Paleoproterozoic volcanism and plutonism in the Wernecke Mountains, Yukon

John R. Laughton, Derek J. Thorkelson[1], Marc-André Brideau
Simon Fraser University[2]

Julie A. Hunt
James Cook University[3]

Laughton, J.R., Thorkelson, D.J., Brideau, M-A. and Hunt, J.A., 2002. Paleoproterozoic volcanism and plutonism in the Wernecke Mountains, Yukon. *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. 139-145.

ABSTRACT

The Paleoproterozoic Slab volcanics occur in three localities in the Wernecke Mountains. The largest exposure is at Slab Mountain and consists of a 0.6 x 0.25 km block of thin, steeply dipping mafic to intermediate lava flows. A zone of Wernecke Breccia (1.60 Ga), which crops out along the exposed margin of this volcanic block suggests that the megaclast foundered into the breccia zone from a higher crustal level. The volcanic rocks are typically aphyric. The groundmass consists mainly of laths of plagioclase (commonly altered to scapolite), anhedral biotite and magnetite. The scapolite, and possibly the biotite and magnetite, likely grew during hydrothermal alteration associated with Wernecke Breccia emplacement. Primary igneous mineralogy is uncertain. The Slab volcanics appear geochemically similar and are probably comagmatic with some of the 1.71 Ga Bonnet Plume River Intrusions. No correlative volcanic strata have been found in the Wernecke Mountains or in the neighbouring Ogilvie Mountains.

RÉSUMÉ

On retrouve les roches volcaniques de Slab, d'âge Paléoprotérozoïque, à trois endroits dans les monts Wernecke. Le plus grand affleurement se situe sur le mont Slab et consiste d'un bloc qui mesure 0,6 sur 0,25 km contenant de minces coulées de lave mafique à intermédiaire abruptement inclinées. Une zone de brèche de Wernecke (1,60 milliard d'années) affleure le long de la marge exposée de ce bloc volcanique; ce dernier serait un mégaclaste qui se serait effondré dans la zone de brèche depuis un niveau supérieur de la croûte. Les roches volcaniques sont typiquement aphyriques. La pâte est principalement constituée de biotite anédrique, de magnétite et de cristaux prismatiques de plagioclase (généralement altérés en scapolite). La scapolite, et peut-être la biotite ainsi que la magnétite, s'est probablement formée pendant l'altération hydrothermale associée à la mise en place de la brèche de Wernecke. La minéralogie des roches ignées primaires est incertaine. Les roches volcaniques de Slab semblent être d'une composition géochimique similaire aux intrusions de la rivière Bonnet Plume, datant de 1,71 milliard d'années; elles sont probablement comagmatiques. Aucune strate volcanique corrélative n'a été trouvée dans les monts Wernecke ni dans les monts Ogilvie avoisinants.

[1]*dthorkel@sfu.ca*

[2]*Department of Earth Sciences, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6*

[3] *School of Earth Sciences, James Cook University, Townsville, Queensland 4811, Australia*

INTRODUCTION

Geological mapping and research was carried out in the summer of 2001 in the northeastern corner of Slats Creek (106D/16) and southeastern corner of Quartet Lakes (106E/1) map areas in a remote part of the Wernecke Mountains approximately 180 km north-northeast of Mayo (Fig. 1). The study area includes 'Slab Mountain' and 'Slab Ridge', informally named features north of the Bonnet Plume River near Latitude 65°N and Longitude 134°W. The terrain is rugged and exposure is excellent. The study area has been of interest to exploration companies since the 1970s and is the site of the Slab mineral occurrence (Yukon MINFILE, 2001, 106O 070). The current investigation is part of a larger program involving personnel from Simon Fraser University (British Columbia), James Cook University (Australia), and the Yukon Geology Program.

