Processes Controlling the Growth and Evolution of Continental Batholiths, Coast Mountains, British Columbia, Canada

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CONVENERS

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INTRODUCTION

This Thompson Field Forum brought together 27 geoscientists in Terrace, British Columbia, Canada, to discuss the processes responsible for production of batholiths in continental magmatic arcs. The forum focused on how the existing petrologic, geochronologic, and structural data for the Coast Mountains batholith can inform modern paradigms for batholith growth and magma genesis. Decades-old models based on a robust but limited dataset along the well-exposed Skeena River corridor between Terrace and Prince Rupert provide a unique opportunity to test modern orogenic models using new techniques and expanded datasets.

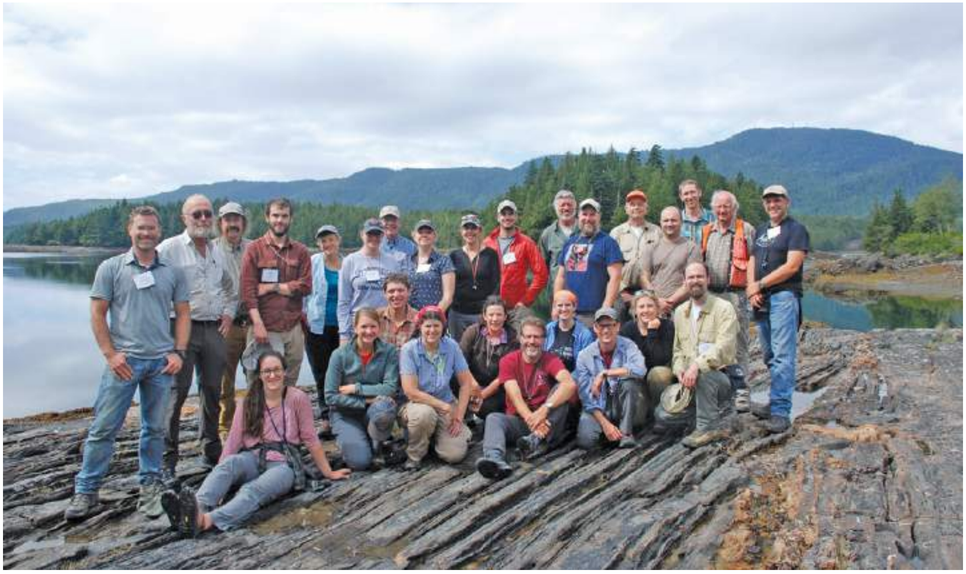
OVERVIEW

The forum introduced participants to the spectacular geology along the Skeena transect across the British Columbia Coast Mountains and focused attention on areas where future study may resolve outstanding questions. We began with an informal Sunday night meeting at the Thornhill Pub in Terrace, continued by exploring the low-grade Intermontane terrane rocks along the eastern flank of the Coast Mountains batholith on Monday, examined the Central Gneiss Complex and associated plutons on Tuesday, utilized bus and helicopter to access the high-grade rocks of the Central Gneiss Complex on Wednesday, boarded a boat in order to access islands in the western metamorphic belt on Thursday, and returned to the bus for stops in the Ecstall pluton on Friday. This final day of the forum for most of the group ended with dinner and an organized discussion on the current state of knowledge and future research directions for research on batholith growth and evolution. Twelve of the group stayed an additional day and used vans on Saturday for a long trip north to board helicopters and fly to the Seabridge Gold KSM property. We were treated to a spectacular look at porphyry copper mineralization freshly exposed by retreating ice along the eastern flank of the Coast Mountains batholith.

SUMMARY OF EXISTING DATA

The Coast Mountains batholith includes 170 to 45 Ma plutons that vary from gabbro to leucogranite that intruded host rocks from two composite terranes (e.g., Cecil et al., 2018). These rocks have provided stimulus for numerous geological research and mapping projects, including the pioneering maps produced by the Geological Survey of Canada, particularly by the late W.W. Hutchison (1982) and J.A. Roddick (1970). These maps delineated the fundamental contacts for the Coast Mountains batholith and the tectonostratigraphic framework that the plutons intruded. The maps served as the foundation for decades of research, led chiefly by Lincoln Hollister and Maria Crawford, who guided numerous projects with students, post-docs, and other colleagues. Their work led to fundamental advances in knowledge of granulite metamorphism, crustal thickening during batholith growth, the production of batholith melts, and collapse of thickened crust during the last stages of batholith growth.

