GEOLOGY | THE GEOLOGICAL SOCIETY OF AMERICA®

https://doi.org/10.1130/G48060.1

Manuscript received 22 June 2020
Revised manuscript received 30 July 2020
Manuscript accepted 30 July 2020

Nailed to the craton: Stratigraphic continuity across the southeastern Canadian Cordillera with tectonic implications for ribbon continent models

M.E. McMechan[1], K.G. Root[2], P.S. Simony[3] and D.R.M. Pattison[3]
[1]Geological Survey of Canada, Natural Resources Canada, 3303 33 Street NW, Calgary, Alberta T2L 2A7, Canada
[2]Consultant, 54 Wildwood Drive SW, Calgary, Alberta T3C 3C5, Canada
[3]Department of Geoscience, University of Calgary, 2500 University Drive NW, Calgary, Alberta T2N 1N4, Canada

ABSTRACT

Cambrian and Upper Devonian to Mississippian strata can be confidently traced westward, without strike-slip offset, from the autochthonous section above North American basement into the southeastern Canadian Cordillera, and are thus "nailed" to the craton. These strata are in turn stratigraphically pinned to older (Mesoproterozoic Belt-Purcell Supergroup, Neoproterozoic Windermere Supergroup, and Ediacaran), intermediate-aged (Ordovician–Silurian), and younger (Permian to Middle Jurassic) strata found only in the mountains, thus linking them to the adjacent autochthonous craton. The overlapping distribution of linking successions, regionally traceable unique stratigraphic horizons in the Belt-Purcell and Windermere Supergroups, and across-strike stratigraphic features show that the entire Cariboo, northern Selkirk, Purcell, and Rocky Mountains are directly tied to the adjacent North American craton without discernible strike-slip or oblique displacement, or substantial purely convergent plate-scale (>400 km) horizontal displacement. They link the entire width of the Belt-Purcell and Windermere basins in the southeastern Canadian Cordillera to the adjacent craton and show that any proposed Cretaceous ribbon continent suture, with its thousands of kilometers of proposed displacement, cannot run through the southeastern Canadian Cordillera.

INTRODUCTION

Several hypotheses have been proposed in recent decades postulating that there is a major suture or subduction zone of Cretaceous age within the foreland of the Canadian and American Cordillera that separates far-traveled or non–North American terrane or "ribbon continent" rocks from North American rocks. These include the Cordilleria (Lambert and Chamberlain, 1988), SAYBIA (Siberia–Alaska–Yukon–British Columbia; Johnston, 2008; Chen et al., 2019), and Rubia ribbon continent models (Hildebrand, 2013, 2014). In the southeastern Canadian Cordillera, the surface location of the suture is interpreted to be along the Southern Rocky Mountain Trench in the Cordilleria model, or adjacent to or at the Kicking Horse Rim Lower Paleozoic facies change in the SAYBIA and Rubia models (Fig. 1). Where this facies change disappears to the south, the suture is interpreted to swing eastward to the Lewis thrust (Fig. 1; Hildebrand, 2013; Chen et al., 2019) or continue southward (Johnston, 2008). According to these models, all pre-Cretaceous strata west of the proposed suture would have moved north thousands of kilometers and represent exotic units. In the Rubia ribbon continent models, this includes all exposures of Mesoproterozoic Belt-Purcell and most exposures of Neoproterozoic Windermere strata. In addition, an implicit assumption in the ribbon continent models is that there was substantial removal of intervening oceanic(?) crust and lithosphere between the craton and ribbon continent. There is little discussion in any of these papers about specific geological evidence that supports the identification of the suture in outcrop, and Johnston (2008) and Chen et al. (2019) referred to the suture as "cryptic." Major stratigraphic and structural summaries of the southeastern Canadian Cordillera by regional experts (e.g., Price, 1981, 1994; Simony and Carr, 2011) have found no evidence for a suture.

The debate over whether there is a hidden or cryptic suture has identified the need to reassess the stratigraphic succession in the southeastern Canadian Cordillera. In this study, we analyzed the stratigraphic succession in terms of its linkage to the adjacent North American craton. Here, we briefly summarize stratigraphic information accumulated by systematic mapping, stratigraphic studies, and subsurface drilling. We focus on key units and features within the Belt-Purcell, Windermere, and Paleozoic to Middle Jurassic successions to document their stratigraphic continuity with the adjacent North American craton and test whether there is an identifiable gap in stratigraphic continuity as proposed by ribbon continent models.