In 1992, geologists of the Pamicon-Equity-Westmin mineral exploration venture first recognized the presence of volcanic rocks on Slab Mountain and Slab Ridge. These rocks were subsequently described, and named the Slab volcanics, by Thorkelson and Wallace (1993) as part of a regional 1:50 000-scale mapping project for the Canada/Yukon Geoscience Office. The Slab volcanics do not appear to correlate with other strata in the Yukon or elsewhere and therefore represent a unique and essentially unstudied geological formation (Thorkelson, 2000). Research in 2001 consisted of detailed mapping, examination, and geochemical sampling of the Slab volcanics. Emphasis was placed on the main exposure of the volcanic rocks, a succession of mainly lava flows on the eastern side of Slab Mountain (Thorkelson, 1993; Fig. 2). Two smaller localities originally noted by members of the Pamicon-Equity-Westmin-Newmont joint venture were also examined (Fig. 1, Localities 2 and 3). This report provides new field observations and petrographic descriptions of all three localities and a brief description of volcanic rock intersected in drill core on the Arch claims, south of the Bonnet Plume River (Fig. 1, Locality 1).

GEOLOGICAL FRAMEWORK

Four main geological units occur in the study area (Fig. 3). The oldest is the ~4-km-thick Fairchild Lake Group of the Wernecke Supergroup, which consists mainly of siltstone and carbonate (Delaney, 1981; Thorkelson, 2000). In the study area, much of the Fairchild Lake Group has been metamorphosed to fine-grained, low-grade schist

