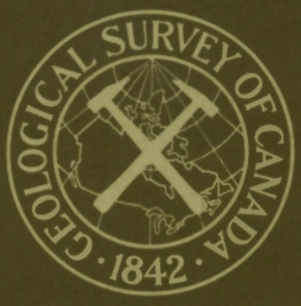

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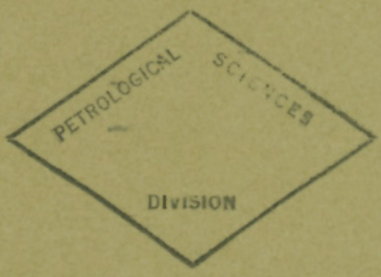

METAMORPHISM AND GRANITIC INTRUSIONS OF PRECAMBRIAN AGE IN SOUTHEASTERN BRITISH COLUMBIA

(Report and figure)

G. B. Leech

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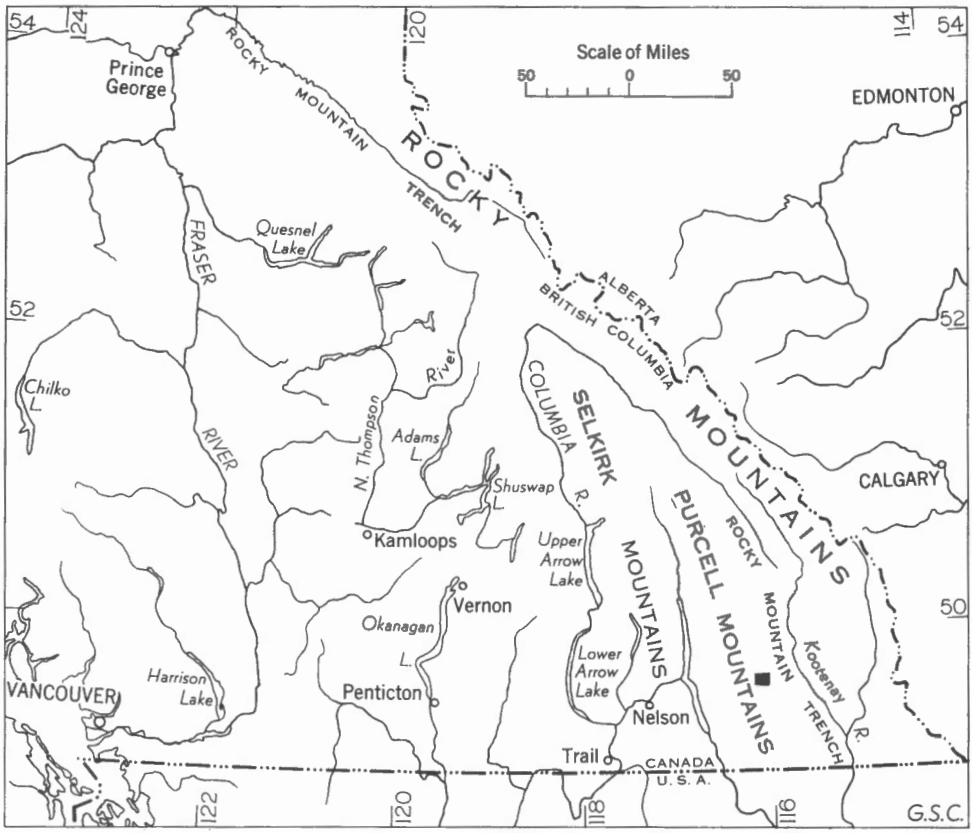

Figure 1. Map showing locality of Precambrian granitic intrusions (black square)

METAMORPHISM AND GRANITIC INTRUSIONS OF PRECAMBRIAN AGE IN SOUTHEASTERN BRITISH COLUMBIA

The only Precambrian granitic intrusions yet recognized in Canada west of the Canadian Shield are in the St. Mary Lake - Kimberley region of the Purcell Mountains in southeastern British Columbia. They confirm the existence of a late Precambrian (Upper Proterozoic) orogeny, between 700 and 800 million years ago, and provide clues to the identification of Precambrian structures.

Regional Setting

The Precambrian sedimentary rocks of the region comprise the Purcell sequence and the Windermere sequence; the latter overlies the Purcell with angular unconformity. Lower Cambrian strata succeed the Windermere sequence unconformably in the eastern Purcell Mountains and Rocky Mountains but apparently conformably in the western Purcell Mountains and Selkirk Mountains. The Purcell succession, at least 35,000 feet thick with base concealed, consists chiefly of siltstone, argillite, and quartzite, but carbonate rocks are important in its upper part. In contrast to the prevailingly fine grained Purcell rocks, the Windermere sequence contains an impressive proportion of coarse clastic rocks, many of which are feldspathic and some of which contain actual granitic boulders.

