PRELIMINARY REPORT ON A PROTEROZOIC (?) STOCK IN THE PURCELL SUPERGROUP AND COMPARISON TO THE CRETACEOUS WHITE CREEK BATHOLITH, SOUTHEASTERN BRITISH COLUMBIA (82F/16, 82K/01)

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KEYWORDS: White Creek Batholith, Hellroaring Creek Stock, Greenland Creek Stock, Proterozoic, Purcell Supergroup, Aldridge Formation, Geochronology.

INTRODUCTION

In southeastern British Columbia many intrusive suites lack conclusive radiometric age dates. The purpose of this B.Sc. project is to study three of the intrusions in the Purcell Mountain Range and provide uranium-lead geochronological results on two of these to refine the igneous magmatic history of the region.

The White Creek Batholith (WCB) and the Greenland Creek Stock (GCS) are located approximately 45 km northwest of Cranbrook, B.C. The Hellroaring Creek Stock (HCS) is situated 15 km west of Cranbrook (Figure 11-1). All three intrude lower greenschist grade regionally metamorphosed Aldridge Formation, a middle Proterozoic basin fill succession (Höy, 1993), and cut the 1467 ± 3 Ma Moyie Sills (Anderson and Davis, 1995). Reesor (1958) completed previous mapping and a comprehensive study of the White Creek Batholith. Since that time, mining companies conducted a number of exploration projects searching for economic deposits of tungsten and massive sulphides. The Hellroaring Creek Stock was originally located by Rice (1941), during a regional study, and a more detailed map was published by Leech (1957). It was regarded as an intrusive of possible economic interest with exploration projects focusing in on the potential for beryllium and industrial minerals.