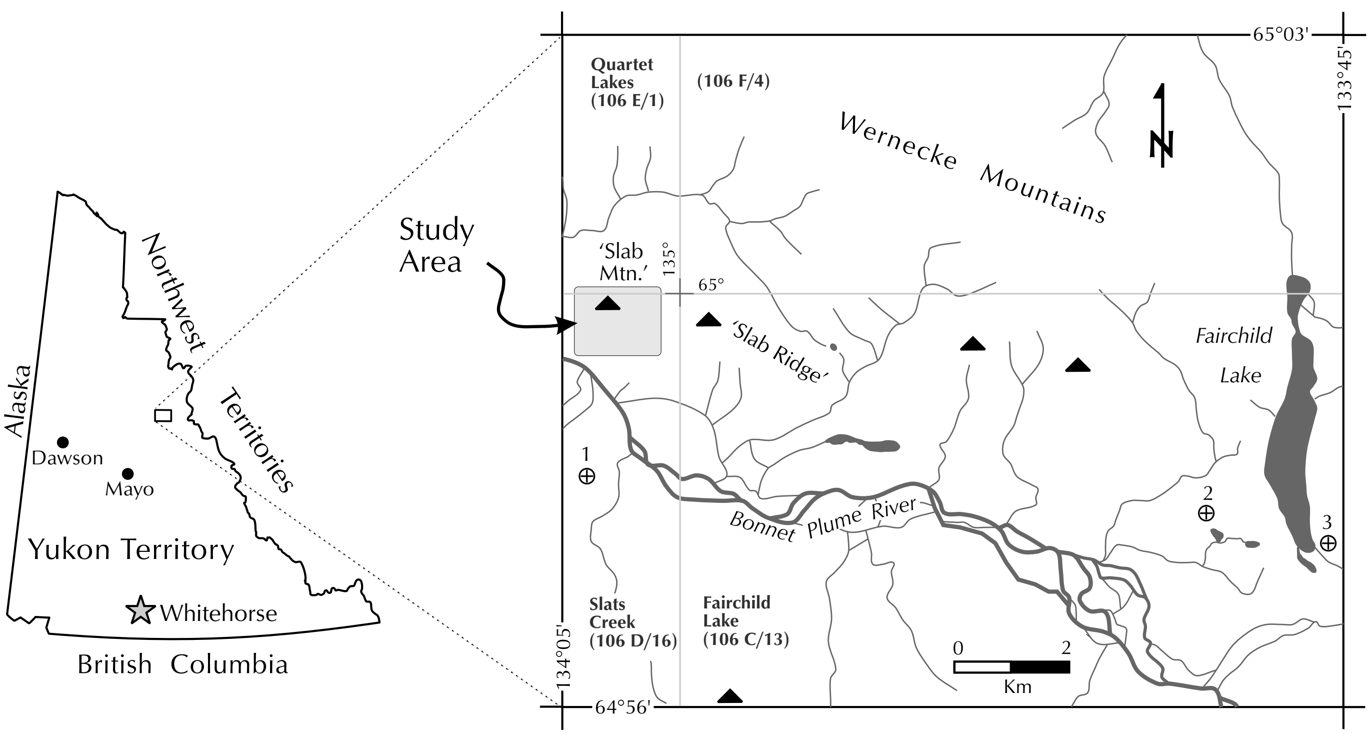

Figure 1. Region of interest in the Wernecke Mountains. Boxed area indicates location of study area. Locations marked with crosses indicate: 1. Arch claims, 2. unnamed locality of Slab volcanic rocks, 3. Fairchild MINFILE occurrence (Yukon MINFILE, 2001, 106C 007).

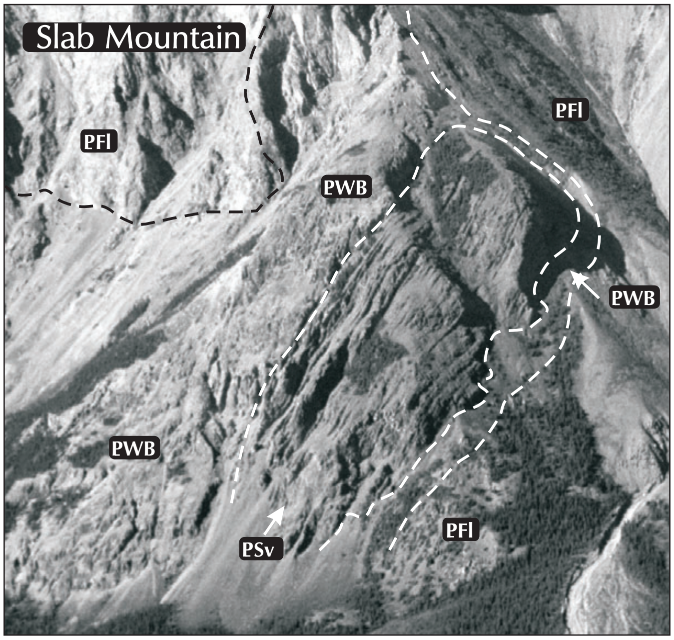

Figure 2. *Eastern side of Slab Mountain, view is approximately north. Wernecke Breccia (PWb) occurs between Fairchild Lake Group (PFl) and Slab volcanics (PSv). Width of frame is approximately 600 m.*

(Brideau et al., this volume). The Bonnet Plume River Intrusions, of mainly dioritic composition, crosscut the Fairchild Lake Group, and have been dated by U-Pb zircon to be ca. 1.71 Ga (Thorkelson et al., 2001a). These relations constrain the age of the Wernecke Supergroup to >1.71 Ga. The Slab volcanics were considered by Thorkelson (2000) to be younger than the Wernecke Supergroup, and possibly comagmatic with the Bonnet Plume River Intrusions. The youngest units in the study area are zones of hydrothermal breccia and megabreccia, collectively called Wernecke Breccia, which crosscut the entire Wernecke Supergroup and Bonnet Plume River Intrusions (Bell and Delaney, 1977; Thorkelson et al., 2001b) and nonconformably underlie the Pinguicula Group (Thorkelson 2000, 2001b; Fig. 3). The zone of Wernecke Breccia at the eastern end of Slab Mountain (Fig. 2) was dated by U-Pb titanite to be ca. 1.60 Ga (Thorkelson et al., 2001b). The main succession of Slab volcanics at Slab Mountain was regarded by Thorkelson et al. (2001b) as a megaclast within this breccia zone (Fig. 4). New field observations presented in this report support the megaclast model for the Slab volcanics and

