British Columbia Geological Survey
Geological Fieldwork 1989

$^{40}Ar/^{39}Ar$ DATING AND THE TIMING OF DEFORMATION AND METAMORPHISM IN THE BRIDGE RIVER TERRANE, SOUTHWESTERN BRITISH COLUMBIA* (92O/2; 92J/15)

By D.A. Archibald, Queen's University
P. Schiarizza, Geological Survey Branch
and J.I. Garver, University of Washington

KEYWORDS: Geochronology, Ar-Ar dating, Bridge River, Tyaughton Creek, Bralorne, Noaxe Creek, Yalakom fault, blueschist, deformation, metamorphism.

INTRODUCTION

The Tyaughton Creek area lies approximately 200 kilometres north of Vancouver on the eastern margin of the Coast plutonic complex and west of the Yalakom fault. This area is the focus of a regional program of $^{40}Ar/^{39}Ar$ dating which was initiated in 1987 in the Warner Pass (92O/3) and Noaxe Creek (92O/2) map areas (Archibald *et al.*, 1989). In 1988 and 1989, the program continued with sampling in the Bralorne (92J/15) and Bridge River (92J/16) map areas (Figure 1-5-1). These latter areas are underlain by rocks of the Bridge River Terrane, and include a fault-bounded panel of blueschist facies metamorphic rocks and the Shulaps ultramafic complex. In this note we report $^{40}Ar/^{39}Ar$ step-heating data for white mica from the blueschist rocks and a hornblende from a porphyry which intruded the Shulaps ultramafic complex near the Yalakom fault.

GEOLOGIC SETTING OF THE SAMPLES

The regional and detailed geology has been outlined in a series of B.C. Ministry of Energy, Mines and Petroleum Resources publications. Of particular relevance to this study are the reports of the blueschist locality in the Eldorado Mountain area (Garver *et al.*, 1989a) and the summary of the geology of the Bridge River Terrane near the Shulaps ultramafic complex (Schiarizza *et al.*, 1989a, 1990, this volume; Calon *et al.*, 1990, this volume). Both samples selected for dating are from the Bridge River Terrane (Potter, 1986) which comprises imbricated Permian(?) to Jurassic oceanic sedimentary and volcanic rocks of the Bridge River complex together with the Shulaps ophiolite complex (Figure 1-5-2).

BLUESCHIST FACIES ROCKS

In the Tyaughton Creek area, blueschist and greenschist facies metamorphic rocks are structurally interleaved with rocks of lower metamorphic grade within a narrow northwest-trending belt that has been traced for 30 kilometres (Schiarizza *et al.*, 1989b). The best exposures occur in the drainage of North Cinnabar Creek where this package is unconformably overlain by middle 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 (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 low-angle 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-grained white mica lies 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.

HORNBLENDE PLAGIOCLASE PORPHYRY

The other sample selected for step-heating is an amphibole from a hornblende plagioclase porphyry dike which outcrops along the northeast margin of the Shulaps ultramafic complex. The hornblende from this sample yielded a $^{40}Ar/^{39}Ar$ total-fusion date of 75.6 ± .8 Ma (Archibald *et al.*, 1989). This area was remapped in 1989 and the interpretation of the geology and the previous date for this sample are revised.

This area was mapped first in 1987 as part of the Noaxe Creek map area (Glover *et al.*, 1988). At that time, the porphyry was considered to have intruded the Yalakom fault zone which was viewed as a zone, some 500 metres wide, characterized by penetratively deformed, serpentinized ultramafic rock, locally altered to a carbonate-quartz-fuchsite assemblage. The porphyry was mapped as a narrow dike, 1500 metres long, between and approximately parallel to two splays of the Yalakom fault. Although the margins of the dike are weakly foliated, it was inferred to have been emplaced after major movement on the fault.

In 1988, the imbricate zone along the south side of the Shulaps ultramafic complex was mapped in detail by T.J. Calon (Memorial University of Newfoundland) and the

* This project is a contribution to the Canada/British Columbia Mineral Development Agreement.

