British Columbia Geological Survey
Geological Fieldwork 1996

U-PB AGES FROM THE SELKIRK ALLOCHTHON, SEYMOUR ARM MAP AREA, SOUTHEAST BRITISH COLUMBIA (82M/8 AND 9)

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KEYWORDS: Goldstream pluton, Downie Creek orthogneiss, Clachnacudainn complex, Lardeau Group, Badshot Formation, geochronology, radiogenic isotopes, U-Pb.

INTRODUCTION

During the course of 1:50 000 scale regional mapping in the Northern Selkirk Mountains (NTS 082M) various granitic rocks were sampled for U-Pb geochronology. This report presents new U-Pb data, interpreted ages, and the implications of these results for two such samples from the Selkirk Allochthon: the Downie Creek orthogneiss, and the Goldstream Pluton.

The Downie Creek orthogneiss consists of a series of foliated granite and granodiorite sheets which intrude a quartz-rich sequence of garnet-muscovite-biotite and chlorite bearing paragneiss and schist within the Selkirk Allochthon. These orthogneisses were affected by regional ductile polyphase contractional deformation and related metamorphism and later overprinted by brittle deformation associated with the Columbia River fault. They are lithologically and structurally similar to, and likely correlative with, Devono-Mississippian gneisses of the Clachnacudainn suite exposed near Revelstoke (Parrish, 1992). U-Pb geochronology of the Downie Creek orthogneiss was undertaken to strengthen or refute this correlation.

The Goldstream Pluton is an elongate, east-trending plutonic complex consisting of granitic to monzodioritic sills intimately mixed with metasedimentary pendants, septa and xenoliths. These granitoids commonly have foliated margins and massive interior zones. The Goldstream Pluton was previously thought to have been emplaced prior to, or during regional deformation, based largely on its regional structural concordance with surrounding foliated country rocks, (Höy, 1979). However, the presence of a chiefly retrograded contact metamorphic aureole, which overprints penetrative foliations in the country rocks, indicates that this body post-dates most of the ductile deformation in the area. This conclusion is further supported by the presence of foliations in xenoliths and pendants, which are interpreted to be correlative with regional deformation fabrics, and are cut by the Goldstream pluton. Hornblende and biotite $^{40}Ar/^{39}Ar$ plateau ages of 114±4.5 Ma and 100±1 Ma, respectively, have been previously reported for the Goldstream pluton, indicating a relatively slow cooling rate for this body (Logan and Colpron, 1995). U-Pb geochronology of this body was carried out to determine its crystallization age, and to complement these $^{40}Ar/^{39}Ar$ cooling data.

REGIONAL GEOLOGY

The Downie Creek area, within the northern Selkirk Mountains, straddles the boundary between rocks assigned to the North American miogeocline and the pericratonic Kootenay Terrane (Wheeler *et al.*, 199?; Wheeler and McFeely, 1991). The area lies in southeastern British Columbia, in the Omineca Morphogeologic Belt, an uplifted region extending the length of the Canadian Cordillera that is underlain extensively by metamorphic and granitic rocks (Gabrielse *et al.*, 1991).