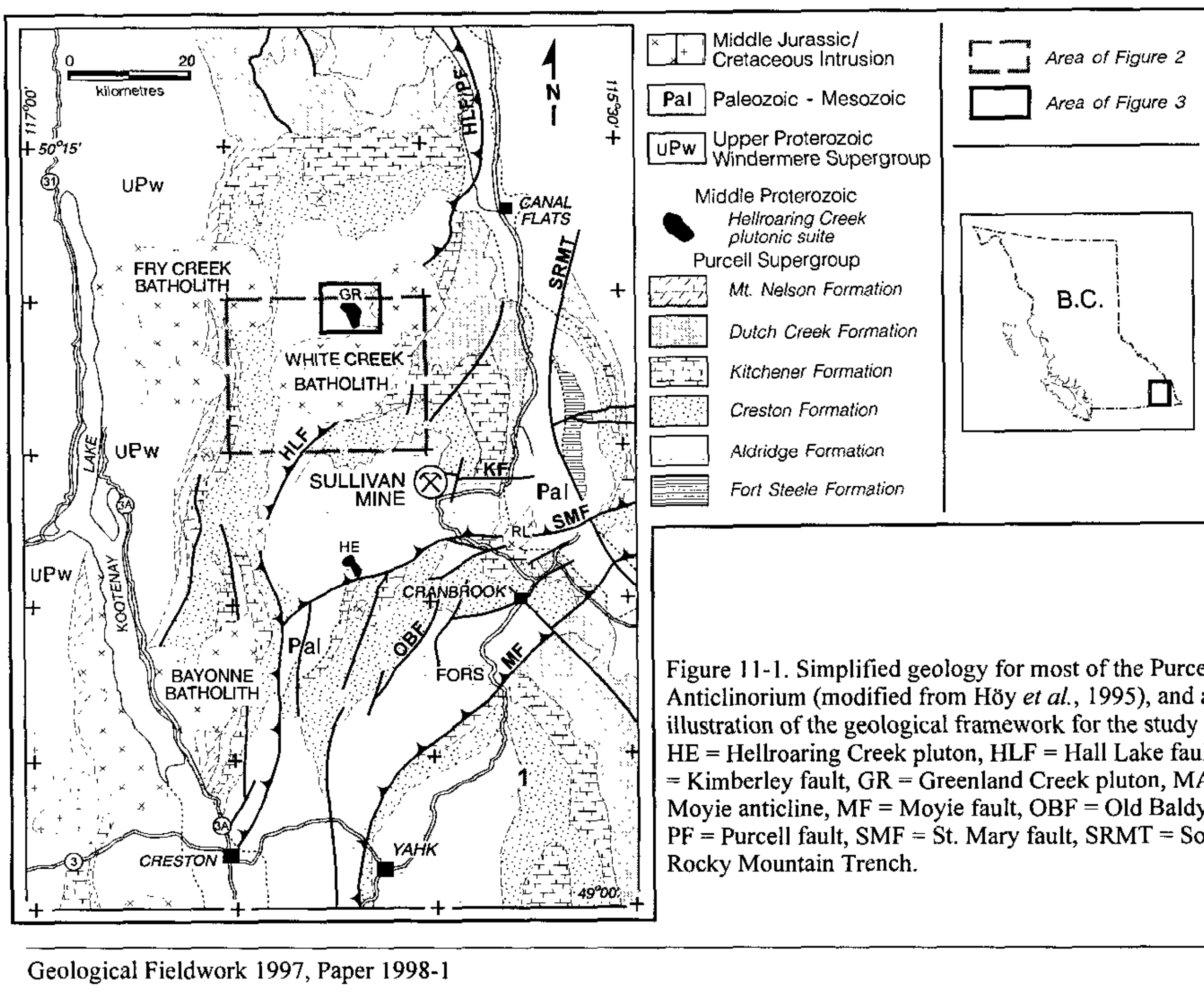

Figure 11-1. Simplified geology for most of the Purcell Anticlinorium (modified from Höy *et al.*, 1995), and an illustration of the geological framework for the study area. HE = Hellroaring Creek pluton, HLF = Hall Lake fault, KF = Kimberley fault, GR = Greenland Creek pluton, MA = Moyie anticline, MF = Moyie fault, OBF = Old Baldy fault, PF = Purcell fault, SMF = St. Mary fault, SRMT = Southern Rocky Mountain Trench.

PROJECT COMPONENTS

The thesis project consists of three main components. The first involved mapping the Greenland Creek Stock during August 1997. The second is a petrological and geochemical study of the pegmatite intrusions, the HCS and the GCS. This aspect of the project will compare the mineralogy and abundance of major elements, trace elements, and rare earth elements to classify and determine the tectonic setting for the two stocks. The third aspect of this study is to obtain precise and accurate U-Pb ages for the Greenland Creek Stock and the White Creek Batholith. An accurate emplacement age for the GCS will link it to either the middle Proterozoic HCS suite or the middle Cretaceous WCB suite. These components will answer questions concerning the Proterozoic tectonic setting, how the intrusive suites are related in the Purcell Supergroup and lead to new constraints on the timing of igneous activity in the area.

WHITE CREEK BATHOLITH

Description

The White Creek Batholith was originally mapped by Reesor (1958), who published a detailed megascopic and microscopic description of the five phases. It is an oval, concentrically zoned igneous body that outcrops over an area of approximately 225 km (Figure 11-2). The oldest unit, forming a rim along the western margin, is biotite granodiorite that grades into hornblende-biotite granodiorite. Inward from these two is a large body of potassic feldspar porphyritic quartz monzonite that comprises most of the eastern half of the batholith. The inner core is a leucocratic quartz monzonite. The fifth phase is a medium grained quartz monzonite that intrudes the two older granodiorite units in the western portion of the body. Aplite and pegmatite dikes are also common in parts of the batholith, especially the porphyritic quartz monzonite phase.