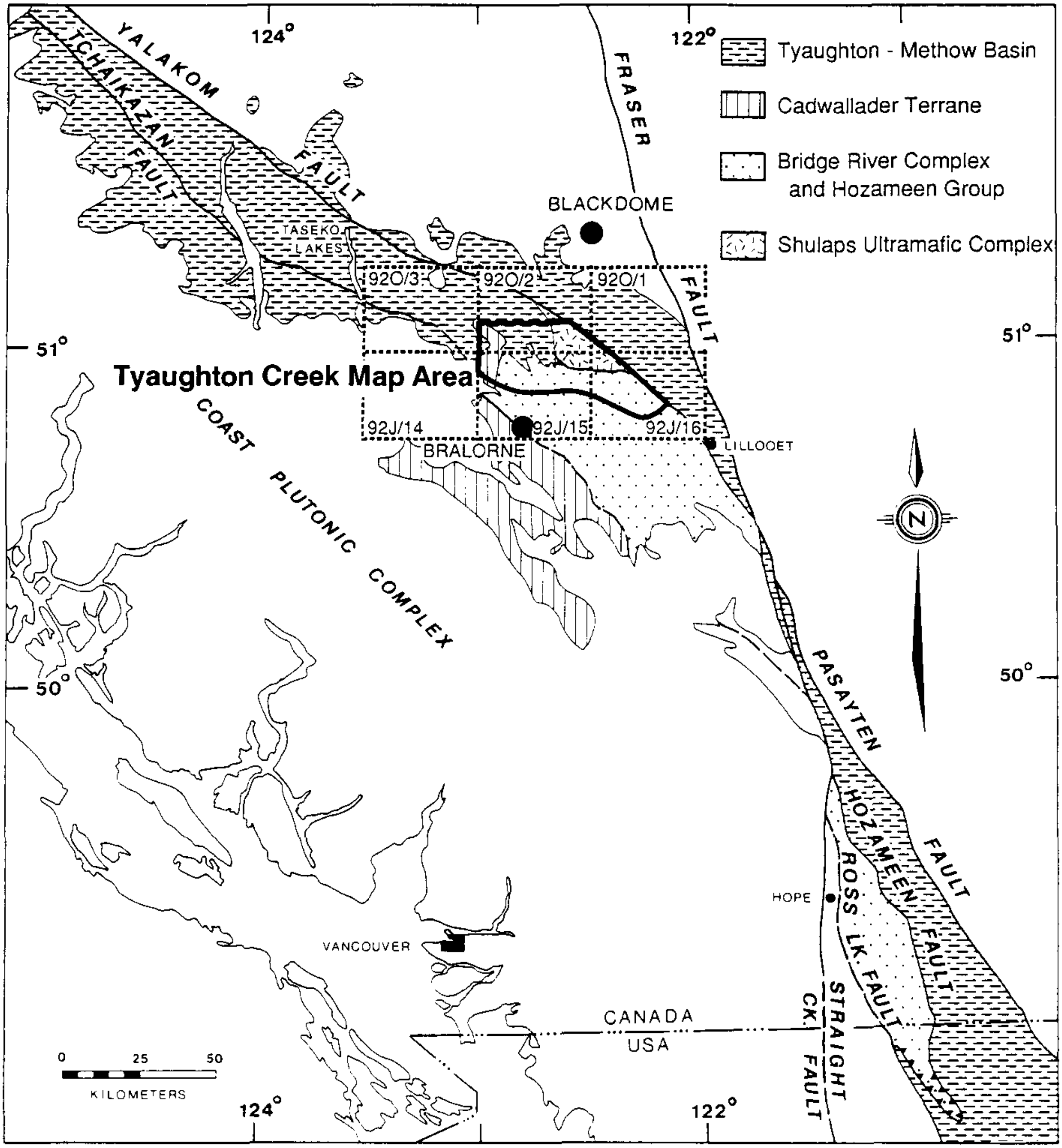

Figure 1-5-1. Location and geological setting, Tyaughton Creek map area.

