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

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

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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 Yalakom fault (Figure 1-8-1). This area is the focus of a regional program of ^{40}Ar/^{39}Ar dating which was initiated in 1987 in the Warner Pass (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. 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 (Bralorne, 92J/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 mélange 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

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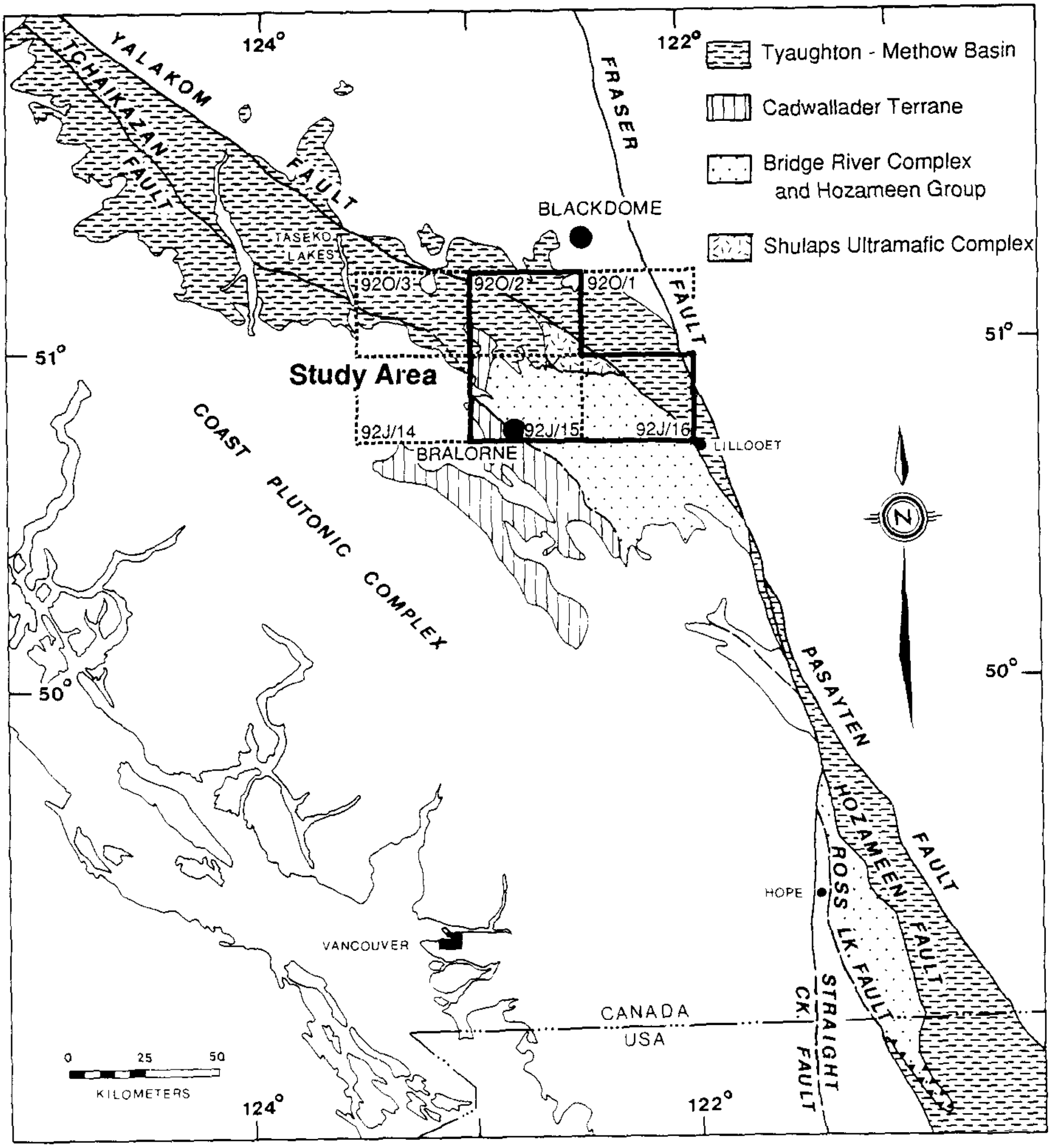

Figure 1-8-1. Location and geological setting, Tascko Lakes–Bridge River map area.