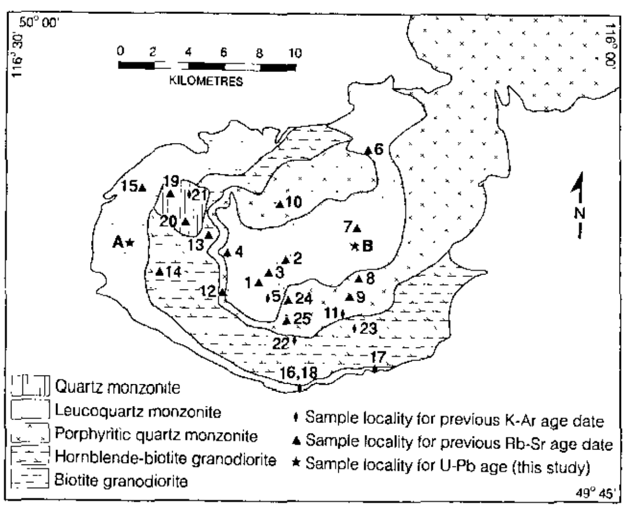

Figure 11-2. Generalized geology and sample locations within the White Creek batholith (after Reesor, 1996, 1958).

Previous Work

The White Creek Batholith has been the focus of a number of geochronological studies summarized in Figure 11-2 and Table 11-1. The study by Wanless *et al.* (1968) emphasized mineralogy, geochemical characteristics and the geologic history of each of the phases. They document a decrease in the content of plagioclase, biotite, hornblende, epidote, and accessories and an increase in microcline, quartz, and muscovite towards the inner core. A Rb-Sr study of the WCB shows that each one of the distinct lithologic zones have different initial $^{87}Sr/^{86}Sr$ isotopic compositions, indicating that the lithologic variations could not be produced solely by inward fractional crystallization during cooling (Wanless *et al.*, 1968).

The Rb-Sr study by Wanless *et al.* (1968) determined the first accurate emplacement age on one of the phases from an Rb-Sr whole rock isochron. They calculated the age of the leucocratic monzonite core at 111 ± 5 Ma ($^{87}Rb = 1.47 \times 10^{-11}$ yr^{-1}) which has since been recalculated to 115 Ma ($^{87}Rb = 1.42 \times 10^{-11}$ yr^{-1}; Brandon and Lambert, 1992). Combining all the mineralogical, geochemical and geochronlogical data, they established four major events: emplacement of the outer margins (126 Ma), consolidation of core rocks (115 Ma), an initial thermal episode (~85 Ma), and a second thermal episode (~65 Ma).

The work of Brandon and Lambert (1992) further constrained the mid-Cretaceous episode by four Rb-Sr combined whole rock-apatite isochron ages; these were 105-115 Ma, including a 105.9 ± 1.2 Ma obtained on the porphyritic granodiorite zone of the WCB. Following this paper, Brandon and Lambert (1994) conducted major element, trace element, and Sr, Nd, Pb, and O isotopic studies to determine the source for the generation of all WCB granitoids. They concluded that at least three pulses of isotopically and chemically distinct magma were present. The first was responsible for the two outer granodiorites, the second for the porphyritic phase, and the third for the monzonite core. From their results, the model calculations favored anatexis of crustal sources, with little geochemical influence of mantle-derived magma. This anatexis was interpreted to have resulted from intra-crustal melting in response to terrane accretion and collision along the western margin of North America.

Current Research

As part of this study, samples were collected from the central and border phases, presumably the youngest and oldest intrusive units, respectively (Figure 11-2). A sample of the biotite granodiorite rim was obtained 1 km west from Price Lake and one from the leucocratic quartz monzonite core 4.5 km north of Skookumchuck Mountain. (Table 11-2) These two phases will be radiometrically dated using isotope dilution thermal ionization mass spectrometry U-Pb methods at the geochronology laboratory, University of Alberta. Concise ages documenting the duration of emplacement of the White Creek Batholith will augment the established geochemical

Table 11-1. Sample localities from studies on the White Creek Batholith after Wanless *et al.*, (1968) and Brandon and Lambert (1994). WRX = whole rock sample

