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Implications of a U-Pb zircon study of Jurassic volcanic ashes, Western Canada Sedimentary Basin for stratigraphy, Cordilleran tectonics, and the International Chronostratigraphic Chart

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Summary

The Jurassic system of the Western Canada Sedimentary Basin (WCSB) records the transition from back-arc to foreland basin tectonic settings at the western margin of ancient North America. We report new U-Pb zircon ages of bentonite layers and other probable volcanic ash components from strata of the Fernie Formation, which encompasses most of the Jurassic in the western portions of the Western Canada Sedimentary Basin and is now deformed in the Rocky Mountain fold-and-thrust belt. The ages come from bentonites in the lower Nordegg Member (Pliensbachian) and an ash layer of the same age in a Lower Fernie phosphatic shale, as well as from the Gryphaea Bed and the Green Beds members (Bathonian and Oxfordian-Kimmeridgian, respectively). The detrital zircon spectra of the last units are indicative of likely contemporaneous ash-fall contributions. We review previously published U-Pb bentonite ages from the Fernie Formation and we present the data in an updated local stratigraphic correlation chart against a time scale that is modified from the current version of the International Chronostratigraphic Chart (ICS v2016/04), which is poorly controlled through most of the Jurassic. The multiple volcanic ashes throughout the Jurassic system support tectonostratigraphic models with western magmatic activity sufficiently nearby to result in ash layers in the WCSB, although it remains difficult to determine particular volcanic source areas. Magmatic rocks in the Omineca crystalline belt and southeastern Quesnellia terrane could account for all of the Fernie ashes, and is currently closest to the depositional basin, but terranes farther afield cannot be ruled out.

Introduction

The Fernie Formation in southwestern Alberta and southeastern British Columbia comprises most of the epicratonic marine Jurassic succession in western parts of the Western Canada Sedimentary Basin (WCSB). We report U-Pb zircon ages from bentonites and inferred ash components from four

marine stratigraphic units of the Fernie Formation sampled at six locations in the central and southern segments of the Rocky Mountains Fold-and-Thrust Belt (RM-FTB). These include: the Pliensbachian lower Nordegg Member and Lower Fernie phosphatic shale, the Bathonian Gryphaea Bed Member and the Oxfordian-Kimmeridgian Green Beds Member (Poulton et al., 1994). We also review previously reported multi-grain U-Pb zircon ages from Early and Middle Jurassic bentonites in other units of the Fernie Formation (Hall et al., 2004). We present our results in a stratigraphic correlation chart for the Jurassic system in southwestern Alberta and southeastern British Columbia that is based on updating the literature on the relevant strata and the ammonite in it. Our, and other data, lead to our proposing new ages on this chart for many of the Jurassic stage boundaries that are not well controlled on the International Chronostratigraphic Chart. The ashes in the Fernie Formation also provide support for a conventional interpretation of the tectonic accretionary history of the Cordillera.

Theory and Method

Bentonite beds assist in correlations of stratigraphic sequences and, integrated with precise biostratigraphy, can provide radiogenic isotope ages which can provide age control for biostratigraphic correlations globally. In Alberta, they contribute to our knowledge of the tectonostratigraphic relationships between the basin and the adjacent Cordilleran terranes, and to further understanding of the setting for economic resource occurrences in the Jurassic system. We have obtained new U-Pb zircon ages by Multicollector-Inductively Coupled Plasma Mass Spectrometry (MC-ICPMS) and single grain Thermal Ionization Mass Spectrometry Isotopic Dilution (ID-TIMS). Interpreting the U-Pb age data from marine members of the Fernie Formation has required reviewing and updating the biostratigraphic knowledge derived from the ammonites they contain, as well as highlighting the currently poorly controlled nature of the ages in the Jurassic portion of the International Chronostratigraphic Chart (ICS v2016/04, online update from Cohen et al., 2013).

Examples

U-Pb ages are reported from the lower Nordegg Member from three localities. Late Pliensbachian ammonites (*Amaltheus*) characterize lower and upper parts of this unit at several localities. Many earlier reports have considered this member to be all or largely Sinemurian in age. Our most northerly sample, from the top of the shaley recessive interval immediately below bluff-forming cherts and limestones along McLeod River south of Cadomin, yielded a TIMS age of 187.21 ± 0.48 Ma.

