$^{40}$Ar/$^{39}$Ar EVIDENCE FOR THE AGE OF IGNEOUS AND METAMORPHIC EVENTS IN THE BRIDGE RIVER AND SHULAPS COMPLEXES, SOUTHWESTERN BRITISH COLUMBIA*

(920/2; 92I/15, 16)

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**KEYWORDS**: Geochronology, argon-argon dating, Bridge River complex, Taseko Lakes, Bridge River, Noaxe Creek, Shulaps ultramafic complex, Tyaughton Creek, deformation, metamorphism.

**INTRODUCTION**

The Taseko Lakes—Bridge River area is situated approximately 200 kilometres north of Vancouver on the eastern margin of the Coast plutonic complex and west of the Yaklakom fault (Figure I-X-1). This area is the focus of a regional program of $^{40}$Ar/$^{39}$Ar dating which was initiated in 1987 in the Warner Pass (920/3) and Noaxe Creek (920/2) map areas (Archibald et al., 1989). In 1988 and 1989, the program continued with sampling in the Bradorne (92I/15) and Bridge River (92I/16) map areas. These latter areas are underlain by rocks of the Bridge River complex, and include a fault-bounded panel of blueschist-facies metamorphic rocks (Garver et al., 1989a). The Shulaps ultramafic complex and the Cadwallader Group (Schiarizza et al., 1989, 1990a), Additional, detailed sampling and mapping in the blueschist locality (Bradorne, 92I/15) were completed in 1990. In this note we report $^{40}$Ar/$^{39}$Ar step-heating data for a white mica sample from the blueschist rocks, a hornblende sample from a package of sheeted mafic dikes emplaced into Bridge River volcanic rocks, and biotite and hornblende samples from rocks in the Shulaps ultramafic complex.

**GEOLOGIC SETTING OF THE SAMPLES**

The regional and detailed geology has been outlined in a series of British Columbia Ministry of Energy, Mines and Petroleum Resources publications and preliminary maps (see Figure 1-8-2). Of particular relevance to this study are the reports of the blueschist locality in the Eldorado Mountain area (Garver et al., 1989a; Garver, 1991, this volume) and the summary of the geology within and adjacent to the Shulaps ultramafic complex (Schiarizza et al., 1989, 1990a; Calon et al., 1990).

**Blueschist Facies Rocks**

In the Tyaughton Creek area, there are three areas of blueschist and greenschist-facies metamorphic rocks structurally interleaved with typical Bridge River rocks of lower metamorphic grade. The larger area is in the watershed of North Cinnabar Creek and is a narrow tectonic lens with a strike length of some 4 kilometres. This package is unconformably overlain by middle to upper Albian rocks of the Taylor Creek Group which contain boulders of blueschist, chert and greenstone.

The blueschist is strongly flattened, locally records isoclinal folding, and commonly has a pronounced crenulation cleavage of variable intensity (Garver et al., 1989a). Two principal mineral assemblages have been recognized in this area: crossite/glaucophane+lawsonite, and crossite/glaucophane+garnet+epidote+white mica. These two assemblages, which represent slightly different pressure/temperature conditions during metamorphism, occur in the same area but are probably separated by faults. Prehnite is present as crosscutting veins in both rock types (Garver et al., 1989b). The sample dated in this study contains the second mineral assemblage and the medium to coarse-grained white mica lies nearly in the plane of the schistosity. Previous K-Ar and Rb-Sr dating of rocks and white mica separates from the same structural panel yielded dates between 195 and 250 Ma (Garver et al., 1989b). Step-heating experiments were undertaken to refine the primary cooling age and to determine the magnitude and timing of later thermal events that are thought to have affected the area.

**Amphibolite Knocker From the Shulaps Ultramafic Complex**

The Shulaps ultramafic complex underlies about 180 square kilometres of the Shulaps Range. The southwestern part of the complex sits structurally above the Cadwallader Group and Bridge River complex in a block of relatively high grade (lower to upper greenschist facies) metamorphic rocks bounded by the Mission Ridge and Marshall Creek faults (Coleman, 1989; Potter, 1986). This part of the Shulaps complex comprises harzburgite tectonite structurally underlain by a thick unit of serpentinite mélangé that includes knockers of an ultramafic-mafic plutonic-volcanic suite characteristic of the upper part of an ophiolite complex (Calon et al., 1990; Schiarizza et al., 1990a), as well as knockers of bedded chert, limestone, sandstone and pebble...
Figure 1-8-1. Location and geological setting, Taseko Lakes–Bridge River map area.
conglomerate. The serpentinite mélangé unit sits struc-
turally above the Cadwallader Group, which in turn sits
structurally above the Bridge River complex. The south-
western serpentinite mélangé unit has been sampled ex-
tensively for dating and amphibole has yielded a 73 Ma date
that is thought to reflect uplift and cooling following syn-
klinematic metamorphism during the latest stages of
emplacement-related deformation within the complex
(Archibald et al., 1989).