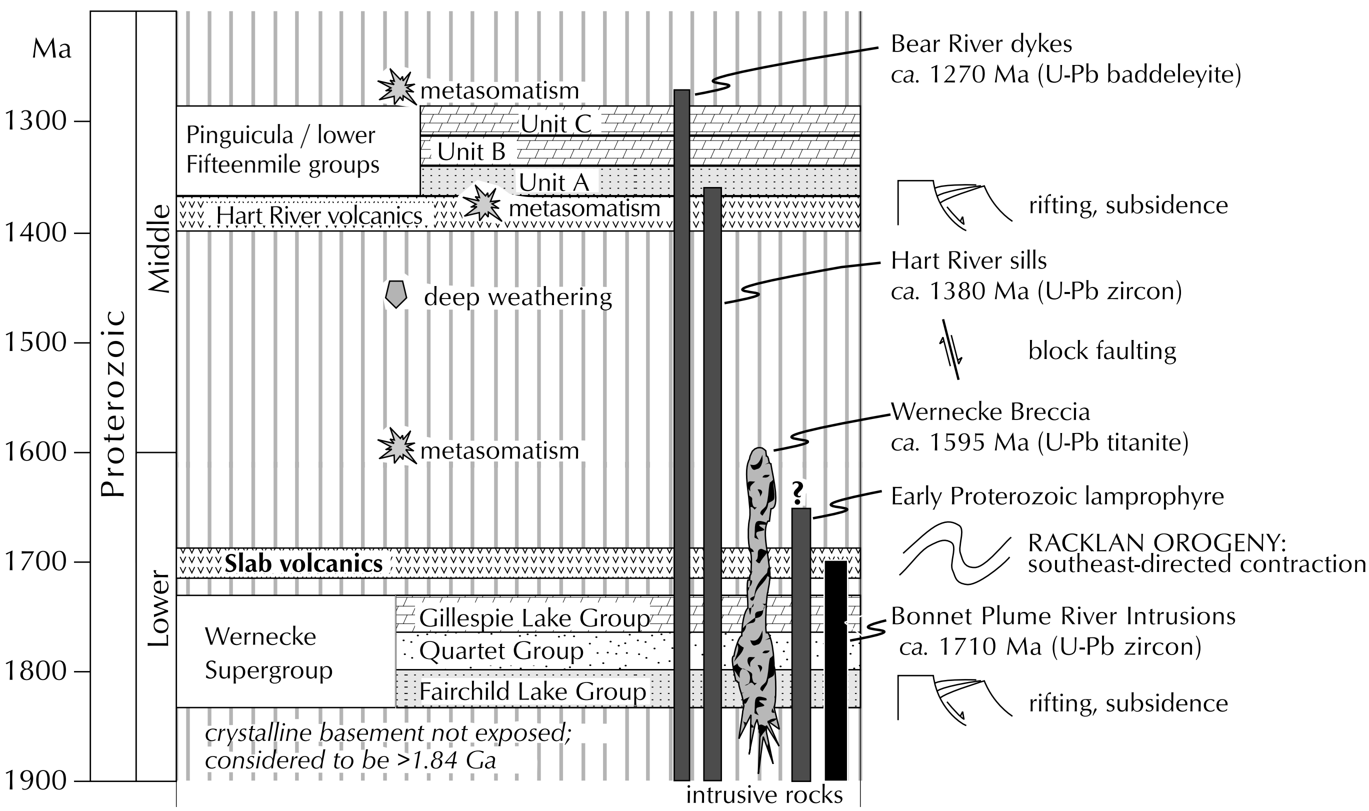

Figure 3. *Representative time stratigraphic column demonstrating the relations between sedimentary deposition, volcanism, plutonism, deformation, brecciation and metasomatism in the Wernecke Mountains. Modified after Thorkelson (2000).*