Rock Unit	#	Sample	Method	Age (Ma)	Reference
Quartz monzonite	19	WRX	Rb-Sr	-	Wanless *et al.* (1968)
	20	WRX	Rb-Sr	-	Wanless *et al.* (1968)
	21	Biotite	K-Ar	18	Lowdon (1961)
Leucoquartz monzonite	1	WRX	Rb-Sr	115	Wanless *et al.* (1968)
	2	WRX	Rb-Sr	115	Wanless *et al.* (1968)
	3	WRX	Rb-Sr	115	Wanless *et al.* (1968)
	4	WRX	Rb-Sr	115	Wanless *et al.* (1968)
	5	WRX	Rb-Sr	115	Wanless *et al.* (1968)
		Biotite	K-Ar	82	Lowdon *et al.* (1962)
		Muscovite	K-Ar	80	Lowdon *et al.* (1962)
	6	WRX	Rb-Sr	115	Wanless *et al.* (1968)
	7	WRX	Rb-Sr	115	Wanless *et al.* (1968)
	A	Zircon	U-Pb	N/A	**Current Study**
Porphyritic quartz monzonite	8	WRX	Rb-Sr	-	Wanless *et al.* (1968)
		WRX-apatite	Rb-Sr	105.9	Brandon and Lambert (1992)
	9	WRX	Rb-Sr	-	Wanless *et al.* (1968)
		WRX-apatite	Rb-Sr	105.9	Brandon and Lambert (1992)
	10	WRX	Rb-Sr	-	Wanless *et al.* (1968)
	11	WRX	Rb-Sr	-	Wanless *et al.* (1968)
		Biotite	K-Ar	60	Lowdon (1961)
	12	WRX	Rb-Sr	-	Wanless *et al.* (1968)
	22	Biotite	K-Ar	29	Lowdon (1961)
	24	WRX-apatite	Rb-Sr	105.9	Brandon and Lambert (1992)
	25	WRX-apatite	Rb-Sr	105.9	Brandon and Lambert (1992)
Hornblende-biotite granodiorite	13	WRX	Rb-Sr	-	Wanless *et al.* (1968)
	14	WRX	Rb-Sr	-	Wanless *et al.* (1968)
	23	Hornblende	K-Ar	87	Lowdon (1961)
Biotite granodiorite	15	WRX	Rb-Sr	-	Wanless *et al.* (1968)
	16	WRX	Rb-Sr	-	Wanless *et al.* (1968)
		Biotite	K-Ar	73	Lowdon *et al.* (1962)
	17	WRX	Rb-Sr	-	Wanless *et al.* (1968)
		Biotite	K-Ar	79	Lowdon (1961)
	18	WRX	Rb-Sr	-	Wanless *et al.* (1968)
		Biotite	K-Ar	56	Lowdon (1961)
	B	Zircon	U-Pb	N/A	**Current Study**

data by Brandon and Lambert (1994) and Wanless *et al.* (1968), constraining the magmatic evolution of the WCB.

HELLROARING CREEK STOCK

Description

The Hellroaring Creek Stock outcrops over an area of 10 km^2 and generally is composed of medium- to coarse-grained granodiorite pegmatite. Ryan and Blenkinsop (1971) recognized four phases based on differences in composition and texture. The first was a coarse-grained albitic granodiorite that consists of feldspar, muscovite and tourmaline phenocrysts in a feldspar-quartz-muscovite groundmass. The second was a granophyre unit, the third a medium-grained tourmaline-free granodiorite. The fourth phase sampled was a medium- to coarse-grained tourmaline-rich granodiorite. Some of the phases were only locally developed and it is likely that others exist as well. For example, a fine-grained aplite unit consisting of tourmaline and garnet was observed along the contacts with the surrounding country rock.

Previous Work

Earlier geochronological studies on the Hellroaring Creek Stock yielded imprecise ages. The first attempt at radiometric dating was using K-Ar methods on a muscovite sample. Lowdon (1961) obtained an age of 705 Ma followed by Hunt (1962), who obtained an age of 769 Ma.. These ages could reflect K-Ar resetting due to a metamorphic event.

The work of Ryan and Blenkinsop (1971) contradicted the previous K-Ar dates and provided the most reasonable age until recently. Using the Rb-Sr whole rock method, they obtained an isochron of 1260 ± 50 Ma. The implications from this data were significant because it indicated that the Hellroaring Creek stock was the oldest intrusion in the Purcell Supergroup. Although more recent work has produced a ~1370 Ma U-Pb monazite age (Mortensen, written comm., 1997) Ryan and Blenkinsop's result was the first indication of a Proterozoic magmatic event in this region.

