Shuswap terrane of British Columbia: A Mesozoic "core complex"

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ABSTRACT

The Shuswap terrane of the northwest Cordillera owes its distinctive characteristics to deformation and high-grade regional metamorphism that occurred primarily during the Mesozoic. Within the terrane, the Monashee Complex, the overlying Selkirk allochthon, and the intervening Monashee decollement record strain and metamorphism that occurred in Middle to Late Jurassic time, during and subsequent to the accretion of a western allochthonous terrane. The Selkirk allochthon moved eastward across the Monashee Complex after emplacement of the western allochthonous terrane but before late Mesozoic to early Cenozoic telescoping of the Rocky Mountain Belt. In this latter event, the Monashee Complex and overlying allochthonous slices were transported eastward relative to the North American craton on a sole fault that developed during listric thrusting of the Rocky Mountain foreland. Synmetamorphic to late-metamorphic elongation lineations and associated fabrics of the mylonitic rocks of the Monashee decollement zone were generated by shear strain during the Middle Jurassic emplacement of the Selkirk allochthon and are not related to any upper crustal extension that occurred in the Tertiary. Uplift, normal faulting, brittle reactivation of the mylonitic decollement zone, widespread resetting of K-Ar and Rb-Sr mineral dates, and arching of the terrane are events that culminated in the Eocene.

INTRODUCTION

In recent years considerable attention has been paid to the origin of Cordilleran metamorphic core complexes. Geological Society of America Memoir 153 (Crittenden et al., 1980) records the similarities of these complexes and points out areas of disagreement concerning their interpretation. All the complexes reveal an early to middle Tertiary deformational and metamorphic overprint that is interpreted to be mainly of extensional origin, and some retain evidence of Mesozoic or older deformation and metamorphism. A detachment fault, which is variably characterized by the presence of lineated mylonitic rocks, brecciation, and retrograde mineral assemblages, separates older metamorphic basement from a younger, generally less metamorphosed cover.

The Shuswap terrane straddles the Washington–British Columbia border (Fig. 1) and is the largest, perhaps most complicated "core complex." We focus here on the northern (Canadian) part of the terrane. Our purpose is to demonstrate that most of its deformation and metamorphism, including major movement on the Monashee decollement, occurred in the Jurassic, following collision and obduction of a composite allochthonous terrane to the west but before deformation in the Rocky Mountain Belt to the east. Tertiary deformation and a thermal event are recognized as a young overprint involving normal faulting, reactivation of the decollement, arching of the previously deformed terrane and resetting of some isotopic systems. Crustal extension on the scale documented in the Basin and Range province has not occurred in the Shuswap terrane of British Columbia north of lat 50°N.

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MONASHEE COMPLEX

Precambrian paragneiss and granitic intrusions with a minimum isotopic age of about 2.2 b.y. (Wanless and Reesor, 1975; Duncan, 1978; Armstrong, Brown, and Read, in prep.) are unconformably overlain by a thin (structural thickness of 2 to 3 km) platform assemblage (McMillan, 1970; Brown, 1980; Read, 1980) that is at least older than late Proterozoic (Okulitch et. al., 1981) and probably as old as 2 b.y. (Armstrong, Brown, and Read, in prep.). These polydeformed and regionally metamorphosed rocks crop out in coalesced structural culminations in the Shuswap terrane west of the Columbia River at Revelstoke and have been named the Monashee Complex (Read and Brown, 1981; Fig. 1).

Large recumbent folds within the complex have been refolded by synmetamorphic and postmetamorphic structures. Regional metamorphism, up to sillimanite grade, occurred during formation of an east-west–trending mineral and stretching lineation, observed within the central parts of the complex, but is most strongly developed adjacent to the Monashee decollement.

The defined western limit of the North American craton appears to lie east of the Monashee Complex and probably does not continue west of the Rocky Mountain Trench (Chandra and Cumming, 1972; Cumming, 1977; Mereu et al., 1977; Spence et al., 1977; Monger and Price, 1979). Palinspastic restoration of cover rocks of the Rocky Mountain Belt places these rocks, which are now situated adjacent to the trench, well to the west of the cratonic margin (Price and Mountjoy, 1970). The Monashee Complex originally must have been situated still farther to the west. A sedimentary basin floored by transitional or oceanic crust presumably separated the complex from cratonic North America (Brown, 1981). Strata within the Selkirk allochthon that now lie east of the Monashee Complex were originally deposited on or to the west of the complex.