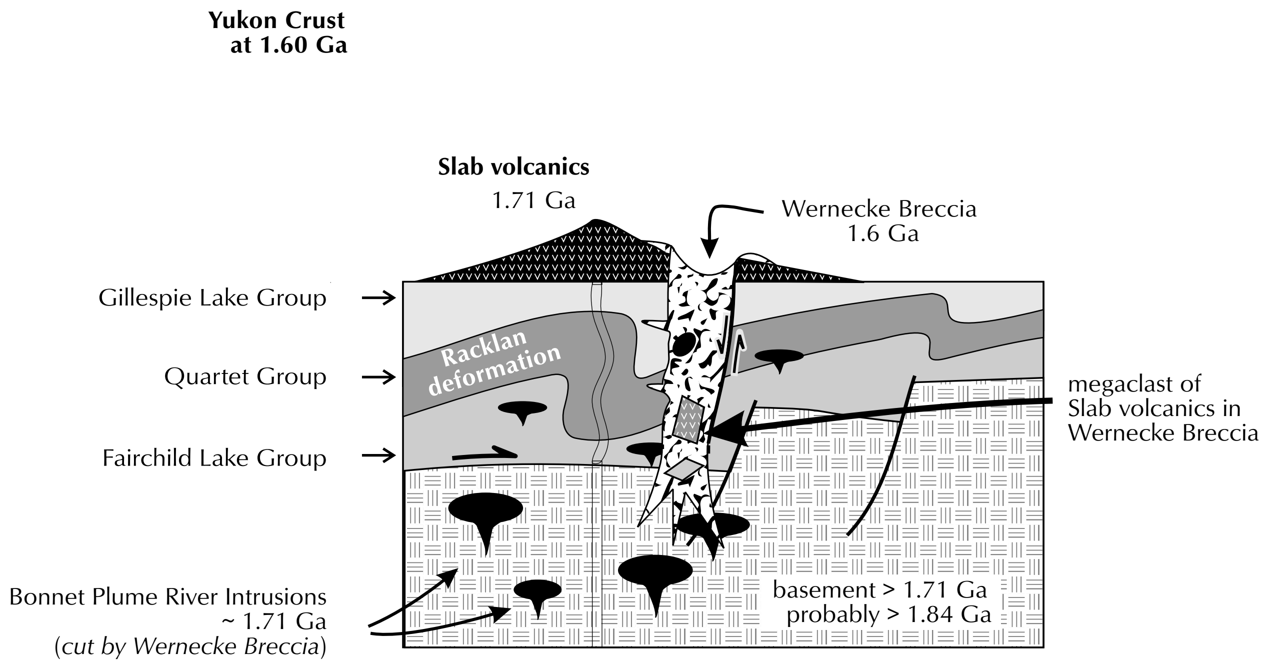

Figure 4. *Cartoon illustrating a hypothetical crustal cross-section, showing relations between Wernecke Supergroup, Slab volcanics, Bonnet Plume River Intrusions and Wernecke Breccia (modified after Thorkelson et al., 2001a).*

suggest that the volcanic rocks are coeval with, or older than, the Bonnet Plume River Intrusions.

SLAB VOLCANICS

The Slab volcanics crop out at one main and two minor localities. At each locality, the volcanic rocks appear to be fragments of a larger succession engulfed by zones of Wernecke Breccia. Physical connections between the volcanic rocks and intact stratigraphic units are absent. Original volcanic textures are commonly visible, whereas deformational features, such as schistosity, crenulations and kink bands, which are locally prominent in nearby exposures of the Fairchild Lake Group, are not evident. Metamorphic grade, although not rigorously determined, appears to be no higher than lower greenschist grade.

MAIN LOCALITY

The largest exposure of the Slab volcanics lies on the eastern end of Slab Mountain (Fig. 2). The volcanic block is roughly rectangular in outcrop, measuring about 250 m in the east-west direction and about 600 m north-south. The volcanic block consists mainly of steeply dipping lava flows with tops to the west. On the west side, a narrow (< 2-m-wide) fault zone, characterized by abundant slickensides, separates the uppermost lava flow from a broad zone (> 300 m wide) of Wernecke Breccia to the west. Along the north and east sides, a thin zone of breccia (0.1 m to 50 m) separates the volcanic rocks from schist of the Fairchild Lake Group and diorite of the Bonnet Plume River Intrusions. At one location, the eastern margin of the volcanic succession is separated from breccia by a 10-m-wide block of diorite. The diorite is chilled against the lowest unit of the volcanic succession and progressively coarsens toward the interior of the intrusion. At approximately 1 m from the chilled margin, the intrusion is a fine-grained diorite composed mainly of interlocking feldspar and pyroxene grains, typical of the intrusions in this area. The southern end of the volcanic succession is overlain by talus.

