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Jurassic back-arc to foredeep trough transition from U-Pb Zircon data, Cordilleran foreland basin in southwestern Canada

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Summary

U-Pb geochronology of detrital zircon from Lower Jurassic to Lower Cretaceous stratigraphic units of the southern Canadian Rocky Mountains fold-thrust belt documents the presence throughout of detrital zircons with ages close to the time of sediment accumulation. This indicates that the drainage systems that discharged into the local expression of the Western Interior Seaway were accessing western contemporaneous igneous sources in the Cordillera starting at least from Early Jurassic, long before the Kimmeridgian initiation of the foredeep trough. Older grains in the Jurassic strata reflect the pre-history of the basin distributive province and show an episodic pattern that includes well-defined lower Paleozoic and Grenvillian maxima, and Paleo- to early Neoproterozoic populations, which may reflect recycling of detrital zircons from older clastic formations uplifted in the eastern part of the orogen, or less likely, eastern sources. The data also provide maximum depositional ages for several stratigraphic units of uncertain age.

Introduction

Sedimentological and paleocurrent data (e.g., Hamblin and Walker, 1978; Poulton et al., 1994), relative crustal subsidence rates (Chamberlain et al., 1989), provenance studies (Ross et al., 2005; Raines et al., 3013), and the earliest dated thrust faults in the Rocky Mountains (Pană and van der Pluijm, 2015) are widely accepted to document the initiation of the Alberta foreland basin during the Late Jurassic. The first appearance of westerly-derived detritus from a rising arc or orogen is often accepted as providing the timing of initiation of the Western Interior foreland basin (Miall, 2009). This paper presents baseline detrital zircon geochronological data sets from Early Jurassic through Early Cretaceous strata of the western portion of the Western Canada Sedimentary Basin (WCSB), now incorporated in the southeastern Canadian RM-FTB. We report for the first time syndepositional detrital zircon ages throughout the Jurassic, which may indicate that drainage systems into the Western Interior Seaway were reaching Cordilleran igneous sources since at least the Early Jurassic.

Theory and Method

Our sampling strategy was designed to cover the entire length of the southern Canadian Foreland belt between ca. 49°30’N and 53°30’N latitude and the entire Early Jurassic to Early Cretaceous stratigraphic succession, which encompasses inferred early stages of the southern Canadian Cordilleran foreland basin. Our sample suite includes 17 samples from all representative coarser clastic units of the Fernie Formation, 8 samples from the first massive thick (commonly >1 m) sandstone bed assigned to the basal Morrissey and Nikanassin formations, and 4 samples from the Cadomin Formation. Approximately 120 individual zircon grains were analysed by LA-ICP-MS from each sample, for a total of 3231 single zircon ages, of which approximately 80% (2600 ages) were used for interpretation, whereas the >10% discordant analyses were rejected. In situ U-Pb zircon data was collected using laser ablation multi collector inductively coupled mass spectrometry (LA-MC-ICP-MS) at the Canadian Centre for Isotopic Micro-analysis (CCIM) of the University of Alberta. For plotting purposes, data were filtered using a 10% discordance filter with the following criteria: for ages less than 500 Ma, concordance was assessed by comparing the ^{206}Pb/^{238}U and ^{207}Pb/^{206}Pb ages, for ages less than 500 Ma, concordance was assessed by comparing the ^{207}Pb/^{235}U and ^{206}Pb/^{238}U ages. All plots were generated using the Isoplot software of Ludwig (2003).

Examples

Crystallization ages for detrital zircons show remarkably similar patterns of peaks and troughs, with some variation in the relative amplitude of the peaks. This suggests that the sources did not vary dramatically throughout the Early Jurassic to Early Cretaceous. With the exception of the Gryphaea Bed silty limestone, the proportion of the youngest zircons with ages approximating the depositional age of the sediment is limited; instead a swath of older ages form the majority of recovered zircon grains. This distribution pattern is common in foreland strata sourced both from units caught in the orogen and from the cratonic foreland (Cawood et al., 2012). Most detrital zircons yielded ages older than ca. 1 Ga with a Paleoproterozoic trough in the 2.5–2.3 Ga range. The absence of zircon grains in the 2.5–2.3 Ga range (Arrowsmith age) and the minor proportion of 2.0–1.9 Ga zircons (Taltson age) suggest that the western Canadian Shield did not represent a significant original source. Instead, characteristic to Precambrian portions in all zircon spectra are “Grenville-aged” grains (1000-1200 Ma) with minor Canadian Arctic signatures (ca. 750–500 Ma), both typical of the miogeoclinal units. Also common to all samples are zircons in the Early Paleozoic (ca. 500–400 Ma) age range, with Carboniferous-Permian (350–250 Ma) and early Neoproterozoic (950–750 Ma) troughs.