MONASHEE DECOLLEMENT

The upper boundary of the Monashee Complex is a zone of mylonitization and detachment faulting that has been named the Monashee decollement (Read and Brown, 1981; Fig. 1). Rocks characteristic of the Monashee Complex have not been found above the decollement; rather, the allochthonous upper plate is composed of several slices with variable stratigraphic assemblages ranging in age from late Proterozoic (Windermere) to Middle Jurassic (see Read and Brown, 1981, for a detailed account).

A mylonite zone up to 1 km thick has been mapped along the eastern segment of the decollement. A narrower, less clearly defined and generally poorly exposed mylonite zone bounds the western flank of the Monashee Complex. Truncations of stratigraphy, structure, and metamorphic isograds in both upper and lower plates have been documented along both flanks, at the base of klippen, and to the north where the decollement wraps around the northern end of the Monashee Complex (Brown, 1980; Read and Brown, 1981).

COLUMBIA RIVER FAULT ZONE

Where the Monashee decollement follows the Columbia River valley, it is called the Columbia River fault zone (Fig. 1). The two names are necessary because most recent motion on this segment of the fault does not everywhere coincide with the older zone of mylonitization. In particular, the Monashee decollement wraps around the northern end of the Monashee Complex, whereas the younger Columbia River fault zone leaves the decollement and continues northward (in the upper plate) along the Columbia River valley (Fig. 1). Post-mylonite motion on the Monashee decollement and Columbia River fault has folded, disrupted, and brecciated the mylonitic layering. Major motion on the Monashee decollement occurred before motion on the northern segment of the Columbia River fault where only brittle features have been developed (Brown, 1980).

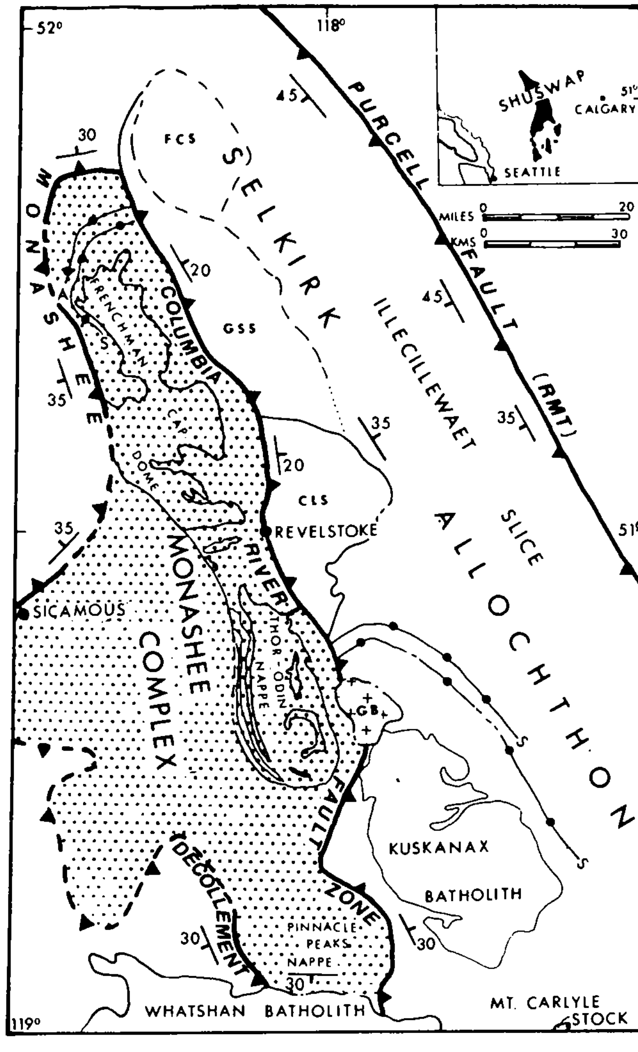

Figure 1. Simplified regional map showing major tectonic elements of Shuswap terrane. Stippled area outlines tectonic window of exposed Monashee Complex. Barbs are on upper plate. FCS = French Creek slice, GSS = Goldstream slice, CLS = Clachnacudainn slice, of Selkirk allochthon. S and A indicate selected axial surface traces of synforms and antiform, respectively, illustrating truncation of folds by Monashee decollement and Columbia River fault. Strike and dip symbols indicate approximate attitudes of dominant foliation in upper and lower plates adjacent to decollement and in upper plate above Purcell fault. GB = Galena Bay stock.