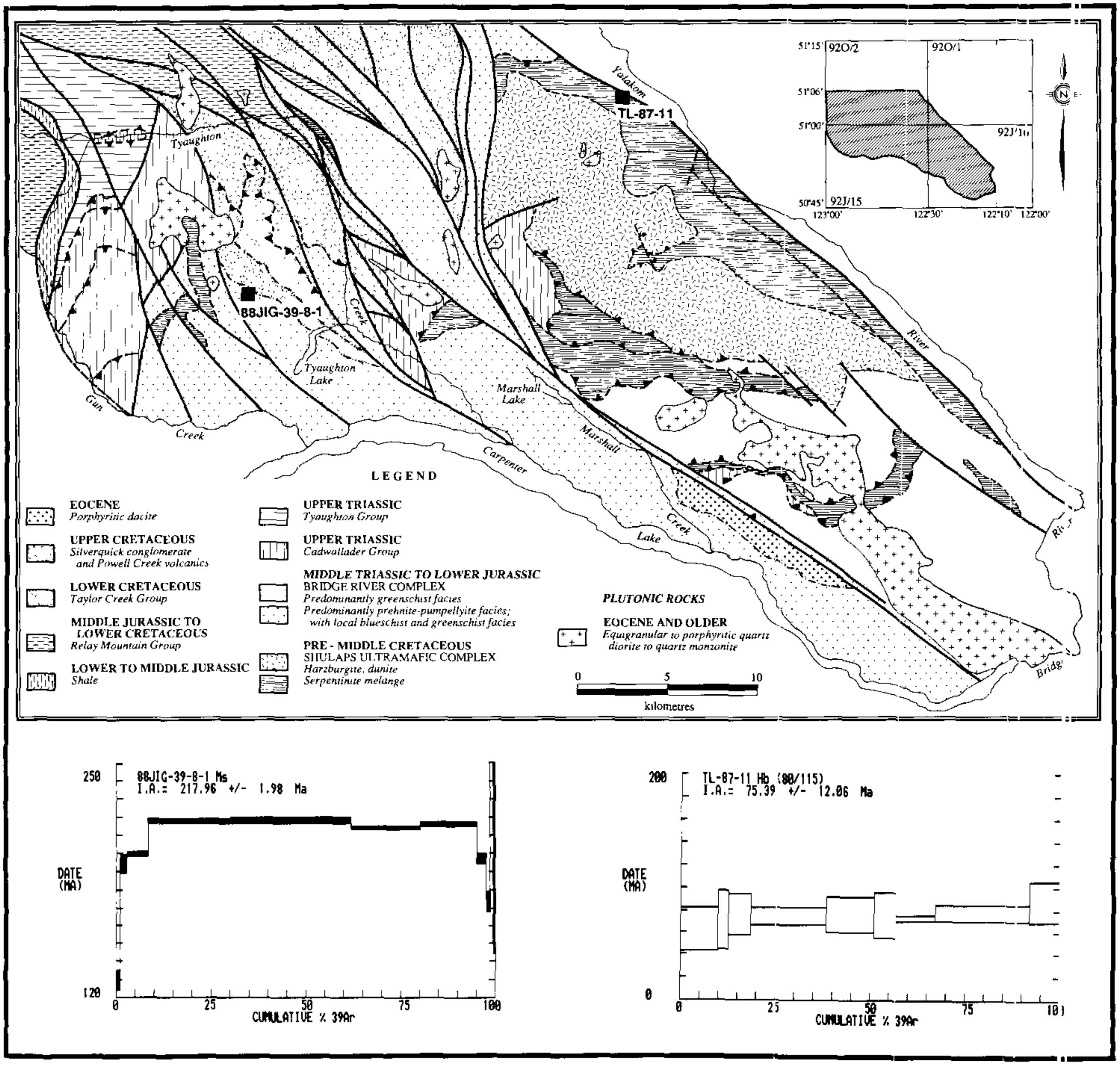

Figure 1-5-2. Sample locations and $^{40}Ar/^{39}Ar$ age spectra for rocks from the Bridge River Terrane, southwestern British Columbia.