The youngest peaks in the Early Jurassic ***Basal sandstone*** are Late Triassic, Hettangian, and late Sinemurian. The Triassic zircon may be explained by erosion of the underlying Triassic strata, which must have had a geographic connection to an adjacent magmatic arc associated with ocean closure (now preserved in the Intermontane belt). The maximum depositional age of the ***Rock Creek Member*** is constrained to latest Aalenian ca. 175 Ma, consistent with the biostratigraphically controlled probable age of its oldest strata. All three ***Gryphaea Bed*** limestone samples yielded mostly euhedral zircon grains and apparently normally distributed data points, either from a single age population that indicates local derivation from a single igneous protolith emplaced immediately prior to the carbonate bed deposition, or more likely from quasi-contemporaneous volcanic activity. Based on the agreement within analytical uncertainty, we have used the zircon ages from the three samples to calculate a weighted mean age of 169.0±1 Ma (a coherent group of 167 grains) which is the best estimate of the igneous source, and implicitly the maximum age of the Gryphaea Beds. Youngest peaks in the ***Passage Beds*** samples, constrain the upper part of the Passage Beds, including the tree root-bearing bed at Banff Circle, to Tithonian (< ca. 150 Ma). A distinctive set of white-weathering turbidite-like sandstone beds at the 'Banff Circle', constrained by our data to be younger than ca. 167 Ma, are difficult to interpret stratigraphically, but lie within the Lower Passage beds according to most authors, and to be westerly sourced (eg.Hamblin & Walker, 1979, Fig. 4, 64-74m), but have been interpreted (Cant & Stockmal, 1999) as structurally rotated Pigeon Creek Member, which would be consisted with the Zr age. The basal sandstones of the ***Morrissey*** and ***Nikanassin*** **formations,** not necessarily correlative along strike, have zircons with youngest peaks showing large age variability and older than the underlying Tithonian upper Passage Beds. The ***Cadomin Formation*** contains two dominant populations, a late Paleoproterozoic population (1950–1700 Ma) – which encompasses the ca. 1850 Ma reported by Leier and Gehrels (2011) and the 1700–1900 Ma range of zircon and monazite ages reported by Ross et al. (2005) from the partly correlative Dalhousie Formation – and a Jurassic to early Cretaceous population (**Fig. 3**). Our youngest age peaks of ca. 120 Ma correspond to the ca. 120 Ma zircon population previously reported from all seven Cadomin samples collected along the foothills of the entire RM-FTB in southern Canada by Leier and Gehrels (2011) and coincide with the Early Cretaceous flare-up in the Coast belt magmatic arc. The presence of ca. 120 Ma zircons (peaks on relative probability diagrams and even slightly younger individual grains) in almost all Cadomin samples, corroborated with the paleontological and stratigraphic data from the overlying late Aptian-early Albian Gething, lower Gladstone and equivalent formations, limits the deposition of the Cadomin Formation to a short, middle Aptian time interval.

Conclusions

Our datasets document the presence of approximately syn-depositional detrital zircons in coarser clastic units throughout the Jurassic Fernie Formation. Because no tectonothermal events contemporaneous with the deposition of the Jurassic Fernie Formation are known to the east, these data provide the first evidence for Cordilleran arc-derived detritus in the basin starting at least as early as the Early Jurassic. A small proportion of the zircon grains in each sample is slightly eroded euhedral, suggesting first-cycle and limited transport and likely producing the youngest major age peaks in each of the analyzed strata which conform with the depositional age of the host sediment. The ages of these grains is taken to indicate transport systems connecting the Fernie depositional basin to a plate margin where the youngest zircon detritus – with ages approximating the times of deposition in the basin – was most likely derived from the magmatic arc associated with ocean closure and/or collision (Cawood et al., 2012). However, the variety of transcurrent and compressional components that have been recognized in the Cordillera preclude recognition of particular source areas or transport vectors.

Sediment provenance is constrained by our detrital zircon data to two distinct source regions, one in the fold-and-thrust belt of the adjacent Canadian Cordillera and the other to the south, including the Cordillera and continental deposits of the United States. We suggest that the marine western edge of the Western Canada Sedimentary Basin received detrital zircon grains from a magmatic accretionary arc source since at least the Early Jurassic. The loss of carbonates and phosphates in the Middle Jurassic in the basin and increasing fine clastic sediment with paleocurrent evidence for northerly transport in the latest Jurassic and earliest Cretaceous indicate gradual transition to a narrow, NNW-SSE oriented foredeep trough with a main fluvial system oriented north-northwest, parallel to the Cordilleran orogenic belt, and consistent with a Jurassic accretionary history.

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