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Forum Reply

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U-Pb dating of calcite veins reveals complex stress evolution and thrust sequence in the Bighorn Basin, Wyoming, USA

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Thacker and Karlstrom (2019) commented on the paper of Beaudoin et al. (2018) by presenting a summary of the published data about exhumation of Laramide arches in Montana, northern Wyoming and western South Dakota. We thank the authors for this comment and wish to reply.

Beaudoin et al. (2018) present U-Pb absolute ages of calcite cements that in-fill tectonic veins developed in the Bighorn basin during the Sevier and Laramide contractional events. At the scale of the basin, we report two trends: (1) an eastward, forelandward propagation of Sevier layer-parallel shortening vein development; and (2) a westward, hinterlandward propagation of Laramide layer-parallel shortening and folding-related vein development. We discuss the consistency between the latter Laramide sequence, valid in the sedimentary cover at the scale of the Bighorn basin, and the published exhumation sequence of the basement arches bounding the basin, i.e. Beartooth arch (West), Wind River range (South) and Bighorn arch (East) (Peyton et al., 2012, Crowley et al., 2002, Fan and Carrapa, 2014, Stevens et al., 2016).

Thacker and Karlstrom (2019) point toward the eastward sequence of development of the Laramide arches at the foreland-scale. The authors oppose this sequence to the westward propagation of Laramide fracture development in the Bighorn Basin that we tentatively relate to a westward sequence of exhumation of the arches bounding the basin, as reported in Fan and Carrapa (2014) based on thermochronological data. A more recent study suggests that cooling of the Beartooth arch might have even started earlier, around ~80 Ma (Carrapa et al., 2019), hence we present an updated version of our results (Fig. 1).

We did not suggest our dataset was representative of the foreland-scale sequence of exhumation of the Laramide arches. However, Thacker and Karlstrom (2019) discard the westward exhumation sequence of the arches around the BHB based on the hypothesis that the oldest cooling age of the Bighorn Mountains (~90 Ma) might represent a structural response to the Sevier forebulge. As recent studies point out that the stress originated from the Laramide flat-slab subduction may have affected the foreland as early as 120 Ma (Carrapa et al., 2019), this speculative interpretation can be questioned. Besides, we consider the westward sweep around the BHB to be supported by the exhumation history of the Wind River range (~85 Ma, rapid phase started ~65 Ma, Stevens et al., 2016), which fits in between the Bighorn arch (~90 Ma) and the Beartooth arch (~80Ma).

We agree that dating vein cements in the sedimentary cover may not date the oldest timing of Laramide basement fault activation but rather a younger, rapid phase of arch exhumation as suggested by Thacker and Karlstrom (2019) or Fan and Carrapa (2014). Indeed, we find the development of the earliest Laramide veins in the sedimentary cover to be synchronous with the rapid phase of exhumation of their closest arches (red dashed frames on Fig.1). Considering that the Laramide-related stress prevailed in the basement since ~90 to 80 Ma, there is a ~20 Ma delay before it was transmitted upward and affected the sedimentary cover, i.e. only once the arch-bounding basement faults were efficiently reactivated (~60 Ma in the West, ~70 Ma in the East). Consequently, a spatial decoupling between the basement and the cover is suggested, with lateral and vertical compartmentalization of stress and strain at the basin-scale.

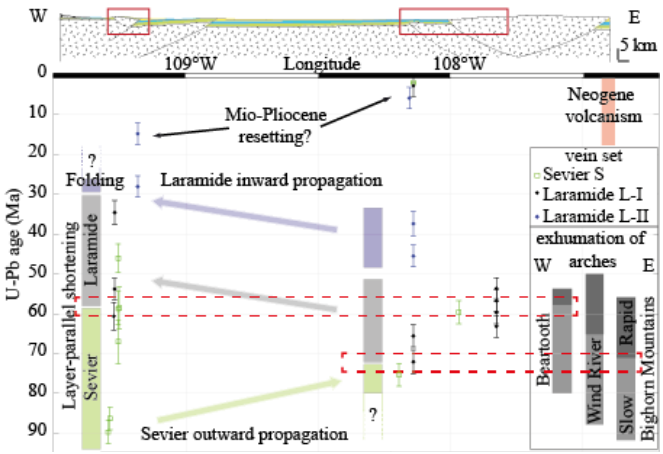

Figure 1. Diagram of U-Pb ages (Ma) of the calcite cements of vein sets versus longitude across the Bighorn Basin, modified after Beaudoin et al. (2018). Right-hand side: ages of exhumation of the basement arches bounding the Bighorn Basin (Wyoming, USA).

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