The only igneous rocks hitherto regarded as Precambrian are the Moyie Intrusions which characteristically are sills of dioritic to gabbroic composition intruded into Purcell strata. These intrusions belong to the volcanic association of igneous rocks and are nontectonic, apparently intruding the Purcell sequence before it was folded. No Moyie Intrusions have been identified cutting Windermere strata.

The grade of regional metamorphism of the Purcell strata is low—near the transition from the quartz-albite-muscovite-chlorite subfacies to the quartz-albite-epidote-biotite subfacies of the greenschist facies. Original sedimentary structures such as crossbedding, graded bedding, flow marks, etc. are well preserved. Locally, however, metamorphism consequent on deformation and granitic intrusion is severe.

Most of the deformation in the Purcell Mountains has been ascribed (e.g. Rice, 1941)[1] to a late Mesozoic orogeny, to which all the granitic intrusions in the district were attributed, and to a much lesser extent to later movements associated with the raising of the adjacent Rocky Mountains, though the Precambrian and Palaeozoic unconformities in the Purcells have long been known. The Mesozoic age of the major intrusions has been corroborated by K-Ar age determinations (Lowdon, 1960, 1961, in press). The discovery of Precambrian granitic intrusions does not invalidate the conclusion that most of the structural relief is Mesozoic and younger, but it does emphasize the importance of Precambrian structures, masked though they may be by younger deformation.

The Purcell strata are distinctly more metamorphosed than Cambrian strata in contact with them, which is not in accord with the concept that the regional metamorphism is due to Mesozoic orogeny. A study of the age of the regional metamorphism of the Purcell strata is in progress, and the tentative conclusion is that Precambrian metamorphism is areally extensive and is not simply an aureole around the known Precambrian granitic intrusions.

Precambrian Intrusions, Metamorphism, and Structures

The known Precambrian granitic intrusions are: first, the Hellroaring Creek stock, which is 2 miles south of St. Mary Lake (Leech, 1957) and 11 miles southwest of Kimberley; second, a small stock just to the east of the Hellroaring Creek stock; and third, a body 4 miles northeast of St. Mary Lake and 5 3/4 miles southwest of Kimberley. The latter is within a discrete area in which the metamorphic grade is well above that characteristic of the region as a whole. This will be referred to as the 'Matthew Creek metamorphic area'. Muscovite from the Hellroaring Creek stock has a K-Ar age of 705 m.y. (Lowdon, 1961). Pegmatitic muscovite from the adjacent small stock yielded a K-Ar age of 675 m.y., which is probably too low due to loss of argon, the mica being cremulated, fractured, and possibly slightly weathered. Muscovite from the body near Matthew Creek, between St. Mary Lake and Kimberley, has a K-Ar age of 745 m.y. Metamorphic muscovite from quartzite in the Matthew Creek metamorphic area has a K-Ar age of 790 m.y.

All three Precambrian granitic intrusions cut the lower division of the Aldridge Formation, which is the oldest unit of the Purcell sedimentary sequence exposed in the Purcell Mountains. In addition, the Hellroaring Creek Stock and its satellite intrude typical

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[1] Names and dates in parentheses refer to publications listed in the References.

examples of the dioritic Moyie Intrusions, thus confirming the Precambrian age of the latter. The relatively high grade Precambrian metamorphism in the Matthew Creek area also involves Aldridge strata and Moyie sills.

The Hellroaring Creek stock was chosen in 1959 for dating because on structural grounds it appeared to be the oldest in the district. Contrary to the usual pattern in which stocks and batholiths cut major faults in the region (e.g. the White Creek batholith and Hall Lake stock cut the Hall Lake fault, and the Bayonne batholith cuts the St. Mary fault), the Hellroaring Creek stock and its metamorphic aureole are truncated by the St. Mary fault.

The Hellroaring Creek stock, 1 square mile in area, consists chiefly of albitic granodiorite with a varied texture; much of it is coarse to pegmatitic. The chief accessory minerals are muscovite and black tourmaline, the latter a conspicuous component. Beryl occurs at the north end of the stock and possibly elsewhere. The stock differs from the younger intrusions by being much more albitic, by containing little or no biotite, by its general coarseness, and by the abundance of tourmaline. It is interesting to note that tourmalinization is a major wall-rock alteration at the Sullivan ore deposit at Kimberley, where the final deposition of the ore, like the intrusion of the Hellroaring Creek stock was younger than Moyie Intrusions but, on the basis of lead-isotope and potassium-argon studies, was nevertheless Precambrian (Leech and Wanless, in press).