authors. This work combined with that by Potter (1986) revealed a zone with up to 1000 metres of structural thickness of penetratively deformed serpentinite mélange which contains knockers of a variety of rock types. This zone is exposed along the southern margin of the Shulaps ultramafic complex where it lies structurally beneath harzburgite with a mantle tectonite fabric (Calon *et al.*, 1990). Although most of the knockers are ultramafic and mafic from the cumulate section of an ophiolite, some low-grade metasedimentary rocks and dioritic plutonic rocks are also present. The larger dioritic bodies occur as flattened pods with variably rodingitized margins. Locally, olivine has been regenerated from serpentine in the mélange. The smallest granitoid pods are completely replaced by rodingite but outcrop in linear (planar) zones suggesting the form of a discontinuous dike. The best-preserved dioritic rocks are characterized by blocky to acicular hornblende phenocrysts and are internally undeformed. In one knocker, an undeformed dike cuts penetratively deformed metasedimentary rocks but does not extend into the enclosing serpentinite.

In 1989 mapping along the north and northeast sides of the Shulaps ultramafic complex (Schiarizza *et al.*, 1990, this volume) revealed that the complex is broadly synformal such that the imbricate zone also outcrops in these areas. Contrary to the interpretation of Glover *et al.* (1988) and Archibald *et al.* (1989) it now appears that this penetratively deformed serpentinite containing knockers of ultramafic rocks, gabbro/amphibolite and aligned pods of hornblende plagioclase porphyry is part of the Shulaps imbricate zone and is not necessarily related to the Yalakom fault. A narrow zone of quartz-carbonate-fuchsite alteration a short distance to the northeast of the sample site may mark the position of the fault, which juxtaposes the Shulaps imbricate zone and Jura-Cretaceous sedimentary rocks to the northeast. Since the imbricate zone is cut by the Yalakom fault, the dike chosen for dating predates at least the latest movement on this fault. As low-potassium amphiboles commonly contain excess argon, step-heating was done to provide a more reliable date for this dike.

$^{40}Ar/^{39}Ar$ 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 30 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 monitors were done in a quartz tube heated using a Lindberg furnace. The bakeable, ultra-high vacuum, stainless steel argon-extraction system is operated on-line to a substantially modified A.E.I. MS-10 mass-spectrometer run in the static mode. Measured mass-spectrometric ratios were extrapolated to zero-time, corrected to an $^{40}Ar/^{36}Ar$ atmospheric ratio of 295.5, and corrected for neutron induced ^{40}Ar from potassium, and ^{39}Ar and ^{36}Ar from calcium. Dates and errors were calculated using formulae given by Dalrymple *et al.* (1981), and the constants recommended by Steiger and Jäger (1977). The errors shown in Table 1-5-1 were used to plot the age spectra in Figure 1-5-2; these represent the analytical precision at 2σ assuming that the error in the J-value is zero.

TABLE 1-5-1
$^{40}Ar/^{39}Ar$ STEP HEATING DATA

88JIG-39-8-1Ms
J = 0.00717

Temp °C	40/39 (1)	36/39 (1)	37/39 (1, 2)	Vol. ^{39}Ar $\times 10^{-8}$ cm³NTP (3)	f39	%^{40}Ar Rad.	Date ± 2σ (4, 5) Ma
500	26.518	0.0548	1.664	0.291	0.0102	39.34	130.4 ± 5.6
575	18.778	0.0100	3.411	0.508	0.0178	85.56	197.3 ± 5.0
675	17.555	0.0033	0.842	1.611	0.0563	94.64	203.3 ± 1.4
750	18.456	0.0007	0.019	6.208	0.2170	98.78	221.8 ± 1.1
800	18.391	0.0004	0.008	9.144	0.3196	99.31	222.2 ± 1.5
850	18.174	0.0008	0.024	5.208	0.1820	98.66	218.4 ± 0.9
900	18.304	0.0007	0.011	4.267	0.1492	98.83	220.2 ± 1.2
960	17.463	0.0037	0.053	0.659	0.0230	93.60	200.1 ± 3.0
1020	18.773	0.0151	0.086	0.283	0.0099	76.11	175.8 ± 5.7
1070	25.391	0.0093	0.202	0.248	0.0087	89.19	271.7 ± 8.0
1200	30.426	0.0428	0.334	0.181	0.0063	58.48	216.8 ± 72.6