The northwestern, northern and eastern portions of the
Shulaps complex comprise harzburgite and underlying ser-
pentinite and serpentinite mélangé which sit structurally
above sub-greenschist facies rocks of the Bridge River
complex (Schiarizza et al., 1990a, b). These rocks are sepa-
rated from the higher metamorphic-grade rocks to the south-
west by a system of faults that may be a northwestern
extension of the northeast-dipping Mission Ridge normal
fault (Coleman, 1989; Schiarizza et al., 1990a, b); they may
comprise a relatively higher slice within the southwest-
vergent Shulaps thrust system than the southwestern
Shulaps complex. Dating of samples from the serpentinite
mélange belt along the western margin of the Shulaps com-
plex was therefore undertaken to compare its thermal his-
tory with that of the southwestern belt. For this study we
selected amphibole from a lens of coarse-grained, massive
to weakly lineated, coarsely brecciated amphibolite 6
metres thick. The sample contains well-preserved brown
amphibole, saussuritized plagioclase and epidote; it is cut
by closely spaced quartz veins.

**Biotite Reaction Zone in the Shulaps
Ultramafic Complex**

The sample is from a mesotamatic reaction zone that
formed around a 1 to 2-metre, siliceous phacoid within
serpentinite of the Shulaps ultramafic complex. The locality
is approximately 10 metres north of a near-vertical, east-
striking fault that juxtaposes serpentinized ultramafic rock
on the north against greenschist-facies metachert, marble
and metabasalt of the Bridge River complex. This fault is
considered to be a component of the Mission Ridge fault
system (Coleman, 1989) because it takes eastward into the
Mission Ridge fault, and westward into a kinematically
congruent east-side-down normal fault system that cuts
through the Shulaps complex (Schiarizza et al., 1990a, b).

The sample was collected from the biotite-rich part of the
reaction zone that surrounds the phacoid of strongly altered
quartz-biotite-feldspar rock. The biotite reaction rim is sev-
eral centimetres thick and is mantled by a thicker zone rich
in quartz-chromite-talc which separates it from unaltered,
dark green serpentinite. The phacoid may be a tectonic
inclusion of the underlying Bridge River schists incorpor-
ated during an earlier episode of thrust faulting, or a tec-
tonothermally reworked, intermediate to felsic dike. As the
Mission Ridge pluton and Rexmount porphyry outcrop a
short distance to the southeast and metasedimentary
knockers have not been mapped in the vicinity, the latter
seems more probable.

The sample consists of quartz, plagioclase and biotite. In
thin section, the biotite is brown, randomly oriented, dis-
plays even extinction, and has very rugged grain boundaries.
The lack of a penetrative fabric in the phacoid or its margin
indicates postemplacement recrystallization that was pri-
marily static in nature. This sample was selected for dating
because potassic rocks are rare in this part of the Shulaps
ultramafic complex, and a biotite date would provide infor-
mation about the late-stage thermal history of this part of the
complex.

**Sheeted Dikes in the Bridge River
Complex**

Schiarizza et al. (1989) describe sheeted mafic dikes
from the Bridge River complex. The dikes selected for this
study outcrop along the Carpenter Lake road and comprise a
set of nearly east-striking, steeply dipping dikes approxi-
mate 15 metres thick. Individually, they are less than 2
metres thick, massive, and display a range of grain sizes;
medium to coarse-grained dikes are most common. Locally,
some of the thicker dikes contain patches of more pegme-
tic and leucocratic rock, as well as 1-centimetre phenocrysts
of plagioclase. They are in intrusive contact with pillowed
volcanic rocks of the Bridge River complex. However, at
the southern contact, the dike appears to be chilled against
and to follow a linear, altered breccia zone. Some internal
contacts and most fracture surfaces in the dikes and the
enclosing volcanic rocks have slickensides with highly vari-
able orientation.

