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A Pangean rim of fire: Reviewing the Triassic of western Laurentia

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ABSTRACT

A synthesis of U-Pb detrital zircon data from the Triassic of western Laurentia is placed in the context of paleogeographic models for Pangea. We find that an emerging body of evidence supports the hypothesis that a Triassic subduction zone and continental magmatic arc system fringed western Laurentia starting in the southwestern United States, continuing northward along the Cordillera, including arc rocks of the Quesnel and Yukon-Tanana terranes, and extending further into the Arctic region. In the context of this geodynamic setting, the western interior basins of North America would have formed, probably by subduction dynamics, as a collage of backarc and retroarc foreland basins. The convergent tectonic model for western Laurentia is consistent with paleogeographic reconstructions that show a subduction zone encircling Pangea, called the Pangean rim of fire.

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INTRODUCTION

Some paleogeographic models have hypothesized that segments of western Laurentia were convergent margins in the Triassic; here we explore the scenario that these segments were connected in forming a continuous convergent margin. The proposition is that during Permian time Pangea was surrounded by a ring of subduction zones forming an outer Pangean rim (Scotese and Langford, 1995), including western Laurentia, that possibly continued through the Triassic as a Pangean rim of fire (Golonka and Ford, 2000) (Fig. 1). Although in accord with Triassic tectonics of the southwestern United States (e.g., Riggs et al., 1996, 2016), those interpretations were inconsistent with accretionary tectonic models for the northern Cordillera of North America that invoke a subduction regime only after collision of exotic terranes in the Jurassic–Cretaceous (e.g., Monger et al., 1982). However, data published in the 2000s show that links between autochthonous Laurentian crust and the Cordilleran pericratonic Yukon-Tanana and Quesnel terranes are older than previously thought (e.g., Colpron et al., 2006; Nelson et al., 2006). Crustal-scale seismic data are interpreted to show that Laurentian basement underlies most of the Canadian Cordillera (Cook et al., 2004), consistent with observations that the pericratonic terranes have basement rocks with Laurentian characteristics (e.g., Roback and Walker, 1995; Piercey and Colpron, 2009). More recent provenance studies have pinned both the Yukon-Tanana and Quesnel terranes proximal to the Western Interior Basin of North America in the Triassic, precluding an intervening basin floored by oceanic crust at that time (Beranek and Mortensen, 2011; Golding et al., 2016b).

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TRIASSIC PROVENANCE OF SOUTHWESTERN CANADA

The preserved portion of the Triassic depositional system in the southern Canadian Cordillera is a westward-thickening succession of easterly derived marine deposits (Gibson, *in* Gordey et al., 1991) containing detrital zircon most likely recycled from Paleozoic strata (Golding et al., 2016a). Evidence for the western margin of the basin is generally lacking except for two upper Triassic samples from Williston Lake that contain a predominant fraction of Late Triassic detrital zircon interpreted as a volcaniclastic record of the Quesnel terrane (Golding et al., 2016b; SC in Fig. 1).

U-Pb Detrital Zircon Geochronology

One Permian and four Triassic sandstone samples were collected from the southern Canadian Cordillera at the McLeod River locality (SC in Fig. 1); the stratigraphy was described in Gibson and Poulton (1994). Samples were analyzed at the University of Calgary using zircon U-Pb isotopic procedures outlined in Matthews and Guest (2016); results are tabulated in the GSA Data Repository Item[1]. The predominant Paleozoic and Precambrian detrital zircon fractions were most likely derived from sedimentary recycling of Paleozoic strata (cf. Hadlari et al., 2015). Permian and Triassic samples contain a small fraction of Permian ages; however, the most notable is a Middle Triassic sample (15-TH-3) that yielded Triassic ages of 239 ± 6 Ma, 248 ±6 Ma, and 248 ±6 Ma that compose 1.6% of the sample and overlap within 2σ error of the presumed Middle Triassic depositional age. For the most part, our results are in

[1]GSA Data Repository Item 2017183, containing U-Pb isotopic detrital zircon data in the format recommended by the PlasmAge community, is available at http://www.geosociety.org/datarepository/2017, or on request from editing@geosociety.org.

