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# Early Triassic development of a foreland basin in the Canadian high Arctic: Implications for a Pangean Rim of Fire

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ABSTRACT

Following the amalgamation of Laurasia and Gondwana to form Pangea, some Triassic tectonic models show an encircling arc system called the "Pangean Rim of Fire". Here we show that the stratigraphy and Early Triassic detrital zircon provenance of the Sverdrup Basin in the Canadian Arctic is most consistent with deposition in a retro-arc foreland basin. Late Permian and Early Triassic volcanism was accompanied by relatively high rates of subsidence leading to a starved basin with volcanic input from a magmatic arc to the northwest. The mostly starved basin persisted through the Middle and Late Triassic with nearly continuous input of volcanic ash recorded as bentonites on the northwestern edge of the basin. In the latest Triassic it is interpreted that decreasing subsidence and a significant influx of sand-grade sediment when the arc was exhumed led to filling of the basin at the end of an orogenic cycle. Combined with other hints of Early Triassic arc activity along the western margin of Laurentia we propose that the Pangean Rim of Fire configuration spanned the entire Triassic. This proposed configuration represents the ring of external subduction zones that some models suggest are necessary for the breakup of supercontinents such as Pangea.

## 1. Introduction

Some recent works on the Triassic tectonics of the western interior basins of North America consider retro-arc interpretations (Riggs et al., 1996, 2016; Dickinson and Gehrels, 2008; Beranek and Mortensen, 2011; Golding et al., 2016; Midwinter et al., 2016), which Hadlari et al. (2017) interpret as an extensive retro-arc system related to a convergent margin that fringed most of a supercontinent, the Pangean Rim of Fire (Fig. 1). The Sverdrup Basin is an Arctic example of one of these western interior basins, but for many years the standard explanation for the Triassic history of the Sverdrup Basin has been post-rift thermal subsidence (e.g., Embry, 1991, 2011). An alternative explanation is that the convergent margin on the outboard side of Chukotka terrane that is documented for the Jurassic (Amato et al., 2015), was established by the Triassic (see Midwinter et al., 2016). The Triassic subduction zone along the western margin of Laurentia provides a new geodynamic explanation for the Sverdrup Basin to have formed as retro-arc foreland basin (Hadlari et al., 2017). This contribution uses new detrital zircon geochronology from Lower and Upper Triassic strata of the Sverdrup Basin to further examine the retro-arc foreland basin model and then to consider implications for the Rim of Fire and the breakup of Pangea.

### 1.1. Geologic setting: tectono-sedimentary provenance of the Sverdrup Basin

The Sverdrup Basin originated as a rift basin in the Carboniferous (e.g., Embry and Beauchamp, 2008), underwent significant subsidence in the Triassic (stratigraphy is shown in Fig. 3), and then Early Jurassic-Early Cretaceous rifting that led to opening of the Amerasia Basin (e.g., Hadlari et al., 2016). The Triassic subsidence has long been considered part of a passive margin process (e.g., Embry, 2011), whereas first indications of a more dynamic tectonic setting were from a provenance study that identified Triassic detrital zircon within Upper Triassic strata from the Sverdrup Basin (Omma et al., 2011). Subsequent studies attribute Triassic sedimentary provenance for the Sverdrup Basin to a Uralian sediment source (see discussions in Miller et al., 2013; Gottlieb et al., 2014; Anfinson et al., 2016), but Midwinter et al. (2016) use Hf isotopes to show that ~350–210 Ma detrital zircon from the Sverdrup Basin are probably incompatible with known igneous rocks in Siberia and near the Urals.

Sediment transport directions into the Sverdrup Basin during the

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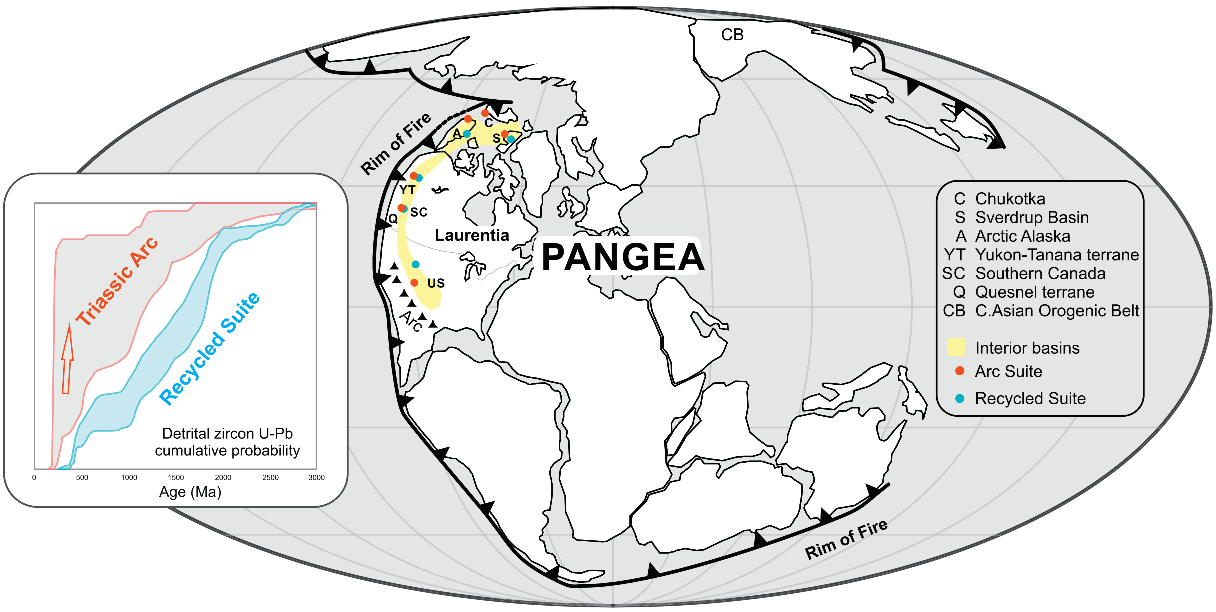