Although these dikes have well-defined internal intrusive
contacts, they are locally severely altered rocks composed
of brown and green amphibole, chlorite, quartz, calcite and
saussuritized plagioclase. Clinopyroxene occurs as remnant
grains, as phenocrysts in chilled margins and as rounded
inclusions in the hornblende. The amphibole occurs as sub-
hedral to euhedral laths and needles and, although well
preserved, commonly displays fracturing and undulatory
extinction in thin section. The green amphibole overgrows
the brown amphibole, forming a thin rim suggesting a
minor greenschist-facies metamorphic overprint, although
regionally, rocks from this part of the Bridge River complex
contain prehnite-pumpellyite facies mineral assemblages.
For this study an attempt was made to separate, and date,
the paragenetically older, brown amphibole.

**40Ar/39Ar ANALYTICAL METHODS**

Mineral separates were prepared using a Frantz magnetic
separator, heavy organic liquids and, where appropriate, by
hand-picking.

Samples and six flux monitors (standards) were irradiated
with fast neutrons in position 5C of the McMaster nuclear
reactor (Hamilton, Ontario) for 29 hours. The monitors were
distributed throughout the irradiation container, and J-
values for individual samples were determined by
interpolation.

Both step-heating experiments and analysis of the moni-
tors were done in a quartz tube heated using a Lindberg
furnace. The bakeable, ultrahigh-vacuum, stainless steel
argon-extraction system is operated online to a substantially
modified, A.E.I. MS-10 mass-spectrometer run in the static

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*Geological Fieldwork 1990, Paper 1991-1*
### TL-88-1a White Mica (~40 mesh)

**Weight (mg) = 100**

<table>
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<th>Temp (°C)</th>
<th>%Ar</th>
<th>DATE ± 2σ</th>
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<tbody>
<tr>
<td>100</td>
<td>105</td>
<td>128°5</td>
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<tr>
<td>150</td>
<td>110</td>
<td>222°7</td>
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<td>200</td>
<td>101</td>
<td>101°3</td>
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### TL-88-24 Biotite 80/140 mesh

**Weight (mg) = 185**

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### TL-88-23 Hornblende 80/140 mesh

**Weight (mg) = 200**

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<td>128°5</td>
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<td>150</td>
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<td>222°7</td>
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<tr>
<td>200</td>
<td>101</td>
<td>101°3</td>
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### TL-88-10 Brown Hornblende 80/120 mesh

**Weight (mg) = 200**

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<td>200</td>
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<td>101°3</td>
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(1) True ratios corrected for fractionation and discrimination.

(2)²⁰⁷⁰Ar/²⁰⁸⁰Ar is corrected for the decay of the Ar during and after irradiation using a 

(3) %Ar of Ar is determined using equilibration peak height and mass spectrometry sensitivity.

(4) Isotope production ratios for the McMaster reactor are from Massie et al. (1981).

(5) Ages calculated using the constants recommended by Steiger and Jager (1977). Errors represent the analytical precision only (i.e., error in J value = 0). Flux monitor used: LP-8 Biotite at 128.5 Ma.

(6) i.e., integrated age for all steps. P.A.I. = plateau age.
Figure 1-8-2. Sample locations and \(^{40}\)Ar/\(^{39}\)Ar age spectra for rocks from the Bridge River and Shulaps complexes, southwestern British Columbia.
RESULTS AND DISCUSSION

Blueschist-Facies Rocks

RESULTS

The age spectrum for the white mica from the blueschist locality (TL-88-1a) is shown in Figure 1-8-2; analytical data are listed in Table 1-8-1. The integrated age of this sample is 229.9±1.3 (2σ) Ma which is in the range of previous dates for this site (Permio-Triassic; Garver et al., 1989b). The 500°C step yields a date of 158 Ma, and dates for subsequent steps are all in excess of 228 Ma. The steps from 725°C to 1200°C yield a well-defined plateau date of 229.8±1.0 (2σ) Ma for 95 per cent of the 39Ar released from the sample. In this temperature range, the 37Ar/39Ar ratio ranges from 0.006 to 0.25 which corresponds to the low Ca/K ratio of phengite (e.g., Sisson and Onstott, 1986). The age spectrum does not record any evidence of a post-Triassic, thermal perturbation. Thus, it appears that blueschist facies metamorphism in the Bridge River complex is a Middle Triassic or older event that ended by 230 Ma.