SELKIRK ALLOCHTHON

The Selkirk allochthon, consisting of at least four tectonic slices, lies structurally above the Monashee decollement. Three of these slices—French Creek, Goldstream, and Clachnacudainn—form the hanging wall of the fault zone north of Revelstoke. To the south, the Clachnacudainn and Illecillewaet slices form the hanging wall. The cover rocks are younger than the Monashee Complex, ranging in age from Proterozoic (Windermere) to Middle Jurassic (Read and Brown, 1981).

Earliest known deformation is recorded in the Illecillewaet slice, south of Revelstoke, where phase-one isoclinal folding and greenschist facies metamorphism of probable Late Devonian time affected the western part of the Selkirk allochthon (Read and Wheeler, 1976). Elsewhere, easterly verging isoclinal folds of phase one are of uncertain age but are known to be older than the Middle Jurassic peak of regional metamorphism. We suggest, on kinematic grounds, that at least some of these phase-one structures of uncertain age may have formed in the Middle Jurassic during accretion of Quesnellia, which is part of an inferred, previously amalgamated terrane that lies west of the Shuswap terrane (see Monger et. al., 1982; Fig. 2A, Table 1). Predominantly westerly verging folds (phase two) developed during the Middle Jurassic metamorphism (Read and Wheeler, 1976; Brown, 1978; Brown and Tippet, 1978; Fig. 2B). These structures are cut by the Monashee decollement at the base of the Selkirk allochthon and clearly predate its emplacement. Late-metamorphic to postmetamorphic, easterly verging (phase three) folds were generated during and after emplacement of the allochthon (Table 1).

TIMING CONSTRAINTS ON MONASHEE DECOLLEMENT AND COLUMBIA RIVER FAULT ZONE

Regional metamorphism that accompanied phase-two folding in the Selkirk allochthon occurred in Middle Jurassic time (Read and Wheeler, 1976; Read and Brown, 1981). Displacement on the Monashee decollement presumably began during this metamorphism, because high-grade metamorphic minerals close to the decollement are aligned parallel to the stretching lineation. The peak of metamorphism occurred between phase-two and phase-three deformation. The decollement cuts phase-two folds but is folded by phase-three folds.

The southern segment of the Columbia River fault, here coincident with the Monashee decollement, is cut by several granitic plutons (Read and Brown, 1981). Galena Bay stock, which has yielded a Rb-Sr whole-rock isochron of 157 ± 2 m.y. B.P. (Armstrong, 1981, personal commun.), was emplaced after formation of the mylonite zone (Read, Armstrong, and Psutka, in prep.). The stock straddles the fault zone and has not been involved in the mylonitization or major displacements that have juxtaposed hanging-wall rocks of the Selkirk allochthon and footwall rocks of the Monashee Complex. The stock is fractured, and since its central part lies unexposed beneath Upper Arrow Lake, minor displacement more recent than 157 m.y. B.P. cannot be ruled out. Brecciated mylonite and fault gouge have been observed at several localities along the Columbia River fault. North of Revelstoke, dikes of probable Tertiary age cut mylonitic layering, but are sheared and truncated by fault-gouge zones (Lane and Brown, in prep.).