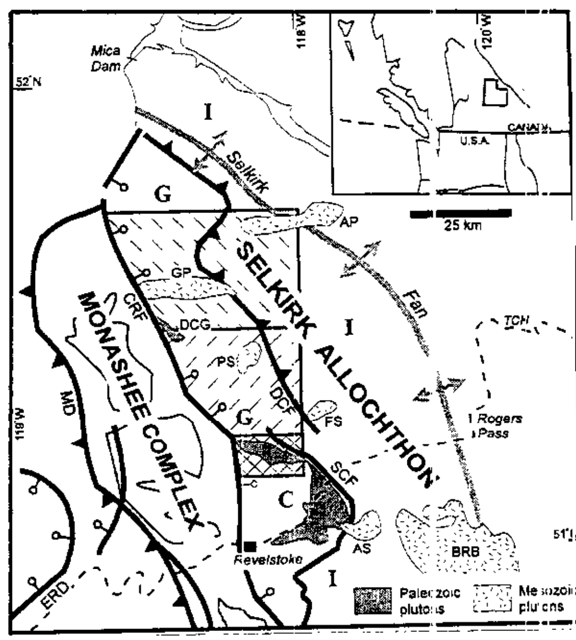

Figure 1: Geological setting and location of the Goldstream River (southeasterly dashed), Downie Creek (southwesterly dashed) and La Forme Creek (hatched) map-areas along the western flank of the Selkirk fan structure, within the Selkirk allochthon; modified after Brown and Lane (1988). I = Illecillewaet slice, G = Goldstream slice, C = Clachnacudainn slice. CRF = Columbia River fault. DCF = Downie Creek fault, SCF = Standfast Creek fault, MD = Monashee décollement, ERD = Eagle River detachment, BRB = Battle Range batholith, AS = Albert stock, FS = Fang stock, PS = Pass Creek pluton, GP = Goldstream pluton, AP = Adamant pluton, DCG = Downie Creek gneiss. TCH = Trans-Canada Highway

