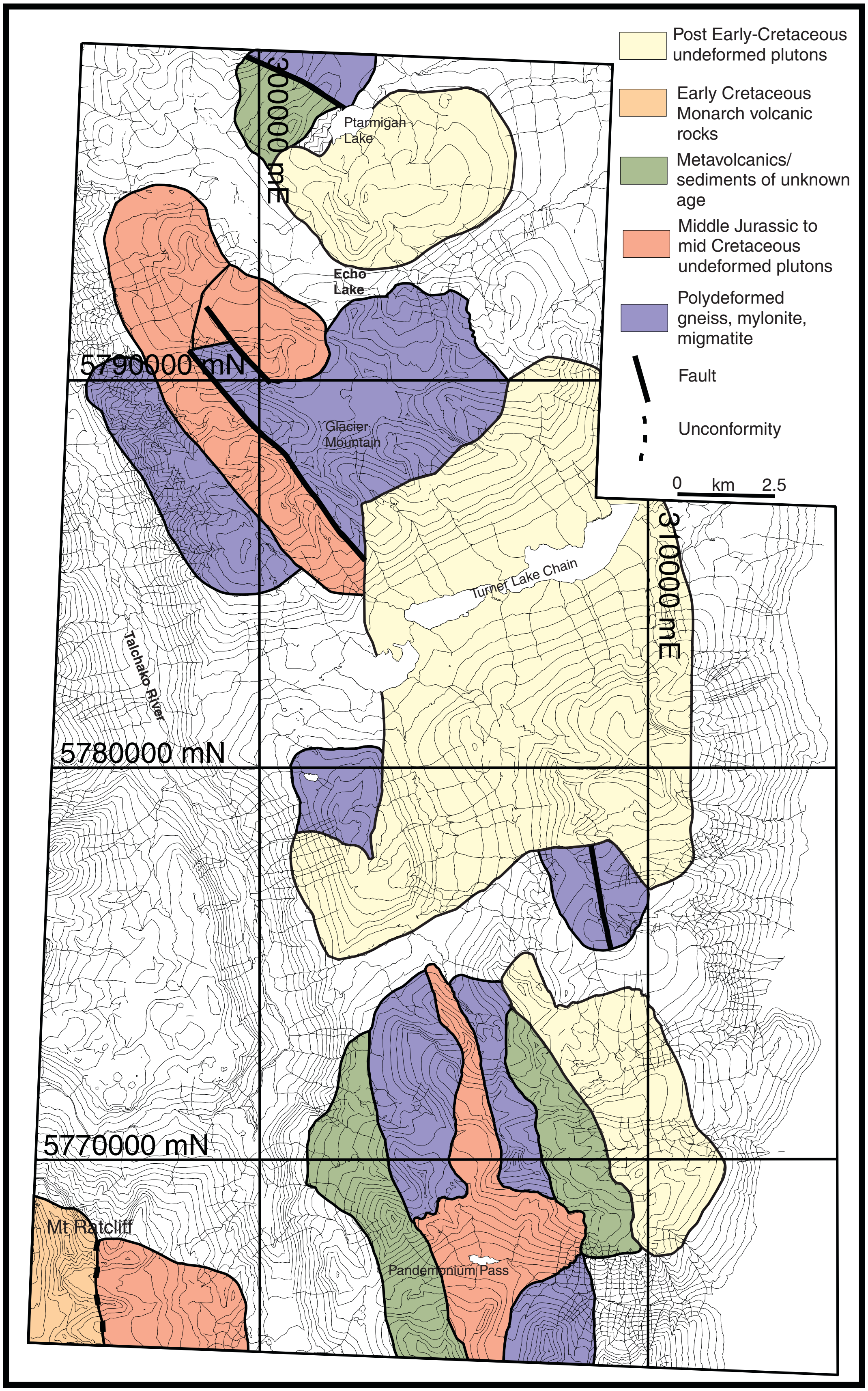

Figure 2. *Generalized geology of the Atnarko metamorphic complex.*

Metamorphic facies range from middle greenschist to upper amphibolite, and rock types range from relatively undeformed metasedimentary and metavolcanic rocks to chlorite schist and garnet amphibolite. Interbeds of pelitic material suggest that the volcanic material was intercalated with clay-rich sediment. Locally, where deformation and metamorphism are less intense, preserved sedimentary features such as bedding can be identified. Deformed cobble conglomerate (Fig. 3) was found at one locality, interbedded with finer grained siliceous sedimentary rocks that appear to pass structurally upward into the metavolcanic rocks.

