Exhumation in the Anaconda Metamorphic Core Complex: Using detrital thermochronology to constrain Eocene extensional deformation and basin formation

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Summary

Metamorphic core complexes (MCC) provide a rare glimpse into the thermomechanical processes in the lithosphere and play a substantial role in the evolution of the crust. To understand extensional processes related to cordilleran collapse, North American MCCs have been extensively studied using bedrock thermochronology and modelling approaches. However, few have considered the syndeformational basin record, which preserves a unique archive of sediment sources adjacent to the MCC highlands. Herein, we use detrital zircon (U-Th)/(He-Pb) double dating and HeFTy 2.0 time-temperature modelling to determine the earliest record of exhumation in the Anaconda MCC.

1. Sediment within the Deer Lodge Valley is locally sourced, with Late Cretaceous - early Eocene ZHe cooling ages across all (U-Pb) crystallization ages. 52% of double-dated grains have lag times that are < 10 m.y.

2. Single- and mutli-sample HeFTy models show a period of rapid cooling starting ca. 65 Ma, which is supported by the presence of short lag times (< 10 m.y).

3. The basin and basement record in tandem show the progressive unroofing of both shallow and deep structural levels. The basin record shows the onset of exhumation began ca. 65 Ma, 10 m.y. prior to previous interpretations utilizing the basement record.

