EPISODIC RIFTING OF WESTERN LAURENTIA

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Summary

In Proterozoic time, a large portion of ancestral North America, commonly referred to as Laurentia, was part of a larger, evolving mega-continent known variably as Arctica, Nena, Kanatia and Rodinia. Models and nomenclature for this evolving landmass are still being developed. Northwestern Laurentia may have been firmly attached to the Australian craton in the Early Proterozoic, as a consequence of a shared collisional event at *ca*. 1.85-1.95 Ga that produced the Wopmay orogeny in Canada and the Barramundi orogeny in Australia. Following these orogenies, western Laurentia underwent at least four discrete rift events. The first occurred in Yukon Territory where the Wernecke basin (*ca*. 1.84-1.72 Ga) formed and filled with ~13 km of clastic and carbonate strata. Subsequent rift events are recorded by the Belt-Purcell basin (1.47-1.37 Ga) of southern British Columbia and the northwestern United States; the Pinguicula basin of Yukon (*ca*. 1.38 Ga); the Hematite Creek, Mackenzie Mountains, and Buffalo Hump basins of Yukon and the northwestern U.S.A. (*ca*. 1 Ga); and the Windermere basins (0.8-0.6 Ga) that extend from Yukon to the southwestern U.S.A. The prominent Muskwa basin of northern British Columbia may correlate with any of the pre-Windermere successions. All of these rift assemblages are thick (1-13 km), and except for the Belt-Purcell basin, contain little or no igneous rock. Most, if not all of the pre-0.8 Ga rift basins appear to be intracratonic features, apparently recording episodic, failed extension prior to the Neoproterozoic when Windermere-aged rifting succeeded and led to development of a deep trough along much of Laurentia. Complete separation of Laurentia from Australia and Antarctica (?) may have occurred during this event, or subsequently during the Early Paleozoic.

Introduction

In Proterozoic time, a large portion of ancestral North America belonged to an evolving continental region that progressively grew by amalgamation with other continental regions. In the terminology of Rogers (1986), ancestral North America was part of the continent Arctica in Early Proterozoic time. Collisions with other Proterozoic continents in Middle and Late Proterozoic time yielded the large continent Nena, followed by the supercontinent Rodinia. Other authors have employed different terminology, and somewhat different models of continental growth. For example, Young (1995) preferred the term Kanatia instead of Nena, and included a different configuration of cratonal constituents (the position of Australia is an important difference). Late Proterozoic to Early Paleozoic rifting led to the break-up of Rodinia, and the dispersion of continental masses. One of the post-Rodinian continents, termed Laurentia, contained most of the crustal components of ancestral North America. Laurentia was subsequently involved in the assembly of the Paleozoic supercontinent Pangea.

Although the term Laurentia is most properly used in the context of post-Rodinian, pre-Pangean tectonics (Rogers, 1996), it has also been used (Hoffman 1989) for the main cratonal core of ancestral North America in earlier times. The term Laurentia is useful in this regard because of continuing uncertainty regarding Early to Late Proterozoic configurations and related terminology. For this reason, the term Laurentia has been used in this abstract to indicate the core of what later became Laurentia *sensu stricto*, which generally correlates with the main region of Precambrian crust presently located in North America.

In Early Proterozoic time, the western margin of Laurentia was probably sutured to the western to southern parts of Australia as a consequence of a shared collisional event from ca. 1.85-1.95 Ga, that produced the Wopmay orogeny in Canada and the Barramundi orogeny in Australia (Hoffman 1989). (Geographical references are given in terms of present Earth coordinates). East Antarctica may also have been part of this Early Proterozoic landmass. Following these orogenies, western Laurentia underwent at least four discrete rift events. These rift events spanned over a billion years. They overlapped with the progressive accretion of crust onto Laurentia, and the assembly of Rodinia. The protracted, episodic history of rifting along the western margin of Laurentia culminated with the Late Proterozoic separation of Australia / Antarctica from Laurentia, and coincided with the break-up of Rodinia.

Episodic rifting

The first rift event (Fig. 1) produced the Wernecke basin in Yukon Territory (*ca*. 1.84-1.72 Ga). Subsequent rift events are recorded by the Belt-Purcell basin (*ca*. 1.47-1.37 Ga) of southern British Columbia and the northwestern United States; the Pinguicula-Lower Fifteenmile basin of Yukon (*ca*. 1.38 Ga); the Hematite Creek, Mackenzie Mountains, Upper Fifteenmile, and Buffalo Hump basins of Yukon and the northwestern U.S.A. (*ca*. 1.0-0.8 Ga); and the Windermere basins (0.8-0.6 Ga) that extend from Yukon to the southwestern U.S.A. The prominent Muskwa basin of northern British Columbia is poorly constrained in age and affinity, and may correlate with any of the pre-Windermere successions.