Current Research

Due to the fact the Greenland Creek Stock may be linked to the Hellroaring Creek Stock, samples were collected from the HCS for geochemical studies. The major elements, trace elements, and rare earth elements of phases with similar mineralogy and texture will be compared to determine if the two pegmatites have similar source magmas.

GREENLAND CREEK STOCK

Description

The Greenland Creek Stock crops out 1 km north of the core phase of the White Creek Batholith (Figure 11-3; Photos 11-1 and 2). It is a typical granitoid pegmatite of variable texture and coarseness (0.5 mm to ~4 cm). The dominant phase is coarse-grained with interlocking feldspars, and quartz and large sheets of muscovite. The second is a relatively equigranular unit composed of 0.5 to 1 cm grains of feldspar, quartz and muscovite. The third and fourth phases appear to occur in conjunction with each other near the contacts of surrounding lower Aldridge Formation and Moyie Sills. The chilled margins of the pluton are aplite with tourmaline needles and coarse sheets of muscovite. A coarse-grained tourmaline-rich pegmatite is associated with this phase.

Although similar in composition, there are a few differences between the HCS and the GCS that were recognized in the field. The first is the abundance of large quartz lenses in the GCS that were rare in the HCS. The second is the presence of garnet (and trace pyrite) that was common in the aplite phases of the HCS, but rarely found in the GCS. And lastly is the size of the tourmaline crystals. The crystals in HCS frequently were up to 8 cm in size but the GCS rarely had tourmaline larger than 4 cm.

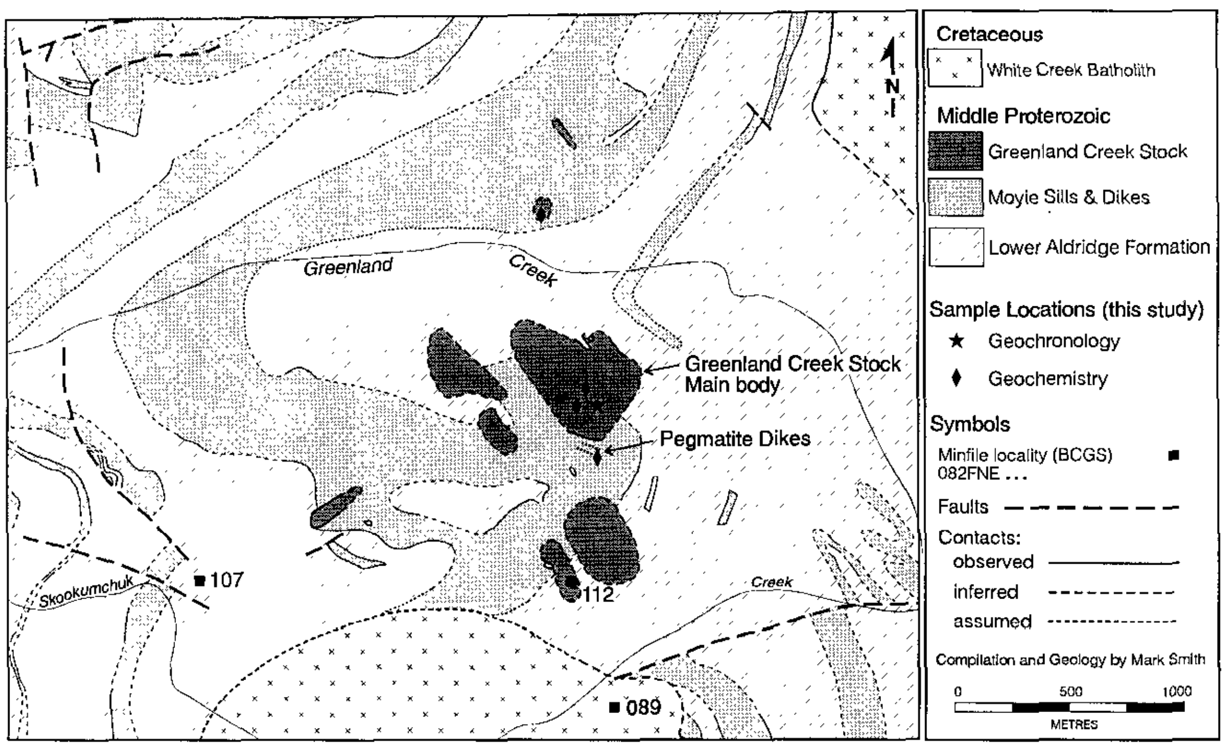

Figure 11-3. Geological compilation map for the Greenland Creek stock area.