STRATIGRAPHIC LINKAGES

Five main tectono-stratigraphic sequences comprise the stratigraphic succession exposed in the southeastern Canadian Cordillera: (1) the Mesoproterozoic Belt-Purcell Supergroup (BPSG); (2) Neoproterozoic Windermere Supergroup (WSG); (3) Ediacaran–Silurian and (4) Middle Devonian–Middle Jurassic sedimentary strata deposited along the rifted margin of the North American craton; and (5) Upper Jurassic–Paleocene foreland basin strata (e.g., Price, 1981). Our analysis is restricted to high-level discussions of stratigraphic details in each pre–foreland basin sequence. We used the "nails and links" principle, which states that if a stratigraphic unit c is observed, in outcrop and/or in boreholes, to lie with depositional contact on cratonal basement, with no tectonic interruptions, it is there "nailed" to the craton. At a place to the west, where units b-c-d can be demonstrated to lie in depositional contact, the sequence b-c-d is nailed together and linked by unit c to the craton.

CITATION: McMechan, M.E., et al., 2020, Nailed to the craton: Stratigraphic continuity across the southeastern Canadian Cordillera with tectonic implications for ribbon continent models: Geology, v. 49, p. , https://doi.org/10.1130/G48060.1

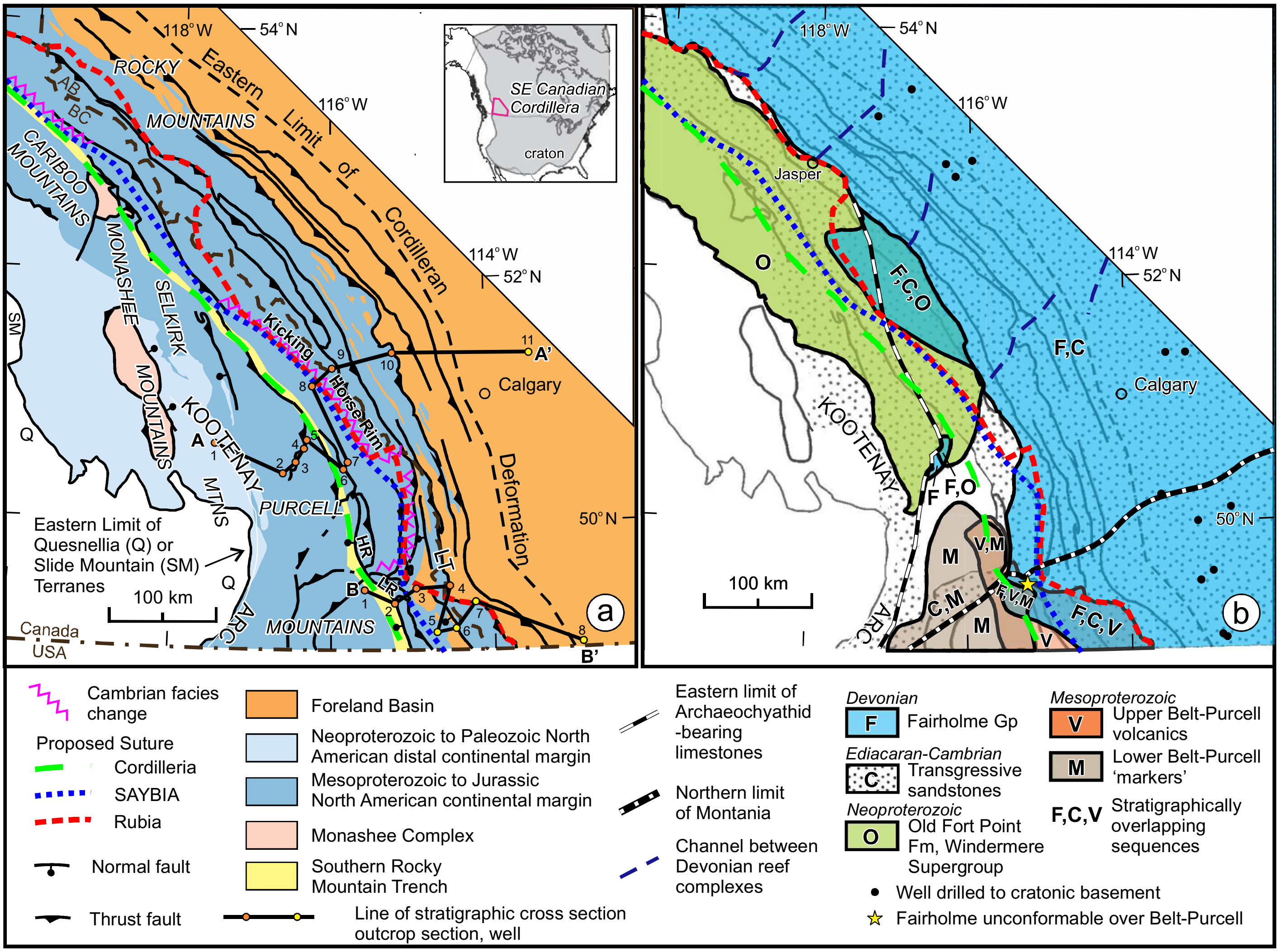

Figure 1. (A) Generalized geology of the southeastern Canadian Cordillera showing locations of postulated ribbon continent sutures (after Lambert and Chamberlain, 1988; Johnston, 2008; Hildebrand, 2013) and lines of stratigraphic cross sections A-A′ and B-B′ (Fig. 2). AB—Alberta, BC—British Columbia, HR—Hughes Range, LR—Lizard Range, LT—Lewis thrust. (B) Distribution of key stratigraphic linkage horizons and features in the southeastern Canadian Cordillera. North edge of Montania is after McMechan (2012) and Zaitlin et al. (2002). Geological base map was modified from Wheeler and McFeely (1991). Linear trends in part B, e.g., Devonian channel trends, are shown to continue unbroken into the Canadian Cordillera because they occur at a high angle to thrusting and are not significantly broken or displaced at regional scale.

Devonian–Middle Jurassic