Weight = 90 mg
Total ^{39}Ar = 28.608 × 10⁻⁸ cm³NTP
I.A. = 218.1 ± 1.9 Ma
P.A. = 221.0 ± 1.2 Ma; 750 to 900°C

TL-87-11 Hb (80/115)
J = 0.00718

Temp °C	40/39 (1)	36/39 (1)	37/39 (1, 2)	Vol. ^{39}Ar $\times 10^{-9}$ cm³NTP (3)	f39	%^{40}Ar Rad.	Date ± 2σ (4, 5) Ma
725	52.752	0.1630	4.401	2.853	0.0978	9.27	62.4 ± 20.1
825	19.175	0.0494	12.065	0.843	0.0289	28.58	70.2 ± 26.8
925	18.164	0.0433	8.749	1.751	0.0600	33.04	76.5 ± 18.8
975	7.548	0.0089	12.086	5.759	0.1975	77.12	74.4 ± 8.2
1000	8.540	0.0116	11.837	3.656	0.1254	69.98	76.4 ± 15.8
1025	11.485	0.0216	11.346	1.691	0.0580	51.72	75.9 ± 20.6
1050	10.654	0.0197	12.528	3.067	0.1052	53.83	73.4 ± 2.8
1100	8.585	0.0116	12.921	7.233	0.2480	71.10	78.0 ± 6.8
1200	11.424	0.0182	11.156	2.313	0.0793	60.11	87.5 ± 17.8

Weight = 200 mg
Total ^{39}Ar = 29.166 × 10⁻⁹ cm³NTP
I.A. = 75.4 ± 12.1 Ma
P.A. = 77.0 ± 10.7 Ma; 925 to 1200°C

(1) True ratios corrected for fractionation and discrimination.
(2) $^{37}Ar/^{39}Ar$ is corrected for the decay of ^{37}Ar during and after irradiation using a ^{37}Ar half-life of 35.1 days.
(3) Volume of ^{39}Ar is determined using equilibration peak height and mass spectrometer sensitivity.
(4) Isotope production ratios for the McMaster reactor are from Masliwec (1981).
(5) Ages calculated using the constants recommended by Steiger and Jäger (1977). Errors represent the analytical precision only (i.e., error in J value = 0). Flux monitor used: LP-6 Biotite at 128.5 Ma.
(6) I.A. – integrated age for all steps. P.A. = plateau age.

RESULTS AND DISCUSSION

BLUESCHIST FACIES ROCKS

RESULTS

The age spectrum for the white mica from the blueschist locality (88JIG-39-8-1) is shown in Figure 1-5-2; analytical data are listed in Table 1-5-1. The integrated age of this sample is 218.1 ± 1.9 (2σ) Ma which is in the middle of the range of previous dates for this site (Permo-Triassic; Garver *et al.*, 1989b). The 500°C step yields a date of 130 Ma, and dates for subsequent steps increase to 222 Ma for the 750°C step. The steps from 750° and 900°C yield a well-defined plateau date of 221.0 ± 1.2 (2σ) Ma for 87 per cent of the ^{39}Ar released from the sample. In this temperature range, the $^{37}Ar/^{39}Ar$ ratio ranges from 0.008 to 0.024 which corresponds to the low Ca/K ratio of phengite (*e.g.*, Sisson and Onstott, 1986). The age spectrum (at least to the 960°C step) approximates the form of a volume diffusion loss-profile. Comparison of the spectrum to computed loss-profiles suggests that the sample has only lost a small amount (<10 per cent) of argon through post-Triassic reheating. Thus, it appears that blueschist facies metamorphism in the Bridge River Terrane was over by at least 221 Ma (Late Triassic time).