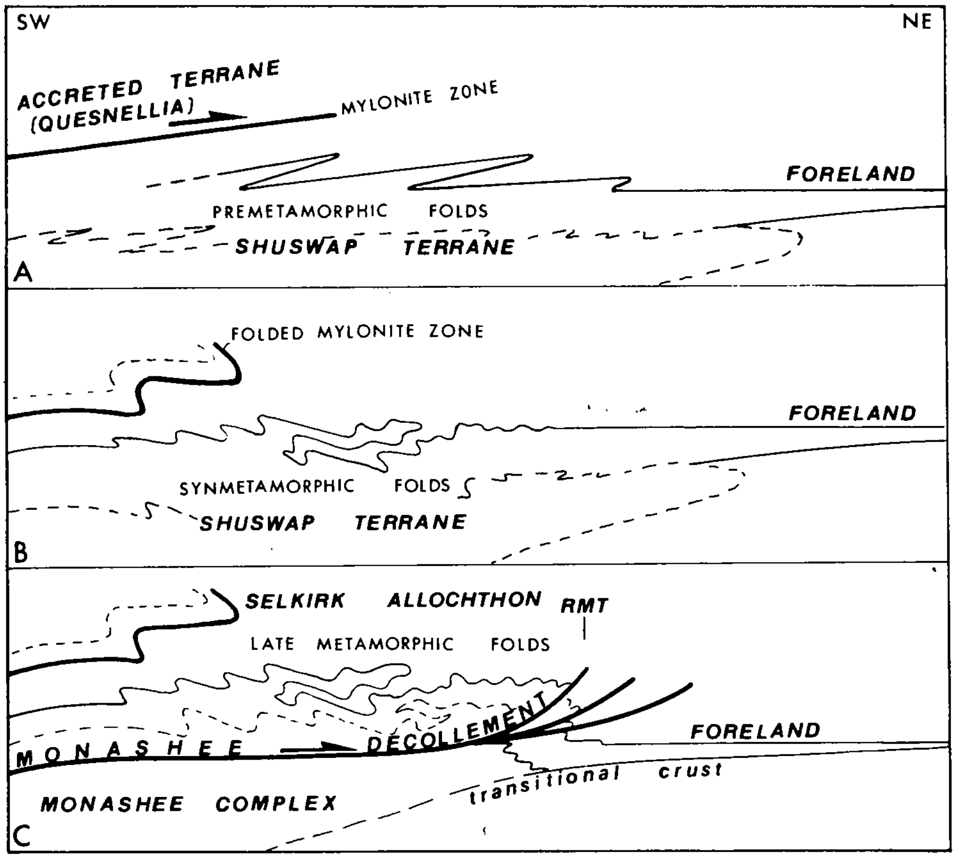

Figure 2. Diagrammatic depiction of Middle to Late Jurassic evolution of Shuswap terrane in vicinity of lat 51° and 52°N. A: Middle Jurassic accretion of Quesnellia and formation of easterly verging premetamorphic (phase one) folds in Shuswap terrane; B: synmetamorphic westerly verging (phase two) folds refold early structures during Middle Jurassic high-grade metamorphism in Shuswap terrane; C: Middle to Late Jurassic detachment and eastward displacement of Selkirk allochthon and generation of late-metamorphic easterly verging (phase three) folds. Eastern flank of Monashee decollement coincides with early trace of Columbia River fault zone.

TABLE 1. STRUCTURAL EVOLUTION OF THE SHUSWAP TERRANE

Time or period	Event
45 to 75 m.y. B.P.	Metamorphism, uplift, and arching of Monashee Complex; late displacement on Columbia River fault zone and Monashee decollement; listric normal faulting
157 ± 2 m.y. B.P.	Intrusion of Galena Bay stock
	Major displacement on Columbia River fault zone and Monashee decollement; east-verging (phase three) folds
164 ± 6 m.y. B.P.	Intrusion of Mount Carlyle Stock Metamorphism West-verging (phase two) folds
171 ± 6 m.y. B.P.*	Intrusion of Kuskanax batholith
Middle Jurassic	Accretion of Quesnellia; east-verging (phase one) folds
373 to 380 m.y. B.P.	Intrusion of granodiorite gneiss
Devonian to Mississippian	Early deformation and metamorphism
840 m.y. B.P.?	East Kootenay orogeny

* J.O. Wheeler (1982, personal commun.)

MESOZOIC EVOLUTION OF THE SHUSWAP TERRANE

Eastward overriding of the Shuswap terrane by Quesnellia in Jurassic time (Monger et al., 1982) apparently initiated ductile strain, regional metamorphism, and low-angle detachment faulting. Between the northwestern flank of the Shuswap terrane and the eastern margin of Quesnellia, a mylonite zone formed before the Middle Jurassic peak of regional metamorphism (Rees, 1981; Struik, 1981). Here, easterly verging isoclinal folds (phase one) in the Shuswap terrane are premetamorphic structures that may have developed during shearing induced by the eastward translation of Quesnellia (Fig. 2A). Westerly verging synmetamorphic folds (phase two) deform the mylonite zone and developed after emplacement of Quesnellia (Fig. 2B).