Study Area Map

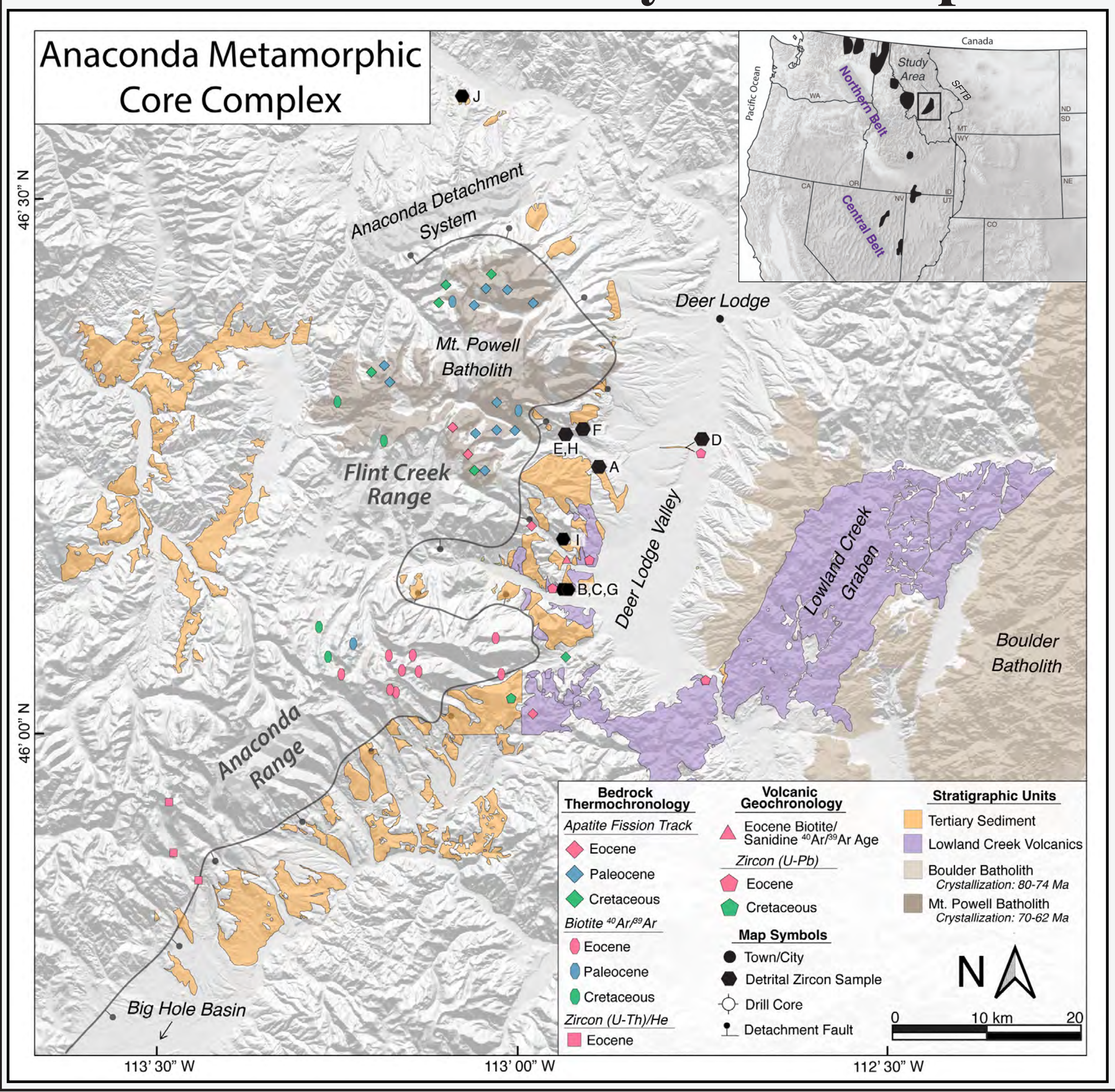
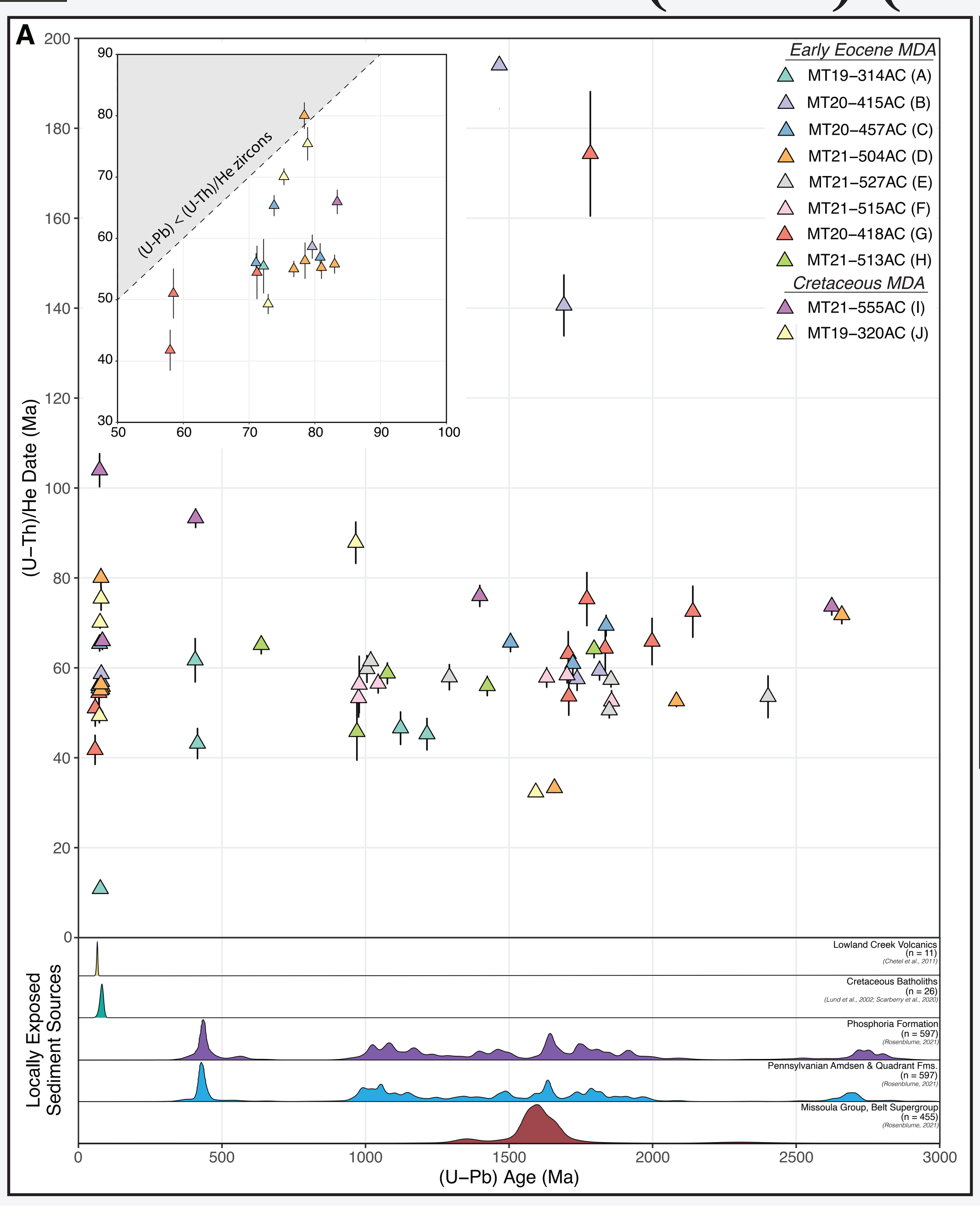