A metarhyolite from the southern area yielded an imprecise Early Jurassic U-Pb age (van der Heyden, 1990). Van der Heyden (1990) correlated the metavolcanic rocks with the Early Jurassic Hazelton Group of Stikinia.

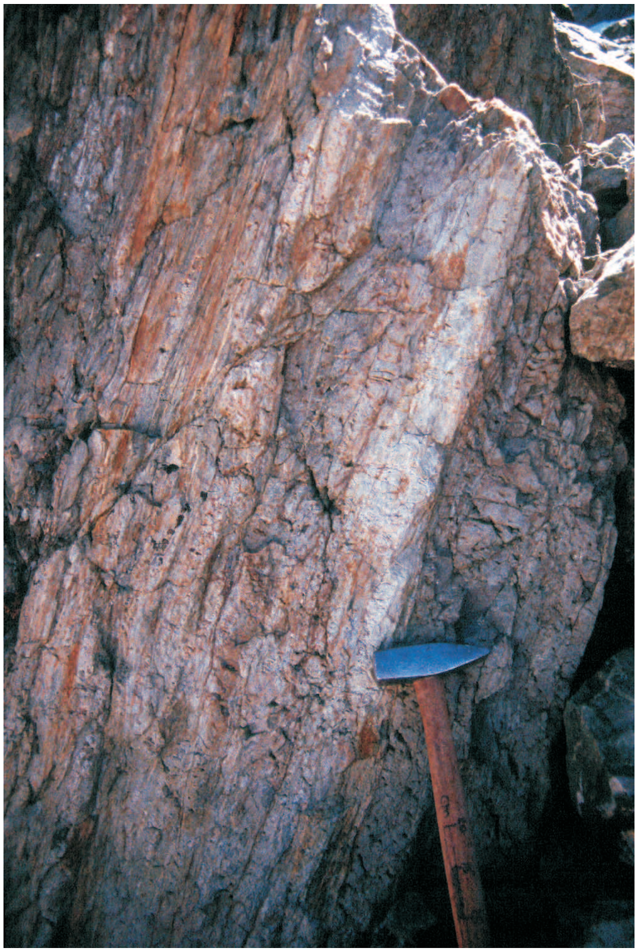

__Figure 3.__ Deformed cobble conglomerate from the Pandemonium Pass area within the Atnarko metamorphic complex.

Gneiss/migmatite (Early Jurassic to Early Cretaceous)

Migmatitic gneiss is exposed in deglaciated zones several kilometres wide in the southern and central portions of the map area. It is characterized by bands of highly folded and transposed mafic and felsic layers. Locally, the mafic and felsic layers are demonstrably migmatite, composed of garnet and amphibole melanosome as well as quartz, plagioclase, muscovite, and garnet leucosome (Fig. 4). The volume of leucosome to melanosome varies considerably. The amphibole is highly strained. The felsic layers are intensely folded, with the feldspar generally undeformed and the quartz typically strained. Felsic intrusions of variable size both crosscut and run parallel to the main structural fabric. Locally, amphibolite contains triangular patches of plagioclase-rich material in the interstices between hornblende grains. Upsection, the plagioclase-rich areas form small dykes, suggestive of partial melting and subsequent melt migration of the felsic material.

__Figure 4.__ Banded migmatite from the Pandemonium Pass area. Dark bands are garnet amphibolite; light layers are undeformed quartz, plagioclase, muscovite, and garnet.

