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Re-evaluation of chronostratigraphic relationships in the vicinity of the Lower Cretaceous Crowsnest Formation (southwestern Alberta)

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Summary

The Crowsnest Formation is a stratigraphic interval in southwestern Alberta that contains pyroclastic deposits that are linked to late Albian (~103 Ma) orogenesis and volcanism in the North American Cordillera (Figure 1A; Adair and Burwash, 1996; Pană et al., 2018). In the Crowsnest Pass region of Alberta (Figure 1A), the Crowsnest Formation is exposed alongside siliciclastic rock units of the Lower Cretaceous Mill Creek Formation and the Upper Cretaceous Blackstone Formation (Figure 1B; Leckie and Burden, 2001). While characterization of stratigraphic relationships between the Crowsnest Formation and the adjacent stratigraphic units has been attempted previously (e.g., Norris, 1964; Leckie and Burden, 2001), the exact stratigraphic position of the Crowsnest Formation relative to these other units remains uncertain (Pană et al., 2018). Constraining chronostratigraphic relationships between the Crowsnest Formation and the adjacent units can help provide insight into the paleogeographic evolution of southwestern Alberta, as well as help elucidate how late Albian orogenesis in the North American Cordillera may have impacted the development of coeval depositional systems in the Alberta Basin.

In this study, we examine new stratigraphic and geochronologic data from the Mill Creek Formation and the Blackstone Formation to further constrain the chronostratigraphic position of the Crowsnest Formation. The study objectives are to: (1) document and analyze stratigraphic architecture in parts of the Mill Creek Formation and the Blackstone Formation that are found adjacent to the Crowsnest Formation; (2) constrain the depositional age of Mill Creek Formation and Blackstone Formation units in the vicinity of the Crowsnest Formation using uranium-lead detrital zircon geochronology; and (3) use the results to help refine the understanding of Cretaceous chronostratigraphic relationships in southwestern Alberta.

Theory / Method / Workflow

Stratigraphic data for this study were derived from Mill Creek Formation and Blackstone Formation units that crop out alongside the Crowsnest Formation in the vicinity of the Municipality of Crowsnest Pass (Figure 1A). Outcrops were primarily characterized via measurement of stratigraphic sections; information on two- and three-dimensional depositional architecture of outcropping units was largely derived from photographs and bedding orientation measurements, as well as via consideration of geospatial data collected along key stratigraphic surfaces. Uranium-lead detrital zircon dates were derived from sandstones sampled from various intervals within the Mill Creek Formation and the Blackstone Formation ($N_{samples}$ = 6; n_{dates} = 3,420; Figure 1B). Uranium-lead detrital zircon dates were acquired using laser ablation inductively coupled

plasma mass spectrometry methods described by Daniels et al. (2018). Depositional ages of rock units were computed from uranium-lead dates following age calculation procedures outlined by Dickinson and Gehrels (2009) and Vermeesch (2021). All newly acquired stratigraphic and geochronologic data were evaluated alongside previously reported stratigraphic and geochronologic data from the region (e.g., Glaister, 1959; Norris, 1964; Mellon, 1967; Pearce, 1970; Adair and Burwash, 1996; Leckie and Burden, 2001; Pană et al., 2018).

Results, Observations, Conclusions

Analysis of stratigraphic data reveals that the Mill Creek Formation and the Crowsnest Formation are separated by a gradational boundary (Figure 1B). Bedding orientations in adjacent Mill Creek Formation and Crowsnest Formation units are similar in most cases; in some locations, deposits of both formations interfinger with one another (cf. Norris, 1964). Analysis of stratigraphic data also shows that the Crowsnest Formation and the Blackstone Formation are separated by a sharp and highly irregular contact that can display up to 40 m of relief in some locations (Figure 1B). While bedding orientations in adjacent Crowsnest Formation and Blackstone Formation units are commonly similar, Blackstone Formation units frequently show evidence for onlap near the contact with the Crowsnest Formation. These observations suggest that the basal contact of the Crowsnest Formation is largely conformable, and that the upper contact could represent an unconformity. These interpretations are supported by preliminary depositional age results from uranium-lead detrital zircon geochronology analyses, which suggest that the deposits of the uppermost Mill Creek Formation possess ages that are similar to those reported from the Crowsnest Formation, whereas basal units of Blackstone Formation units yield ages that are definitively younger than the Crowsnest Formation. We conclude that the development of an unconformity at the interface between the Crowsnest Formation and the Blackstone Formation is linked to variable erosion of the landscape following the accumulation of Crowsnest Formation deposits (Glaister, 1959; Norris, 1964; Mellon, 1967; Pearce, 1970). This period of erosion is most likely tied to late Albian tectonic uplift in the Crowsnest Pass region, which is thought to be closely linked to subduction on the western margin of North America during that time (Monger, 1989; Price, 1994; Evenchick et al., 2007; Pană and van der Pluijm, 2015).