**Fig. 1.** Triassic paleogeography showing the Pangean Rim of Fire (see Hadlari et al., 2017; and sources therein), which was modified from Lawver and Gahagan (1993) and Scotese and Langford (1995).

Triassic indicate that a northwestern source fed the northwestern part of the basin and a different southeastern source provided sediment to its southeastern part (Embry, 2009; Midwinter et al., 2017). Accordingly, both Anfinson et al. (2016) and Midwinter et al. (2016) subdivide Late Triassic detrital zircon samples into those located mainly on the northern side of the basin containing Triassic detrital zircon within Triassic strata and a simple recycled Devonian clastic wedge character on the southeastern side of the basin. Volcanic ash beds that are common throughout the entire Triassic succession on the northwestern side of the Sverdrup Basin (Griesbach Creek in Fig. 2), first reported by Midwinter et al. (2016), are critical to deducing that the proximal northwestern source region was characterized by Triassic igneous activity. The combination of Triassic ash beds with U-Pb and Hf data from Permian-Triassic detrital zircon from Triassic strata of the Sverdrup Basin led Midwinter et al. (2016) to propose that part of Chukotka terrane was a magmatic arc in the Triassic, which places the Sverdrup Basin in a retro-arc setting if restored using the rotational model for the Arctic Ocean based on Grantz et al. (1979). Evidence for such a convergent margin could be a suprasubduction volcanic assemblage from the Velmay terrane, which is interpreted by Parfenov et al. (2010) to have occupied the outboard edge of Chukotka and dated by Ledneva et al. (2016) to the Late Triassic.

In contrast to the Late Triassic, there are far fewer constraints on the Early Triassic provenance of the Sverdrup Basin. Published detrital zircon data from the Lower Triassic strata of the northwestern Sverdrup Basin are limited to a single sample of the Blind Fiord Formation (stratigraphy is shown in Fig. 3) with a very low number of analyses (n = 40) that yielded a significant fraction of 19 grains between 290 and 265 Ma (Omma et al., 2011). It is difficult to make firm provenance interpretations from such a small sample size, but speculation is that there was either a Permian igneous source proximal to the northwestern Sverdrup Basin or that sediment was transported from the Urals (see discussion in Omma et al., 2011). From additional detrital zircon data Alonso-Torres et al. (2018) interpret Middle and Upper Permian sedimentary provenance of the Sverdrup Basin to have been sourced from a proximal igneous source north of the Basin. In the Permian-Triassic stratigraphic section at Greisbach Creek (Fig. 2), volcanic ash beds are first described here from the Upper Permian part of the stratigraphy preserved below the Blind Fiord Formation. The combination of Upper Permian and Triassic ash beds are most likely a volcanic record of the igneous source for Permian-Triassic detrital zircon within the Sverdrup Basin and so detrital zircon analysis was conducted on latest Permian and Lower Triassic volcanic ash and sandstone samples.

## 2. Materials and methods

Samples were collected from Griesbach Creek on northwestern Axel Heiberg Island in 2015 and 2016. A 1300 m thick stratigraphic section, shown in Fig. 4, from the Upper Permian Trold Fiord Formation to the base of the Upper Triassic Heiberg Formation was measured at Griesbach Creek near the type section for the Griesbachian substage of the Early Triassic (Tozer, 1967). Detrital zircon U-Pb analyses were conducted at the University of Calgary using sample preparation and zircon U-Pb isotopic procedures outlined by Matthews and Guest (2017). U-Pb isotopic age data were filtered using Concordia ages by considering those with a probability of concordance of 5% or more. Results are shown in the relative age probability plots in Fig. 4. Concordia ages for the Devonian clastic wedge reference spectrum were calculated by B. Davis and shown in Hadlari et al. (2014a). Maximum depositional ages were calculated using a weighted mean of the youngest age cluster with overlapping 2-sigma errors, excluding grains with < 60 ppm Uranium. Maximum depositional ages are reported with 2σ errors that include both random and systematic errors (Table 1).

## 3. Results

### 3.1. U-Pb LA-ICP-MS geochronology

Two tuff beds from the Trold Fiord Formation were sampled at Griesbach Creek (Fig. 5). They were both processed and analysed using procedures for detrital zircon analysis and so as much as possible the preparation yields a random selection of grains rather than the typical procedure for a volcanic rock which would preferentially select primary igneous grains.

Sample *Trold-1* (15-DTA-04A) is a bentonite 2 cm thick that lies approximately 5 m above the sub-Trold Formation unconformity (Fig. 4). From 205 analyses with a probability of concordance of 5% or greater (n = 205), 10 are Archean (5%), 17 are between 2000–1750 Ma (8%), 91 are 1650–900 Ma (43%), 58 are 660–350 Ma (28%), and 19 are 350–250 Ma (9%). The accessory detrital component forms most of