The migmatite exhibits characteristics of partial melt and injected melt; some of the closer plutons, such as a garnet-bearing tonalite found within the zone, may be the source material for the injected phases.

Zones of lesser migmatization are defined by gneiss characterized by alternating bands of hornblende and biotite, with layers of quartz, plagioclase, and muscovite (Fig. 5).

Monarch sequence (Early Cretaceous)

The Monarch sequence consists of boulder conglomerate, volcanic breccia, andesitic to basaltic flows, and intercalated fine-grained sedimentary units. These rocks are well exposed west of the Talchako River near the base of Mount Ratcliff, where they unconformably overlie a ca. 155 Ma (P. van der Heyden, unpub. data, 1991) epidote- and chlorite-altered quartz diorite (Fig. 2). Although the contact is slightly sheared, no evidence was found for significant displacement along the surface. The beds of the Monarch sequence are steeply dipping to vertical and slightly overturned at the base. The entire package youngs to the west.

The base of the Monarch sequence is a conglomerate characterized by boulder- to pebble-sized, well rounded to subangular clasts of quartz diorite, amphibolite, and fine-grained sedimentary rocks (Fig. 6). The quartz diorite clasts have the same epidote and chlorite alteration as the underlying pluton. The conglomerate is exposed for approximately 200 m on one side of a snowfield; a large package of volcanic breccia and flows takes its place on the other side. The breccia, which forms beds several metres thick, consists of large

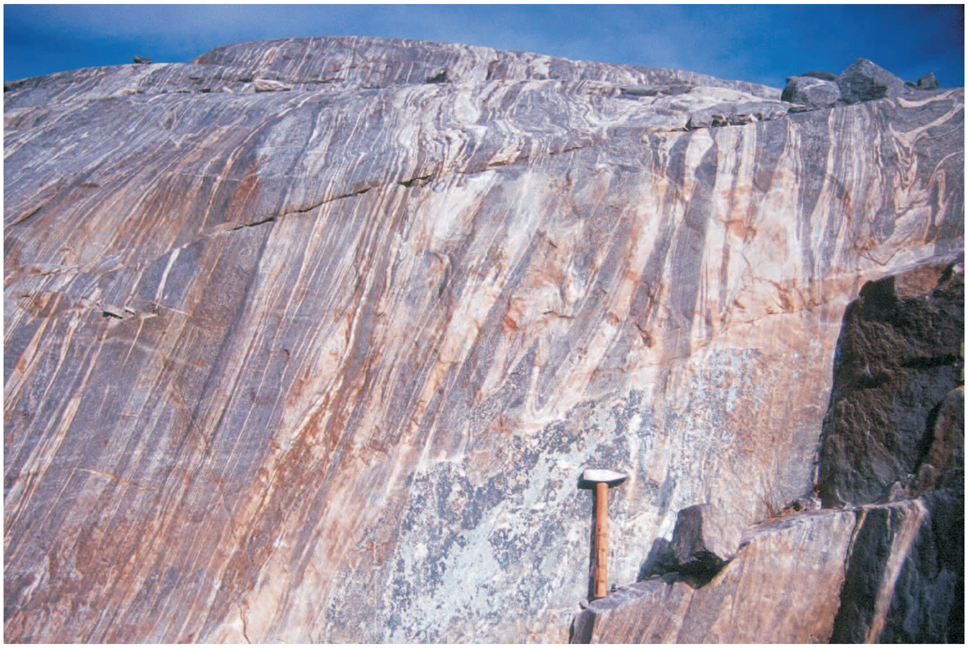

Figure 5.

Compositionally layered gneiss from the Glacier Mountain area (view to the northeast).

Figure 6.

Basal conglomerate of the Monarch volcanic rocks.

(up to 50 cm), subangular to angular clasts of plagioclase-and hornblende-phyric andesite within a matrix of similar composition. It ranges in colour from reddish purple to green, with no apparent change in composition of clasts or matrix. Interbeds of finer grained, volcaniclastic material occur throughout the breccia, as do metre-thick plagioclase-phyric andesitic flows. The flows are remarkably similar to dykes that crosscut the underlying pluton.

