geoconvention
Virtual Event
September 21-23
2020
CSPG • CSEG • CWLS • GAC • MAC • IAH

The Early Paleozoic Windermere High, southern Canadian Cordillera: Implications for the continuity of the Lower Paleozoic tectonostratigraphic succession and for Early Paleozoic Tectonics

Kevin G. Root, Gran Tierra Energy

Philip S. Simony, Professor Emeritus, Department of Geoscience, University of Calgary

Introduction

Uppermost Neoproterozoic and Lower Paleozoic strata can be confidently correlated from wells in the Plains, through outcrops in the Rockies, and across the Purcell Mountains to the Selkirk Mountains (Fig. 1; Simony et al., 2020). These correlations present a coherent view of deposition at the Early Paleozoic Laurentian passive margin, and firmly establish that all of the strata are of North American affinity. This observation contradicts the proposals of tectonic hypotheses such as the Cordilleria model (Chamberlain and Lambert, 1985), the SAYBIA model (Johnston, 2008; Chen et al., 2019), and the Rubia ribbon continent model (Hildebrand, 2013) that there is a major tectonic suture present within the Rockies that separates North American rocks from allochthonous 'ribbon continent' rocks.

The Uppermost Neoproterozoic and Lower Paleozoic sequence in the eastern Purcell Mountains and western Rocky Mountains in SE British Columbia at approximately 50° 30' N latitude is anomalously thin compared to strata to the east and west, and locally absent, due to the presence of a paleo-high called the Windermere High (Fig. 1). The Windermere High and other Early Paleozoic highs such as the Dogtooth High (Kubli and Simony, 1992) and the Kinbasket High (Hrudey, 2002) are interpreted to have formed during Early Paleozoic extensional events at the outer, western region of the ancient Laurentian passive continental margin.

Distribution and Correlations of Uppermost Neoproterozoic and Lower Paleozoic Strata

In the Plains, Foothills, and Front and Eastern Main Ranges of the Rockies the Lower Paleozoic sequence comprises a basal sandstone succession (Gog Group and Basal Sandstone Unit) and overlying shallow water, dominantly carbonate strata. Strata as young as the Ordovician-Silurian Beaverfoot Formation are preserved locally in the Main Ranges below the sub-Devonian unconformity. Further east, in the Front Ranges and the Plains, the upper portions of the Lower Paleozoic succession have been removed by erosion below the sub-Devonian unconformity due to uplift of the Western Alberta Ridge.

A facies change, initially recognized by McConnell (1887), is present at a fault-controlled north-northwest-trending syndepositional high called the Kicking Horse Rim, located at the boundary between the Eastern and Western Main Ranges (Aitken, 1971). Most of the shallow water Cambrian and Ordovician carbonate strata change to the southwest across this trend into 'deeper water' mudstone, argillaceous limestone, and limestone that were deposited within the White River Trough as turbidites, debris flows, and hemipelagic deposits in the Chancellor Group, McKay Group, and Glenogle Formation. (Fig.1; Aitken, 1971; Cook, 1975; Stewart,

1991; Collom et al., 2009). Two carbonate successions, the Upper Cambrian Lyell – Ottertail – Jubilee Formation and the Ordovician – Silurian Beaverfoot Formation, do not change facies across the Kicking Horse Rim and continue westward as shallow water carbonates. Although the facies transition is complicated by Cambrian gravity-glide megatruncation surfaces (Stewart, 1991), lateral continuity can be directly observed across the facies transition for some Middle Cambrian units (see descriptions and photographs in Cook, 1975; Stewart 1991; Aitken, 1997; Collom et al; 2009; Johnston et al., 2009). None of the published geological studies in this area have recognized any relationships that indicate that a major suture is present, as hypothesized in the ribbon continent hypotheses (Johnston, 2008; Hildebrand, 2013; Chen et al., 2019).

Lower Paleozoic strata thicken to the west across the Kicking Horse Rim facies change and reach thicknesses of 7500 m or more within the White River Trough (Fig. 1). The Lower Paleozoic succession thins systematically southwestward, however, across the Western Rockies and the eastern Purcell Mountains due to periods of reduced subsidence and uplift on the Windermere High. At the culmination of the Windermere High, at Delphine Creek, the entire Lower Paleozoic section is missing, and Devonian strata overlie anomalously thin Neoproterozoic Windermere Supergroup strata.