The lowest recessive beds of the Nordegg Member in its type area, exposed east of the bridge over Shunda Creek along Highway 11 east of Nordegg, contain two thin orange bentonite layers within 1 m of the unconformable contact with the Mississippian Shunda Formation. The lower bentonite yielded a MC-ICPMS zircon age of 186.8 ± 1.5 Ma. A specimen of *Amaltheus* aff. *gibbosus* from about 7 m above the dated bentonite, provides an oldest limiting age (Late Pliensbachian, Margaritatus Zone) for the

bentonite, and Pliensbachian coccoliths including *Mitrolithus elegans* and *Similiscutum obtusus* occur in a 10 cm-thick soft fissile black shale about 2.5 m above the base of the Nordegg Member.

Our most southerly Nordegg samples are from the Prairie Creek quarry southwest of Rocky Mountain House. Here, the lower Fernie Formation includes five thin layers of bentonite, two of which have been TIMS-dated at 186.28 ± 0.48 Ma and 185.25 ± 0.66 Ma. The lower two bentonites are intercalated with several brown sandstone beds that have not been previously described in the Nordegg Member. They contain large oysters and crustacean (?) impressions currently without precise biostratigraphic value, whereas the upper three bentonites are in dark grey silty shale and platy cherty limestone typical of the Nordegg Member. The U-Pb data from the Nordegg Member contribute to dating the Pliensbachian stage.

The unnamed basal unit of the Fernie Formation, near the Alberta-British Columbia border along Highway 3 west of the Alexander Creek bridge, contains a locally developed black, richly phosphatic limestone and overlying shale in which a 2 cm-thick, white silt-like layer occurs. While not a bentonitic clay, it produced a narrowly-defined detrital zircon spectrum which indicates a single dominant zircon population typical for a volcanic ash fall, with age 186.21+1.48/-2.89 Ma. This indicates the presence of beds younger than those previously known from Early Sinemurian ammonites (*Arnioceras telferi*; Frebold, 1957) and allows correlation with the lower Nordegg Member to the north.

The 1-m thick Gryphaea Bed sandy limestone, sampled at Grassy Mountain and the Adanac South mine road, contains an ammonite fauna that includes early *Kepplerites* ammonites of probable Middle Bathonian age, previously considered Late Bathonian. Each of the three samples analyzed yielded an apparently normally distributed Jurassic zircon population, indicating a single dominant age population, likely from a 169 +1/-0 Ma ash fall event contemporaneous with the carbonate deposition, and contributing data to the age of the Bathonian stage.

Two samples from the Green Beds Member yielded TIMS ages of 152.22 ± 0.44 Ma at the Line Creek bridge over Elk River, B.C. and 157.84 ± 0.52 Ma near Webb Creek along Carbondale River, Alberta. The age obtained from the Carbondale River sample is consistent with the Late Oxfordian or Early Kimmeridgian bivalve *Buchia concentrica* reported from very nearly the same locality (Poulton, 1989).

Conclusions

U-Pb dating of Jurassic volcanic ashes in the Fernie Formation of southwestern Alberta and southeastern British Columbia Rocky Mountains and Foothills, integrated with ammonite biostratigraphy, constrain ages and correlations within the Western Canada Sedimentary Basin and suggest relationships with more westerly Cordilleran tectonic events. Their abundance demonstrates the proximity of volcanic ash sources throughout the Jurassic. Although Jurassic igneous rocks contemporaneous with the Fernie ashes are known throughout the Canadian Cordilleran from areas farther west (Coast Plutonic belt) and

north (Yukon-Tanana terrane), the now proximal Quesnellia-Stikinia island arc terranes and the Omineca crystalline belt provide likely sources, conforming with the prevailing terrane accretion paradigm that includes Early Jurassic accretion at about the same latitude.

Our data analysis has encouraged us to suggest ages in a new regional correlation chart for some of the poorly controlled Middle and Upper Jurassic stage boundaries that differ from recent versions of the International Chronostratigraphic Chart but better integrate other radiometric ages published globally.

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