The Early Proterozoic Wernecke basin (Thorkelson in press) records two main events of subsidence as demonstrated by two grand-cycles of clastic-to-carbonate sedimentation. The basin contains up to 13 km of strata (Wernecke Supergroup), all of which are sedimentary. Basin development occurred after *ca*. 1.84 Ga, but before the emplacement of the post-sedimentary Bonnet Plume River intrusions at *ca*. 1.72 Ga. The relationship of these dykes to basin formation and infilling is tenuous because the Wernecke basin was deformed by a weak orogenic event termed the Racklan orogeny prior to 1.6 Ga, and the relative timing between magmatism and contraction has not been resolved. Thus, the dykes may have been generated by extension as the terminal manifestation of rift development, or alternatively, as magmas unrelated to the Wernecke rift basin, and derived from plume activity after the Racklan orogeny..

The tectonic significance of the Wernecke basin is not well understood. Seismic investigations and stratigraphic correlations suggest that the Wernecke basin extended inland for hundreds of km inland, to the east. The basin may have been a failed intracratonic extensional basin akin to the broadly coeval Athabasca and Thelon basins in the interior of Laurentia. Alternatively, it may represent a more evolved rift which led to passive margin development along the western margin of Laurentia that was subsequently closed during the Racklan orogeny.

Voluminous hydrothermal systems at ca. 1.6 Ga led to emplacement of numerous large breccia zones in the Wernecke basin. These features may have been generated by igneous activity at depth, possibly linked to mantle plume activity, but the degree of crustal extension is considered to be minor.

The Middle Proterozoic Belt-Purcell basin (Ross *et al*. 1992) has been more definitely constrained as an intracratonic rift basin, with total accumulations up to 20 km thick (Fig. 1). Built on crust as young as 1.58 Ga, infilling of this basin began with voluminous clastic sedimentation, and emplacement of the synsedimentary Moyie sills at ca. 1.45 Ga. Younger parts of the Belt-Purcell succession include carbonate and minor volcanic rocks. Both lacustrine and marine environments have been proposed. Detrital zircon and paleocurrent studies indicate input of sediment from the west, possibly from the Gawler craton of South Australia. Like the older Wernecke basin to the north, the Belt-Purcell basin has limited along-strike continuity, inferring that basin evolution was localized, did not progress into a continent-splitting rift system, and did not lead to passive margin development.

The Pinguicula-Lower Fifteenmile basin in Yukon (Eisbacher 1981; Abbott 1997; Thorkelson in press) was generated toward the end of Belt-Purcell deposition (Fig. 1). Pinguicula deposition began with minor conglomerate and sandstone, evolved toward mudrock, and concluded with shallow-water carbonate, achieving a cumulative thickness of 3.5 km. Localized, pronounced thinning of strata in the Pinguicula succession, and abrupt facies changes across block faults in the Fifteenmile succession, indicate deposition within a broad basin punctuated by fault-bounded highlands and depocentres. The lower parts of the Pinguicula were intruded by the Hart River sills at *ca*. 1.38 Ga. Volcanics associated with these sills locally form the base to the succession, inferring that the Hart River magmatic event extended from just before to just after basal sedimentation.

Following Pinguicula-Fifteenmile deposition, a large region of Laurentia was affected by mafic volcanism and dyking during the *ca*. 1.27 Ga Mackenzie igneous event. This plume-generated event was focused in northern Laurentia (Canadian arctic), where it is inferred to have caused uplift and extension. Dykes of this age are also present in Yukon, indicating some extension of western Laurentia at this time. However, large-magnitude extension and related basin development in western Laurentia has not been identified for this time.

The Hematite Creek, Mackenzie Mountains, and Buffalo Hump basins developed at *ca*. 1 Ga (Fig. 1), although age control is poor and some parts of these successions may be considerably older (Jefferson and Parrish 1989; Ross *et al*. 1992; Rainbird *et al*. 1997; Thorkelson in press). Detrital zircon and muscovite in these successions were apparently derived from the Grenville orogen and the U.S.A. midcontinental anorogenic granites via continent-scale river systems. Thicknesses in these successions range from *ca*. 1-4 km. Igneous rocks are not associated with these basins, which record relatively modest subsidence and inferred extension.

The terminal Proterozoic extensional event (Fig. 1) is represented by the Windermere basins (Eisbacher 1981; Ross 1991; Narbonne and Aitken 1995) and correlative units in the U.S.A. (0.8-0.6 Ga). The Windermere basins contain varied and disparate assemblages of clastic and carbonate rock. Some of the more prominent stratigraphic successions include the Windermere Supergroup in Yukon, the Northwest Territories and British Columbia; the Mt. Harper Group and the Hyland Group (in part) in Yukon; and the Coates Lake Group in the Northwest Territories. These successions range from *ca*. 3-8 km thick, and are characterized by their basal conglomerates and grits, and glaciogenic diamictites of both Sturtian and Varangian ages. Mafic igneous rocks are present as volcanics and intrusions at or near the bases of several successions but, overall, are low in abundance.