Southwest of the Windermere High, across the Mount Forster Thrust in the western Purcell and Selkirk Mountains, significant thicknesses of Lower Cambrian and overlying Lardeau Group metamorphosed and highly deformed clastics and volcanics are present (Fig. 1; Fyles and Eastwood, 1964; Kraft, 2013). There are few age data for Lardeau Group strata, but the succession is overlain by the Upper Devonian Mount Sproat assemblage (Thompson et al., 2006; Kraft, 2013); this constrains the age of the underlying Lardeau Group strata to be Late Devonian or older. Kraft (2013) speculated that the upper unit of the Lardeau Group, the Broadview Formation sandstone and conglomerate, may correlate with the Middle Devonian Mount Forster Formation of the Purcell Mountains, and this suggestion has been followed in Fig.1.

Although the details of western boundary of the Windermere High are obscured by the Mesozoic Mount Forster Thrust fault, there presumably were one or more significant southwest-side-down extensional faults that bounded the high on the southwest. Several stratigraphic units, including multiple members of the Neoproterozoic(?) Mount Nelson Formation, and the Toby Formation and the Horsethief Creek Group of the Neoproterozoic Windermere Supergroup, as well as Lower Cambrian strata, can be confidently recognized in both the footwall and the hanging wall of the fault.

Additional highs were present during the Early Cambrian to the north of the Windermere High; these include the Dogtooth High (Kubli and Simony, 1992) and the Kinbasket High (Hrudey, 2002). In these regions, strata younger than Early Cambrian are not present, and thus the post-Early Cambrian record of activity on these highs is not preserved.

Extensional Tectonics

Evidence for Late Neoproterozoic and Early Paleozoic extensional tectonic activity in the region includes the significant extensional faults inferred to separate the crest of the Windermere High from the subsiding Lardeau Trough to the west (Fig. 1) as well as the extensional faults at the

Kicking Horse Rim (Aitken, 1971; Collom et al., 2009; Johnston et al., 2009). Additional evidence for extension includes the local presence of mafic volcanic and volcanogenic rocks within Cambrian strata within the White River Trough (Norford and Cecile, 1994; Larson and Price, 2006) and mafic volcanics within the Lower Paleozoic Lardeau Group in the Lardeau Trough (Fyles and Eastwood, 1964; Kraft, 2013). Intrusive alkaline, ultrabasic diatreme breccia pipes and dikes were intruded locally in the White River Trough during the Late Ordovician and between the Early Silurian and Middle Devonian (Leech, 1958; Helmstaedt et al., 1988; Pell, 1994). The Windermere High is interpreted to have formed as a rift shoulder related to the Early Paleozoic extension within the Lardeau Trough to the west.

References

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., 1971. Control of Lower Paleozoic sedimentary facies by the Kicking Horse Rim, Southern Rocky Mountains: Canada. Bulletin of Canadian Petroleum Geology 19 (3), 557–569.

Aitken, J.D., 1997. Stratigraphy of the Middle Cambrian platformal succession, southern Rocky Mountains: Geological Survey of Canada, Bulletin 398, 322 p.

Chamberlain, V.E. and Lambert, R.St J., 1985. Cordilleria, a newly defined Canadian microcontinent: Nature 314, 707-713.

Chen, Y., Gu, 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. 10.1038

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. 277. 63-85.

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)

Fyles, J.T. and Eastwood, G.E.P., 1962. Geology of the Ferguson area, Lardeau district, British Columbia: B.C. Department of Mines and Petroleum Resources, Bulletin 45, 92 p.,

Henderson, G.G.L.,1954. Geology of the Stanford Range of the Rocky Mountains, Kootenay District, B.C. Department of Mines, Bulletin 35, 90 p.

Helmstaedt, H.H., Mott, J.A., Hall, D.C., Schulze, D.J. and Dixon, J.M., 1988. Stratigraphic and structural setting of intrusive breccia diatremes in the White River - Bull River area, southeastern British Columbia. B.C. Ministry of Energy, Mines, and Petroleum Resources, Geological Field Work 1987. Paper 1988-1. p. 363-367.