Novel/Additive Information

The results presented in this study provide a novel high-resolution perspective into the depositional timing of units that are found adjacent to the Crowsnest Formation, which offers new insight into Cretaceous chronostratigraphic relationships in southwestern Alberta. Additionally, the newly acquired detrital zircon dates can be used to investigate how sediment provenance may have changed in the region through time, which will assist with reconstructing sediment-routing systems that developed before, during, and after the development of the Crowsnest Formation. Moreover, the results of the study can be used to help better characterize the role of late Albian orogenesis in the development of accommodation in the southwestern part of the Alberta Basin.

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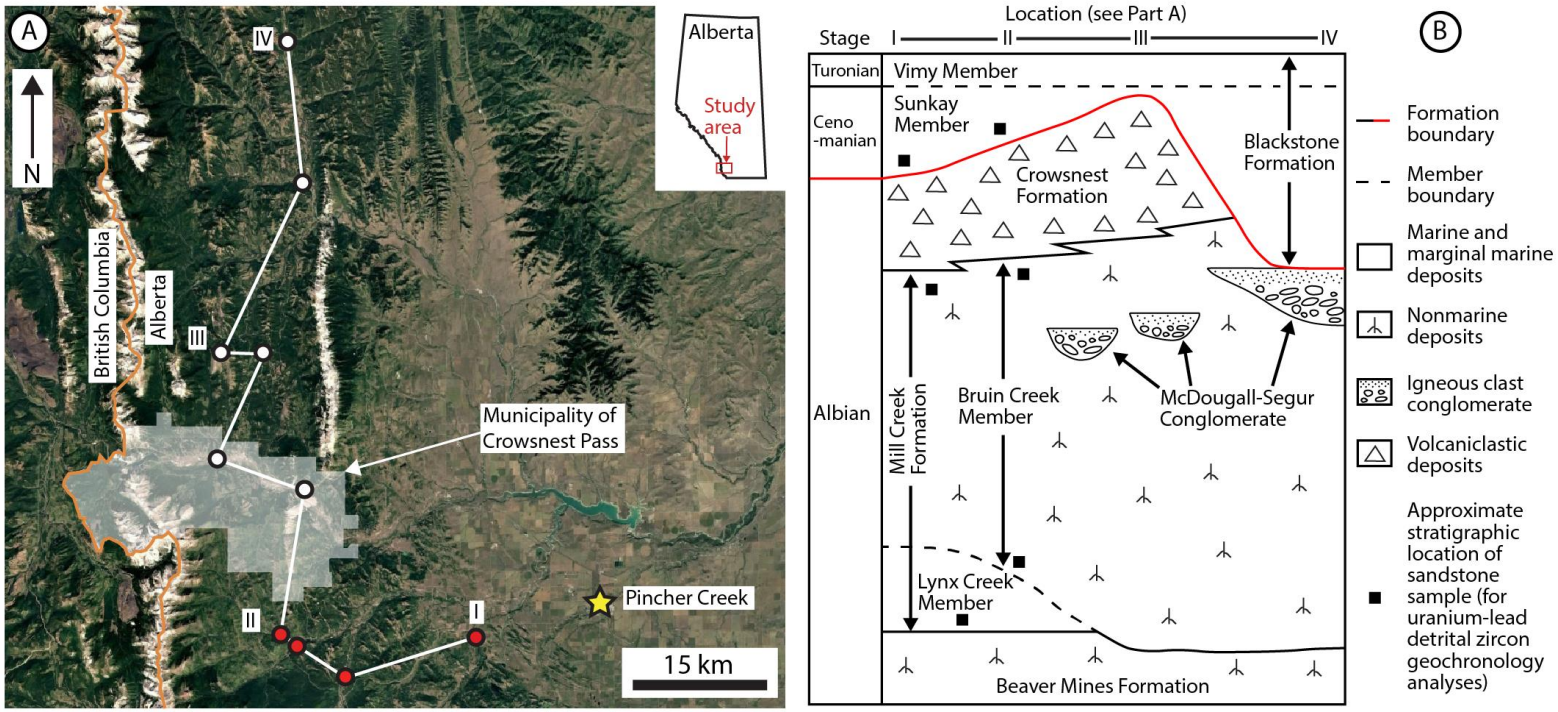

Figure 1. Overview of the outcrop locations and the stratigraphic units that were examined in this study. (A) Summary of outcrop locations characterized as a part of this study (satellite image data: Landsat, Copernicus, 2024, http://www.google.com/earth/index.html). Outcrop locations where new stratigraphic sections were measured and sandstone samples were collected for geochronologic analysis are indicated with red dots. Other outcrop locations that were visited are indicated with white dots. (B) Summary of interpreted chronostratigraphic relationships in the vicinity of the Crowsnest Formation (modified from Leckie and Burden, 2001). Chronostratigraphic relationships were constrained using information gleaned from all outcrop locations visited as a part of this study (see Part A for an overview). The chronostratigraphic boundary that separates Albian- and Cenomanian-aged deposits has been indicated with a red line.