Upper Devonian and Mississippian strata have been subdivided into multiple formations and members that have been traced in detail in petroleum wells on the autochthonous cratonic basement in the Alberta Plains and in outcrops across the Rocky Mountains (e.g., Fig. 2, section B-B′). In particular, prominent northeast-trending reefs, channels, and barriers in the Upper Devonian Leduc Formation (part of the Woodbend Group in the plains and Fairholme Group in the cordillera) have been mapped across the plains and into and across the eastern Rocky Mountains without strike-slip offset (Fig. 1B; e.g., Switzer et al., 1994). Fairholme Group strata unconformably overlie Middle Devonian strata in the western Rocky Mountains and Purcell Mountains, and Cambrian to Ordovician strata at most localities in the eastern Rocky Mountains (Fig. 2). Locally, along the north edge of the prominent northeast-southwest–trending paleogeographic feature called Montania (Fig. 1B; Deiss, 1941), the Upper Devonian Fairholme Group sits directly on middle and upper BPSG strata (Fig. 1B; Benvenuto and Price, 1979). Unconformably underlying Middle Devonian, Ordovician, Cambrian, and Mesoproterozoic BPSG strata and overlying Pennsylvanian to Middle Jurassic strata are linked to the adjacent craton by the Upper Devonian to Mississippian succession to which they are nailed by depositional contacts.

Ediacaran–Silurian

Middle and upper Cambrian strata have been subdivided into several formations and grand cycles of alternating detrital and carbonate facies (Aitken, 1968, 1993). These carbonate and shale formations can be confidently traced in deep petroleum exploration wells in the plains, where they occur in autochthonous sections above basement and above a transgressive middle Cambrian "basal sandstone," into outcrops in the Rocky Mountains (Slind et al., 1994), as far as the Kicking Horse Rim (Figs. 1B and 2, section A-A′). In the southern part of the study area, the middle Cambrian succession can be traced from the plains, where it unconformably overlies Paleoproterozoic and Archean basement, to the Rocky Mountains, where it unconformably overlies BPSG strata as far as the Rocky Mountain Trench (Fig. 2, section B-B′; Slind et al., 1994). The middle Cambrian succession thus links Mesoproterozoic BPSG strata to the adjacent craton.

Upper Cambrian to Silurian strata are preserved in the Rocky Mountains north of Montania. They are linked to the adjacent craton by underlying middle Cambrian and overlying Devonian strata, to which they are nailed