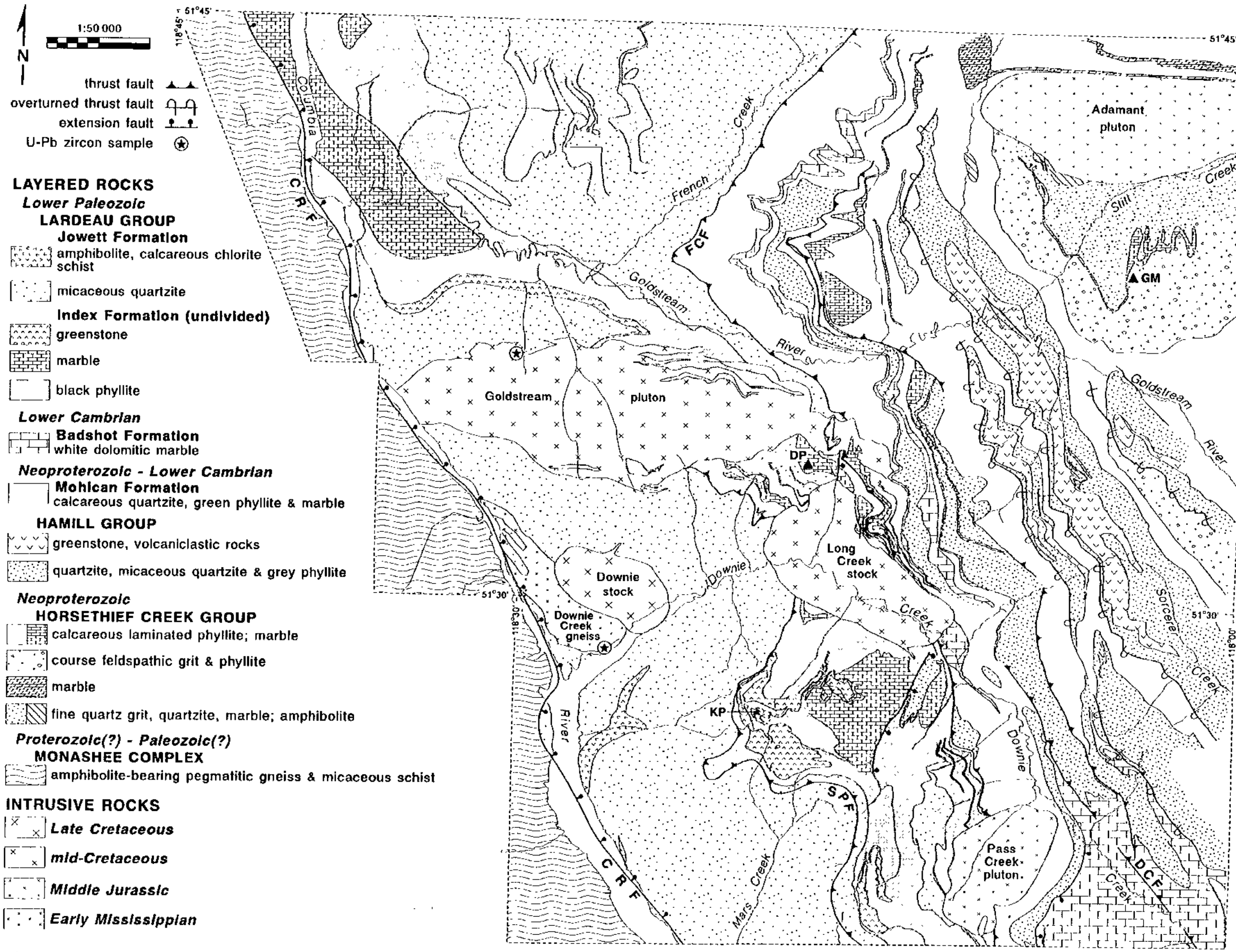

Figure 2. Geological map of the Goldstream River and Downie Creek areas compiled from mapping completed in 1996, from Colpron *et al.* (1995) and from Logan *et al.* (1996). U-Pb zircon sample sites are shown by stars. Topographic features: GM = Goldstream Mountain, DP = Downie Peak, KP = Keystone Peak. Faults: CRF = Columbia River Fault, FCF = French Creek Fault, DCF = Downie Creek Fault, SPF = Standard Peak Fault.

The study area lies within the Selkirk Allochthon, a regional nappe structure related to thick-skinned thrusting that formed largely during Middle Jurassic to Paleocene contractional deformation and telescoping associated with the accretion of arc and oceanic terranes from the west (Price, 1981; Brown *et al.*, 1986, 1992a). This contractional deformation resulted in a complex pattern of superposed folding and faulting, dominated by the northwest-trending Selkirk fan structure. The eastern flank of this structure is characterized by a northeast-verging imbricate thrust system; the western flank is dominated by southwest-verging fold-nappes and thrust faults (Wheeler, 1963, 1966; Raeside and Simony, 1983). Eocene brittle extensional structures, such as the Columbia River fault which defines the western margin of the Selkirk Allochthon, overprint earlier contractional features (Figure 1).

Stratigraphic units recognized and subdivided within dominantly metasedimentary sequences of the northern Selkirk Mountains (Figure 2) include the Neoproterozoic Horsethief Creek Group (Windermere Supergroup), the Eocambrian Hamill Group, the Lower Cambrian, *Archaeocyathid*-bearing Badshot Formation, and the lower Paleozoic Lardeau Group (Wheeler, 1963, 1965). These rocks have been intruded by granitoids belonging to several plutonic suites (Gabrielse and Reesor, 1974; Armstrong, 1988; Woodsworth *et al.*, 1991): Devono-Mississippian orthogneisses of the Clachnacudainn suite; syn- to late-deformational, Middle Jurassic (*ca.* 180-165 Ma) alkaline and calc-alkaline granitoids of the Kuskanax and Nelson plutonic suites, respectively; Mid-Cretaceous (*ca.* 110-90 Ma), two-mica and biotite-hornblende granites and granodiorites of the largely post-deformational Bayonne plutonic suite; and, a less voluminous Late Cretaceous (*ca.* 70 Ma) suite of leucogranites (Parrish, 1992).

LOCAL GEOLOGY

DOWNIE CREEK ORTHOGNEISS

Biotite-hornblende granite, quartz monzonite and granodiorite gneiss crop out at Downie Creek (Figure 2), and extend north into the Goldstream River map area, where they have been included in a mixed package of orthogneiss and paragneiss (Logan and Colpron, 1995). Late Cretaceous two-mica granite of the Downie stock intrudes the eastern edge of the gneiss and the Columbia River fault separates it from rocks of the Monashee Complex to the west.