DISCUSSION

The white mica from the blueschist contains a record of only one tectonothermal event. Blueschist-facies metamorphism is a low-temperature event (300-400°C; Sisson and Onstott, 1986) and the mica may have grown in this temperature range. As the mica grew syntectonically, the 230 Ma plateau date for the mica implies that both deformation (development of schistosity) and metamorphism are at least this old. The two K-Ar dates older than this (reported by Garver et al., 1989b) remain problematic, and additional analyses of white mica are planned; these will include white mica from blueschist cobbles in the Dash conglomerate at the base of the Taylor Creek Group.

Archibald et al. (1990) reported an age spectrum for nearly identical white mica (but from a different sample) that yielded a 221 Ma plateau segment as well as a 500°C step, indicating that the area was affected by a thermal event in post-Late Triassic time. Based on modelling of this previously reported age spectrum, the thermal event must have been of short duration and/or of low temperature (the closure temperature of argon diffusion in white mica is 350°C); an original cooling age only slightly greater than the 221 Ma plateau date (225-230 Ma) was favoured for this sample. The new data support this conclusion and suggest that blueschist-facies metamorphism ended in Middle Triassic time.

The post-Triassic thermal overprint was inferred by Archibald et al. (1990) to reflect structural thickening associated with a protracted episode of contractional deformation that affected the region in mid-Cretaceous time. The latest manifestation of this deformation is reflected in the sample area by a system of northeast-vergent thrusts within the Bridge River complex and a large overturned footwall fold outlined by unconformably overlaying mid-Cretaceous rocks of the Taylor Creek Group and Silverquick conglomerate (see Garver, 1991, this volume). These mid-Cretaceous clastics were deposited during the earlier stages of contractional deformation, which generated a complex system of southwest-vergent thrust and reverse faults (Garver, 1989; Schiarizza et al., 1990a, c; Colom et al., 1990). Partial argon loss during this protracted contractional event may explain the wide range of K-Ar dates for blueschist rocks reported by Garver et al. (1989a); crenulation of the blueschist rocks is variable and most white mica porphyroblasts show degrees of kinking. It is possible that the variable development of a crenulation cleavage, interpreted by Garver (1991, this volume) to be related to Cretaceous contraction, may have facilitated partial argon loss.

Amphibolite Knocker from the Shulaps Ultramafic Complex

RESULTS

The age spectrum for the amphibole from the knocker (TL-88-23) is shown in Figure 1-8-2; analytical data are listed in Table 1-8-1. The integrated age for this sample is 253.7±14.7 Ma (2σ). The four lowest temperature steps are characterized by low radiogenic content, erratic 37Ar/39Ar ratios and large errors. In contrast, the remaining, higher temperature steps representing 83 per cent of the total 39Ar, have a consistent 37Ar/39Ar ratio averaging 2.7±3 (2σ), are much more radiogenic and represent the main pulse of argon release from the amphibole. These steps define a plateau date of 260.8±10.7 (2σ) Ma. Although the analytical errors are large (due to the small volume of argon released in each step), there is no evidence in the age spectrum of a later thermal overprint. To test for the presence of initial argon, an Ar-Ar correlation analysis was done for the plateau segment. This revealed an initial 40Ar/36Ar ratio of 257±68 (2σ) (slightly less than the expected atmospheric argon ratio of 295.3) and an older age for the plateau segment of 271±16 Ma (2σ; MSWD=0.9 for steps: 940°C to 1200°C). We consider the correlation plot date to be a reliable cooling age for this sample. This age spectrum indicates that this part of the Shulaps complex records a different thermal history than the southwestern part of the complex, and that the amphibolite cooled following metamorphism in Early Permian time.