The volcanic rocks on eastern Slab Mountain consist of 35 mafic-intermediate lava flows that dip roughly 70° to the northwest. Flow thickness averages 4 m, but ranges from 0.8 m to 14 m. Lava flows throughout the succession commonly display prominent, amygdaloidal and locally auto-brecciated bottoms, typically 1.5 m to 2 m thick, which grade into massive, recessive lava, ~1 m thick, which grades upward into a prominent 2-m-thick scoriaceous flow top. The flows are variably amygdaloidal, with vesicles commonly filled with quartz, white and pink calcite, tremolite, biotite, chlorite and apatite. The distribution of pipe vesicles and scoria in the lava flows confirms the tops-to-the-northwest facing direction of the succession.

The basal volcanic unit is a 14-m-thick volcanic breccia. A 6-m-thick, blocky weathering, moderately vesiculated lava flow lies between the basal breccia and a 10-m-thick, prominent, volcanic tuff breccia. A succession of conformable vesiculated, aphyric lava flows of variable thickness overlies this volcaniclastic unit. A thin (1.4 m) sandstone interbed is located approximately one-third of the way up the succession. Load structures in the sandstone indicate stratigraphic tops to the northwest. Clastic units are absent above the sandstone interbed. Pipe vesicles up to 1.5 cm in diameter and 12 cm in length occur in the basal part of the lava flow that directly overlies the sandstone. Hydrothermal veins composed of powdery, white, fine-grained minerals cut many of the flows. Where the veins are thick (> 2 cm) and abundant, the lavas are deformed into local zones of crackle breccia.

Figure 5. *Megaclast of Bonnet Plume River Intrusion in Wernecke Breccia on Slab Mountain.*

The thinness and scoriaceous character of the lava flows suggests that they were deposited as pahoehoe lavas in a subaerial environment. No indicators of subaqueous deposition, such as pillows, pillow breccias, or intercalations of hyaloclastite, have been recorded. The abundance of these thin lava flows, and a paucity of clastic rock at all localities indicate that the volcanic succession was dominated by mafic flows and is likely to have formed part of a shield volcano.

The Slab volcanics are mainly aphyric and composed of plagioclase, biotite and magnetite. Rare thick flows (> 8 m) show no noticeable differences in grain size throughout. Towards the bottom of the succession, a 6-m-thick flow contains conspicuous, large (up to 2 cm) trachytically aligned laths of euhedral plagioclase which are concentrated in the lower 30 cm. The groundmass of ~0.4-mm-long interlocking laths of plagioclase feldspar is commonly weakly flow aligned. Replacement and recrystallization of plagioclase by scapolite is seen in many of the flows examined. Expected mafic minerals such as hornblende and augite are conspicuously absent. Subhedral groundmass magnetite is ubiquitous. The biotite exists as 0.1 mm grains that occur both individually and in clusters. Whether this assemblage is primary (of igneous origin) or secondary (caused by alteration) is under investigation.

Two small, nearby occurrences of the Slab volcanics are included in this locality. Both occur as clasts within Wernecke Breccia. On Slab Mountain and Slab Ridge, Wernecke Breccia mainly consist of angular to well rounded clasts of siltstone and schist derived from the surrounding Fairchild Lake Group, and subordinate clasts of diorite derived from the Bonnet Plume River Intrusions. Clasts range from pebble-size fragments, to 60-m blocks located on the south side of Slab Mountain (Fig. 5). One clast of the Slab volcanics is boulder-sized (1.5 m in diameter) and crops out in a thick zone of Wernecke Breccia, approximately 5 m west of the top lava flow. It is petrographically similar to the lava flows of the main succession. The other clast is a 2 m by 3 m, fine-grained, amygdaloidal and locally auto-brecciated fragment of lava within Wernecke Breccia on the crest of Slab Ridge.