Figure 1: Simplified geologic map of the Anaconda metamorphic core complex and associated Deer Lodge Valley showing detrital zircon sample locations from this study (black hexagon) and previously published geochronologic and thermochronologic dates from both the footwall and the hanging wall of the metamorphic core complex. Bedrock apatite fission track thermochronology is from Baty (1973) and Foster et al. (2010), bedrock biotite $^{40}Ar/^{39}Ar$ thermochronology is from Marvin et al. (1989) and Foster et al. (2010), bedrock zircon (U-Th)/He thermochronology is from Howlett et al. (2021). Volcanic biotite and sanidine $^{40}Ar/^{39}Ar$ geochronology and zircon (U-Pb) geochronology is from Scarberry et al. (2019). Mapped stratigraphic units and location of the anaconda detachment system is from Lonn et al. (2004) and Scarberry et al. (2019). *Inset Map:* Map showing the MCCs (black) within North America and the location of study area in relation to the Sevier Fold-and-Thrust Belt (SFTB). Canada and the Pacific Ocean are also labelled.

1. Detrital Zircon (U-Th)/(He-Pb) Double Dating



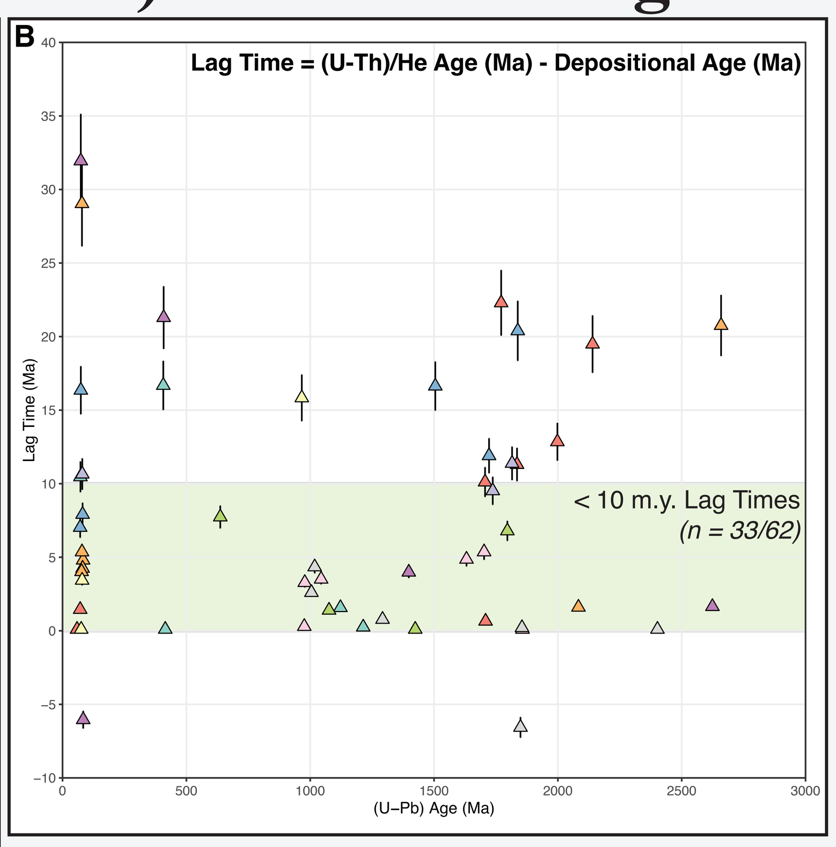


Figure 2: Summary of double-dated detrital zircon grains in the Deer Lodge Valley. A) Zircon (U-Th)/He cooling age v. (U-Pb) crystallization age, with errors shown in 1σ. One (U-Th)/He date at 632 Ma has been excluded from the graph. Bottom portion shows interpreted source rocks which are locally exposed within the footwall of the Anaconda MCC. Cretaceous batholiths include the Boulder Batholith, the Pioneer Batholith, and the Mt. Powell Batholith (Fig. 1). Letters next to sample names correspond to sample labels in Fig. 1. B) Lag time, which is the difference between (U-Th)/He cooling age and depositional age, plotted against (U-Pb) crystallization ages. Transparent green bar indicates grains with <10 m.y. lag times, and highlights that short lag times are distributed across all (U-Pb) crystallization ages.