DISCUSSION

The amphibolite knocker sampled from the serpentinite mélangé along the northwestern margin of the Shulaps complex is lithologically similar to the samples from the southwestern part of the complex reported on previously (Archibald et al., 1989). Both samples are thought to have been
derived from mafic plutonic rocks of the Shulaps ophiolite complex. Synkinematic metamorphism indicated by their textures and mineralogy is attributed to ocean-floor processes during the protracted constructional phase of the ophiolite complex; this interpretation follows the recognition of similar ductile deformation fabrics in the large ultramafic-mafic plutonic blocks of the southwestern serpentinite mélangé belt which developed during and between plutonic episodes (Caton et al., 1990). Amphibole from the knocker in the southwestern mélangé belt yielded a plateau date of 72.6±0.5 Ma, suggesting that it was reheated to at least greenschist-facies conditions and cooled through approximately 500°C in Late Cretaceous time (Archibald et al., 1989). Cretaceous heating of the southwestern serpentinite mélangé belt is consistent with its structural setting within the metamorphic belt bounded by the Mission Ridge and Marshall Creek faults (Potter, 1986; Coleman, 1989; Schiarizza et al., 1990a, b); at least some of the heating is attributed to intrusion of a suite of late kinematic dioritic dikes which caused local prograde metamorphism within the mélangé (Archibald et al., 1989, 1990; Calon et al., 1990).

The 271 Ma date for the amphibolite knocker along the northwestern margin of the Shulaps complex is interpreted to be the age of cooling following metamorphism, deformation and plutonism related to ocean-floor construction of the Shulaps ophiolite. There is no indication of the late Cretaceous heating that affected the southwestern serpentinite mélangé belt, despite the fact that Late Cretaceous dikes and plugs are found throughout the northern part of the complex (Leech, 1983; Archibald et al., 1989, 1990; Schiarizza et al., 1990a, b). The lack of a Cretaceous overprint may reflect a structurally high origin for the northern and eastern Shulaps complex; these rocks may have been subsequently down-dropped on faults related to the Eocene Mission Ridge fault (Figure 1-8-2).

The Early Permian date provides the first direct evidence of the age of the oceanic crust and upper mantle represented by the Shulaps ultramafic complex. The new date is almost identical to recent U-Pb zircon dates obtained by Leitch (1989) from diorite and soda granite of the Bralorne intrusive complex, 20 kilometres to the southwest, which, together with associated ultramafic rocks, has also been inferred to be of ophiolitic affinity (Wright, 1974; Leitch, 1989). The Permian dates corroborate the correlation implied by Wright et al. (1982) who included the Shulaps complex, together with ultramafic and associated rocks near Bralorne, in the Bridge River ophiolite assemblage. The Permian dates also corroborate the structural interpretation advanced by Schiarizza et al. (1990c) which suggests that the rocks near Bralorne are actually part of the same imbricate thrust sheet as the Shulaps complex, which is repeated across a relatively late southwest-vergent reverse fault defining the eastern margin of the Bralorne fault system.

**BIOTITE REACTION ZONE IN THE SHULAPS ULTRAMAFIC COMPLEX**

**RESULTS**

The age spectrum for biotite from the biotite reaction zone (TL-88-24) is shown in Figure 1-8-2 and the analytical data are presented in Table 1-8-1. The sample yielded an integrated age of 46.4±0.6 Ma. With the exception of the first two and the last two steps (representing <5% of the gas released) the sample yields a well-defined plateau corresponding to an age of 46.6±0.5 Ma. This is interpreted as indicating the time the rock cooled through the argon closure temperature of biotite (ca. 280°C).

**DISCUSSION**

In light of the probable igneous origin, boudinage and postkinematic recrystallization of this rock, the 40Ar/39Ar plateau from the biotite is interpreted as the time of postemplacement cooling. In rocks 20 kilometres to the southeast, Coleman and Parrish (1990) have documented an Eocene plutonic event broadly synchronous with ductile deformation associated with dextral strike-slip faulting. Their U-Pb data indicate a period (48.5 and 46.5 Ma) of ductile deformation and dextral movement within the Bridge River schists related to strike-slip faulting on the northwest-trending Yakakom fault system. Intrusion of hornblende porphyry and felsite continued through later brittle phases of deformation, which included rapid uplift and tectonic denudation along the Mission Ridge fault (Coleman, 1989). Our data suggest that the southern part of the Shulaps ultramafic complex was the locus of Eocene granitoid emplacement and was involved in this Eocene tectonic event.