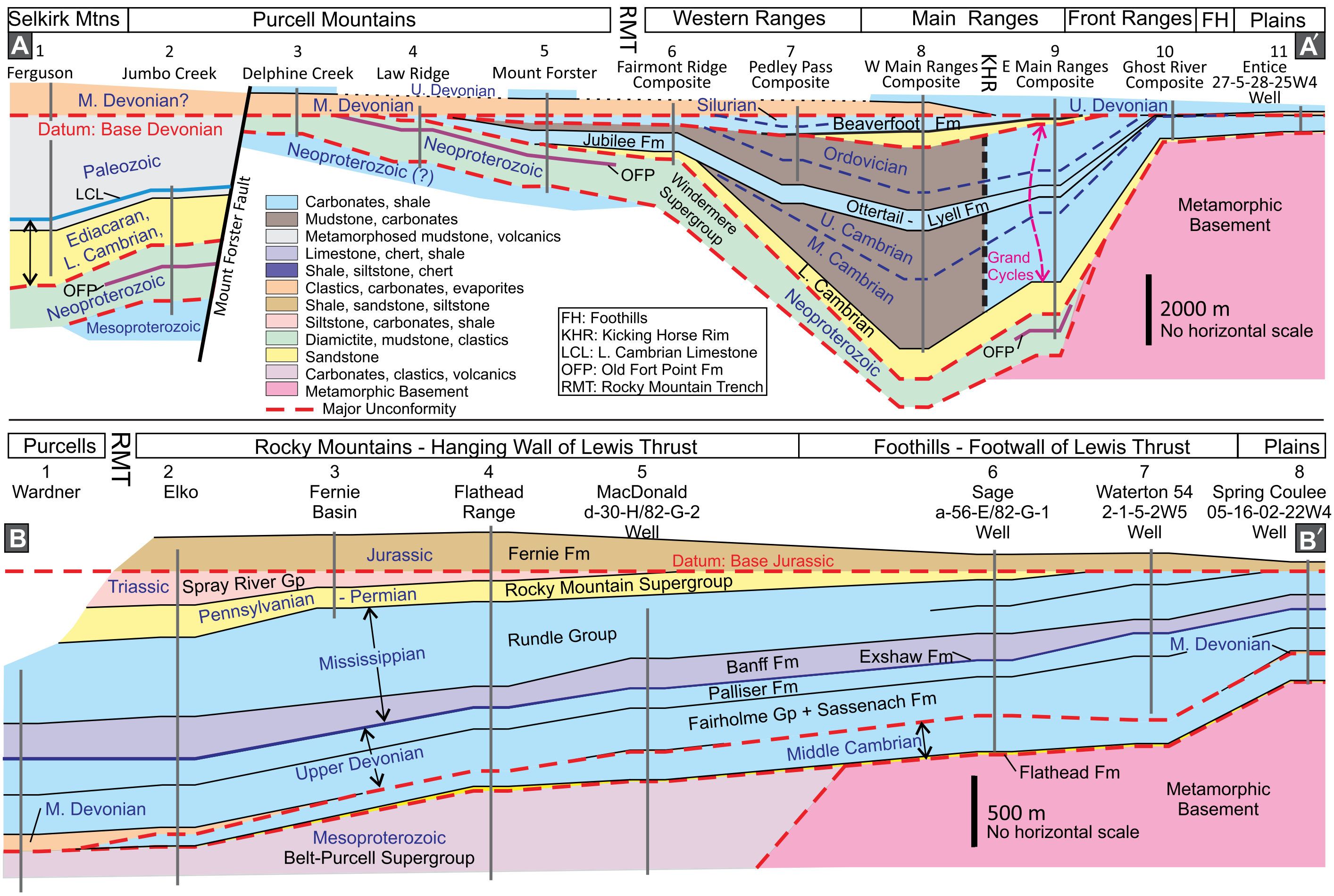

Figure 2. (A) Stratigraphic cross section A-A′ from the Selkirk Mountains to plains across the Windermere High, and (B) stratigraphic cross section B-B′ from the eastern Purcell Mountains to plains above paleogeographic high Montania. See Figure 1A for cross-section locations. Sources of information: Stott and Aitken (1993), Stewart et al. (1993), Collom et al. (2009), Root (2001), and references therein.

by depositional contacts (Fig. 2, section A-A′). At the Kicking Horse Rim, which is a fault-controlled, syndepositional feature (Aitken, 1971), most of the middle Cambrian to Silurian shallow-water, carbonate-dominated succession changes facies southwestward into “deeper-water” mudstone and limestone successions (Fig. 2, section A-A′). The discovery of exquisitely preserved middle Cambrian soft-bodied fossils in the Burgess Shale immediately west of the Kicking Horse Rim led to several detailed studies of the Cambrian facies change. These have documented margin collapse, synsedimentary, gravity-glide megatruncation surfaces, and discontinuous normal faults or small-displacement (<3 km) thrust faults of Cretaceous age along the facies change (e.g., Cook, 1975; Stewart et al., 1993). They have also demonstrated lateral continuity across the facies transition of several middle Cambrian units using stratigraphic and paleontological relationships (see descriptions and photographs in Cook [1975]; Collom et al., 2009). Two carbonate units—the upper Cambrian Lyell–Ottertail–Jubilee formation and the Ordovician–Silurian Beaverfoot Formation—do not change facies at the Kicking Horse Rim. They continue westward to the Purcell Mountains (Fig. 2, section A-A′). The observed stratigraphic continuity across the facies change rules out the possibility of it being the site of a ribbon continent tectonic suture as postulated by Johnston (2008), Hildebrand (2013), or Chen et al. (2019).