Fine-grained laminated siltstone and argillite are intercalated within the volcanic sequence and within the upper portion of the conglomerate. Beds are several metres thick, and in places show normal grading indicating younging to the west. The black to dark grey argillite typically weathers rusty brown.

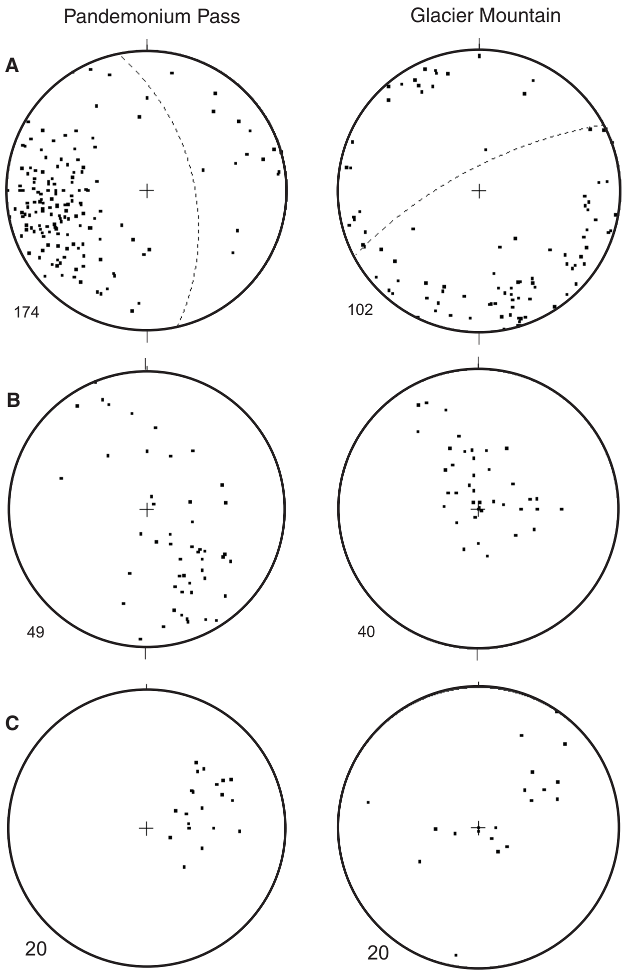

Figure 7. *Lower-hemisphere-projection, equal-area stereonet plots from the Pandemonium Pass and Glacier Mountain areas.* ***A****) Poles to main gneissic foliation.* ***B****) Fold axes.* ***C****) Stretching lineations.*

On the basis of fossil and isotopic analyses, the age of the Monarch sequence is Early Cretaceous (van der Heyden, 1990; Struik et al., 2002). For a more complete description of the Monarch sequence, *see* Haggart et al. (2003).

STRUCTURE

Pandemonium Pass area

The Pandemonium Pass area is characterized from west to east by mid-greenschist-facies, moderately to highly deformed metavolcanic rocks that grade into upper- amphibolite-facies, highly transposed and strained rocks that again grade back into mid-greenschist-facies rocks. The main foliation strikes to the northwest and dips gently to steeply to the east-northeast (Fig. 7). At least three phases of folding were observed. Tight to isoclinal F$_1$ and F$_2$ fold axes with Type III interference patterns are common within F$_2$ fold hinges throughout the area (Fig. 8). Both F$_1$ and F$_2$ folds verge to the west-southwest in well exposed asymmetrical fold trains. Fold amplitudes vary

Figure 8. *Type III refolded folds within migmatite from Pandemonium Pass.*

from centimetres to metres, and sheath folds are locally developed. F_3 folds are open to closed, with fold hinges that plunge moderately to steeply to the east. F_3 folds have caused F_1 and F_2 fold axes to plunge toward both northwest and southeast (Fig. 7). Where developed, stretching lineations defined by elongated quartz grains plunge consistently east-northeastward (Fig. 7). Stretching lineations were likely developed during contraction that led to the development of F_1 and F_2 folds.