The small Precambrian intrusion 1/3 mile east of the Hellroaring Creek stock is a similar pegmatite which also contains abundant tourmaline and is reported to have yielded beryl.

The Hellroaring Creek stock occupies the axial region of a northwesterly-plunging anticline, to which its long axis is parallel. It transects the Aldridge beds and the intercalated Moyie sills that outline the fold, cutting progressively upward to the north, and it is discordant to minor tectonic structures in the sediments. It is therefore believed to be intrusive into a pre-existing anticline. This anticline may however have been further accentuated during the Mesozoic orogeny; at least one zone of intense crushing cuts the stock, but unfortunately the stock's borders are so poorly exposed that the amount of shearing along them is unknown.

The anticline is one of a series of similar small and medium-sized folds that are thought, by analogy, to be probably initially Precambrian and further deformed later. These folds are just west of the axis of the segment of the Purcell geanticline that lies north of the St. Mary fault (Leech, 1959).

Leucocratic coarse-grained to pegmatitic granodiorite intrusions occur in at least the northern part of the Matthew Creek metamorphic area. They are obscured by overburden but many are probably sills, though the largest body, which occupies at least the mid part of the area outlined diagrammatically on the map (Leech, 1957), is definitely transgressive. This intrusion is in or near the crestal zone of a complex anticline. The intrusions contain abundant muscovite and they differ from the Hellroaring Creek stocks in that tourmaline is not conspicuous. Deformation is evidenced by bent and fractured muscovite and feldspar crystals and by irregular stringers and lenses of quartz which cut feldspar. The K-Ar age of 745 m.y. yielded by deformed muscovite is regarded as minimal.

The Matthew Creek metamorphic rocks outcrop in the axial zone of the geanticline and involve the stratigraphically lowest rocks exposed in the Purcell Mountains. The metamorphic area is probably oval-shaped, with its major axis about 5 miles long and striking northwest, but the only outcrops of it are at the northwest and southeast ends, the rest lying beneath alluvium of St. Mary Valley. The rocks are strata of the lower division of the Aldridge Formation and sills of the Moyie Intrusions. The sediments have been converted into rather vitreous quartzites and to glistening mica schists whose chief components are muscovite, quartz, biotite, and sericite, with various amounts of sillimanite and garnet. Tourmaline is a ubiquitous accessory mineral and graphite occurs in some of the schist. The metamorphic grade of these rocks is the almandine amphibolite facies, which is markedly higher than the lower- to mid-zone of the greenschist facies that characterizes most of the rest of the region.

Metamorphic muscovite from quartzite in the Matthew Creek metamorphic area yielded a K-Ar age of 790 m.y., a younger age limit for the metamorphism and for the Moyie Intrusions, which are affected by it.

Open folds of various scales are numerous in the Matthew Creek metamorphic area. The smaller ones, which are the only ones completely exposed, resemble those elsewhere in the district inasmuch as their axial planes strike northwesterly and dip steeply westward and most plunges are gently northward. The schists are in part crenulated and cut by slip cleavage related to the crenulations. The crenulations are not characteristic of the less metamorphosed rocks of the region but are not necessarily evidence of a separate period of deformation; they may instead reflect the special physical characteristics of the schists.

Northerly trending minor folds with steep east limbs and westward-dipping axial planes characterize the segment of the Purcell geanticline at and north of Kimberley. Lamprophyre dykes occupy fractures that cut these folds in the Sullivan Mine, and one such

dyke yielded biotite at least as old as 765 m.y. (Lowdon, 1960; Leech and Wanless, in press). These particular minor folds are therefore Precambrian and are older than most of the structural relief of the Purcell geanticline. The geanticline originated before and, probably, during Windermere deposition and supplied sediments for the latter (Walker, 1926; Reesor, 1957) but most of its deformation is younger, as is evidenced by the fact that the angular discordance between Purcell and Palaeozoic beds in it is small in comparison to their present inclinations.