The oldest part of the Ediacaran to Silurian sequence consists of local accumulations of Ediacaran sandstone, conglomerate, and volcanics, deposited within half grabens during a period of rifting, which are found within the Rocky Mountains, western and northern Purcell Mountains, and Selkirk Mountains (e.g., Colpron et al., 2002). This sequence is unconformably overlain by a widely distributed transgressive, postrift, quartzite-dominated succession that ranges in age from Ediacaran in the west to early Cambrian in the eastern Rocky Mountains. The lower Cambrian quartzite succession thins to the east and is either overlapped by or transgressive into the middle Cambrian sandstone found in the plains and the Southern Rocky Mountains (e.g., Aitken, 1993; Slind et al., 1994). In either case, the transgressive quartzite is nailed to the craton and links the unconformably underlying Ediacaran and Neoproterozoic WSG strata to the adjacent craton.

In the western and northern parts of the study area, a triplet succession of lower Cambrian quartzite overlain by shale and then limestone that commonly contains Archaeocyathids occurs in the eastern Cariboo, Selkirk, western and northern Purcell, and adjacent Rocky Mountains. The eastern limit of the Archaeocyathid limestone can be traced southwestward from near Jasper in the Rocky Mountains to the west side of the Purcell Mountains (Fig. 1B). Neither the eastern limit of the Archaeocyathid limestone nor the northeast-southwest–trending edge of Montania is offset by any tectonic boundary (Fig. 1B).

Neoproterozoic

The ca. 720–570 Ma WSG forms a thick (up to 9 km) stratigraphic sequence north of Montania. Diamictite of probable glaciogenic origin is present at the base of the WSG at many localities in the Purcell Mountains and commonly contains clasts derived from the BPSG. Most of the overlying succession consists of siliciclastic strata deposited in a turbidite fan or slope setting (e.g., Ross and Arnott, 2007). The Old Fort Point Formation forms a unique marker within this sequence characterized by brightly colored slates, organic-rich slate, limestone, quartzite, and local diamictite (Smith et al., 2011). The Old Fort Point Formation has been recognized in outcrop in the Rocky, Purcell, Selkirk, and Cariboo Mountains and stratigraphically links all these areas together (Figs. 1 and 2). The WSG is unconformably overlain by the Ediacaran to lower Cambrian transgressive sandstone near Lake Louise, in the Rocky Mountains, and is therefore linked to the adjacent craton. The WSG pinches out to the east and does not extend into the plains.

Mesoproterozoic

The ca. 1500 to ca. 1370 Ma BPSG forms a thick (18–20 km) package that is widely exposed in the southeastern Canadian Cordillera and adjacent United States. Up to 12 km of marine turbidite rift basin sediments with intercalated tholeiitic sills of the lower BPSG were deposited in the axis of a northwest-trending rift basin along the western edge of the Purcell Mountains (Lydon, 2010). Although facies changes occur between eastern and western exposures in the rift sag deposits of the BPSG (e.g., Hein and McMechan, 1994; Lydon, 2010), two stratigraphically unique intervals tie all BPSG exposures in Canada together. More than 20 distinctive laminated "marker" intervals are present within the lower BPSG turbidite rift basin assemblage in the Middle Aldridge Formation (Pritchard Formation in the United States; Hamilton et al., 2000). The "markers" have been recognized, mapped, and correlated in outcrop and core from the Hughes and Lizard Ranges of the western Rocky Mountains across the southern Purcell Mountains to the eastern Selkirk Mountains near 49°N (Fig. 1B; Cominco Limited reports, archived in the Geological Survey of Canada [Calgary] collections.) They have also been recognized in the United States to the south of the Lewis and Clark line (transverse structure that crosses the North American Cordillera from northeastern Washington to central Montana) (Brown et al., 2011, and other maps in series; Paul Ransom, 2019, written commun.). These markers stratigraphically tie all these areas together. Volcanic flows and tuffs of the upper BPSG are exposed in the eastern Purcell Mountains and the Rocky Mountains, including in the Lewis thrust sheet. These volcanic rocks stratigraphically overlie the "marker" intervals in the eastern Purcell Mountains and the western Rocky Mountains and link the BPSG in the areas covered by the "'markers" to the easternmost exposures of the BPSG in the Lewis thrust sheet (Fig. 1B). In addition, clasts derived from uplifted BPSG strata occur in strata of the Neoproterozoic WSG and in conglomerates of lower Cambrian and Middle Devonian age and tie these four successions together.