The Downie Creek orthogneiss includes sills and sheets of foliated granitic orthogneiss up to 1,000 metres thick. It varies in modal composition from biotite-hornblende granodiorite to granite and is I-type in character. Typically, the gneiss is strongly foliated, with biotite and rarely hornblende-rich mafic layers and flattened quartz and plagioclase-rich felsic layers (Photo 1). Oval aggregates of biotite crystals give the gneiss a distinctive spotted texture and locally define a good lineation. Local low strain zones within the gneiss are characterized by rounded inclusions of fine-grained mafic diorite within a more felsic granite to quartz monzonite matrix.

Gneiss bodies intrude a thick, predominantly quartzose package of medium-bedded micaceous quartzite with thin-interlayered metapelitic horizons, muscovite-biotite schist and coarse garnet amphibolite. Regionally, the micaceous quartzite package occupies a stratigraphic position between the Index and Jowett formations of the Lower Paleozoic Lardeau Group. Schists and quartzites adjacent to the gneisses contain synkinematic garnet pophyroblasts, which are commonly mantled by retrograde chlorite rims. Regional relationships indicate a Middle Jurassic age for the southwesterly-verging deformation and the peak of regional metamorphism (Archibald *et al.*, 1983; Brown *et al.*, 1992b).

Photo 1. Foliated biotite monzodiorite of the Downie Creek orthogneiss, 1 kilometre east of zircon sample location on Highway 23.

Photo 2. Biotite quartz monzonite; felsic phase of the Goldstream pluton. Penetratively foliated inclusions in the intrusion indicate it postdated the dominant Mesozoic phase of deformation.

GOLDSTREAM PLUTON

The Goldstream pluton is an elongate, east-trending intrusive complex consisting of monzodiorite and granite sills intimately mixed with pendants, septa and xenoliths of foliated, dominantly metasedimentary country rock. The pluton is a composite body consisting predominantly of an older hornblende biotite monzodiorite phase (dated in this study) and a younger, more felsic, biotite quartz monzonite to granite phase.

The apparent structural concordance of locally foliated granitic sheets with regionally foliated country rock led previous workers to the conclusion that the Goldstream pluton pre-dated, or was synchronous with contractional deformation in the area (Höy, 1979). Subsequent workers have re-evaluated the contact relationships of the Goldstream pluton and now believe that its emplacement post-dates most of the ductile contractional structures and fabrics in the area. Critical features observed which led to this re-interpretation are: randomly oriented porphyroblasts within contact metamorphosed penetratively foliated metapelitic country rocks; foliations in xenoliths and pendants, interpreted to be correlative with regional deformation fabrics, are cut by the Goldstream pluton; and, reinterpretation of the biotite foliation, locally present within the granitic phase of the pluton, as either a magmatic foliation or a ghost foliation inherited from assimiliated xenoliths (Photo 2).

U-PB GEOCHRONOLOGY

In this section we report new U-Pb data and interpreted ages for the Downie Creek orthogneiss and Goldstream pluton. A brief description of each rock sample is followed by a discussion of the U-Pb geochronology, including zircon descriptions and data interpretation. U-Pb data are tabulated in Table 1 and plotted on concordia diagrams in Figure 3 and 4. Sample preparation and U-Pb analyses were carried out at the Geochronology Laboratory of the University of British Columbia. Complete U-Pb analytical procedures employed at the UBC Geochronology Laboratory are reported in Mortensen *et al.* (1995).

Zircons were selected for analysis on the basis of their magnetic susceptibility, clarity, colour, grain size and morphology. In general only high quality, crack- and inclusion-free grains were chosen. All fractions were then air abraded (Krogh, 1982), removing about 10-20 volume per cent of each grain.