OTHER LOCALITIES

Volcanic rocks have been found at two other localities in the region. One locality is situated about 10 km east-southeast of Slab Mountain, north of the Bonnet Plume River (Fig. 1, Locality 2). The outcrop is a 150-m-high cliff face that is continuous for 500 m. Exposure is excellent and field relations are discernable. Three separate 50-m-wide blocks of dark grey volcanic rocks outcrop along the face. Each block is surrounded on all exposed sides by large (> 70 m) bodies of Wernecke Breccia. A 2-m-diameter rounded boulder of Slab volcanics was found and sampled in the breccia at the west end of the outcrop and appears to be a milled fragment derived from the larger succession. The groundmass consists of interlocking laths of plagioclase and anhedral grains of biotite and magnetite, and is indistinguishable from typical groundmass in the flows at the main succession on Slab Mountain.

The other locality is approximately 1 km south of Fairchild Lake, 14 km east-southeast of Slab Mountain (Fig. 1, Locality 3), at the Fairchild mineral occurrence (Yukon MINFILE, 2001, 106C 007). The outcrop is on a low, 200-m-wide rocky knob situated in the valley bottom east of the Bonnet Plume River. The exposure is continuous and consists of dark grey, fine-grained aphyric lava. Two exposures of Wernecke Breccia, each about 20 m across, appear to crosscut the volcanic rocks. The rock has a conspicuous spotty hornfels appearance caused by replacement of plagioclase and other minerals by scapolite. Anhedral biotite and subhedral magnetite occur throughout. The rocks are petrographically similar to flows of the main volcanic succession at Slab Mountain and are tentatively correlated with them.

Rock that appears to be correlative with the Slab volcanics was intersected in core at the Arch claims south of the Bonnet Plume River (Fig. 1, Locality 1). The suspected volcanic rocks occur in a 70-cm interval of core and are bounded by Wernecke Breccia. Mineralogically and texturally, they are similar to the volcanic rocks at the locality south of Fairchild Lake, including conspicuous light-coloured, spherical patches (2 mm) of scapolite.

INTERPRETATION OF FIELD RELATIONS

The chilling of a dioritic Bonnet Plume River Intrusion against a lava flow of the Slab volcanics on Slab Mountain indicates that Bonnet Plume River Intrusion magmatism post-dates, or is coeval with, the Slab volcanics. The Slab volcanics are therefore constrained in age to > 1.71 Ga. The two igneous units may be comagmatic, and part of the same volcano-plutonic complex.

We interpret all blocks of volcanic rocks discussed as megaclasts derived from a volcanic succession that became incorporated into zones of Wernecke Breccia through explosive brecciation and foundering (Fig. 4; Thorkelson et al., 2001b). The smaller exposures, such as those on Slab Ridge and northwest of the main succession on Slab Mountain, are clearly visible as clasts in the breccia. The main block of volcanic rocks on Slab Mountain is also surrounded by breccia, except where the volcanic rocks are intruded by a Bonnet Plume River Intrusion. At that location, the breccia engulfs both the volcanic rocks and the intrusion. Slickensides between breccia and the northwest side of the main block indicate that subsequent faulting occurred; however, we contend that the displacements are minor and that the fundamental process linking the breccia to the volcanic rocks is hydrothermal brecciation. Engulfment of the volcanic rocks by breccia is also evident at the locality 10 km southeast of Slab Mountain.

If the Slab volcanics are relics of a larger volcanic succession, at what stratigraphic position did this succession lie? No proximal volcanic rocks are known from the Wernecke Supergroup, in the immediate vicinity or elsewhere, despite excellent exposure (Thorkelson, 2000). Moreover, the volcanic rocks were deposited subaerially, in contrast to the marine environment of the Wernecke Supergroup (Delaney, 1981), making the Wernecke Supergroup an unsuitable stratigraphic unit to host the volcanism. If the Slab volcanics were deposited prior to the Wernecke Supergroup, then their current position within breccia flanked by the Fairchild Lake Group would require upward motion from depth. This option seems unlikely because of the enormous size of some of the blocks, especially the main succession on Slab Mountain. In addition, the metamorphic grade of the volcanic rocks appears to be no higher than the Wernecke Supergroup, inferring that they did not originally underlie the Wernecke succession. Consequently, the most suitable stratigraphic position for the volcanic succession is above the Wernecke Supergroup.