Hildebrand, R.S., 2013. Mesozoic assembly of the North American Cordillera: Geological Society of America Special Paper 495, 162 p.

Hrudey, M.G., 2002. Geology of Blackwater Ridge, northern Purcell Mountains, eastern British Columbia. M.Sc. Thesis, University of Calgary, 161 p.

Johnston, S.J., 2008. The Cordilleran Ribbon Continent of North America: Annual Review of Earth and Planetary Sciences. 36. 495-530. 10.1146/annurev.earth.36.031207.124331.

Johnston, P.A., Johnston, K.J., Collom, C.J., Powell, W.G., and Pollock, R.J., 2009. Palaeontology and depositional environments of ancient brine seeps in the Middle Cambrian Burgess Shale at The Monarch, British Columbia, Canada. Palaeogeography, Palaeoclimatology, Palaeoecology. 277. 86-105.

Kraft, J.L., 2013. Stratigraphy, paleogeography and tectonic evolution of early Paleozoic to Triassic pericratonic strata in the northern Kootenay Arc, southeastern Canadian Cordillera, British Columbia. Ph.D. thesis, University of Alberta, Edmonton, Canada, 361 p.

Kubli, T.E. and Simony, P.S., 1992. The Dogtooth High, northern Purcell Mountains, British Columbia. Bulletin of Canadian Petroleum Geology 40 (1), 36-51.

Larson, K.P. and Price, R.A., 2006. The southern termination of the Western Main Ranges of the Canadian Rockies, near Fort Steele, British Columbia: stratigraphy, structure, and tectonic implications. Bulletin of Canadian Petroleum Geology 54 (1), 37-61.

Leech, G.B.,1958. Fernie map area, west half, British Columbia 82G W1/2. Geological Survey of Canada, Paper 58-10, 40 p.

McConnell, R.G., 1887. Report on the geological structure of a portion of the Rocky Mountains, accompanied by a section measured near the 51st parallel. Geological Survey of Canada, Annual Report, New Series, v. 11, p. 1-41.

Norford, B.S., 1981. Devonian stratigraphy at the margins of the Rocky Mountain Trench, Columbia River, southeastern British Columbia. Bulletin of Canadian Petroleum Geology 29 (4), 540-560.

Norford, B.S. and Cecile, M.P., 1994. Cambrian and Ordovician volcanic rocks in the McKay Group and Beaverfoot Formation, western ranges of the Rocky Mountains, southeastern British Columbia. In: Current Research Geological Survey of Canada, Paper 94-1B, p. 83-90.

Pell, J. 1994. Carbonatites, nepheline syenites, kimberlites and related rocks in British Columbia. British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Survey Branch, Bulletin, No. 88, 136 pp.

Reesor, J.E., 1973. Geology of the Lardeau map area, east half, British Columbia. Geological Survey of Canada, Memoir 369, 129 p.

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 49 (1), 7-36.

Simony, P.S., Root, K.G., McMechan, M.E., and Pattison, D.R.M,, 2020. Stratigraphic continuity across the southern Canadian Cordilleran Foreland Thrust and Fold Belt: Implications for tectonic models. GeoCanada 2020 abstract.

Stewart, W.D., 1991. Stratigraphy and sedimentology of the Chancellor succession (Middle and Upper Cambrian), southeastern Canadian Rocky Mountains: Ph.D. thesis, University of Ottawa, Ottawa, Canada, 534 p.

Thompson, R.I., Glombick, P., Erdmer, P., Heaman, L.M., Lemieux, Y., and Daughtry, K.L.. 2006. Evolution of the ancestral Pacific margin, southern Canadian Cordillera: Insights from new geologic maps. Geological Association of Canada Special Paper. 45. 433-482.

Warren, M.J., 1997. Crustal extension and subsequent crustal thickening along the Cordilleran rifted margin of ancestral North America, western Purcell Mountains, southeastern British Columbia. Ph.D. thesis, Queen's University, 361 p.

