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Direct dating of orogenic deformation in forelands: insights from LA-ICP-MS U-Pb dating of tectonic veins in the Sevier-Laramide Bighorn Basin, Wyoming, USA.

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Recent developments of U-Pb geochronology applied to calcite cements of faults/veins allow direct dating of the sequence of orogenic deformation. Our study builds on a well characterized basin-scale fracture system to assess whether U-Pb geochronology can refine our understanding of stress loading across foreland fold-and-thrust belts.
In the Bighorn basin (BHB), vein sets defined by homogeneous orientation and consistent relative chronology were interpreted as related to Sevier and Laramide layer-parallel shortening (LPS) and Laramide folding. The eastward foreland-propagating thin-skinned Sevier belt formed during Cretaceous-Paleogene times. Thick-skinned Laramide deformation occurred from 80-70 to 55-45 Ma, overlapping with younger stages of Sevier deformation. Published apatite fission track thermochronology indicates that(1) the Bighorn Mountains (BM, east BHB) exhumed rapidly between 91 and 57 Ma (2) exhumation in the Beartooth Arch (BA, northwest BHB) started by 65 Ma and increased since 57 Ma, and (3) exhumation in the Wind River Arch (WRA, south-west of BHB) started by 90-85 Ma and increased between 65 and 50 Ma.
This study reports in-situ LA-ICP-MS U-Pb dating of tectonic vein cements from several basement-cored anticlines. E-W to WNW-ESE veins interpreted as related to Sevier LPS are dated 70-60 Ma (west BHB) and ∼59 Ma (east BHB). NE-SW to ENE-WSW veins interpreted as marking Laramide LPS comprise cements dated 61-54 Ma (west BHB) and 69-57 Ma (east BHB). Laramide syn-folding veins are dated at ∼45 Ma (east), while few older ages (∼90 Ma) were obtained (west BHB). Some Sevier and Laramide veins also yield unexpected younger ages (32-14 Ma and ∼3 Ma).
Our results include: (1) eastward propagation of Sevier fracturing, possibly related to the Sevier front migration; (2) Laramide LPS started earlier in eastern BHB, in agreement with thermochronology that suggests BM started to exhume first, followed by WRA then BA; (3) the youngest Sevier deformation overlapped the oldest Laramide fracturing; (4) Laramide folding may have occurred as recently as 45 Ma.
While most U-Pb ages likely reflect the periods of vein opening and fluid precipitation, younger ages suggest that the isotopic system does not reflect the time of initial fluid flow despite the absence of any obvious textural evidence for vein re-opening or cement dissolution-reprecipitation. This indicates either that fractures may have remained open without healing, or that a resetting of the isotopic system has occurred during post-Laramide extensional/thermal events. The range of U-Pb ages documented for veins of a given set suggests a significant duration of the fracturing event and/or that fractures may require variable durations to heal. The study confirms that vein sets are reliable markers of (far-field) orogenic stress loading in forelands. However, U-Pb ages inconsistent with both the orientations and the textural characteristics of veins may indicate either that attribution of individual fractures to a given set on the sole basis of orientation may be sometimes wrong, and/or that U-Pb ages must be interpreted carefully in the light of the regional geological history.