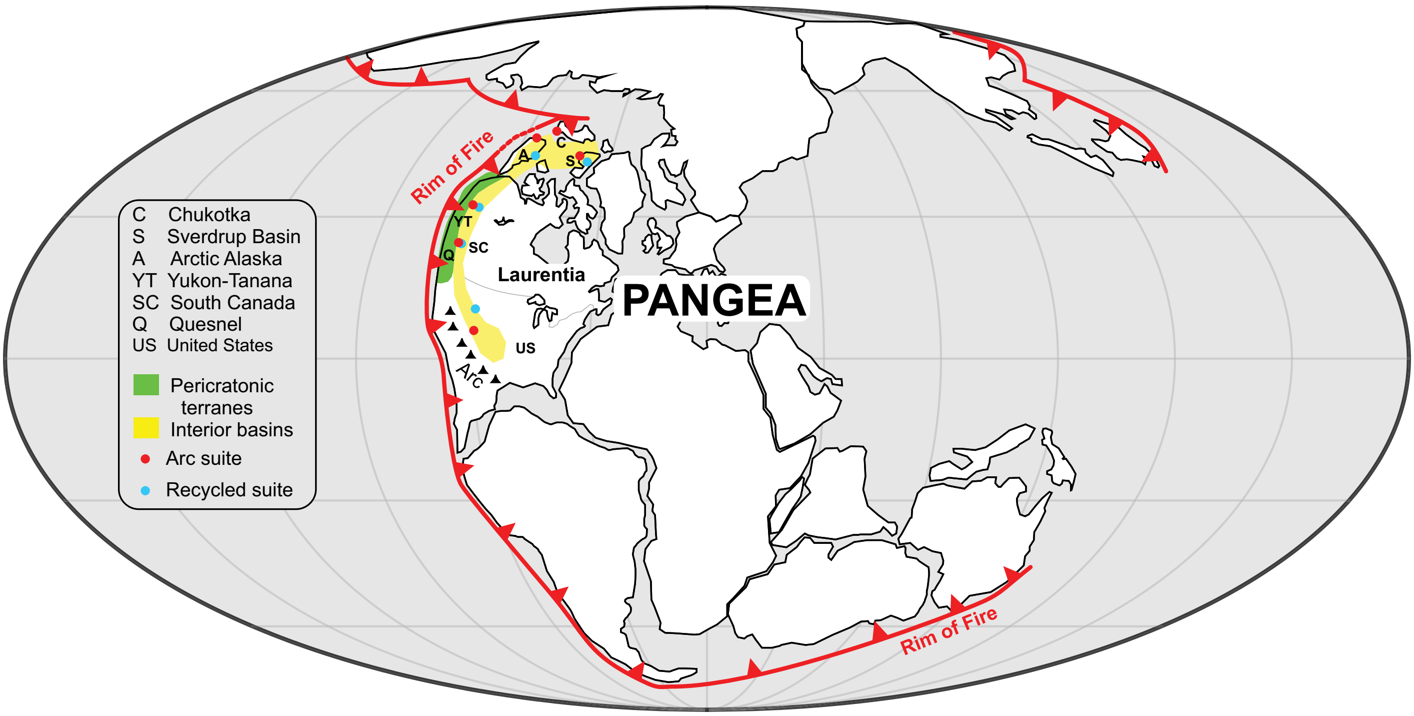

Figure 1. Mollweide projection of Pangea in the Late Triassic. Paleogeography from Lawver and Gahagan (1993) and Scotese and Langford (1995) is modified by updating pericratonic terranes (Beranek and Mortensen, 2011; Golding et al., 2016b) and the tectonic setting of Arctic Laurentia (Midwinter et al., 2016).

the recycled suite (Fig. 2), but considering the known Late Triassic volcaniclastic input documented by Golding et al. (2016b), the nearly syndepositional ages from McLeod River most likely extend the record of pericratonic volcaniclastic input from the Late to the Middle Triassic. Other explanations, such as margin-parallel sediment transport, seem unlikely because the dual provenance signatures are quite distinct (Fig. 2).