DISCUSSION

The white mica from the blueschist contains a record of two tectonothermal events. The earlier event is Late Triassic or older and is revealed in the broad plateau segment of the age spectrum. 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 221 Ma plateau date implies that both deformation and metamorphism are at least this old.

The low dates for the initial steps indicate that the area was affected by a thermal event in post-Late Triassic time. This fact may provide an explanation of the wide range of dates reported by Garver *et al.* (1989b). The older K-Ar dates [244 ± 7 (1σ) Ma] may be from samples which experienced overprinting to a lesser degree. Ideally, the age of the overprint should be given by the first fraction of argon released in a step-heating experiment; for small losses, the higher temperature plateau segment should approach the "true" cooling age of the sample. In practice, however, the age of the initial step is a relatively inaccurate estimate and only serves as a guide (usually a maximum) to the timing of the event. The region contains several small, high-level, mid-Cretaceous and younger plutons which may have overprinted the white mica; however, there are none within a kilometre of the sample site. It is more probable that the overprint is the result of a more pervasive thermal event that may have been coincident with structural thickening associated with contractional deformation between 110 and 85 Ma (Garver, 1989).

As noted by Garver *et al.* (1989a), in this area, overturned strata of the mid-Cretaceous Taylor Creek Group and overlying Silverquick conglomerate are in apparent thrust contact with upright strata of the Silverquick conglomerate. Unconformably underlying the Taylor Creek Group are the blueschist and greenschist rocks of the Bridge River Terrane. The overturning and thrusting occurred during a widely-recognized phase of mid-Cretaceous compressional tectonics that ended prior to emplacement of several Late Cretaceous plutons of the coast plutonic complex (85 Ma; Garver *et al.*, 1989a). The 130 Ma date from the first step of the age spectrum suggests that this event was the source of the thermal disturbance recorded in the age spectrum of the white mica. Based on modelling of the age spectrum, the thermal event must have been of short duration and/or 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) is favoured for this sample. The two K-Ar dates older than this (reported by Garver *et al.*, 1989b) remain problematic and additional analyses of white mica are planned.

HORNBLENDE PLAGIOCLASE PORPHYRY

RESULTS

The age spectrum for the amphibole from the hornblende plagioclase porphyry (TL-87-11) is shown in Figure 1-5-2; analytical data are listed in Table 1-5-1. The integrated date for this age spectrum is 75.4 ± 12.1 (2σ) Ma which is identical to the previously reported $^{40}Ar/^{39}Ar$ total-fusion date (Archibald *et al.*, 1989). The three lowest temperature steps are characterized by low radiogenic content, erratic $^{37}Ar/^{39}Ar$ ratios and large errors. In contrast, the remaining, higher temperature steps, representing 81 per cent of the total ^{39}Ar, have a consistent $^{37}Ar/^{39}Ar$ ratio in the range 11.2 to 12.9, are much more radiogenic and represent the main pulse of argon release from the amphibole. These steps define a plateau date of 77 ± 11 (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 or of the presence of initial argon, and thus, we consider the plateau date to be a reliable cooling age. This date indicates that the dike is not younger than Late Cretaceous.

DISCUSSION

The amphibole from the diorite dike in the imbricate zone within the lower structural levels of the Shulaps ultramafic complex yielded a cooling age of 77 ± 11 Ma. This may or may not be the time of emplacement, however, the date does indicate that the dike cooled through 500°C (the approximate closure temperature for argon diffusion in hornblende) in Late Cretaceous time. These dikes are common in the imbricate zone, were emplaced synkinematically and appear to have been the source of major reheating in this structural panel. Evidence of reheating in the imbricate zone is preserved in the age spectrum for amphibole in a knocker of brecciated amphibolite (Archibald *et al.*, 1989). This rock is from the southern part of the imbricate zone and presumably is the same age as the oceanic crust that formed part of the protolith of the Shulaps complex. The plateau segment in this age spectrum is, within analytical error, identical to the age from the diorite dike. There is no evidence of the undoubtedly older, seafloor metamorphism that produced the rock, or of cooling related to mid-Jurassic obduction as postulated by Potter (1986). Thus, the brecciated amphibolite was reheated to at least greenschist-facies conditions and cooled through 500°C in Late Cretaceous time.