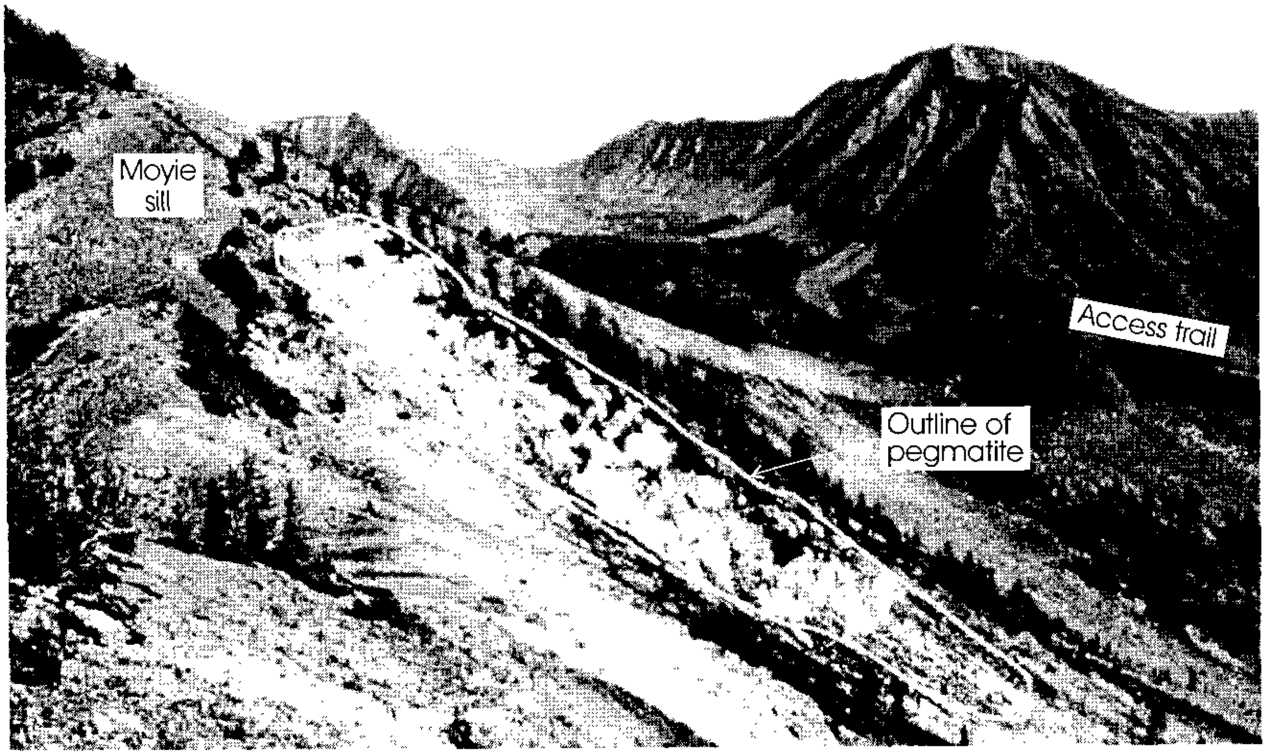

Photo 11-1. View to 340° to the westernmost satellitic phase of the Greenland Creek stock where it intrudes lower Aldridge Formation and a Moyie sill. Contacts are sharp and intrusive with no evidence of faulting. Access trail to the Greenland Creek tungsten occurrences (see Perry and Hodgson, 1980) is evident along the right side of the photo.

Photo 11-2. View to 340° to a series of white weathering, leucocratic tourmaline-muscovite pegmatite and medium-grained quartz monzonite dikes hosted in a massive Moyie sill gabbro along the southern contact zone of the main Greenland Creek stock (see Figure 11-3 for location marked as "Pegmatite Dikes").