TRIASSIC RIM OF FIRE

Interior basins of the southwestern United States are recognized as a Triassic backarc system (Busby-Spera, 1988; Riggs et al., 1996). Middle and upper Triassic strata deposited in the backarc basin and the Sonoma foreland basin contain abundant arc-derived Middle and Late Triassic detrital zircon (Riggs et al., 1996, 2016; Dickinson and Gehrels, 2008). In addition, the Chinle Formation contains 228–220 Ma tuffaceous sandstones consistent with proximity to the western arc (Atchley et al., 2013).

In the southern Canadian Cordillera, crustal-scale seismic reflection profiles are interpreted to show Laurentian crust below pericratonic terranes instead of a crustal-scale suture (Cook et al., 2004), consistent with Proterozoic basement within the Quesnel terrane (Erdmer et al., 2002) and tentative geochemical ties of the Quesnel terrane to Laurentia in the Triassic (Unterschutz et al., 2002). This results in a view of the Quesnel

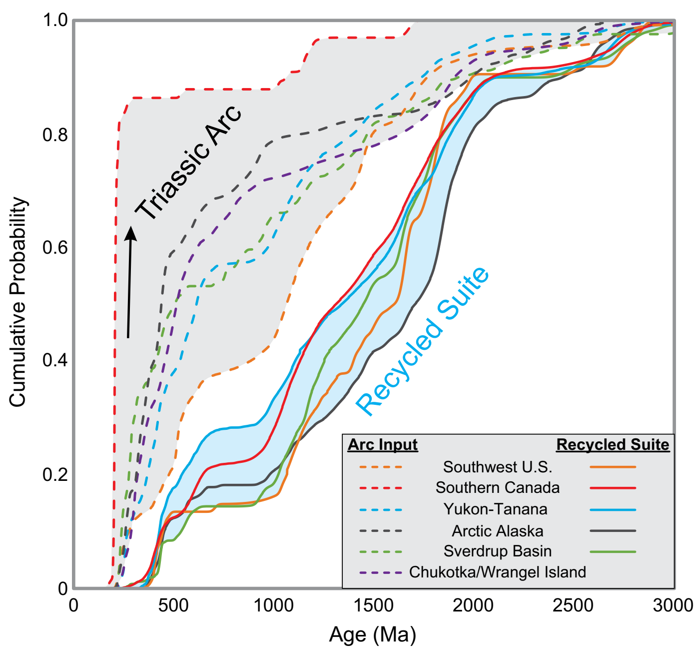

Figure 2. Cumulative probability plot of U-Pb detrital zircon data showing the duality of age signatures along the western length of Laurentia in the Triassic. The arc-type group is characterized by abundant Triassic zircon within Triassic strata and is proposed have been shed from a western convergent margin into the interior basins. The recycled suite is simply a record of the Paleozoic basin history preceding retroarc foreland subsidence in the Triassic. Data sources: United States (U.S.)—Dickinson and Gehrels (2008), May et al. (2013); southern Canada—Golding et al. (2016a, 2016b), this study; Yukon-Tanana terrane—Beranek et al. (2010), Beranek and Mortensen (2011); Arctic Alaska—Miller et al. (2006), Gottlieb et al. (2014); Sverdrup Basin—Miller et al. (2006), Omma et al. (2011), Midwinter et al. (2016); Chukotka—Miller et al. (2006, 2010), Tuchkova et al. (2011), Amato et al. (2015).

terrane as a Mesozoic arc built upon Laurentian basement, beginning by at least ca. 230 Ma (Erdmer et al., 2002). The pericratonic framework is consistent with upper Triassic sandstones from the far western edge of the Western Interior Basin that have yielded detrital zircon age spectra dominated by 210–200 Ma ages interpreted to be the volcaniclastic record of the Quesnel terrane volcanic arc (Golding et al., 2016b), in addition to ca. 248–220 Ma detrital zircon indicating sedimentary connection (Golding et al., 2016b; this study).