In this scenario, the volcanic succession, probably a shield volcano, would have been fragmented, along with the underlying zones of Wernecke Supergroup and the Bonnet Plume River Intrusions, by explosive hydrothermal activity during formation and emplacement of two zones of Wernecke Breccia (Thorkelson et al., 2001b). Large blocks of the volcanic succession would have fallen into dilatant zones near the tops of the breccia zones and become surrounded by hydrothermal fluids and clasts derived predominantly from the Wernecke Supergroup. Local scapolite alteration of the Slab volcanics supports the foregoing model of hydrothermal brecciation and foundering. Scapolite-after-plagioclase is present in clasts of the Bonnet Plume River Intrusions (Thorkelson et al., 2001a, b) and appears to be an alteration signature of igneous rock incorporated into the breccias.

CONCLUSIONS

The Slab volcanics occur at three main localities in the Wernecke Mountains. They are characterized by their dark grey, vesicular, aphyric appearance. Petrographically, they consist of a groundmass of interlocking laths of plagioclase, anhedral biotite and magnetite. Scapolite occurs locally as light grey patches and spherical porphyroblasts, commonly replacing plagioclase. The mineral assemblage, including scapolite, may be a product of metasomatism related to brecciation. In all localities, the volcanic rocks are in contact with zones of Wernecke Breccia and are interpreted to be megaclasts within the breccia. At one locality, the volcanic rocks are intruded by an Early Proterozoic Bonnet Plume River Intrusion, constraining the age of the volcanic rocks to > 1.71 Ga. The megaclasts of the Slab volcanics are relics of a larger but entirely eroded volcanic succession, probably a shield volcano that overlay the Wernecke Supergroup.

ACKNOWLEDGEMENTS

Access to the study area and samples of drill core were provided by Richard Gorton of Newmont Mines Limited. Funding was provided by a LITHOPROBE grant to D.J. Thorkelson, a Northern Studies Training Program grant to J.R. Laughton, an NSERC undergraduate scholarship to M-A. Brideau, and the Yukon Geology Program.

REFERENCES

Bell, R.T. and Delaney, G.D., 1977. Geology of some uranium occurrences in Yukon Territory. Current Research, Part A, Geological Survey of Canada, Paper 77–1A, p. 33–37.

Brideau, M-A., Thorkelson, D.J., Godin, L. and Laughton, J.R., 2002 (this volume). Paleoproterozoic deformation of the Racklan Orogeny, Slats Creek (106D/16) and Fairchild Lake (106C/13) map areas, Wernecke Mountains, Yukon. *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. 65-72.

Delaney, G.D., 1981. The mid-Proterozoic Wernecke Supergroup, Wernecke Mountains, Yukon Territory. *In:* Proterozoic Basins of Canada, F.H.A. Campbell (ed.), Geological Survey of Canada, Paper 81-10, 23 p.

Thorkelson, D.J., 2000. Geology and mineral occurrences of the Slats Creek, Fairchild Lake and “Dolores Creek” areas, Wernecke Mountains, Yukon Territory (106D/16, 106C/13, 106C/14). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Bulletin 10, 73 p.

Thorkelson, D.J. and Wallace, C.A., 1993. Development of Wernecke Breccias in Slats Creek (106D/16) map area, Wernecke Mountains, Yukon. *In:* Yukon Exploration and Geology 1992, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 19–30.

Thorkelson, D.J., Mortensen, J.K., Creaser, R.A., Davidson, G.J. and Abbott, J.G., 2001a. Early Proterozoic magmatism in Yukon, Canada: Constraints on the evolution of northwestern Laurentia. Canadian Journal of Earth Sciences, vol. 38, p. 1479-1494.

Thorkelson, D.J., Mortensen, J.K., Davidson, G.J., Creaser, R.A., Perez, W.A. and Abbott, J.G., 2001b. Early Mesoproterozoic intrusive breccias in Yukon, Canada: The role of hydrothermal systems in reconstructions of North America and Australia. Precambrian Research, vol. 111, p. 31-55.

Yukon MINFILE, 2001. Fairchild Lake and Nash Creek areas, 106C and 106D. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada.