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New U-Pb ages from the Eastern Coast Belt, southern British Columbia

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GSC Pacific

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Abstract: Six new U-Pb ages for southern Coast Belt plutons are presented. A 66.6 ± 1.1 Ma titanite age from the Machmell pluton within the southern Coast shear zone provides a maximum age for motion at that location. In the eastern Waddington thrust belt, the Homathko Peak tonalite, a fault slice within the belt, is 153.4 ± 0.3 Ma; the postkinematic Tiedemann pluton is early Tertiary.

In the Mount Raleigh area, a monazite date of 85.0 ± 0.5 Ma provides a minimum age for crystallization and a maximum age for amphibolite-facies metamorphism of the Sisyphus Creek leucogranite. The synkinematic Mount Gilbert pluton crystallized at 83.6 ± 0.2 Ma, indicating that metamorphism and thrusting in the Mount Raleigh pendant occurred at that time. The postkinematic Bishop River pluton intruded at 72.2 ± 0.4 Ma.

Similarities between the Mount Raleigh and eastern Waddington areas indicate that they form part of an extensive Late Cretaceous fold-and-thrust belt in the eastern Coast Belt.

Résumé : On présente six nouvelles datations U-Pb de plutons situés dans le sud du Domaine côtier. Un âge de 66,6 ± 1,1 Ma pour la titanite du pluton de Machmell dans le sud de la zone de cisaillement du Domaine côtier fournit un âge maximal pour le déplacement à cet endroit. Dans l'est de la zone de chevauchement de Waddington, la tonalite de Homathko Peak, écaille au sein de la ceinture, date de 153,4 ± 0,3 Ma; le pluton post-cinématique de Tiedemann remonte au Tertiaire précoce.

Dans la région du mont Raleigh, la datation d'une monazite à 85,0 ± 0,5 Ma permet d'établir l'âge minimal de la cristallisation et l'âge maximal du métamorphisme du faciès des amphibolites du leucogranite de Sisyphus Creek. Le pluton syncinématique de Mount Gilbert s'est cristallisé à 83,6 ± 0,2 Ma, ce qui indique qu'il y a eu métamorphisme et charriage dans l'apophyse de Mount Raleigh à cette époque. L'intrusion du pluton post-cinématique de Bishop River remonte à 72,2 ± 0,4 Ma.

Les similarités observées entre la région du mont Raleigh et la partie est de la région de Waddington indiquent qu'ils font partie d'une vaste zone de plissement et de chevauchement du Crétacé tardif dans l'est du Domaine côtier.

INTRODUCTION

The Coast Belt, nearly 1800 km long, forms the core of one of the longest mountain belts on the western edge of North America and one of the largest Mesozoic and Tertiary granitoid and metamorphic complexes anywhere. The Coast Belt was the site of voluminous calc-alkaline plutonism from Early Jurassic and Eocene time and records several large-scale tectonic events (e.g. Woodsworth et al., 1991; van der Heyden, 1992; Journeay and Friedman, 1993). A major question in Coast Belt tectonics and the subject of much ongoing research is the mid-Cretaceous to Eocene structural history of the Coast Belt (e.g. Andronicos et al., 1999, at the latitude of Prince Rupert; Journeay and Monger, 1998, for the south end of the Coast Belt; and Rusmore and Woodsworth, 1994, for the region in between; and references therein).

The mid-Cretaceous history of the belt is mainly one of formation and synchronous shortening of a volcanic arc or arcs and development of a northwest-striking thrust belt along much of its length; this belt is west-vergent on the west side of the orogen (e.g. Rubin et al., 1990; Journeay and Friedman, 1993) and east-vergent on the east (e.g. Rusmore and Woodsworth, 1994). The early Tertiary tectonic history is perhaps less well understood. The major early Tertiary structure recognized to date is the Coast shear zone, which extends over 1200 km from Juneau, Alaska, southeastward within the Coast Belt (Fig. 1). It is steeply dipping in most places and had a northeast-side-up sense of shear during its history.

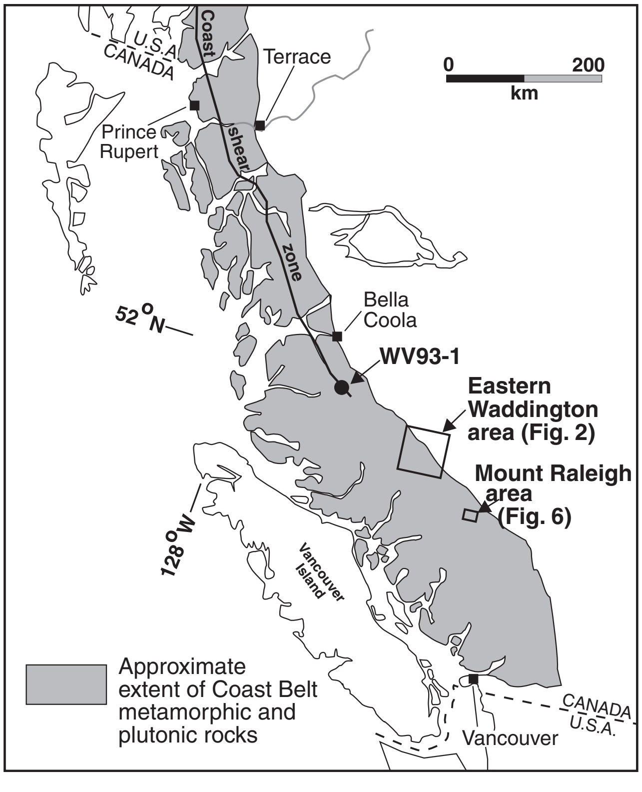

Figure 1. Location map of the southern Coast Belt, showing areas discussed in this paper.

Although a moderate number of reliable U-Pb ages on plutons from the Coast Belt near Vancouver (Parrish and Monger, 1992; Journeay and Friedman, 1993), few U-Pb dates have been published for the large region between the area of their work and Bella Coola (Fig. 1). This paper reports six new U-Pb ages for granitoid rocks in this relatively little-studied area of the south-central Coast Belt of British Columbia. The samples were collected as part of detailed studies designed to illuminate the Cretaceous and early Tertiary structural history of the eastern part of the Coast Belt (Fig. 1). Sample locations (UTM co-ordinates) are given in Table 1.

One sample (WV93-1) is from mylonitic tonalite near the presently known southern end of the Coast shear zone, in northeastern Rivers Inlet map area (92M/9). A regional geological framework and other U-Pb, Ar-Ar, and K-Ar dates for this area have been given by Roddick (1996); detailed structural studies and related U-Pb dates are from Rusmore et al. (1999) and from unpublished data of M.E. Rusmore, G.E. Gehrels, and G.J. Woodsworth (1999).

Two samples (WV89-7 and WV89-71) are from the eastern Waddington thrust belt along the east margin of the Coast Belt (NTS 92N/7 and 92N/6 respectively). The geology of the area has been described by Rusmore and Woodsworth (1991, 1993, 1994) and references therein. Parrish (1992) and Hunt and Roddick (1992) reported previous U-Pb and Ar-Ar geochronology related to this project.

Three samples (WV91-52, WV91-53, and WV91-54) come from the Mount Raleigh area (92K/16) in the northeastern Bute Inlet map area. Woodsworth (1979), Kerrick and Woodsworth (1989), and Rusmore and Woodsworth (1991) have discussed the geology and regional setting of the area; previous K-Ar dating is summarized in Woodsworth (1979).

ANALYTICAL METHODS

Three of the samples (WV89-7, WVR89-71, and WV91-53) were analyzed at the Geochronology Laboratory, Geological Survey of Canada (GSC), and the other three samples, at the Geochronology Laboratory at the University of British Columbia (UBS). Uranium-lead isotope dilution analytical methods utilized in this study are outlined in Parrish et al. (1987) for samples analyzed at the GSC and in Mortensen et al. (1995) for those analyzed at UBC. Multigrain zircon fractions analyzed were very strongly air abraded following the method of Krogh (1982). The treatment of analytical errors for both data sets follows Roddick (1987). Analytical results are given in Table 1 and displayed in the concordia diagrams. Errors on the ages are reported at the 2 σ level in the text and in Table 1.

Table 1. Uranium-lead analytical data and sample locations.

							Radiogenic ratios (±1σ, %)[g]			Ages (Ma, ±2σ)[g]		
Formation[a]	Wt.[b] (µg)	U (ppm)	Pb[c] (ppm)	$^{206}\text{Pb}^{d}/^{204}\text{Pb}$	Pb[e] (pg)	$^{208}\text{Pb}^{f}$ (%)	$^{206}\text{Pb}/^{238}\text{U}$	$^{207}\text{Pb}/^{235}\text{U}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{206}\text{Pb}/^{238}\text{U}$	$^{207}\text{Pb}/^{235}\text{U}$	$^{207}\text{Pb}/^{206}\text{Pb}$
WV93-1, 'Machmell pluton' (NTS 92M/9, UTM 9, 695175E, 5729760N)[2]												
A c,p	368	318	3.6	3569	23	12	0.01105 ± 0.16	0.0728 ±0.24	0.04780 ± 0.13	70.8 ± 0.2	71.4 ± 0.3	89.2 ± 6.4
B m,p	235	355	3.9	2816	20	12	0.01076 ± 0.12	0.0705 ± 0.25	0.04752 ± 0.16	69.0 ± 0.2	69.2 ± 0.3	75.6 ± 7.8
C m,p,e	205	375	4.1	3314	15	12	0.01063 ± 0.13	0.0696 ± 0.21	0.04744 ± 0.13	68.2 ± 0.2	68.3 ± 0.3	71.3 ± 6.2
T1 m	1385	133	1.8	84	1847	32	0.01037 ± 0.66	0.0678 ± 2.3	0.04739 ± 2.0	66.5 ± 0.9	66.6 ± 3.0	69 ± 96
T2 m	1260	113	1.6	75	1662	35	0.01039 ± 0.85	0.0678 ± 3.4	0.04735 ± 2.9	66.6 ± 1.1	66.6 ± 4.4	67 ± 146
WV89-7, Homathko Peak tonalite (NTS 92N/7, UTM 10, 389600E, 5692000N)[1]												
A m,p	79	189	4.1	778	27	8.1	0.02205 ± 0.12	0.1494 ± 0.33	0.04913 ± 0.27	140.6 ± 0.3	141.3 ± 0.9	154.0 ± 13
B f,eq	65	244	5.8	1441	17	9.2	0.02407 ± 0.11	0.1634 ± 0.17	0.04923 ± 0.11	153.3 ± 0.3	153.6 ± 0.5	158.8 ± 5.0
C f,st	72	158	3.7	1134	15	7.6	0.02412 ± 0.13	0.1639 ± 0.23	0.04929 ± 0.17	153.6 ± 0.4	154.1 ± 0.7	161.6 ± 7.9
D f,st	108	187	4.4	328	104	8.3	0.02414 ± 0.25	0.1652 ± 0.91	0.04962 ± 0.80	153.8 ± 0.8	155.2 ± 2.6	177.4 ± 38
WVR89-71, Tiedemann pluton (NTS 92N/6, UTM 10, 353800E, 5697700N)[1]												
A m,el	167	200	1.8	1144	18	8.9	0.00906 ± 0.11	0.0592 ± 0.22	0.04740 ± 0.17	58.1 ± 0.1	58.4 ± 0.2	69.3 ± 8.1
B m,eq	160	158	1.4	534	28	8.2	0.00919 ± 0.13	0.0606 ± 0.36	0.04784 ± 0.29	59.0 ± 0.1	59.8 ± 0.4	91.4 ± 14
C c,p	301	170	1.6	1396	24	8.6	0.00980 ± 0.11	0.0643 ± 0.17	0.04761 ± 0.12	62.9 ± 0.1	63.3 ± 0.2	79.9 ± 5.5
E m,el	234	224	2.0	3134	9	9.2	0.00895 ± 0.11	0.0586 ± 0.21	0.04748 ± 0.17	57.5 ± 0.1	57.8 ± 0.2	73.2 ± 8.0
F m,eq	82	206	1.9	878	11	7.6	0.00935 ± 0.14	0.0616 ± 0.34	0.04777 ± 0.29	60.0 ± 0.2	60.7 ± 0.4	87.6 ± 14
WV91-54, Sysiphus Creek complex (NTS 92K/16, UTM 10, 403100E, 5638150N)[2]												
A m,p,e	151	831	14	7820	17	6.3	0.01688 ± 0.10	0.1129 ± 0.19	0.04849 ± 0.10	107.9 ± 0.2	108.6 ± 0.4	123.5 ± 4.9
B m,p,e,ti	126	1081	17	5401	26	6.1	0.01653 ± 0.15	0.1110 ± 0.23	0.04871 ± 0.12	105.7 ± 0.3	106.9 ± 0.5	133.9 ± 5.6
C f,p,e	157	884	15	9073	16	7.2	0.01699 ± 0.15	0.1142 ± 0.24	0.04875 ± 0.16	108.6 ± 0.3	109.8 ± 0.5	135.6 ± 7.7
D f,p,e,ti	94	1156	19	8448	14	6.7	0.01700 ± 0.10	0.1136 ± 0.19	0.04846 ± 0.10	108.6 ± 0.2	109.2 ± 0.4	121.6 ± 4.7
E m,p,e,ti	104	1126	18	10585	11	6.5	0.01682 ± 0.10	0.1122 ± 0.19	0.04841 ± 0.10	107.5 ± 0.2	108.2 ± 0.4	119.1 ± 4.8
G f,p,e,ti	22	1192	19	2823	10	6.5	0.01671 ± 0.12	0.1118 ± 0.24	0.04851 ± 0.16	106.8 ± 0.3	107.6 ± 0.5	124.3 ± 7.8
M2 (4)	33	3073	204	5375	16	82	0.01330 ± 0.14	0.0873 ± 0.22	0.04762 ± 0.12	85.2 ± 0.2	85.0 ± 0.4	80.6 ± 5.5
M3 (5)	26	2936	181	4374	14	80	0.01330 ± 0.13	0.0872 ± 0.22	0.04756 ± 0.14	85.2 ± 0.2	84.9 ± 0.4	77.3 ± 6.9
WV91-53, Mount Gilbert pluton (NTS 92K/16, UTM 10, 407350E, 5635400N)[1]												
A m,eq	285	339	4.2	4426	18	6.1	0.01304 ± 0.17	0.0857 ± 0.16	0.04767 ± 0.15	83.5 ± 0.3	83.5 ± 0.3	83.1 ± 7.3
B m,p	341	276	3.5	1534	50	6.6	0.01304 ± 0.11	0.0861 ± 0.23	0.04786 ± 0.19	83.5 ± 0.2	83.8 ± 0.4	92.2 ± 9.0
C c,p,el	344	305	3.8	4762	18	6.6	0.01306 ± 0.10	0.0861 ± 0.13	0.04778 ± 0.07	83.7 ± 0.2	83.8 ± 0.2	88.4 ± 3.2
D m,eq	306	273	3.4	2678	25	6.5	0.01300 ± 0.17	0.0868 ± 0.18	0.04846 ± 0.17	83.2 ± 0.3	84.5 ± 0.3	121.6 ± 8.0
T1 cc	341	513	7.5	387	380	20	0.01293 ± 0.18	0.0850 ± 0.49	0.04761 ± 0.40	82.8 ± 0.3	82.8 ± 0.8	82.6 ± 19
T2 cc	250	636	9.2	443	302	19	0.01301 ± 0.18	0.0855 ± 0.46	0.04768 ± 0.38	83.3 ± 0.3	83.3 ± 0.7	83.2 ± 18
WV91-52, Bishop River pluton (NTS 92K/16, UTM 10, 412850E, 5645750N)[2]												
A cc,p,e	249	292	3.2	2873	18	7.0	0.01125 ± 0.10	0.0741 ± 0.23	0.04778 ± 0.15	72.1 ± 0.1	72.6 ± 0.3	88.6 ± 7.2
C c,p,e,ti	236	323	3.5	3064	17	6.8	0.01128 ± 0.11	0.0740 ± 0.24	0.04758 ± 0.16	72.3 ± 0.2	72.5 ± 0.3	78.2 ± 7.4
D m,p,e	223	345	3.8	2938	18	7.7	0.01123 ± 0.13	0.0740 ± 0.24	0.04781 ± 0.15	72.0 ± 0.2	72.5 ± 0.3	89.7 ± 7.1
E m,p,e	290	278	3.0	3947	14	7.5	0.01122 ± 0.09	0.0735 ± 0.21	0.04754 ± 0.13	71.9 ± 0.1	72.1 ± 0.3	76.3 ± 6.3
F m,p,e,ti	138	329	3.6	2292	14	7.0	0.01123 ± 0.10	0.0735 ± 0.24	0.04743 ± 0.17	72.0 ± 0.1	72.0 ± 0.3	70.9 ± 8.0

[1] Analyzed at the GSC; [2] Analyzed at UBC; UTM co-ordinates are NAD27.

[a] T=titanite; M=monazite (number=number of grains analyzed); zircon fractions were all strongly abraded; grain size: cc=>180mm, c= <180 µm and >134µm, m=<134µm and >104µm, f=<104µm; morphology: e=elongate, p=prismatic, ti=tips, eq=equant, st=stubby prisms.

[b] Error on weight = ± 1 µg.

[c] Total radiogenic Pb.

[d] GSC: Measured ratio corrected for spike and Pb fractionation of 0.09±0.03%/AMU. UBC: Measured ratio corrected for spike and Pb fractionation of 0.0043±20%/AMU (Daly collector) and 0.0012±7%/AMU and laboratory blank Pb of 5–10 pg ± 20%.

[e] Total common Pb on analysis corrected for fractionation and spike.

[f] Corrected for blank and common Pb (Stacey-Kramers model Pb composition equivalent to the $^{207}\text{Pb}/^{206}\text{Pb}$ age).

[g] Corrected for blank Pb and U and common Pb (Stacey-Kramers model Pb composition equivalent to the $^{207}\text{Pb}/^{206}\text{Pb}$ age).

RESULTS AND INTERPRETATIONS

Machmell pluton (WV93-1)

This sample of tonalite was collected from within what is interpreted by M.E Rusmore, G.E. Gehrels, and G.J. Woodsworth (unpub. data, 1999) as the southern extension of the Coast shear zone (Fig. 1). The dated sample is mylonitic and has clearly been affected by motion on the shear zone. It was collected near the northeast margin of what Roddick (1996) called the 'Machmell pluton', but, because it was collected from within a major shear zone, assignment to this pluton is tentative.

High-quality zircon and titanite were recovered and fractions of each were analyzed. Zircon is clear and colourless to very pale pink, with grain shapes varying from stubby and elongate prismatic to equant multifaceted. No cores were observed during grain selection. Titanite is clear and yellow and grains are typically euhedral, flattened, and pyramidal.

Three analyzed zircon fractions define a linear array, from discordant fraction A to concordant fraction C (Table 1, Fig. 2). A regression line through these data gives a lower intercept of 67.8 +0.7/-1.6 Ma with a mean square of weighted deviates (MSWD) of 0.10, interpreted as the crystallization age for this pluton. Minor inherited zircon is inferred to be present in fraction B, and is clearly evident in discordant fraction A. An imprecise upper intercept of 440 +172/-164 Ma provides an estimate of the average age of inherited zircon components in these fractions. Two titanite analyses give overlapping results, with a mean $^{206}\text{Pb}/^{238}\text{U}$ age of 66.6 ± 1.1 Ma. This date is interpreted as a minimum crystallization age for the pluton, reflecting the lower closure temperature for the U-Pb system in titanite (~600–650°C) compared to zircon. The titanite date of

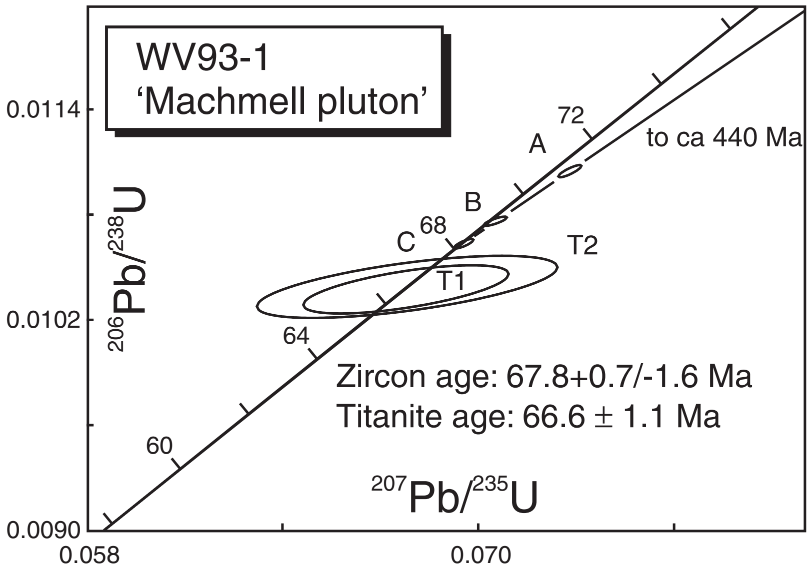

Figure 2.

Concordia plot for zircon and titanite from sample WV93-1 from the 'Machmell pluton'. A, B, C are the zircon fractions analyzed; T1 and T2 are the titanite analyzed. Error ellipses reflect 2 σ uncertainty.

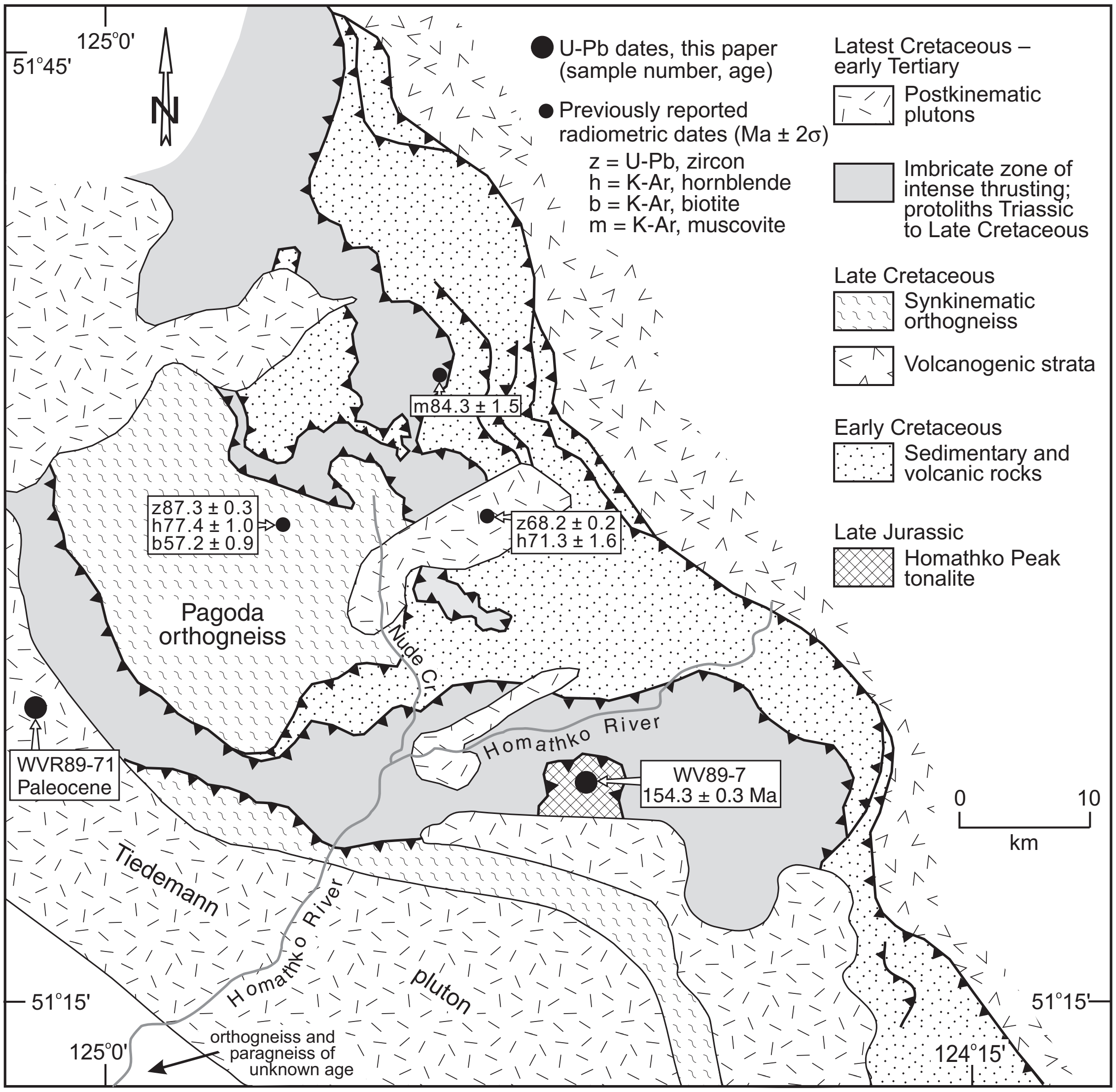

*Figure 3. Generalized geological map of part of the eastern Waddington thrust belt (*modified from *Rusmore and Woodsworth, 1994), showing previous geochronological work (*from *Parrish, 1992; Hunt and Roddick, 1992) and locations of the samples dated in this study.*

66.1 ± 1.1 Ma also provides a maximum age for motion on the shear zone, which is associated with subsolidus mylonitic deformation at this location.

Eastern Waddington thrust belt

The eastern margin of the Coast Belt in the Mount Waddington map area is a series of east-verging imbricate faults and folds, termed the 'eastern Waddington thrust belt' (Fig. 3; Rusmore and Woodsworth, 1991, 1993, 1994, and references therein). The thrust belt carried Triassic rocks correlated with the Intermontane superterrane, Early Cretaceous volcanic and clastic rocks, and volcanic and plutonic rocks of the active Coast Belt arc northeastward, away from the core of the arc during the early Late Cretaceous (Rusmore and Woodsworth, 1994). Two samples dated by Parrish (1992) and one dated by Hunt and Roddick (1992) showed that the thrust belt was active between about 87 and 82 Ma and that deformation had ceased by 89 Ma (Rusmore and Woodsworth, 1994). The following two samples were collected to help define the ages of rocks within the thrust belt and the timing of deformation.

Homathko Peak tonalite (WV89-7)

This sample is from a large, tabular body of tonalite that forms a thrust slice within the imbricate zone of the eastern Waddington thrust belt (Fig. 3). The tonalite has long been assumed to be Jurassic (e.g. Tipper, 1969) on the basis of the following: 1) it has an altered nature and greenschist-facies mineral assemblages; 2) it lithologically resembles boulders present in the Early Cretaceous Cloud-Drifter formation found elsewhere in the thrust stack (Umhoefer et al., 1994); and 3) it contains numerous metamorphosed mafic dykes, which are absent from younger plutons. Sample 89WV-7 is a medium-grained, unfoliated, equigranular, greenish tonalite collected from the least altered and least deformed part of the tonalite body.

The sample contains abundant colourless, clear zircon with a minor to moderate number of fluid inclusions. No cores or overgrowths were observed. Zircon fractions analyzed included large prismatic to slightly more elongate crystals (fraction A); equant, multifaceted grains (fraction B); and stubby prismatic zircons (fractions C and D). Analyses from fractions B, C, and D overlap each other and intersect concordia. The weighted average of the $^{206}Pb/^{238}U$ ages of these three fractions is 153.4 ± 0.3 Ma, which we take as the best estimate for the crystallization age of the rock (Table 1, Fig. 4). Discordant zircon fraction A is interpreted to have undergone Pb loss.

The Late Jurassic age for this tonalite is consistent with numerous other Late Jurassic dates from the southern Coast Belt (e.g. Journeay and Friedman, 1993). In particular, it is very similar to the 156 ± 2 Ma age obtained by van der Heyden (1991) from tonalite of the Atnarko Complex on the east side of the Coast Belt at about latitude 52°N. Like the Homathko Peak tonalite, the Atnarko body is highly altered and cut by numerous metamorphosed mafic dykes.

Tiedemann pluton (WVR89-71)

The Tiedemann pluton (Roddick and Tipper, 1985) is a large, northwesterly trending granite to granodiorite pluton that marks the western limit of structures currently recognized as part of the eastern Waddington thrust belt (Fig. 3). It is an unfoliated, locally megacrystic body that intrudes the southwestern margin of the thrust belt.

Sample WVR89-71 is a light grey, fine- to medium-grained, unfoliated biotite granite with large K-feldspar megacrysts. The rock is fresh and unaltered. The sample yielded abundant, high quality zircons with very minor fluid

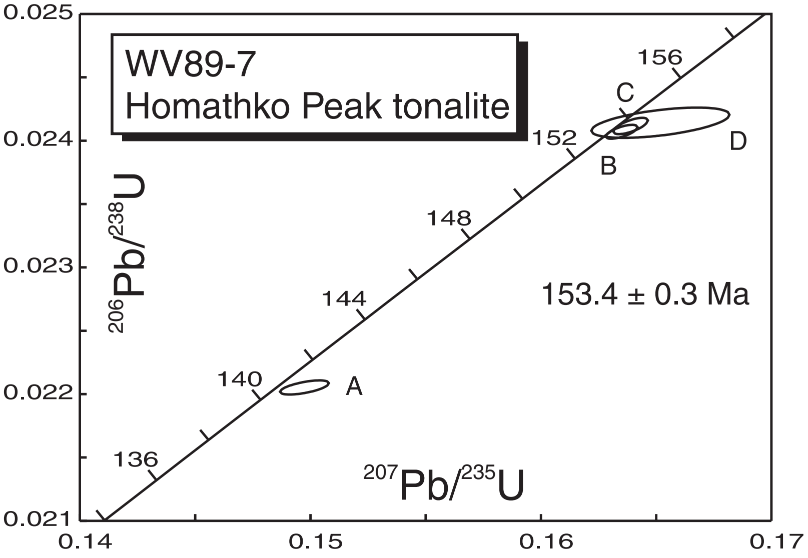

Figure 4.

Concordia plot for zircon from sample WV89-7 from the Homathko Peak tonalite. A, B, C, D are the zircon fractions analyzed. Error ellipses reflect 2 σ uncertainty.

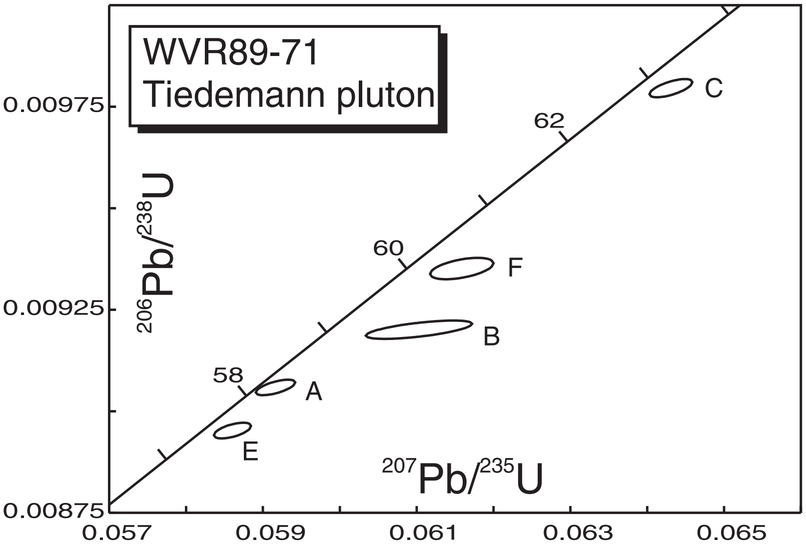

Figure 5.

Concordia plot for zircon from sample WVR89-71 from the Tiedemann pluton. A, B, C, E, F are the zircon fractions analyzed. Error ellipses reflect 2 σ uncertainty.

inclusions. Zircons are very clear with no evidence of core material. The morphologies of analyzed zircons include elongate prismatic crystals (fractions A and E); equant, multifaceted grains (fractions B and F); and large, prismatic crystals (fraction C). Fraction A is the most concordant datum, plotting just below concordia at about 58 Ma (Table 1, Fig. 5). Fraction E has probably undergone minor Pb loss. If the age of the rock is ca. 58 Ma, fractions B, C, and F may contain minor inherited components; however, this interpretation of the discordance is speculative.

The best interpretation that can be made from this data set is that the rock is probably Paleocene. If accurate, the results confirm that thrusting in the eastern Waddington thrust belt had ceased by the early Tertiary (Rusmore and Woodsworth, 1994).

Mount Raleigh area

The following summary of the geology of the area is adapted from Woodsworth (1979), Kerrick and Woodsworth (1989), and unpublished field work (1991) by two of us (GJW and MER). The central part of the Mount Raleigh area is underlain by a pendant of metamorphosed stratified rocks of probable Triassic to Early Cretaceous age. The pendant is in contact with four sharply contrasting plutonic suites (Fig. 6). The Ixion Creek pluton of presumed Jurassic age resembles the Homathko Peak tonalite in lithology and alteration and is in probable (?)thrust fault contact with the pendant. The Sisyphus Creek complex (informal name) is a heterogeneous assemblage consisting of foliated, leucocratic, garnet-two-mica granite and subordinate migmatite, mafic gneiss, and amphibolite. Leucogranite of the Sisyphus Creek complex intrudes amphibolite-facies rocks of the Mount Raleigh pendant. The relatively aluminous, K-rich composition of this S-type granitoid rock is markedly different from the I-type compositions of other plutonic rocks in the study area (Woodsworth, 1979), and is consistent with derivation from a supracrustal, perhaps pelitic, source. On the basis of structural and metamorphic criteria, the Ixion Creek and Sisyphus Creek bodies predate regional amphibolite-facies metamorphism and coeval deformation of the stratified rocks. The foliated Mount Gilbert pluton on the south side of the pendant and satellite stocks was intruded during metamorphism. The dominantly unfoliated, tonalite to granodiorite Bishop River pluton and its satellites intrude the stratified rocks on their north side and postdate regional metamorphism and deformation.

No previous U-Pb dating has been done in this area; previous K-Ar dates are discussed below. Samples from all suites but the Ixion Creek pluton were collected to constrain the age of deformation and metamorphism in the pendant.

Sisyphus Creek complex (WV91-54)

This sample of fine-grained, recrystallized, fresh, leucocratic, garnet-two-mica granite was collected in an area of the complex that is free from screens, inclusions, and schlieren (Fig. 6). The 10 kg sample yielded abundant zircon and a modest quantity of monazite, both of high quality. Zircon appears to comprise a single population; grains are clear, colourless to pale pink and commonly occur as euhedral, elongate prisms. Both igneous zoning and rare cores have been observed. Monazite is clear to pale yellow with no visible internal structure or inclusions. Grains are commonly subhedral with prismatic or tabular aspects.

Six analyzed multigrain zircon fractions give discordant results with U-Pb ages of about 106 Ma to 109 Ma and $^{207}Pb/^{206}Pb$ ages between about 120 Ma and 135 Ma (Fig. 7). Two overlapping monazite analyses exhibit slight reverse discordance and yield a mean $^{207}Pb/^{235}U$ date of 85.0 ± 0.5 Ma. Two distinct interpretations for these data are consistent with existing geological constraints. In one interpretation, monazite records the crystallization age of the granite, with the older zircons representing inherited core ages. In the other, monazite records the age of amphibolite-grade metamorphism and zircon retains some information about the age of an older (likely pre-Late Cretaceous) granite protolith. In the context of the first interpretation, localized melting of

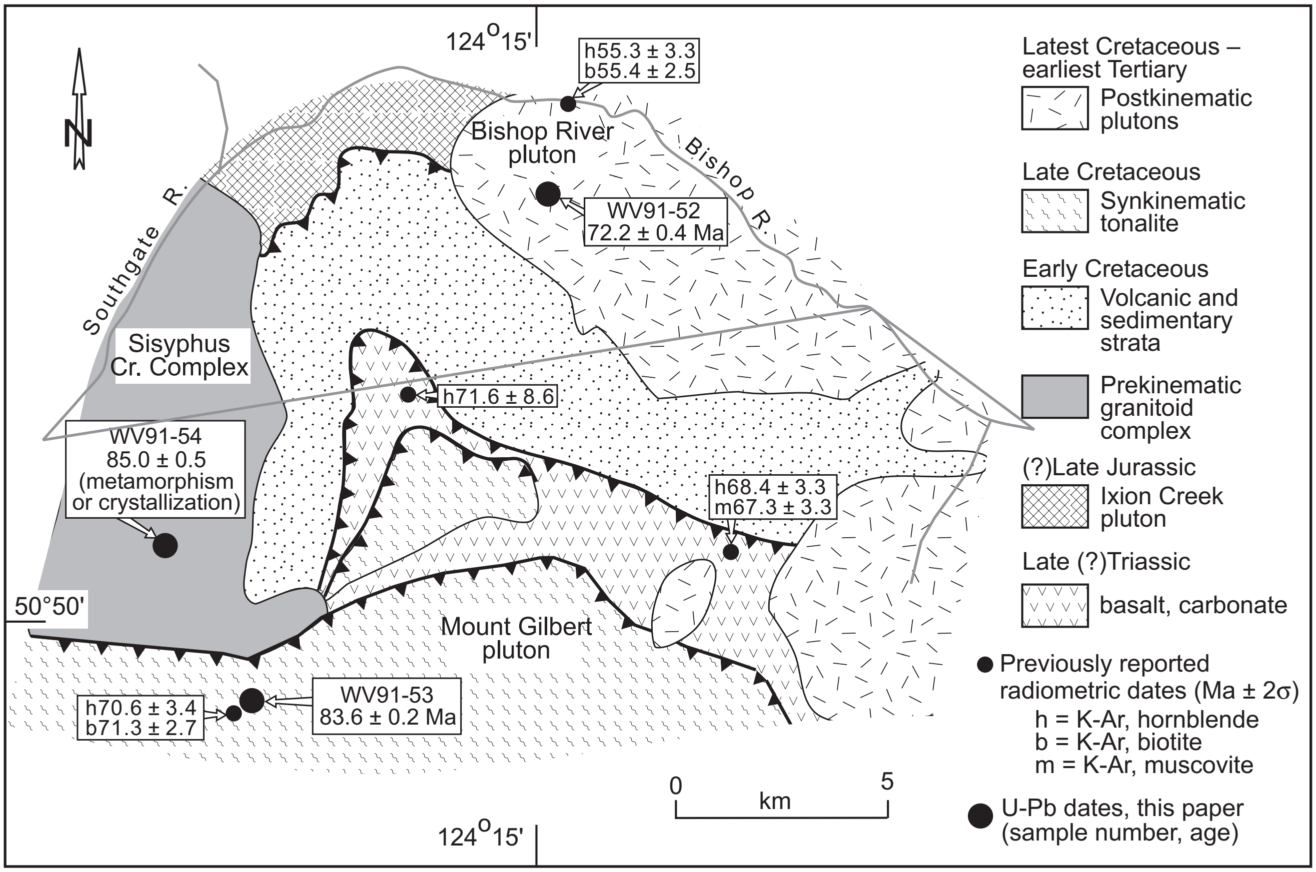

Figure 6. *Generalized geological map of the Mount Raleigh area (*modified from *Woodsworth, 1979), showing previous K-Ar work (*from *Wanless et al., 1974) and locations of the samples dated in this study.*

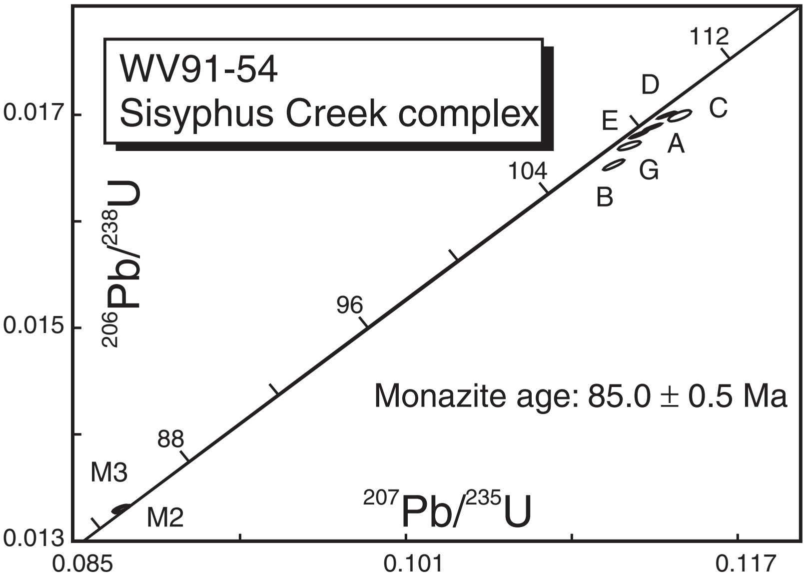

Figure 7.

Concordia plot for zircon and monazite from sample WV91-54 from the Sisyphus Creek complex. A, B, C, D, E, G are the zircon fractions analyzed. Error ellipses reflect 2 σ uncertainty.

pelitic source rocks was associated with Late Cretaceous magmatism and the intrusion of the adjacent Mount Gilbert pluton. In the second interpretation, pre-Late Cretaceous protolith granite of the Sisyphus Creek complex underwent Late Cretaceous amphibolite-grade metamorphism.

Mount Gilbert pluton (WV91-53)

Sample WV91-53, collected near the northern margin of the Mount Gilbert pluton (Fig. 6), is a medium- to coarse-grained, biotite-hornblende tonalite. The specimen is fresh and unaltered and has small amounts of magmatic epidote. The sample and much of the Mount Gilbert pluton have a moderately strong foliation that has been interpreted as a subsolidus, deformational fabric formed during pluton emplacement and thrusting northward over the metamorphic rocks of the Mount Raleigh pendant (Woodsworth, 1979).

The sample contains abundant, clear, euhedral zircon with minor fluid inclusions and no apparent cores or overgrowths. Morphologies of analyzed zircons include equant, multifaceted crystals (fractions A, D) and well faceted prisms to more elongate grains with good igneous zoning (fractions B, C). Three of the zircon fractions (A, B, C) overlap each other; fractions A and B intersect concordia. A weighted average of the ^{206}Pb/^{238}U ages of the three fractions is 83.6 ± 0.2 Ma (Table 1, Fig. 8), which is interpreted to be the best estimate for the age of the rock. Zircon fraction D is interpreted to contain an inherited component and to have undergone a minor amount of Pb loss. Two fractions of clear, golden-brown, subhedral to anhedral titanite fragments were also analyzed from this sample. One fraction (T2) overlaps the zircon analyses and the interpreted crystallization age of the rock. The other fraction (T1) is slightly younger, although it overlaps within error of fraction T2.

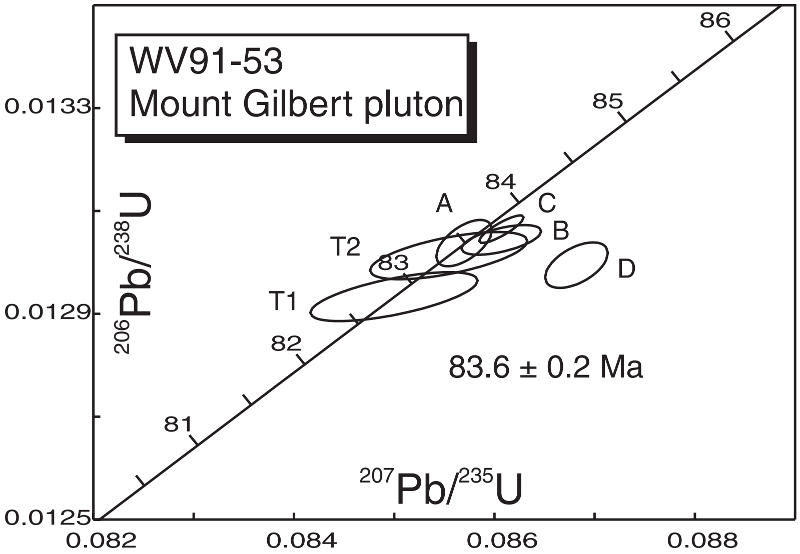

Figure 8.

Concordia plot for zircon and titanite from sample WV91-53 from the Mount Gilbert pluton. A, B, C, D are the zircon fractions analyzed; T1 and T2 are the titanite analyzed. Error ellipses reflect 2 σ uncertainty.

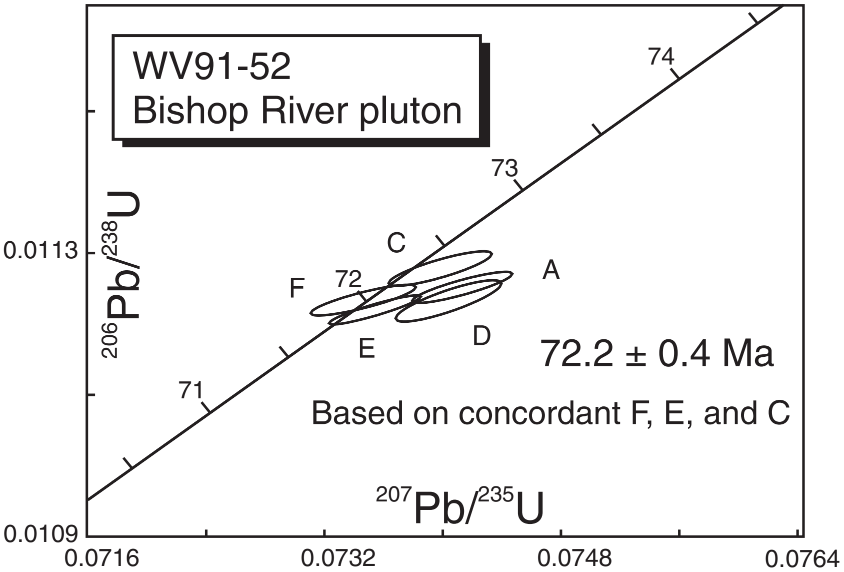

Figure 9.

Concordia plot for zircon from sample WV91-52 from the Bishop River pluton. A, C, D, E, F are the zircon fractions analyzed. Error ellipses reflect 2 σ uncertainty.

Bishop River pluton (WV91-52)

This sample was collected from the southwestern part of the pluton, about 1.5 km from its intrusive contact with the Mount Raleigh pendant (Fig. 6). The rock is fresh, homogeneous, unfoliated hornblende-biotite tonalite. The sample yielded high-quality zircon and titanite. Zircon is clear, pale pink, and commonly occurs as euhedral, stubby to elongate, prismatic grains. Five analyzed zircon fractions cluster on and to the right of concordia at about 72 Ma (Table 1, Fig. 9). An age estimate of 72.2 ± 0.4 Ma is based on the median ^{206}Pb/^{238}U age of concordant fraction F and marginally concordant fractions E and C. Discordant fractions are inferred to contain minor inherited zircon from their relatively old ^{207}Pb/^{206}Pb ages. Discordant fractions A and D likely lost minor quantities of radiogenic Pb.

Discussion of the Mount Raleigh results

The Sisyphus Creek complex was thought, erroneously, by Woodsworth (1979) to be Paleozoic and to be correlative with the Central Gneiss Complex found in the core of the Coast Belt north of Bella Coola (Fig. 1). Garnet-two mica leucogranite of the Sisyphus Creek complex is mineralogically and compositionally consistent with derivation from a pelitic source. U-Pb data and geological constraints do not allow us to resolve whether Late Cretaceous monazite dates record crystallization or metamorphism of this unit. However, this ca. 85 Ma anatectic or metamorphic event is clearly temporally associated with intrusion of the adjacent Mount Gilbert pluton.

The crystallization age for the Mount Gilbert pluton is 83.6 ± 0.2 Ma. On the basis of field and textural evidence, the pluton appears to have been emplaced during upper-amphibolite-facies metamorphism in the Mount Raleigh pendant and thrust northerly over stratified rocks during metamorphism (Woodsworth, 1979; Kerrick and Woodsworth, 1989). This conclusion is supported by monazite dates from the Sisyphus Creek complex of 85.0 ± 0.5 Ma, interpreted as representing the age of anatectic melting/crystallization or metamorphism for that body. Taken together, the dates indicate that deformation and amphibolite-facies metamorphism in the Mount Raleigh pendant was active at least from 85 ± 0.5 Ma to 83.6 ± 0.2 Ma.

The Bishop River pluton was intruded at 72.2 ± 0.4 Ma, after deformation and metamorphism in the Mount Raleigh pendant had ceased.

Potassium-argon dates from the Mount Raleigh area were reported in Wanless et al. (1974) and discussed by Woodsworth (1979). Potassium-argon dates from the Sisyphus Creek complex, the Mount Gilbert pluton, and amphibolite-facies metamorphic rocks of the Mount Raleigh pendant range from 68.4 ± 3.3 Ma to 71.6 ± 8.6 Ma and include a concordant hornblende-biotite pair from the Mount Gilbert pluton (70.6 ± 3.4 Ma, biotite; 71.3 ± 2.7 Ma, hornblende). These dates indicate cooling of the plutons and pendant between about 84 Ma (peak metamorphism and emplacement of the Mount Gilbert pluton) and about 72–70 Ma (emplacement of the Bishop River pluton and cooling of the Mount Gilbert biotite below a closure temperature of about 250°C). Potassium-argon dates for the Bishop River pluton range from 57.5 ± 2.6 Ma to 55.3 ± 3.3 Ma. A concordant biotite-hornblende pair at 55.3 Ma suggests rapid early Eocene cooling of this body.

Similarities between the eastern Waddington thrust belt and the Mount Raleigh pendant are many. The Pagoda orthogneiss has a crystallization age (87 ± 0.3 Ma, Parrish, 1992) similar to that of the Mount Gilbert pluton; both bodies have synkinematic deformational fabrics that were developed during intrusion and metamorphism of nearby stratified rocks. Both are biotite-hornblende tonalite and contain accessory magmatic epidote. Metamorphism in the eastern Waddington area and in the Mount Raleigh pendant produced inverted metamorphic gradients in which grade increases from northeast to southwest through a series of northwest-striking, southwest-dipping isograds. Metamorphism in both areas is of the low-pressure, medium- to high- temperature, andalusite + sillimanite style.

The eastern Waddington thrust belt was active at 84 Ma and probably at 87 Ma, and peak amphibolite-facies metamorphism probably occurred about 84–82 Ma (Rusmore and Woodsworth, 1994). In that area, the Pagoda orthogneiss was emplaced synkinematically and during amphibolite-facies metamorphism of the thrust belt (Rusmore and Woodsworth, 1994). Northeast-directed thrusting in the Mount Raleigh area took place at about 84 Ma, on the basis of the U-Pb age of the synkinematic Mount Gilbert pluton and monazite dates for the Sisyphus Creek complex. Both areas had similar cooling histories and, in both areas, postkinematic plutons were emplaced in the early Tertiary.

We are reluctant to push the structural similarities too far, as the field work in the Mount Raleigh area dates from the early 1970s and is not, by modern standards, rigorous. From the geochronological similarities between the two areas we conclude that the eastern Waddington and Mount Raleigh areas form part of a single, extensive, Late Cretaceous fold-and-thrust belt in the eastern Coast Belt and along its eastern side of the Coast Mountains, as proposed by Rusmore and Woodsworth (1991).

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