Northwest-striking high strain zones of varied widths are common in the Pandemonium Pass area. These shear zones are folded by F_3 and are hypothesized to be related to F_1 and F_2 events. Several large (up to 40 m wide), north-to northeast-striking, southeast-dipping fault zones are found throughout the Pandemonium Pass area. Fault lineations, defined by elongated hornblende crystals (now chlorite), polished grooves, and deflection of the main foliation, indicate an oblique dextral, top-to-the-southwest sense of shear. The faults have both brittle and ductile characteristics, with well developed S-C or Riedel fabrics and small (millimetre-scale) crosscutting quartz veins.

Several brittle, northeast-verging contractional faults, from one to several metres wide, crosscut almost all other structures. Their relationship with the other structures in the area is unknown. Rusmore and Woodsworth (1994) documented northeast-verging contractional structures of the East Waddington thrust belt southeast of the study area and suggested that movement within the belt occurred between 87 and 84 Ma.

Glacier Mountain area

Within the Glacier Mountain area, the main foliation strikes southwest and dips steeply to the northwest (Fig. 7). F_1 and F_2 folds are well developed, as are Type III interference patterns. The F_1 and F_2 fold axes plunge moderately to steeply toward the west-southwest and east-northeast, 90E from F_1 and F_2 folds in the Pandemonium Pass area. The folds are asymmetrical and verge to the southeast. F_3 fold axes plunge shallowly to steeply toward the north-northwest. Stretching lineations, defined by elongated quartz grains, plunge to the northeast and southwest and likely have been folded about the F_3 fold axis (Fig. 7).

Northwest-striking, steeply dipping mylonite zones and large (tens of metres wide) brittle/ductile faults are common in the Glacier Mountain area. The brittle/ductile faults offset most structures, except small fractures.

METAMORPHISM

The Pandemonium Pass area is characterized by metamorphic rocks that grade from lower greenschist to upper amphibolite facies. The change in metamorphic grade lies along a large high-strain zone cored by upper-amphibolite-facies migmatite and gneiss and rimmed on either side by lower grade rocks (Fig. 2). Unmetamorphosed plutonic rocks intruded across the zone, locally increasing temperature and the metamorphic grade of the contact rocks.

Rocks in the Glacier Mountain area have metamorphic grades similar to those of the Pandemonium Pass area; however, the spatial relationships are not as well understood. The gneiss and migmatite are mid- to upper amphibolite facies, locally retrogressed to mid-greenschist. Most rocks exhibit contact metamorphism near contacts with plutons.

DISCUSSION

The structural and metamorphic relationships in the Pandemonium Pass area suggest the presence of a high-strain zone, with geometries and kinematics consistent with west-southwest-directed contraction. The precise age of the high-strain zone is unknown; however, van der Heyden (1991) proposed a Middle Jurassic age for shear zones developed along the western margin of the Atnarko metamorphic complex, on the basis of U-Pb data from crosscutting and deformed intrusive rocks.

The boundary between the Intermontane and Insular superterranes is thought to occur near the Atnarko metamorphic complex. We hypothesize that the contractional structures observed in the Pandemonium Pass area are associated with the accretion of the Intermontane and Insular superterranes in this area.

We propose that the migmatite and highly strained amphibolite-facies rocks represent the response of deeper rocks to the contraction associated with accretion. We hypothesize that significant volumes of granitic material were emplaced during the contractional orogenic events along large zones of high strain, which are thought to be an effective mechanism by which melts can migrate to the upper crust (Brown and Solar, 1998).

Northeast- and southwest-striking foliations and asymmetrical folds in the Glacier Mountain and Ptarmigan Lake areas (van der Heyden, 1991; Israel and Kennedy, 2002) are consistent with southeast-directed shortening. Some of this contraction may be related to the East Waddington Thrust Belt (Rusmore and Woodsworth, 1994) or the mid-Cretaceous, southwest-vergent Coast Belt thrust system (Journeay and Friedman, 1993). More detailed mapping is required in order to decipher the relationship between the two northern structural zones and the Pandemonium Pass area.