Sedimentary basins near the restored northwestern margin of Laurentia have a very consistent character of Triassic detrital zircon within Triassic strata, from the northern Cordillera (Beranek and Mortensen, 2011), through the Arctic (Miller et al., 2010; Amato et al., 2015), and in the Sverdrup Basin (Midwinter et al., 2016), whereas the inboard portions were dominated by sedimentary recycling of older strata (e.g., Hadlari et al., 2015). Samples from the Yukon-Tanana terrane and Western Interior Basin east of the Tintina fault are critical because they were not displaced in a strike-slip sense after the Triassic, negating complexities involving large-scale orogen-parallel translations. The reconstruction of Pangea illustrates our proposed retroarc extensional model for the Arctic Ocean in the Mesozoic (Hadlari et al., 2016; Midwinter et al., 2016), which is similar to Nokleberg et al. (2000), and shows the general location of detrital zircon samples from both the outboard arc-derived and the inboard recycled suites (see detailed discussion in Midwinter et al., 2016). There are other interpretations for Triassic detrital zircon provenance in the Arctic Alaska and Chukotka terranes that invoke sediment transport from the Urals (e.g., see discussions in Gottlieb et al., 2014; Anfinson et al., 2016), but there are no known Triassic igneous rocks in the Urals that could have served as an adequate zircon source to supply northwestern Laurentia (see discussion in Midwinter et al., 2016; e.g., Pease et al., 2014). There are, however, igneous rocks from the southern or outboard side of the Chukotka terrane that Parfenov et al. (2010) interpreted to be the leading edge or forearc of the Chukotka terrane, and that Ledneva et al. (2016) characterized as a suprasubduction assemblage and dated to the Late Triassic.

The simplest explanation for the presence of Triassic detrital zircon in Triassic strata from basins of western Laurentia is that pericratonic terranes hosting Triassic igneous rocks were part of an arc system that extended from the southwestern United States through the North American Cordillera and into the western Arctic. Arc rocks are documented in the southwestern United States and the Quesnel, Yukon-Tanana, and Chukotka terranes, with the exception of the Arctic Alaska terrane, and so the subduction zone in Figure 1 is dashed adjacent to Arctic Alaska. The consistent duality of detrital zircon signatures for each region (Fig. 2) is most consistent with volcaniclastic influx along the entire western margin because margin-parallel transport would most likely mix and dilute the Triassic signal along strike, but the duality is quite coherent.

TRIASSIC RETROARC FORELAND BASINS

Our proposed Triassic Pangean rim of fire places the sedimentary basins of western Laurentia in a continental retroarc setting. Although some portions with local extension may have been backarc basins (e.g., Wyld, 2000), the continent-scale linear continuity of subsidence to form thick deposits of lower Triassic mudstone followed by Late Triassic filling of the basin by sandstone is consistent with the record of a widespread foreland basin system. A general detrital zircon provenance model subdivides foreland basins into three depositional systems (Hadlari et al., 2014): (1) a western orogen-proximal system with direct input from a magmatic arc, (2) a central basin axial system characterized by sediment starvation and/or orogen-parallel sediment transport, and (3) an eastern craton-proximal system undergoing flexure that derived zircon from recycling of older strata. The reason that the preserved portion of the basin is dominated by sedimentary recycling and that there is only a minor syntectonic character to the deposits is because the western orogenic side of the basin was uplifted, eroded, and cannibalized during the Jurassic–Early Cretaceous Columbian orogeny and the Cretaceous–Paleocene Laramide orogeny.

SUMMARY AND CONCLUSIONS

The combination of U-Pb detrital zircon data from the southwestern United States across the Canadian Cordillera to the Arctic supports the Triassic Pangean rim of fire hypothesis. In the southwestern United States the continental arc, backarc basin, and foreland settings are well documented. Evidence for an equivalent arc along the western margin of the southern Canadian Cordillera is based on a combination of crustal-scale seismology, Laurentian affinity of the pericratonic Quesnel and Yukon-Tanana terranes, and Triassic detrital zircon found in the westernmost portions of the Western Interior Basin. The continuation of this continental arc in the northern Cordillera and Arctic seems likely based on the close association of the Yukon-Tanana terrane with Laurentia and the presence of Triassic detrital zircon in the more outboard-facing settings of the Arctic Alaska and Chukotka terranes, as well as in the Sverdrup Basin. Application of a foreland basin provenance model along the entire western margin of Laurentia explains the inboard-outboard duality of Late Triassic detrital zircon signatures, as well as the general predominance of sedimentary recycling in the preserved sedimentary deposits of the western interior basins.

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