Previous Work

Although originally mapped and described by Reesor (1958) as part of the mid-Cretaceous White Creek batholith, his more recent compilation map designates it as a Proterozoic intrusion (Reesor, 1996). Since his original mapping, work on and near the Greenland Creek Stock has been limited to exploration companies searching for economic deposits. A number of detailed maps were produced, most notably by AMAX (Perry and Hodgson, 1980), and were used in conjunction with this study (Figure 11-3).

In 1995 a government geophysical survey was conducted in the Purcell Mountains. One of the interesting anomalies was a Th/K low over the Greenland Creek Stock that was strikingly similar to the signature over the HCS (Lowe *et al.*, 1997). These new data, along with geological comparison, has led to speculation that the GCS is mid-Proterozoic in age, and part of the Hellroaring Creek suite rather than part of the mid-Cretaceous suite.

Current Research

The main focus of this thesis study is to compare the Greenland Creek Stock to the Hellroaring Creek Stock and the White Creek Batholith. Geological mapping was conducted in the area, and a detailed map was compiled using earlier work done by AMAX (Perry and Hodgson, 1980). From this study, four intrusive phases were recognized and sampled in the field. These phases are mineralogically and texturally very similar to those present in the Hellroaring Creek Stock, located 45 km to the south. Each of these phases was sampled and geochemical analyses of major elements, trace elements, and rare earth elements will be performed to more accurately provide comparisons. The equigranular sample (location in Table 11-2) will be used for the U-Pb age date and determination of an epsilon Nd value. The epsilon Nd value will help measure the amount of influence mantle or crustal sources had in the formation of the magma. These will be compared to the values obtained by Brandon and Lambert (1994) for the WCB. The geochemical data will be used to classify the units and pegmatite to attempt to resolve the question of the source of the stock and its tectonic setting.

DISCUSSION

The lack of conclusive U-Pb radiometric dates on many of the intrusive suites in southeastern British Columbia has led to a great deal of speculation about the geologic history of the region. If successful, the U-Pb ages obtained in this study on the White Creek Batholith will provide an accurate estimate of emplacement history and constrain the timing of this mid-Cretaceous magmatic event. The age date on the Greenland Creek Stock, used in conjunction with the geochemical analyses will attempt to determine its tectonic environment and link it to either the Proterozoic or Cretaceous plutonic episode.

The Proterozoic history of the Purcell Supergroup has recently been the source of debate. The collisional tectonic event associated with the HCS magmatism is known as the East Kootenay Orogeny (McMechan and Price, 1982). However, Doughty and Chamberlain (1996) concluded that an extensional event occurred in the Belt Supergroup (correlates to the Purcell Supergroup) further south in Montana. They show that the circa 1370 Ma tectonothermal event involved burial metamorphism, bimodal magmatism and partial melting of high grade metasedimentary rock. They also showed that extensional deformation was concentrated in the deeper level high grade rocks. If an extensional event caused the plutonism, then the term orogeny is incorrect.

The goal of this study is to analyze the mineralogy and geochemistry of the two pegmatites and obtain a precise and accurate age on the GCS. The U-Pb age on the GCS will resolve whether the intrusion is linked to either, the mid-Proterozoic HCS or the mid-Cretaceous WCB. Although pegmatites may not be good discriminators for a granitoids' tectonic environment, they potentially are the only evidence of Proterozoic plutonism at ~1370 Ma. The new data should help to classify the stocks, correlate the magmatic episodes in the Belt-Purcell Supergroup and lead to insights as to whether there was an East Kootenay orogenic or extensional event.

ACKNOWLEDGMENTS

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Table 11-2. UTM coordinates for U-Pb samples collected for the current study (± 50 m; in NAD83).

Sample #	Rock Type	Easting (m)	Northing (m)
Green1	Equigranular granitoid pegmatite	558170	5536800
WCB-A	Biotite granodiorite	543250	5525700
WCB-B	Leucoquartz monzonite	543450	5525700

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