There is little dispute concerning the rift origin of the Windermere basins. However, the significance of Windermere rifting remains uncertain because a subsequent rift event at the beginning of the Paleozoic is implied by the age and thickness profile of the Paleozoic miogeocline. Thus, the question remains, did Windermere rifting lead to separation and dispersion of a conjugate landmass in the Proterozoic, or was final separation accomplished much later, during the earliest Paleozoic? Regardless of the answer, the Windermere rift event is recognized along much of the western margin of Laurentia, and represents the first extensional event to ply the length of the continent.

Conclusions

The western margin of Laurentia was the site of repeated Proterozoic rifting, *ca*. 1.8-0.6 Ga. Most, if not all of the pre-0.8 Ga rift basins appear to be intracratonic features, apparently recording episodic, failed extension. Basin morphology varied from the large, miogeocline-like Early Proterozoic Wernecke basin, to the relatively contained Middle Proterozoic Belt-Purcell basin. Mafic magmatism, in most cases, was volumetrically subordinate to sedimentation, and in no case did mafic magmatism increase in abundance with higher stratigraphic position. Thus, the magmatism appears to have been controlled by initial basinal extension, possibly triggered by an initial mantle perturbation. Conceivably, some of these basins were driven by abrupt lateral perturbations in the underlying mantle, possibly generated by the impingement of a "starting mantle plume head."

The pre-Windermere basins compare favourably, in some ways, with the Michigan, Illinois and Williston basins of mainly Paleozoic age. These saucer-like supra-cratonic basins each contain approximately 3 km of sedimentary strata, and are devoid of contemporaneous igneous rock. They contain abundant evaporites, and clearly record restricted aqueous environments. They may be regarded as thinner, more poorly developed versions of the Proterozoic basins. With more vigorous extension and subsidence, the Paleozoic basins may have developed igneous components, and more abundant siliciclastic strata. In other ways, the Proterozoic basins are more akin to passive margin successions, particulary in their early history of magmatism, demonstrated relationship to block faulting (some basins), and thicker accumulations of siliciclastic strata.

In summary, the post-1.85 Ga Proterozoic history of western Laurentia is dominated by repeated basin-forming events coupled with minor igneous activity, which together define a prolonged, yet punctuated, history of rifting. With the possible exception of the Wernecke rift event, all of the pre-Windermere rifting episodes failed to produce substantial separation of crust, and must be considered as intracratonic features. Windermere rifting was clearly a more through-going tectonic and magmatic event which led to development of a deep trough or set of basins along much of western Laurentia. Whether this event, or subsequent Paleozoic rifting, was responsible for the complete separation of Laurentia from continental crust to the west remains uncertain.

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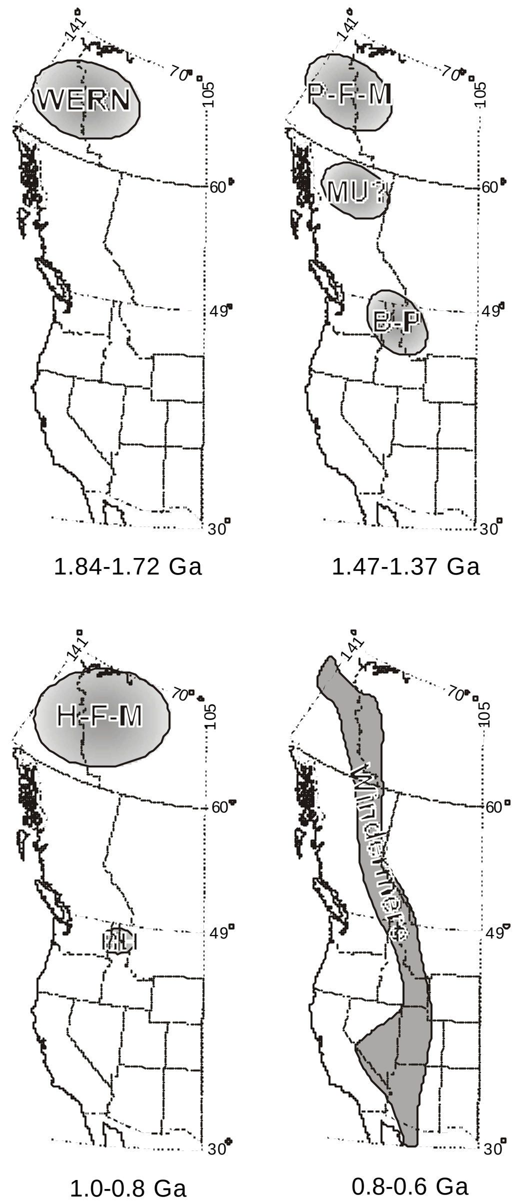

Fig. 1. Major Proterozoic rift basins of western Laurentia. Wern=Wernecke; P-F-M=Pinguicula, lower Fifteenmile, and lower Mackenzie Mountains; MU=Muskwa (age uncertain); B-P=Belt Purcell; H-F-M=Hematite Creek, upper Fifteemile, and upper Mackenzie Mountains; BH=Buffalo Hump.