DOWNIE CREEK ORTHOGNEISS

An approximately 20 kg sample of penetratively foliated, light grey to white, biotite quartz monzonite was collected from a road cut located north of Downie Creek on B.C. Highway 23. The outcrop has been cut by younger (post-ductile deformation) leucocratic veins and dikes, and has been chlorite-altered along steep brittle fractures related to the Columbia River fault zone. Sampling was restricted to the least altered, granitic phase of the gneiss. The sample yielded abundant high quality, clear, colourless to rarely pale yellow, euhedral, stubby to elongate prismatic zircons.

Four analysed zircon fractions are disposed along a linear trend that indicates the presence of inherited zircon (Figure 3). A chord passed through these data gives an early Mississippian lower intercept of 354.4+/-1.0 Ma (MSWD=2.87), which is considered as the best estimate for the igneous age of this rock. An upper intercept of 2.3±0.07 Ga gives an indication of the average age of inherited zircon in the analysed fractions. The coarsest stubby grains contain significant inherited zircon (fraction A), while finer and elongate grains (fractions B and D) and tips manually broken from elongate grains (fraction C) contain a greater late Paleozoic magmatic component.

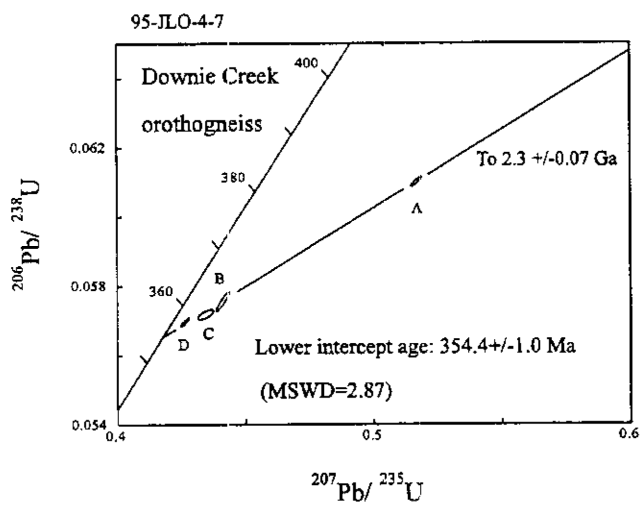

Figure 3: Concordia plot for the Downie Creek orthogneiss. Error ellipses are plotted at the 2σ level of precision. See text for details.

GOLDSTREAM PLUTON

An approximately 25 kg sample of hornblende biotite monzodiorite, the older phase of the pluton, was collected from a roadcut along the northern margin of the pluton, approximately 7 kilometres southwest of the Goldstream Mine. It comes from the same site as the sample 93JLO15-100, from which biotite and hornblende $^{40}Ar/^{39}Ar$ cooling ages were previously determined (Logan and Colpron, 1995: sample). The rock is massive and homogeneous, with no penetrative foliations developed and primary igneous textures are well preserved. It is apparently unaltered, with the exception of minor chlorite coated fractures.

This rock yielded abundant high quality, clear, colourless equant, stubby prismatic to elongate prismatic, and acicular zircon.

Five zircon fractions are concordant and overlapping at about 104 Ma (Figure 4). The best estimate for the age of the rock, which is 104.3+1.4/-1.8 Ma, is based on the average $^{206}Pb/^{238}U$ age of all fractions. The quoted error envelope is derived from the total overlap of all error ellipses with the concordia curve.

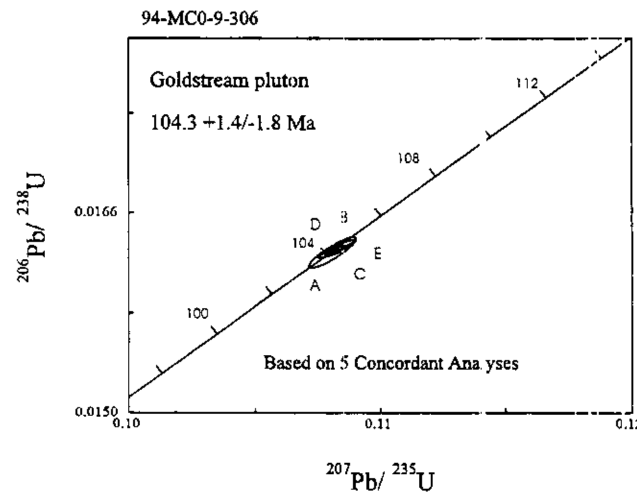

Figure 4: Concordia plot for the Goldstream pluton. Error ellipses are plotted at the 2σ level of precision. See text for details.