The lower depositional contact of the BPSG is not exposed in Canada, and the succession is absent in the subsurface of the Alberta Plains (e.g., Slind et al., 1994). Direct linkage to the adjacent craton is provided by unconformable contacts ("nails") with overlying middle Cambrian and Devonian to Mississippian strata (Figs. 1 and 2). Correlation to Belt-Purcell sections that are interpreted to have been deposited unconformably on parautochthonous and autochthonous North American basement rocks in central Montana (Schieber, 1989; Lydon, 2010) forms another linkage to the craton.

DISCUSSION AND CONCLUSIONS

The Cordilleria, SAYBIA, and Rubia ribbon continent models were inspired in large part by paleomagnetic data, which indicated that western and central portions of the northern Cordillera had been displaced northward by as much as 3000 km between 90 and 50 Ma (e.g., Beck and Noson, 1972; Irving et al., 1996). Significantly less displacement is documented across strike-slip faults in the western and central Cordillera (e.g., Gabrielse et al., 2006). Proposed ribbon continent models offer more easterly options for much of this displacement. An abrupt westward decrease in the depth to the lithosphere-asthenosphere boundary occurs near the Southern Rocky Mountain Trench, and the SAYBIA and Rubia ribbon continent models have been proposed as an explanation (Hildebrand, 2014; Chen et al., 2019, and references therein).

Our analysis of stratigraphic continuity shows that Ediacaran to Cambrian and Devonian to Mississippian strata are directly traceable from autochthonous sections in the Alberta Plains into and across the mountains (Figs. 1 and 2) and are thus stratigraphically nailed to the craton. Using the "nails and links" principle, these units link all pre-Cretaceous strata exposed in the Cariboo, northern Selkirk, Purcell, and Rocky Mountains of the southeastern Canadian Cordillera to the adjacent craton, including the BPSG and WSG successions (Figs. 1 and 2). The recurrent observation of depositional contacts nailing multiple units precludes the existence of accretion boundaries of any orientation. Published interpretations of detrital zircon provenance from adjacent North American basement (Gehrels and Pecha, 2014; Matthews et al., 2017) for Neoproterozoic, Ediacaran to lower Cambrian, and Ordovician sandstones exposed in the southeastern Canadian Cordillera provide further evidence that these strata have not been displaced significant distances northward relative to North American basement as would be expected with the ribbon continent models.

The northern edge of Montania, the eastern limit of Archaeochyathid limestone, and channels in the Devonian reef complexes form important across-strike stratigraphic markers that, taken together, extend across the plains to the western Purcell Mountains. Their continuity (Fig. 1B) precludes any significant oblique or strike-slip offset, or substantial purely convergent plate-scale (>400 km) horizontal displacement across this entire area.

ACKNOWLEDGMENTS

This manuscript benefited from the constructive comments and reviews of Maurice Colpron, R.D. (Bob) McMechan, Glen Stockmal, and an anonymous reviewer. Support was provided by the Canada3D project of the Geological Survey of Canada and Natural Sciences and Engineering Research Council of Canada Discovery Grant 037233 to Pattison. This is Natural Resources Canada contribution number 20200340.

REFERENCES CITED

Aitken, J.D., 1968, Cambrian sections in the easternmost southern Rocky Mountains and the adjacent subsurface, Alberta: Geological Survey of Canada Paper 66-23, 96 p.

Aitken, J.D., 1993, Cambrian and Lower Ordovician–Sauk Sequence, *in* Stott, D.F., and Aitken, J.D., eds., Sedimentary Cover of the Craton, in Canada: Geological Survey of Canada Geology of Canada Series 5, p. 96–124.

Beck, M.E., Jr., and Noson, L., 1972, Anomalous paleolatitudes in Cretaceous granitic rocks: Nature–Physical Science [London], v. 235, p. 11–13, https://doi.org/10.1038/physci235011a0.

Benvenuto, G.L., and Price, R.A., 1979, Structural evolution of the Hosmer thrust sheet, southeastern British Columbia: Bulletin of Canadian Petroleum Geology, v. 27, p. 360–394.

Brown, D.A., MacLeod, R.F., and Wagner, C.L., compilers, 2011, Geology, St. Mary Lake, British Columbia: Geological Survey of Canada Open-File 6308, scale 1:50,000, https://doi.org/10.4095/288567.

Chen, Y., Yu, J.G., Currie, C.A., Johnston, S.T., Hung, S.H., Schaeffer, A.J., and Audet, P., 2019, Seismic evidence for a mantle suture and implications for the origin of the Canadian Cordillera: Nature Communications, v. 10, 2249, https://doi.org/10.1038/s41467-019-09804-8.