Geological (e.g., Crawford et al., 1987) and geophysical studies (e.g., Morozov et al., 1998) outline the crustal architecture of the Coast Mountains batholith near Terrace–Prince Rupert. This architecture includes a fundamental offset of the Moho and prominent structural break known as the Coast shear zone. West of this shear zone, the crust averages ~26 km in thickness and includes rocks of the Insular superterrane, which includes the Alexander, Yukon-Tanana, and Wrangellia terranes. East of this shear zone, the crust averages 30 km in thickness and includes rocks of the Intermontane superterrane, here primarily Stikinia. Jurassic and Early Cretaceous plutons occur across the batholith and may represent disparate arcs. By mid-Cretaceous time, however, a single eastward migrating arc was established (Gehrels et al., 2009). The Late Cretaceous core of the batholith is east of the Coast shear zone and includes numerous plutons and the granulite facies rocks of the Central Gneiss Complex. Pioneering work on this granulite delineated the early high P and T conditions and the partial melt reactions in the Central Gneiss Complex, which was rapidly exhumed during the Eocene (Hollister, 1982). Partial melting in the Central Gneiss Complex was synchronous with intrusion of large plutons (e.g., Kasiks Sill), which include both mantle and crustal signatures. Rapid exhumation of the Central Gneiss Complex is interpreted to have been accommodated by top-to-the-east detachment faults between about 55 and 50 Ma. The Shames River detachment is the structurally lowest and most significant shear zone of this system. This detachment




Left: Field Forum participants pose on rocks of the Western Metamorphic Belt. Right: Lincoln Hollister imparts his enthusiasm about rocks in the Coast Mountains batholith. Photos by Chris Mattinson.

juxtaposes high-grade metamorphic rocks of the Central Gneiss Complex with greenschist facies rocks of Stikinia. Higher in the detachment system, rocks within Stikinia are cut by both high- and low-angle normal faults. Evidence of this extensional faulting is largely lacking in areas to the north and south. Forum participants examined the main elements of this complex orogen and participated in lively discussion of existing models, fundamental questions regarding batholith growth in general, and the central Coast Mountains batholith in particular, and directions for future work. Some of these thoughts are summarized in the following section and may help guide future researchers to use the Coast Mountains batholith to address key questions about crustal evolution at convergent margins.

QUESTIONS ABOUT BATHOLITH GROWTH AND EVOLUTION

Batholiths are the exhumed roots of magmatic arcs and contain evidence of the processes that form continental crust. These processes and those related to batholith evolution continue to pose several problems in modern geology. Some of these questions, discussed during the forum, follow.

1. *What are the processes and conditions responsible for the observed temporal and spatial variations in magmatism?*

Gehrels et al. (2009) and Cecil et al. (2018) document the timing of intrusion along more than 1000 km of the Coast Mountains batholith. The data demonstrate both the across-strike variation and the episodic nature of magmatism. In addition, Cecil et al. (2018) document that brief high flux events (HFE) vary temporally along the strike of the Coast Mountains batholith. Future work is needed to associate these HFE with specific crustal and mantle processes.

2. *What processes are responsible for the structural framework of the Coast Mountains batholith during batholith growth, and how did these processes affect magmatism?*

Late Cretaceous crustal thickening is best demonstrated by metamorphic *P-T-t* paths from the Western Metamorphic Belt along the western flank of the Coast Mountains batholith and the Central Gneiss Complex. The structural and tectonic framework for this event is not well understood. Thrust faulting likely played a significant role, especially within the Central Gneiss Complex, but its cause and relation to proposed strike-slip faulting remains uncertain. Similarly, whether the prominent crustal break currently marked by the 65–55 Ma Coast shear zone was the locus of older strike-slip faulting is unknown. The final stage of batholith construction at this latitude was marked by crustal extension in the early Tertiary; the apparent lack of this crustal collapse along strike in the batholith leaves open questions regarding the significance of extension in batholith evolution, the driving forces of extension, and the tectonic framework of the Coast Mountains batholith in early Tertiary time.

3. *What are the causal relationships between magma generation, deformation, and metamorphism?*

Voluminous plutons in the Coast Mountains result in limited preservation of metamorphic rocks. Thus, it is difficult to evaluate whether metamorphism resulted in partial melting or played a less direct role in HFE. Geochronologic data indicate that some metamorphism was synchronous with ca. 80 Ma HFE within the Coast Mountains batholith. Lu-Hf garnet ages of >100 Ma in the Western Metamorphic Belt (Wolf et al., 2010) indicate that the earliest metamorphism along the western flank of the Coast Mountains batholith preceded HFE. Additional studies are needed to better document the timing of metamorphism within and adjacent to the Coast Mountains batholith and to integrate these events with the structural and tectonics evolution of the batholith.

4. *What is the contribution of sediments to magmatism?*

The limited preservation of metamorphic rocks also makes evaluation of sediment contributions to magma generation difficult. Thus, possible relamination of sediments to the base of the crust may only be evaluated through isotopic and trace element signatures.

5. *What drives magma generation at mid to lower crustal levels (e.g., Kasiks Sill)?*

Plutons within the Central Gneiss Complex contain evidence for

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significant crustal contributions (Hollister and Andronicos, 2006). Additional petrologic and geochronologic research is required to better evaluate the proportion of mantle and crustal contributions and assess the conditions that triggered crustal melting.

FUTURE DIRECTIONS

The conveners are excited by the scientific enthusiasm and knowledge displayed by the participants. The spectacular outcrops led to numerous discussions about the research needed to further our understanding of magma generation and batholith evolution. We look forward to future research addressing the many open questions highlighted by this Thompson Field Forum.

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