DISCUSSION

DOWNIE CREEK ORTHOGNEISS

The Downie Creek orthogneiss has yielded a U-Pb zircon, lower intercept crystallization age of 354.4 ±1.0 Ma, which overlaps, within precision, with a U-Pb age of 358±6 Ma for the Clachnacudainn gneiss (Parrish, 1992). The similar ages, composition and structural setting of the Downie Creek and Clachnacudainn gneisses provide strong evidence that they belong to a single Devono-Mississippian plutonic suite. They are likely part of a more extensive suite of Late Paleozoic rocks which also includes the Seymour Range gneiss (359±3 Ma; Parrish, 1992), and the Mount Fowler gneiss, (372±6 Ma; Okulitch *et al.*, 1975), located west of the Monashee Décollement.

GOLDSTREAM PLUTON

U-Pb data presented herein establish a mid-Cretaceous age of 104.3 +1.4/-1.8 Ma for igneous crystallization of the early phase of the Goldstream pluton, which can be considered as a maximum age for

TABLE 1. U-Pb ANALYTICAL DATA FOR INTRUSIVE ROCKS FROM THE DOWNIE CREEK AREA

Fraction[1]	Wt	U[2]	Pb*[3]	^{206}Pb[4]	Pb[5]	^{208}Pb[6]	Isotopic ratios (1σ,%)[7]			Apparent ages (2σ,Ma)[7]	
	mg	ppm	ppm	^{204}Pb	pg	%	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{206}Pb$
Downie Creek orthogneiss: 95-JLO-4-7											
A m,N5,p,s	0.120	5584	37	12597	21	11.1	0.06101 (0.12)	0.5169 (0.19)	0.06145 (0.09)	381.8 (0.9)	655.0 (4.1)
B m,N5,p,s	0.117	663	39	5868	47	11.2	0.05755 (0.24)	0.4411 (0.29)	0.05559 (0.11)	360.7 (1.7)	436.0 (4.8)
C m,N5,p,ti	0.071	733	43	1086	172	11.6	0.05717 (0.12)	0.4345 (0.35)	0.05511 (0.27)	358.4 (0.9)	417 (12)
D f,N5,p,e	0.088	703	42	16132	13	12.8	0.05695 (0.12)	0.4264 (0.19)	0.05430 (0.09)	357.1 (0.8)	383.4 (4.2)
Goldstream pluton: 94-MCO-9-106											
A c,N1,p,e	0.269	406	7	2452	45	20.4	0.01629 (0.38)	0.1081 (0.44)	0.04814 (0.20)	104.1 (1.6)	106.1 (9.6)
B m, N1,p,e	0.255	411	8	4038	27	21.0	0.01635 (0.10)	0.1086 (0.22)	0.04815 (0.13)	104.6 (0.2)	106.5 (6.3)
C f, N1,p,e	0.163	378	7	2855	22	22.1	0.01627 (0.09)	0.1080 (0.23)	0.04811 (0.16)	104.1 (0.2)	104.8 (7.5)
D c, N1,eq	0.175	444	8	1635	49	20.1	0.01631 (0.10)	0.1082 (0.25)	0.04812 (0.17)	104.3 (0.2)	105.3 (8.1)
E m, N1,p,e	0.100	401	8	2637	16	22.2	0.01631 (0.10)	0.1082 (0.22)	0.04811 (0.14)	104.3 (0.2)	104.7 (6.8)

Notes: Analytical techniques are listed in Mortensen *et al.* (1995).