2. HeFTy Inverse Thermal History Models

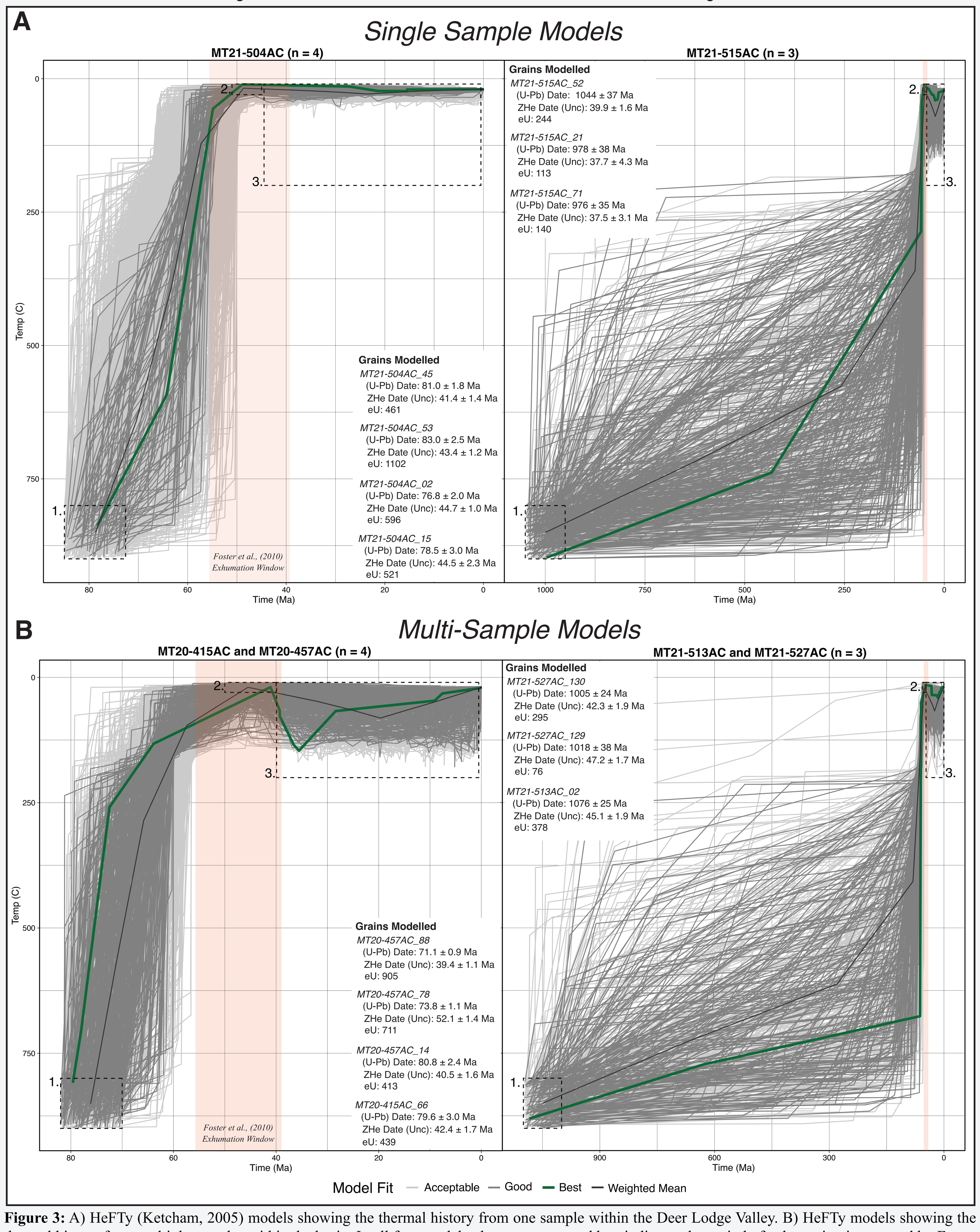


Figure 3: A) HeFTy (Ketcham, 2005) models showing the thermal history from one sample within the Deer Lodge Valley. B) HeFTy models showing the thermal history from multiple samples within the basin. In all four models, the transparent red box indicates the period of exhumation interpreted by Foster et al. (2010) using basement thermochronology. Constraint box 1 indicates the crystallization age based on (U-Pb) dating, constraint box 2 indicates deposition within the basin based on calculated maximum depositional ages, and constraint box three allows for post-depositional re-heating following deposition until the modern. ZHe Date (Unc) is the uncorrected (U-Th)/He date, eU is the effective uranium.