On the eastern side of the Shuswap terrane, a younger mylonite zone developed between the Selkirk allochthon and the Monashee Complex (Fig. 2C). In this zone, mylonite fabrics developed in response to the eastward displacement of the Selkirk allochthon (Murphy, 1980; Read and Brown, 1981; Brown and Murphy, 1982). The mylonite zone along the Monashee decollement and the Columbia River fault zone truncates second-phase folds. Early motion on the decollement and fault zone outlasted the peak of regional metamorphism and terminated before emplacement of the Galena Bay stock at 157 m.y. B.P. It probably reflects progressive west to east shearing and detachment of cover rocks above the Monashee Complex. East of the Selkirk allochthon, in the vicinity of the Rocky Mountain Trench, the eastward displacement of the allochthon may have been accommodated initially by shortening of the toe of the allochthon during phase-three folding and finally by listric thrusting in the vicinity of the Rocky Mountain Trench along the Purcell and adjacent faults. Listric thrust faults east of the Rocky Mountain Trench displace metamorphic isograds and truncate easterly directed phase-three folds (Simony et. al., 1980).

Since Middle Jurassic time, cover rocks have been telescoped and transported progressively eastward relative to the craton in at least three episodes. The earliest one is

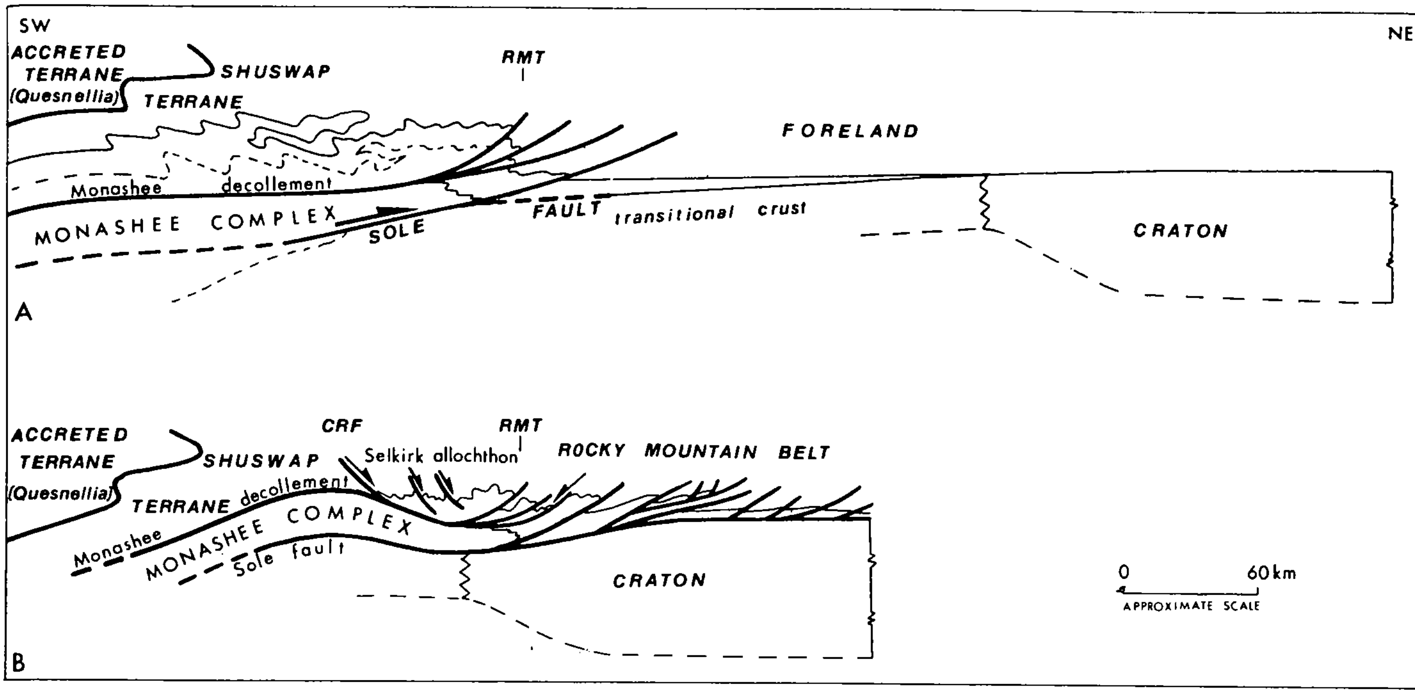

Figure 3. Approximately scaled diagrams depicting Late Jurassic to Eocene evolution of Shuswap terrane and Rocky Mountain Foreland Thrust and Fold Belt in vicinity of lat 51° and 52°N. A: Late Jurassic initiation of thrust faulting east of Rocky Mountain Trench (RMT), with growth of inferred sole fault; B: Eocene arching of Shuswap terrane, reactivation of Columbia River fault zone, and development of minor listric normal faults after completion of thrusting in Rocky Mountain Belt; CRF = late trace of Columbia River fault.

the accretion of Quesnellia before the Middle Jurassic regional metamorphism (Fig. 2A). The next episode occurred during the eastward transport of the Selkirk allochthon along the Monashee decollement, Columbia River fault zone, Purcell thrust, and other faults (Fig. 2C). This occurred in Middle to Late Jurassic time, after the regional metamorphism and deformation that developed the Shuswap terrane. Because significant motion on the Monashee decollement and Columbia River fault terminated before extensive shortening in the Rocky Mountain Belt, it is necessary to postulate the existence of a sole fault beneath the Monashee Complex (Fig. 3A). In the last episode this fault carried the Shuswap terrane and overlying Quesnellia eastward relative to the craton as listric thrust faults migrated eastward across the Rocky Mountain Belt.

TERTIARY EVOLUTION OF THE SHUSWAP TERRANE