The trends of Precambrian folds in the St. Mary Lake - Kimberley district apparently were similar to the present trends, which are ascribed to late Mesozoic orogeny; and evidence from other localities supports the view that in general the Precambrian and Mesozoic structural trends in the site of the Purcell Mountains were similar. The unconformity between the Windermere and Purcell sequences provides such evidence. J.E. Reesor (oral communication) states that the Windermere sequence rests on almost the same parts of the Purcell for considerable distances in a northwesterly direction, parallel with the trend of the younger folds; whereas it rests on considerably different stratigraphic levels in the direction across this trend, and he accordingly concludes that the pre-Windermere fold trends were roughly the same as the dominant younger trends.

The similarity of Precambrian and Mesozoic structural trends increases the probability that many folds owe part of their development to each period of deformation, which indicates the difficulty of recognizing those that were initially Precambrian.

Other Regional Considerations

The importance of the sub-Windermere tectonic break, relative to whatever sub-Cambrian discontinuity there may be, has become increasingly apparent (Reesor, 1957). Nevertheless the pre-Windermere activity has generally been thought (Walker, 1926; Rice, 1937, 1941; Reesor, 1957) to involve merely uplift, tilting, and mild folding and to have been more nearly epeirogenic than orogenic. White (1959)—citing the evidence of uplift, tilting, mild folding, dioritic intrusions, and a locality at which Schofield reported extreme structural discordance between Purcell and Cambrian strata—expressed the opinion that the pre-Windermere tectonism was an orogeny—the East Kootenay orogeny. He did not comment, however, on the non-orogenic character of the dioritic (Moyie) intrusions nor on Rice's (1937) interpretation that the discordance reported by Schofield is due to faults.

The Precambrian granitic intrusions and metamorphism reported here are concrete evidence of orogeny. Its age relative to the Windermere sequence must be determined from regional considerations

because the rocks are not in contact. Nevertheless, because the pre-Windermere disturbance was much greater than the possible post-Windermere one, the intrusion and metamorphism are considered pre-Windermere and, less probably, intra-Windermere, in age.

The source of the granitic cobbles and boulders in the Windermere Toby conglomerate near Canal Flats and Windermere, British Columbia, and of the feldspar fragments in the younger Windermere Horsethief Creek Group is still in doubt, and unfortunately these materials are unsuitable for K-Ar age determination. The restricted distribution but local abundance and large size of the granitic boulders and cobbles suggest a nearby source. On the other hand there are indications that the source is not the Precambrian intrusions described here: much of the granitic rock in the Toby conglomerate is gneissic, whereas the recognized Precambrian granitic and metamorphic rocks are not gneissic; there is considerable doubt that post-Purcell intrusions were unroofed in time to supply debris to the basal Windermere beds; and furthermore the abundance and relatively wide distribution of detrital feldspar in the Horsethief Creek Group imply a larger source. The source may be a 'basement high' beneath the Rocky Mountains, like that inferred from the presence of a local concentration of granitic debris in basal Devonian beds there (Leech, 1958).

The recent junction of mapping in British Columbia (Leech, 1960; Price, in press) with that in Montana (Johns, 1961; Ross, 1959) proves conclusively that the highest units of the Missoula Group along the International Boundary are continuous with units within the upper part of the Purcell sequence. Correlations of units of the Missoula Group along the International Boundary with formations in the type area of the Missoula Group near Missoula, Montana, are uncertain (Ross, 1959). There is no apparent evidence of an unconformity within the group, but neither is there a demonstrable unconformity, in the type area, between the Missoula Group and strata thought to be Middle Cambrian (Nelson, in Nelson and Dobell, 1961). Nelson suggested that the tectonic conditions that prevailed during deposition of the Belt series (Missoula Group and older groups equivalent to the lower part of the Purcell sequence) persisted into Middle Cambrian time in the Missoula region. In support of this possibility he cited the apparent conformity of Windermere and early Cambrian strata in British Columbia, but without reference to the unconformity between the Windermere and Purcell sequences.

This unconformity is part of the evidence that confirms Deiss' (1941) concept of "Montania", in the north at least. During deposition of the Windermere strata the northwest limit of this positive area was near the present limit of exposure of Purcell strata in the Purcell Mountains (Reesor, 1957). The part north of the ancient Moyie fault was inundated in late Lower Cambrian time; but farther south the land existed until Middle Cambrian time, as shown along the Rocky

Mountain Trench just north of the International Boundary, where Middle Cambrian strata rest unconformably on Purcell strata that are assigned to the Missoula Group on the Montana side of the boundary.

The granitic intrusions and the metamorphism described here were associated with the rise of Montania. Tectonism was apparently less severe farther south but the determination of its southern extent is clearly important.

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