conglomerate. The serpentinite mélange unit sits structurally above the Cadwallader Group, which in turn sits structurally above the Bridge River complex. The southwestern serpentinite mélange unit has been sampled extensively for dating and amphibole has yielded a 73 Ma date that is thought to reflect uplift and cooling following synkinematic 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 serpentinite and serpentinite mélange which sit structurally above sub-greenschist facies rocks of the Bridge River complex (Schiarizza *et al.*, 1990a, b). These rocks are separated from the higher metamorphic-grade rocks to the southwest by a system of faults that may be a northwestward 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 complex was therefore undertaken to compare its thermal history 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 metasomatic 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 traces 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 several 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 incorporated during an earlier episode of thrust faulting, or a tectonothermally 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, displays even extinction, and has very ragged grain boundaries. The lack of a penetrative fabric in the phacoid or its margin indicates postemplacement recrystallization that was primarily 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 information 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 approximately 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 pegmatitic 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 variable 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 subhedral 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 rind 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.

$^{40}Ar/^{39}Ar$ 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 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 monitors 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

TABLE 1-8-1
^{40}Ar/^{39}Ar STEP-HEATING DATA

TL-88-1a White Mica (−40 mesh)

Weight (mg) = 100
J = 0.006888

Temp. °C	40/39 (1)	36/39 (1)	37/39 (1, 2)	Vol. ^{39}Ar × 10^{-8} cc NTP (3)	f39	%^{40}Ar Rad.	DATE (4, 5)	± 2σ Ma
500	38.423	0.0845	0.592	0.156	0.0044	34.81	158.3	±33.4
575	27.209	0.0254	4.707	0.326	0.0093	73.71	234.1	± 7.3
675	22.104	0.0050	0.919	1.051	0.0299	93.55	240.4	± 4.3
725	20.909	0.0043	0.130	2.056	0.0585	93.96	229.0	± 2.5
775	20.631	0.0034	0.017	3.294	0.0937	95.00	228.5	± 0.4
800	20.440	0.0018	0.009	4.310	0.1226	97.36	231.8	± 0.7
825	20.364	0.0022	0.015	8.643	0.2458	96.78	229.6	± 0.8
850	20.497	0.0027	0.014	4.832	0.1374	96.07	229.5	± 0.8
875	20.509	0.0025	0.006	5.920	0.1684	96.37	230.3	± 0.8
900	20.236	0.0021	0.015	2.220	0.0631	96.88	228.5	± 1.3
1000	20.507	0.0027	0.028	1.795	0.0510	96.11	229.7	± 2.4
1200	21.908	0.0066	0.250	0.560	0.0159	91.18	232.6	± 5.0
				35.163			229.9	± 1.3

Total ^{39}Ar = 35.163 × 10^{-8} cm^3 NTP
I.A. = 229.9±1.3 Ma
P.A. = 229.8±1.0 Ma
Plateau steps: 725 to 1000°C

TL-88-23 Hornblende 80/140 mesh

Weight (mg) = 200
J = 0.007

Temp. °C	40/39 (1)	36/39 (1)	37/39 (1, 2)	Vol. ^{39}Ar × 10^{-8} cc NTP (3)	f39	%^{40}Ar Rad.	DATE (4, 5)	± 2σ Ma
700	100.838	0.2808	12.947	0.0897	0.0601	18.65	224.8	±40.4
800	34.480	0.0682	11.829	0.0524	0.0351	44.03	183.6	±19.8
870	41.555	0.0981	13.367	0.0349	0.0234	32.59	164.7	±91.0
940	35.333	0.0556	26.631	0.0780	0.0523	59.03	249.8	±32.0
1000	27.030	0.0246	28.050	0.4842	0.3247	80.68	260.6	± 8.1
1040	31.048	0.0391	24.846	0.1333	0.0894	68.64	254.7	± 6.8
1070	35.353	0.0512	25.984	0.0955	0.0640	62.59	263.9	±30.1
1100	28.684	0.0285	28.741	0.3090	0.2072	77.95	266.9	± 6.3
1200	29.893	0.0348	28.069	0.2144	0.1438	72.44	259.0	± 8.8
				1.4912			253.7	±14.7

Total ^{39}Ar = 1.4912 × 10^{-8} cm^3 NTP
I.A. = 253.7±14.7 Ma
P.A. = 260.8±10.7 Ma
Plateau steps: 940 to 1200°C