FUTURE WORK

Dating of the structural events is imperative in order to understand the observed relationships in the Atnarko metamorphic complex. Both U-Pb and Ar-Ar dating techniques will be employed at the University of British Columbia over the next year. Geobarometry and geothermometry will be used to determine the depth of the metamorphic events, and detailed mapping will be carried out in several areas with high-strain zones to map their geometry and kinematics.

ACKNOWLEDGMENTS

Thanks to Tim Barry, who provided excellent field assistance during the summer field season. The logistical support provided by the GSC and British Columbia Geological Survey is greatly appreciated. We thank Jim Haggart, Brian Mahoney, and Larry Diakow for their help with all aspects of the field work. Special thanks to Nathalie Marchildon for taking the time to join us in the field and for providing excellent insight with respect to migmatitic rocks. Extremely safe and reliable helicopter support was provided by Richard Lapointe of West Coast Helicopters. Comments made by Bert Struik led to an improvement of the manuscript and were much appreciated. Portions of the field work were funded by an NSERC operating grant to L. Kennedy.

REFERENCES

Brown, M. and Solar, G.
1998: Granite ascent and emplacement during contractional deformation in convergent orogens; Journal of Structural Geology, v. 20, no. 9/10, p. 1365–1393.

Haggart, J.W., Mahoney, J.B., Diakow, L.J., Woodsworth, G.J., Gordee, S.M., Snyder, L.D., Poulton, T.P., Friedman, R.M., and Villeneuve, M.
2003: Geological setting of the eastern Bella Coola map area, west-central British Columbia; Geological Survey of Canada, Current Research 2003–A4.

Hrudey, M.G., Struik, L.C., Diakow, L.J., Mahoney, J.B., Woodsworth, G.J., Sparks, H.A., Kaiser, E.A., and Gleeson, T.P.
2002: Plutonic rocks of the eastern Bella Coola map area, southwest British Columbia; Geological Survey of Canada, Current Research 2002–A9, 10 p.

Israel, S.A. and Kennedy, L.A.
2002: Reconnaissance of structural geology of the Atnarko metamorphic complex, southern Tweedsmuir Park, British Columbia; Geological Survey of Canada, Current Research 2002–A12, 8 p.

Journeay, J.M. and Friedman, R.M.
1993: The Coast Belt thrust system: Evidence of Late Cretaceous shortening in southwest British Columbia; Tectonics, v. 12, no. 3, p. 756–775.

Rusmore, M.E. and Woodsworth, G.J.
1994: Evolution of the eastern Waddington thrust belt and its relation to the mid-Cretaceous Coast Mountain arc, western British Columbia; Tectonics, v. 13, no. 5, p. 1052–1067.

Rusmore, M.E., Woodsworth, G.J., and Gehrels, G.E.
2000: Late Cretaceous evolution of the eastern Coast Mountains, Bella Coola, British Columbia; in Tectonics of the Coast Mountains, Southeastern Alaska and British Columbia, (ed.) H.H. Stowell and W.C. McClelland; Geological Society of America Special Paper 343, p. 89–106.

Struik, L.C., Mahoney, J.B., Hrudey, M.G., Diakow, L.J., Woodsworth, G.J., Haggart, J.W., Sparks, H.A., and Kaiser, E.A.
2002: Lower Cretaceous stratigraphy and tectonics of eastern Bella Coola map area, southwest British Columbia; Geological Survey of Canada, Current Research 2002–A11, 10 pages.

van der Heyden, P.
1990: Eastern Margin of the Coast Belt in west-central British Columbia; *in* Current Research, Part E; Geological Survey of Canada, Paper 90–1E, p. 171–182.
1991: Preliminary U-Pb dates and field observations from the eastern Coast Belt near 52°N, British Columbia; *in* Current Research, Part A; Geological Survey of Canada, Paper 91–1A, p. 79–84.

Geological Survey of Canada Project 000025