Collom, C.J., Johnston, P.A., and Powell, W.G., 2009, Reinterpretation of 'Middle' Cambrian stratigraphy of the rifted western Laurentian margin: Burgess Shale Formation and contiguous units (Sauk II megasequence), Rocky Mountains, Canada: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 277, p. 63–85, https://doi.org/10.1016/j.palaeo.2009.02.012.

Colpron, M., Logan, J.M., and Mortensen, J.K., 2002, U-Pb zircon age constraint for late Neoproterozoic rifting and initiation of the Lower Paleozoic passive margin of western Laurentia: Canadian Journal of Earth Sciences, v. 39, p. 133–143, https://doi.org/10.1139/e01-069.

Cook, D.G., 1975, Structure Style Influenced by Lithofacies, Rocky Mountain Main Ranges, Alberta–British Columbia: Geological Survey of Canada Bulletin 233, 73 p., 3 sheets, https://doi.org/10.4095/103987.

Deiss, C.F., 1941, Cambrian geography and sedimentation in the central Cordilleran region: Geological Society of America Bulletin, v. 52, p. 1085–1115, https://doi.org/10.1130/GSAB-52-1085.

Gabrielse, H., Murphy, D.C., and Mortensen, J.K., 2006, Cretaceous and Cenozoic dextral orogen-parallel displacements, magmatism and paleogeography, north-central Canadian Cordillera, *in* Haggart, J.W., Enkin, R.J. and Monger, J.W.H., eds., Paleogeography of the North American Cordillera: Evidence for and against large-scale displacements, Geological Association of Canada Special Paper 46, p. 255-276.

Gehrels, G.E., and Pecha, M., 2014, Detrital zircon U-Pb geochronology and Hf isotope geochemistry of Paleozoic and Triassic passive margin strata of western North America: Geosphere, v. 10, p. 49–65, https://doi.org/10.1130/GES00889.1.

Hamilton, J.M., McEachern, R.G., and Owens, O.E., 2000, A history of geological investigations at the Sullivan Deposit, *in* Lydon, J.W., Höy, T., Slack, J.F., and Knapp, M., eds., The Geological Environment of the Sullivan Pb-Zn-Ag Deposit, British Columbia: Mineral Deposits Division of the Geological Association of Canada Special Publication 1, p. 4–11.

Hein, F.J., and McMechan, M.E., 1994, Proterozoic and Lower Cambrian strata of the Western Canada sedimentary basin, *in* Mossop, G.D., and Shetsen, I., eds., Geological Atlas of Western Canada: Calgary, Canada, Canadian Society of Petroleum Geologists–Alberta Research Council, p. 57–67.

Hildebrand, R.S., 2013, Mesozoic Assembly of the North American Cordillera: Geological Society of America Special Papers, v. 495, 162 p., https://doi.org/10.1130/SPE495.

Hildebrand, R.S., 2014, Geology, mantle tomography, and inclination corrected paleogeographic trajectories support westward subduction during Cretaceous orogenesis in the North American Cordillera: Geoscience Canada, v. 41, p. 207–224, https://doi.org/10.12789/geocanj.2014.41.032.

Irving, E., Wynne, P.J., Thorkelson, D.J., and Schiarizza, P., 1996, Large (1000 to 4000 km) northward movements of tectonic domains in the northern Cordillera, 83 to 45 Ma: Journal of Geophysical Research, v. 101, B8, p. 17901–17916, https://doi.org/10.1029/96JB01181.

Johnston, S.J., 2008, The Cordilleran ribbon continent of North America: Annual Review of Earth and Planetary Sciences, v. 36, p. 495–530, https://doi.org/10.1146/annurev.earth.36.031207.124331.

Lambert, R.St.J., and Chamberlain, V.E., 1988, Cordilleria revisited, with a three-dimensional model for Cretaceous tectonics in British Columbia: The Journal of Geology, v. 96, p. 47–60, https://doi.org/10.1086/629192.

Lydon, J.W., 2010, Tectonic Evolution of the Belt-Purcell Basin: Implications for the Metallogeny of the Purcell Anticlinorium: Geological Survey of Canada Open-File Report 6411, 40 p., https://doi.org/ 10.4095/261389.

Matthews, W., Guest, B., and Madronich, L., 2017, Latest Neoproterozoic to Cambrian detrital zircon facies of western Laurentia: Geosphere, v. 14, p. 243–264, https://doi.org/10.1130/GES01544.1.