**SHEETED DIKES IN THE BRIDGE RIVER COMPLEX**

**RESULTS**

The age spectrum for a separate of brown amphibole from the centre of a 1.5-metre dike (TL-88-10) is shown in Figure 1-8-2; analytical data appear in Table 1-8-1. The sample yielded an integrated date of 108±7 Ma. The low-temperature steps (<980°C) are characterized by high 37Ar/39Ar ratios and high atmospheric argon contamination and account for 12 per cent of the 39Ar released from the sample. The higher temperature steps are more radiogenic and most of the gas released in these steps has a 37Ar/39Ar ratio of approximately 9.5 suggestive of release from a single phase. The release of 39Ar centred on a temperature of 1040°C is typical of hornblende rather than actinolite. These higher temperature steps (1010 to 1200°C) define a plateau date of 105±6 Ma. A correlation plot for the eight steps from 980 to 1200°C yields a well-defined isochron age of 107±3 Ma (2σ) and an initial 40Ar/39Ar ratio of 277±36 (2σ) with an MSWD of 2. The initial ratio is slightly lower than atmospheric argon and does not indicate the presence of excess argon. This date is the best estimate of the age of this sample and suggests that the area cooled through the argon closure temperature of hornblende in mid-Cretaceous time.

**DISCUSSION**

The sheeted dikes within the Bridge River complex were presumed by Schiarizza et al. (1989) to be an intrusive phase of the Bridge River greenstones, emplaced in a
spreading-centre environment within the Bridge River ocean basin. It is unlikely, however, that the mid-Cretaceous date reflects the age of relict Bridge River oceanic crust because cherts from the immediate area are Late Triassic in age (Cordey, 1986) and are only known to be as young as Middle Jurassic for the complex as a whole (F. Cordey, personal communication, July, 1990). The presence of the green amphibole rims suggests that the date may reflect cooling following reheating of the dikes under conditions sufficient to reset the K-Ar system of amphibole, but any such reheating is not reflected in surrounding Bridge River rocks which are at prehnite-pumpellyite metamorphic grade (Potter, 1986; Schiarizza et al., 1989, 1990a). It is considered more likely that the dikes are the products of a relatively magmatic event, unrelated to the ocean-floor construction of the plutonic-volcanic elements of the Bridge River complex. The multiple emplacement of the dikes may have been the source of heat for the alteration event (autometamorphism); thus the 107 Ma date is thought to indicate that dike emplacement and related alteration processes ended in late Early Cretaceous time. If dike emplacement was not a protracted event, then the 107 Ma date for the amphibole would provide a good estimate of the age of the dikes.

Regionally the latter part of the Early Cretaceous marked the beginning of a protracted episode of contractional deformation that extended into Late Cretaceous time (Garver, 1989; Schiarizza et al., 1990c). The early stages of deformation involved southwest-verging thrust imbrication of the Shulaps complex, Bridge River complex and Cadwallader Group, and deposition of a thick accumulation of synorogenic clastic sediments represented by the Taylor Creek Group. Therefore the sheeted gabbroic dikes were apparently emplaced during the final collapse and destruction of the Bridge River oceanic crust, rather than during construction of Bridge River oceanic crust as previously inferred (Schiarizza et al., 1989). The Early Cretaceous gabbroic dikes described herein, together with Late Cretaceous dioritic dikes emplaced during the late stages of contractional deformation within the Shulaps complex (Archibald et al., 1989, 1990), suggest that a prolonged episode of mafic to intermediate magmatism was coincident with the contractional deformation.

**SUMMARY AND CONCLUSIONS**

There are several conclusions which may be drawn concerning the timing of deformation, metamorphism and magmatism in the Taseko Lakes – Bridge River area:

- Blueschist-facies metamorphism and attendant deformation within the fault-bounded panels of blueschist are Middle Triassic or older events (230 Ma).

- The Shulaps complex is at least Permian (270 Ma) as the northwestern part of the complex records probable sea-floor metamorphism of at least this age. This age is nearly identical to the age of the Bralorne diorite and supports the correlation of the two mafic-ultramafic suites.

- The southern Shulaps ultramafic complex cooled through the argon closure temperature of biotite at 46.6 Ma during the waning stages of Middle Eocene magmatism and tectonism.

- Undefomed but hydrothermally altered, sheeted, gabbroic dikes were emplaced into the Bridge River complex at or before 107 Ma. They may be part of a suite of synorogenic mafic to intermediate intrusions emplaced during Early to Late Cretaceous contractional deformation.

- The step-heating results for amphibole from the Shulaps complex are consistent with a structural interpretation which suggests that the northern and eastern parts of the complex have been down-dropped and juxtaposed against higher grade rocks in the southwestern part of the complex by Eocene extension faults.

**ACKNOWLEDGMENTS**

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