Although *major* ductile strain and associated displacements recorded in the Monashee Complex and Selkirk allochthon were completed before the end of the Jurassic, there is ample evidence of regional Tertiary uplift, normal faulting, and high heat flow in the Shuswap terrane (see Cheney [1980] for recent discussion of events in northern Washington, and Ewing [1981] for a review of early Tertiary events in southern British Columbia and the northwestern United States). K-Ar biotite dates generally record a distinct episode of Eocene resetting of both old basement terrane and overlying metasedimentary assemblages, implying anomalous thermal activity, rapid uplift, and accelerated erosion (Reesor, 1965, 1970; Fox et al., 1977; Brown et al., 1981; Mathews, 1981). Locally developed north-south–trending normal faults and dikes imply only limited east-west extension of the upper crust (Fox et al., 1977; Price, 1979; Price et al., 1981).

Arching of the Shuswap terrane, development of late normal faults, and reactivation of the Columbia River fault and Monashee decollement probably occurred during the Eocene "thermal event" (Fig. 3B). However, listric normal faulting above a brittle detachment surface on the scale reported in the core complex terranes of the Basin and Range province has not been documented in the Shuswap terrane of British Columbia north of lat 50°N.

DISCUSSION

An understanding of the tectonic significance of the Shuswap terrane requires evaluation of both its Mesozoic and Cenozoic history. We have presented a model of Mesozoic evolution that links Jurassic folding, metamorphism, mylonitization, and detachment faulting to collision and eastward overriding of Quesnellia. The main events took place between about 171 and 157 m.y. B.P. The deformed edifice, consisting of Quesnellia and the Shuswap terrane, was then carried eastward relative to the North American craton as thrust faulting migrated eastward across the Rocky Mountain Foreland.

Davis and Coney (1979) and Coney (1980) put forward the hypothesis that all Cordilleran metamorphic core complexes owe their distinctive characteristics to crustal extension that is thought to have been associated with Tertiary igneous activity and the widespread resetting of K-Ar and Rb-Sr mineral dates. In particular, they, and some other authors, suggested that elongation lineations and associated mylonitic fabrics, observed in the mylonitic zones of the complexes, were generated during Tertiary ductile crustal extension and that listric normal faults are a higher-level brittle manifestation of the same phenomenon. We have argued that the mylonitic zone that overlies the Monashee Complex originated in the Jurassic rather than in the Tertiary. Tertiary normal faults cannot be related to the ductile strain that generated these mylonites. If a brittle to ductile transition zone of Tertiary age exists in the Shuswap terrane of British Columbia, it has yet to be identified.

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