McMechan, M.E., 2012, Deep transverse basement structural control of mineral systems in the southeastern Canadian Cordillera: Canadian Journal of Earth Sciences (Revue Canadienne des Sciences de la Terre), v. 49, p. 693–708, https://doi.org/10.1139/e2012-013.

Price, R.A., 1981, The Cordilleran foreland thrust and fold belt in the southern Canadian Rocky Mountains, *in* McClay, K.R., and Price, N.J., eds., Thrust and Nappe Tectonics: Geological Society [London] Special Publication 9, p. 427–448, https://doi.org/10.1144/GSL.SP.1981.009.01.39.

Price, R.A., 1994, Cordilleran tectonics and the evolution of the Western Canada Sedimentary Basin, *in* Mossop, and G.D., Shetsen, I., eds., Geological Atlas of Western Canada: Calgary, Alberta, Canadian Society of Petroleum Geologists–Alberta Research Council, p. 13–21.

Root, K.G., 2001 Devonian Antler fold and thrust belt and foreland basin development in the southern Canadian Cordillera: Implications for the Western Canada Sedimentary Basin: Bulletin of Canadian Petroleum Geology, v. 49, p. 7–36, https://doi.org/10.2113/49.1.7.

Ross, G.M., and Arnott, R.W.C., 2007, Regional geology of the Windermere Supergroup, southern Canadian Cordillera and stratigraphic setting of the Castle Creek study area, Canada, *in* Nilsen, T.H., et al., eds., Atlas of Deep-Water Outcrops: American Association of Petroleum Geologists Studies in Geology 56, chapter H, https://doi.org/10.1306/12401038St563286.

Schieber, J., 1989, The origin of the Neihart Quartzite, a basal deposit of the mid-Proterozoic Belt Supergroup, Montana, U.S.A.: Geological Magazine, v. 126, p. 271–281, https://doi.org/10.1017/S0016756800022366.

Simony, P.S., and Carr, S.D., 2011, Cretaceous to Eocene evolution of the southeastern Canadian Cordillera: Continuity of Rocky Mountain thrust systems with zones of "in-sequence" mid-crustal flow: Journal of Structural Geology, v. 33, p. 1417–1434, https://doi.org/10.1016/j.jsg.2011.06.001.

Slind, O.L., Andrews, G.D., Murray, D.L., Norford, B.S., Paterson, D.F., Salas, C.J., Tawadros, E.E., and Aitken, J.D., 1994, Middle Cambrian to Lower Ordovician strata of the Western Canada Sedimentary Basin, *in* Mossop, G.D., and Shetsen, I., eds., Geological Atlas of Western Canada: Calgary, Alberta, Canadian Society of Petroleum Geologists–Alberta Research Council, p. 87–108.

Smith, M.D., Arnaud, E., Arnott, R.W.C., and Ross, G.M., 2011, The record of Neoproterozoic glaciations in the Windermere Supergroup, southern Canadian Cordillera, *in* Arnaud, E., Halverson, G.P., and Shields-Zhou, G., eds., The Geological Record of Neoproterozoic Glaciations: Geological Society [London] Memoir 36, p. 413–424, https://doi.org/10.1144/M36.37.

Stewart, W.D., Dixon, O.A., and Rust, B.R., 1993, Middle Cambrian carbonate-platform collapse, southeastern Canadian Rocky Mountains: Geology, v. 21, p. 687–690, https://doi.org/10.1130/0091-7613(1993)021<0687:MCCPCS>2.3.CO;2.

Switzer, S.B., Holland, W.G., Christie, D.S., Graf, G.C., Hedinger, A.S., McAuley, R.J., Wierzbicki, R.A., and Packard, J.J., 1994, Devonian Woodbend-Winterburn strata of the Western Canada sedimentary basin, *in* Mossop, G.D., and Shetsen, I., eds., Geological Atlas of Western Canada: Calgary, Alberta, Canadian Society of Petroleum Geologists–Alberta Research Council, p. 164–202.

Wheeler, J.O., and McFeely, P., 1991, Tectonic Assemblage Map of the Canadian Cordillera and Adjacent Parts of the United States of America: Geological Survey of Canada Map 1712A, scale 1:2,000,000, 1 sheet, https://doi.org/10.4095/133549.

Zaitlin, B.A., Warren, M.J., Potocki, D., Rosenthal, L., and Boyd, R., 2002, Depositional styles in a low accommodation foreland basin setting: An example from the Basal Quartz (Lower Cretaceous), southern Alberta: Bulletin of Canadian Petroleum Geology, v. 50, p. 31–72, https://doi.org/10.2113/50.1.31.

Printed in USA