3. Basin record vs. Basement record

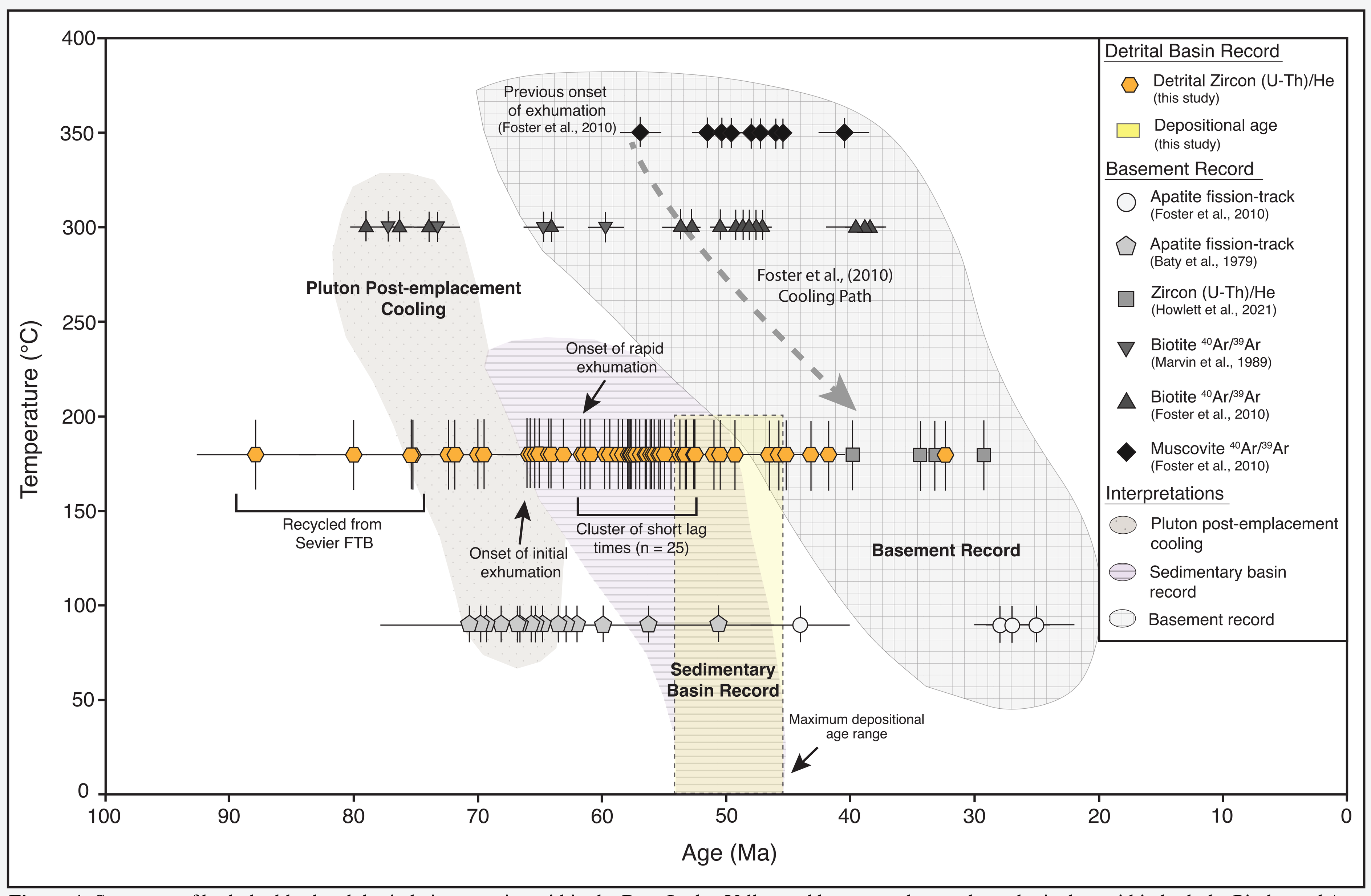


Figure 4: Summary of both double-dated detrital zircon grains within the Deer Lodge Valley and basement thermochronologic data within both the Pintler and Anaconda ranges. Tan outline shows interpreted record of post-emplacement pluton cooling, purple outline shows the interpreted path of cooling within the basin record, the gray outline shows the previously interpreted record of exhumation in the basement record. Transparent yellow bar shows the range of maximum depositional ages from this study. Errors are shown in 1σ.

Conclusions and Implications

This study used the detrital basin record to show that the Anaconda MCC started extending ~ 10 m.y. earlier than previously suggested from the basement record. This study also shows that basin formation and MCC exhumation are intimately linked, and that deposition within the Deer Lodge Valley started by 55 Ma. These new findings have implications for the evolution of the North American Cordillera since they suggest the earliest MCC extension was coeval with the final stages of Laramide-style contractional deformation. Syn-contractional extension could potentially be caused by gravitational collapse of overthickened crust or lower crustal flow in the hinterland of the Cordillera.

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