The duration of this reheating event is, at present, unknown. Within the study area, most magmatic rocks that postdate the 85 Ma and older Coast plutonic complex are Paleocene or younger (Archibald *et al.*, 1989) rather than Late Cretaceous. However, on a regional scale, there is evidence of plutonic/thermal activity in the interval from 78 to 73 Ma. In the Warner Pass map area, sericitic alteration and alunite associated with mineralization yield total-fusion $^{40}Ar/^{39}Ar$ dates in this range (Archibald *et al.*, 1989). Further, rocks with a similar thermotectonic history are present in the North Cascades crystalline core of Washington and southern British Columbia, which by mid-Cretaceous time shares the same tectonic history and was probably continuous along strike to the south of the study area. The crystalline core contains granitoid rocks of this age, many of which have both primary and cooling ages in this interval (Tabor *et al*. 1989; Journeay and Csontos, 1989). Some of these are epidote tonalites which were emplaced at deep crustal levels. Although circumstantial, the scattered occurrences of dates in this range in the Tyaughton Creek area may reflect this short-lived episode of magmatic activity. It is possible that in British Columbia plutonic rocks of this age were emplaced where the crust was cut by major faults such as the basal décollement of the Shulaps ultramafic complex or the Yalakom and Marshall Creek strike-slip faults which bound the western and northeastern margins of the Shulaps complex.

SUMMARY AND CONCLUSIONS

Several conclusions may be drawn concerning the timing of deformation and metamorphism in the Bridge River Terrane:

- Blueschist facies metamorphism and attendent deformation within the fault-bounded panels of blueschist are Late Triassic events (>221 Ma). As the age of the Bridge River complex is in part Permo-Triassic, subduction may have involved relatively young oceanic crust.
- Imbrication of the blueschist-bearing rocks and adjacent rocks, both of which contain metamorphic prehnite, may have been an Early Cretaceous event ($\approx$130 Ma) or a mid-Cretaceous event ($\approx$110–95 Ma) related to major structural thickening which produced increased thermal activity. This thermal event was (locally) short lived and temperatures were probably much less than 350°C.
- Hornblende diorite dikes intruded the imbricate zone at the base of the Shulaps ultramafic complex in Late Cretaceous time (>77 Ma) during the final stages of emplacement and uplift of the complex. This event predates, or was synchronous with at least some of the movement on the Yalakom fault. The dikes appear to be restricted to the Shulaps complex which suggests that bounding faults acted as a conduit that tapped (deep?) sources of magma.
- Although Rusmore *et al.* (1988) argue for Middle Jurassic terrane accretion during closure of the Bridge River–Cache Creek ocean basin, to date, there is no isotopic evidence of thermal activity related to this event in the Tyaughton Creek map area.

ACKNOWLEDGMENTS

This project was funded in part by the Canada/British Columbia Mineral Development Agreement through research agreements to D.A.A. and J.I.G. Partial support for field and laboratory expenses was provided by an Energy, Mines and Resources Canada Research Agreement to D.A.A. The Geochronology Laboratory at Queen's University is supported by a National Science and Engineering Research Council operating grant and a Queen's University Advisory Research Committee grant to E. Farrar.

REFERENCES

Archibald, D.A., Glover, J.K. and Schiarizza, P. (1989): Preliminary Report on $^{40}Ar/^{39}Ar$ Geochronology of the Warner Pass, Noaxe Creek and Bridge River Map Areas (92O/3, 2; 92J/16); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork 1988, Paper 1989-1, pages 145-151.

Calon, T.J., Malpas, J.G. and Macdonald, R. (1990): The Anatomy of the Shulaps Ophiolite; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork 1989, Paper 1990-1, this volume.