TL-88-24 Biotite 80/140 mesh

Weight (mg) = 185
J = 0.007

Temp. °C	40/39 (1)	36/39 (1)	37/39 (1, 2)	Vol. ^{39}Ar × 10^{-8} cc NTP (3)	f39	%^{40}Ar Rad.	DATE (4, 5)	± 2σ Ma
500	22.217	0.0697	0.155	0.523	0.0084	7.26	20.27	±3.82
540	6.845	0.0116	0.118	1.263	0.0203	50.05	42.76	±0.77
580	4.789	0.0037	0.083	3.598	0.0579	76.98	45.96	±0.64
625	4.196	0.0015	0.023	7.742	0.1247	89.39	46.75	±0.35
670	4.079	0.0012	0.001	6.764	0.1089	90.99	46.28	±0.26
710	4.299	0.0019	0.000	3.350	0.0539	86.68	46.46	±0.72
760	4.662	0.0034	0.000	2.001	0.0322	77.89	45.29	±1.30
810	4.594	0.0027	0.000	2.127	0.0342	82.18	47.06	±1.53
860	4.221	0.0014	0.000	3.819	0.0615	89.65	47.17	±0.51
910	4.011	0.0008	0.000	9.026	0.1453	93.82	46.91	±0.35
960	3.959	0.0007	0.000	11.216	0.1806	94.38	46.58	±0.31
1010	4.073	0.0011	0.010	9.331	0.1502	91.95	46.69	±0.42
1060	5.298	0.0050	0.341	0.809	0.0130	72.40	47.82	±4.55
1200	7.299	0.0105	0.755	0.536	0.0086	57.94	52.66	±3.55
				62.105			46.37	±0.58

Total ^{39}Ar = 62.105 × 10^{-8} cm^3 NTP
I.A. = 46.37±0.58 Ma
P.A. = 46.62±0.52 Ma
Plateau steps: 580 to 1060°C

TL-88-10 Brown Hornblende 80/120 mesh

Weight (mg) = 200
J = 0.007

Temp. °C	40/39 (1)	36/39 (1)	37/39 (1, 2)	Vol. ^{39}Ar × 10^{-8} cc NTP (3)	f39	%^{40}Ar Rad.	DATE (4, 5)	± 2σ Ma
825	25.987	0.0582	11.421	0.2009	0.0563	37.00	118.4	± 1.1
900	20.062	0.0337	28.618	0.0803	0.0225	60.87	150.6	±18.4
925	19.529	0.0417	16.726	0.0563	0.0158	43.20	104.6	±43.9
950	14.552	0.0210	13.807	0.0798	0.0224	64.25	115.4	±13.8
980	10.346	0.0080	12.278	0.3226	0.0905	85.97	109.8	± 7.7
1010	9.735	0.0067	11.043	0.4535	0.1272	87.83	105.6	± 4.7
1040	9.672	0.0067	9.207	0.8371	0.2348	86.52	103.3	± 6.2
1070	10.260	0.0080	9.527	0.6117	0.1716	83.62	105.9	± 1.7
1100	11.189	0.0107	9.533	0.5013	0.1406	77.99	107.6	± 4.4
1130	13.090	0.0179	9.299	0.2760	0.0774	64.68	104.5	±12.6
1160	21.174	0.0497	9.066	0.0760	0.0213	33.82	88.8	± 8.1
1200	22.816	0.0461	9.699	0.0702	0.0197	43.36	121.5	±22.1
				3.5655			107.6	± 6.7

Total ^{39}Ar = 3.5655 × 10^{-8} cm^3 NTP
I.A. = 107.6±6.7 Ma
P.A. = 105.2±5.7 Ma
Plateau steps: 1010 to 1200°C

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(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.