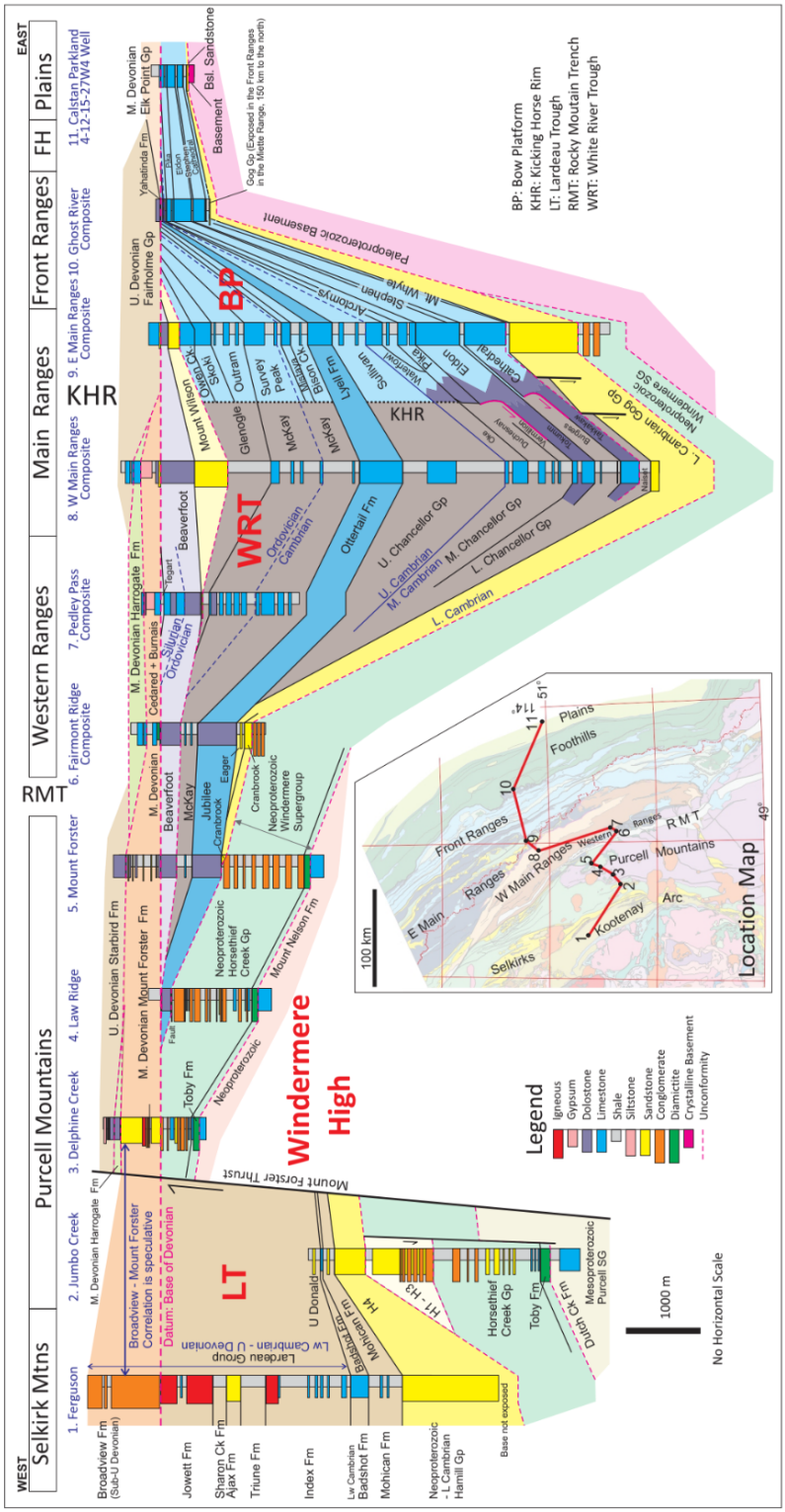

Fig. 1. Stratigraphic cross-section from the Selkirk Mountains to the Plains. Datum is the base of the Devonian. Sources of data: Henderson, 1954; Leech, 1958; Fyles and Eastwood, 1962; Reesor, 1973; Aitken, 1968, 1971; Cook, 1975; Norford, 1981; Stewart, 1991; Warren, 1997; Root, 2001; Collom et al., 2009; Kraft, 2013.