[1] Upper case letter = fraction identifier; All zircon fractions air abraded; Grain size, intermediate dimension: c= >180 μm and >134μm, m= <134μm and >104μm, f= <104μm; Magnetic codes:Franz magnetic separator sideslope at which grains are nonmagnetic (N) or Magnetic (M); e.g., N1=nonmagnetic at 1°; Field strength for all fractions =1.8A; Front slope for all fractions=20°; Grain character codes: b= broken fragments, e=elongate, eq=equant, p=prismatic, s=stubby, t=tabular, ti=tips.

[2] U blank correction of 1-3pg ± 20%; U fractionation corrections were measured for each run with a double ^{233}U-^{235}U spike (about 0.005/amu).

[3] Radiogenic Pb

[4] Measured ratio corrected for spike and Pb fractionation of 0.0043/amu ± 20% (Daly collector) and 0.0012/amu ± 7% and laboratory blank Pb of 10pg ± 20%. Laboratory blank Pb concentrations and isotopic compositions based on total procedural blanks analysed throughout the duration of this study.

[5] Total common Pb in analysis based on blank isotopic composition

[6] Radiogenic Pb

[7] Corrected for blank Pb, U and common Pb. Common Pb corrections based on Stacey Kramers model (Stacey and Kramers, 1975) at the age of the rock or the $^{207}Pb/^{206}Pb$ age of the fraction.

the plutonic complex. These data corroborate field relationships indicative of late-to post-deformational emplacement, with respect to contractional structural elements of the Selkirk Allochthon.

The U-Pb igneous crystallization age of 104.3 +1.4/-1.8 Ma for the Goldstream Pluton is consistent with a previously determined biotite $^{40}Ar/^{39}Ar$ plateau cooling age of 100±1 Ma, but conflicts with a hornblende $^{40}Ar/^{39}Ar$ cooling age of 114±4.5 Ma. Data from this latter age did not yield a good plateau, and we interpret these results as anomalously old, possibly due to the presence of excess radiogenic Ar.

The age and stuctural style of the pluton are consistent with it belonging to the mid-Cretaceous Bayonne Plutonic suite of southeastern British Columbia.

CONCLUSIONS

The Downie Creek area is underlain by variably metamorphosed Lower Paleozoic rocks of the Hamill and Lardeau groups, and the intervening Badshot Formation. The area is intruded by several composite granitic bodies. Data from this study and others (R.L. Armstrong; U.B.C. data file) indicate the presence of at least four intrusive suites: Early Mississippian (Downie Creek orthogneiss, circa 354 Ma), mid-Cretaceous (Goldstream Pluton, circa 104 Ma), Late Cretaceous (Downie stock, circa 66 Ma) and post-Late Cretaceous leucogranite and pegmatites. Contact relations and structural/textural features suggest that peak metamorphism and ductile deformation in the Downie Creek area occurred prior to intrusion of the Goldstream Pluton, probably during Middle Jurassic time.

Another long-lived intrusive centre occurs north of Revelstoke in the Clachnacudainn Range. The Clachnacudainn igneous complex (Crowley, 1992) is composed of mainly 5 granitoid suites, similar in age and composition to those at Downie Creek. It intrudes Lower Paleozoic (?) rocks in the northern part of the Clachnacudainn salient of Wheeler (1963, 1965).

The similar stratigraphic, magmatic and deformational history preserved at Downie Creek and in the Clachnacudainn complex suggest continuity along the east side of the Monashee complex between these two areas (Figure 1). This supports Crowley's (1992) contention that the Standfast Creek fault is a tectonically insignificant fault and the Clachnacudainn igneous complex is, like the Downie Creek area, an integral part of the Selkirk allochthon.

ACKNOWLEDGMENTS

We thank Verna Vilkos, who provided insightful and essential assistance with diagram preparation. In addition, Bill McMillan and Chris Rees are thanked for their careful review of the paper.

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