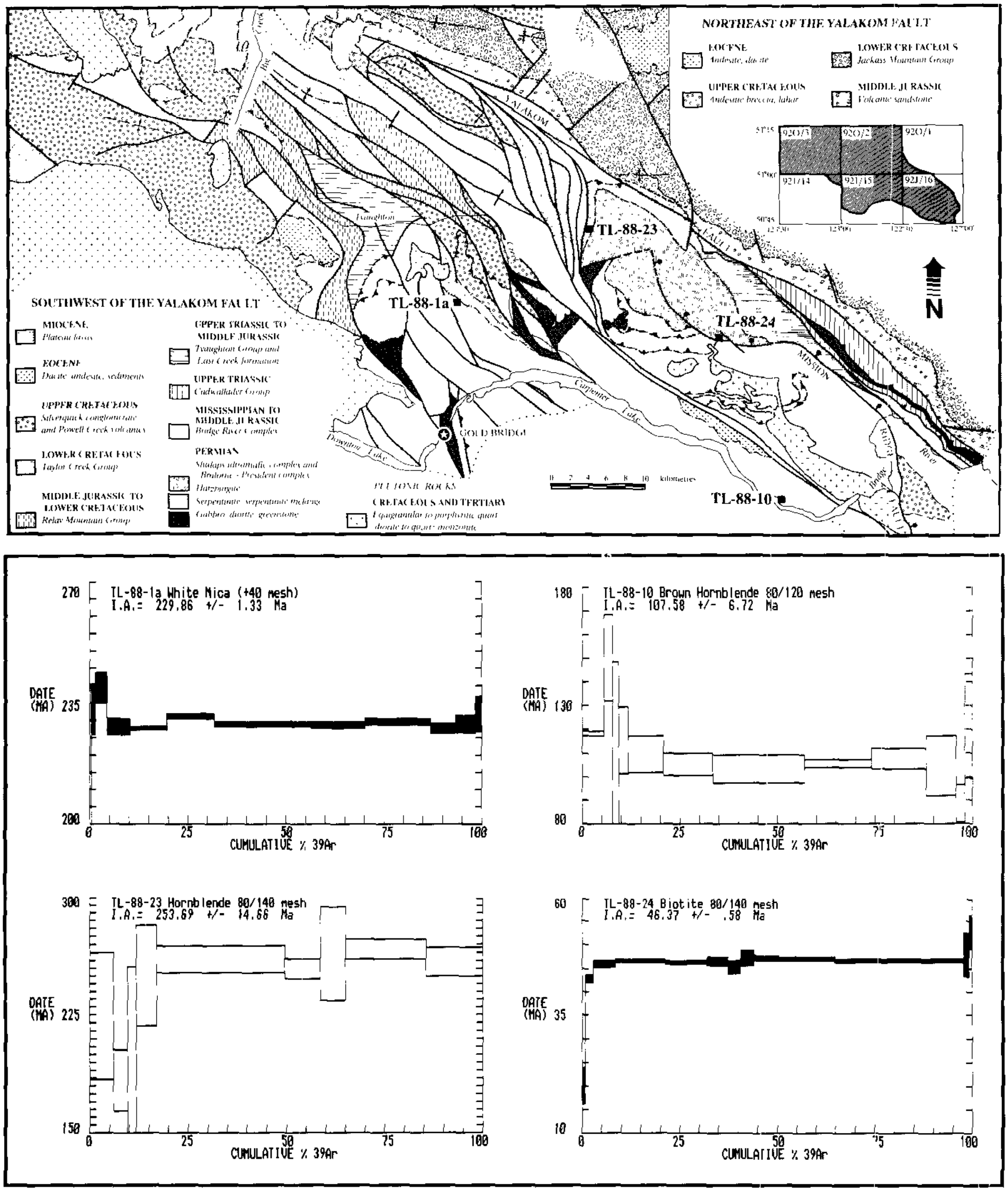

Figure 1-8-2. Sample locations and $^{40}Ar/^{39}Ar$ age spectra for rocks from the Bridge River and Shulaps complexes, southwestern British Columbia.

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 1-8-1 were used to plot the age spectra in Figure 1-8-2; these represent the analytical precision at 2σ assuming that the error in the J-value is zero.

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 (Permo-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° to 1200°C yield a well-defined plateau date of 229.8±1.0 (2σ) Ma for 95 per cent of the ^{39}Ar released from the sample. In this temperature range, the $^{37}Ar/^{39}Ar$ 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 overlying 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; Calon *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 date for this age spectrum is 253.7±14.7 Ma (2σ). The four 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 83 per cent of the total ^{39}Ar, have a consistent $^{37}Ar/^{39}Ar$ ratio averaging 27±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 $^{40}Ar/^{36}Ar$ ratio of 257±68 (2σ) (slightly less than the expected atmospheric argon ratio of 295.5) and an older age for the plateau segment of 271±16 Ma (2σ; MSWD=0.9 for steps: 940° 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 mélange 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 mélange belt which developed during and between plutonic episodes (Calon *et al.*, 1990). Amphibole from the knocker in the southwestern mélange 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 mélange 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 mélange (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 mélange belt, despite the fact that Late Cretaceous dikes and plugs are found throughout the northern part of the complex (Leech, 1953; 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 $^{40}Ar/^{39}Ar$ 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 Yalakom 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 $^{37}Ar/^{39}Ar$ ratios and high atmospheric argon contamination and account for 12 per cent of the ^{39}Ar released from the sample. The higher temperature steps are more radiogenic and most of the gas released in these steps has a $^{37}Ar/^{39}Ar$ ratio of approximately 9.5 suggestive of release from a single phase. The release of ^{39}Ar 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 $^{40}Ar/^{36}Ar$ 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 young 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 ocean basin, 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 attendent 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.
- Undeformed 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.

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