Dalrymple, G.B., Alexander, E.C.Jr., Lanphere, M.A. and Kraker, G.P. (1981): Irradiation of Samples for $^{40}Ar/^{39}Ar$ Dating Using the Geological Survey TRIGA Reactor; *U.S. Geological Survey*, Professional Paper 1176, 55 pages.

Garver, J.I. (1989): Basin Evolution and Source Terranes of Albian-Cenomanian Rocks in the Tyaughton Basin, Southern British Columbia: Implications for Mid-Cretaceous Tectonics in the Canadian Cordillera; unpublished Ph.D. thesis, *University of Washington*, 227 pages.

Garver, J.I., Schiarizza, P. and Gaba, R.G. (1989a): Stratigraphy and Structure of the Eldorado Mountain Area, Chilcotin Ranges, Southwestern British Columbia (92O/2; 92J/15); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork 1988, Paper 1989-1, pages 131-143.

Garver, J.I., Till, A.B., Armstrong, R.L. and Schiarizza, P. (1989b): Permo-Triassic Blueschist in the Bridge River Complex, Southern British Columbia; *Geological Society of America*, Abstracts with Programs, Volume 21, Number 5, page 82.

Glover, J.K., Schiarizza, P. and Garver, J.I. (1988): Geology of the Noaxe Creek Map Area (92O/2); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork 1987, Paper 1988-1, pages 105-123.

Journeay, M. and Csontos, L. (1989): Preliminary Report on the Structural Setting along the Southeast Flank of the Coast Belt, British Columbia; *in* Current Research, Part E, *Geological Survey of Canada*, Paper 89-1E, pages 177-187.

Masliwec, A. (1981): The Direct Dating of Ore Minerals; unpublished M.Sc. thesis, *University of Toronto*.

Potter, C.J. (1986): Origin, Accretion and Post-accretionary Evolution of the Bridge River Terrane, Southwest British Columbia; *Tectonics*, Volume 5, pages 1027-1041.

Rusmore, M.E., Potter, C.J. and Umhoefer, P.J. (1988): Middle Jurassic Terrane Accretion along the Western Edge of the Intermontane Superterrane, Southwestern British Columbia; *Geology*, Volume 16, pages 891-894.

Schiarizza, P., Gaba, R.G., Glover, J.K. and Garver, J.I. (1989a): Geology and Mineral Occurrences of the Tyaughton Creek Area (92O/2, 92J/15, 16); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork 1988, Paper 1989-1, pages 115-130.

Schiarizza, P., Gaba, R.G., Garver, J.I., Glover, J.K., Church, B.N., Umhoefer, P.J., Lynch, T., Sajgalik, P.P., Safton, K.E., Archibald, D.A., Calon, T., Maclean, M., Hanna, M.J., Riddell, J.L. and James, D.A.R. (1989b): Geology and Mineral Potential of the Tyaughton Creek area (92J/15, 16; 92O/2); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1989-4.

Schiarizza, P., Gaba, R.G., Coleman, M. and Garver, J. I. (1990): Geology and Mineral Occurrences of the Yalakom River Area; *B.C. Ministry of Energy, Mines and Petroleum Resources,* Geological Fieldwork 1989, Paper 1990-1, this volume.

Sisson, V.B. and Onstott, T.C. (1986): Dating Blueschist Metamorphism: A Combined $^{40}Ar/^{39}Ar$ and Electron Microprobe Approach; *Geochimica et Cosmochimica Acta,* Volume 50, pages 2111-2117.

Steiger, R.H. and Jäger, E. (1977): Subcommission on Geochronology: Convention on the Use of Decay Constants in Geo- and Cosmo-chronology; *Earth and Planetary Science Letters,* Volume 36, pages 359-362

Tabor, R.W., Haugerud, R.A. and Miller, R.B. (1989): Overview of the Geology of the North Cascades; *American Geophysical Union,* International Geological Congress Trip T307, 62 pages.

NOTES