Evidence for for episodic slip along the Heart Mountain landslide

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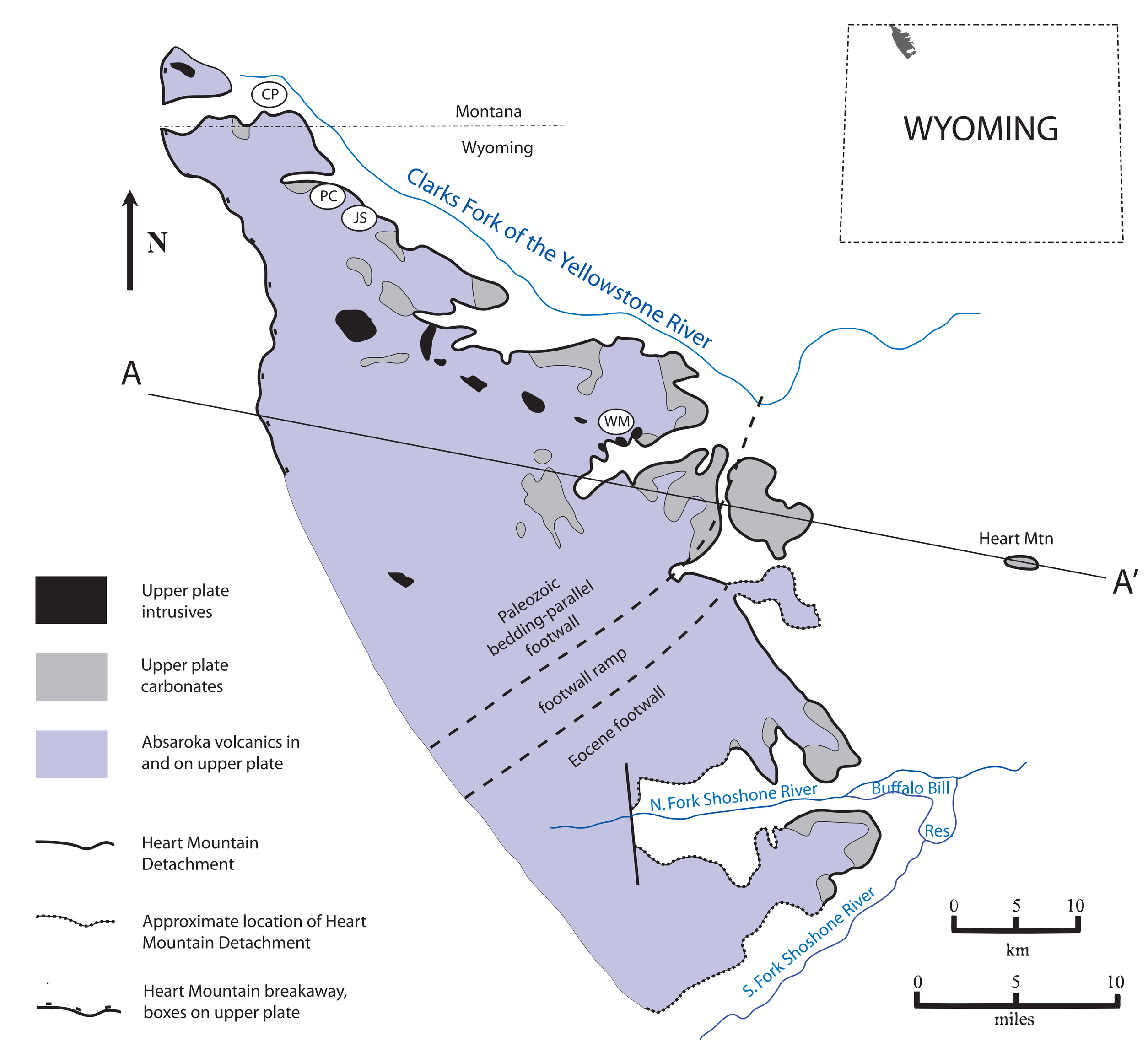
Abstract

The Heart Mountain detachment has been the target of detailed geological and geochemical studies over the last century (e.g. Dake, 1916, Bucher, 1933, Pierce, 1957, 1973; Hughes, 1970; Hauge, 1985, 1990; Malone, 1995; Templeton et al., 1995; Anders et al., 2000, 2010; Douglas et al., 2003; Beutner and Gerbi, 2005; Craddock et al. 2009, 2012; Beutner and Hauge, 2009), as it is a rootless detachment of great size but enigmatic slip conditions. It is exposed over an area of approximately 3,400 km2, dips on average 2° to the SE, and may include displacements of the hanging wall up to 50 km to SE.

Although there is strong consensus that the detachment represents a large-scale collapse feature on the flanks of a volcanic center, there is little agreement as regards the issue of whether it is a catastrophic landslide (e.g. Beutner and Craven, 1996; Craddock et al., 2012), slow-moving extensional allochthon (Hauge, 1985, 1990), or a combination of a slow-moving slide ending with a catastrophic event (Beutner and Hauge, 2009), with most researchers favoring a catastrophic emplacement. However, our preliminary research has found evidence of multiple brecciation events at the hand-sample scale, multiple clastic dike injection events. Further investigation at the thin-section scale will likely make significant contributions to our understanding of the slip kinematics.

Heart Mountain Detachment Geometry



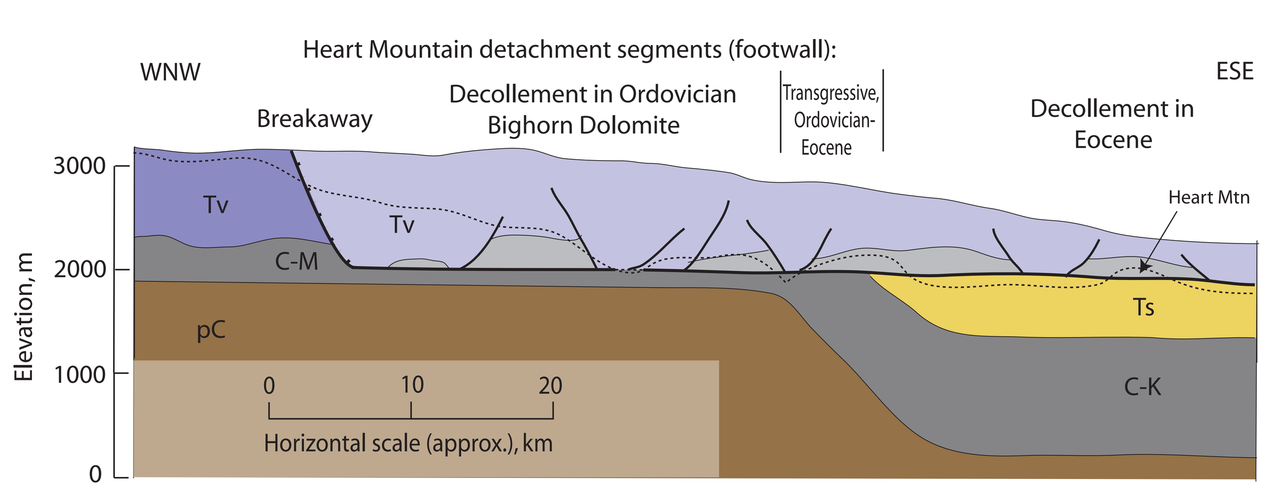
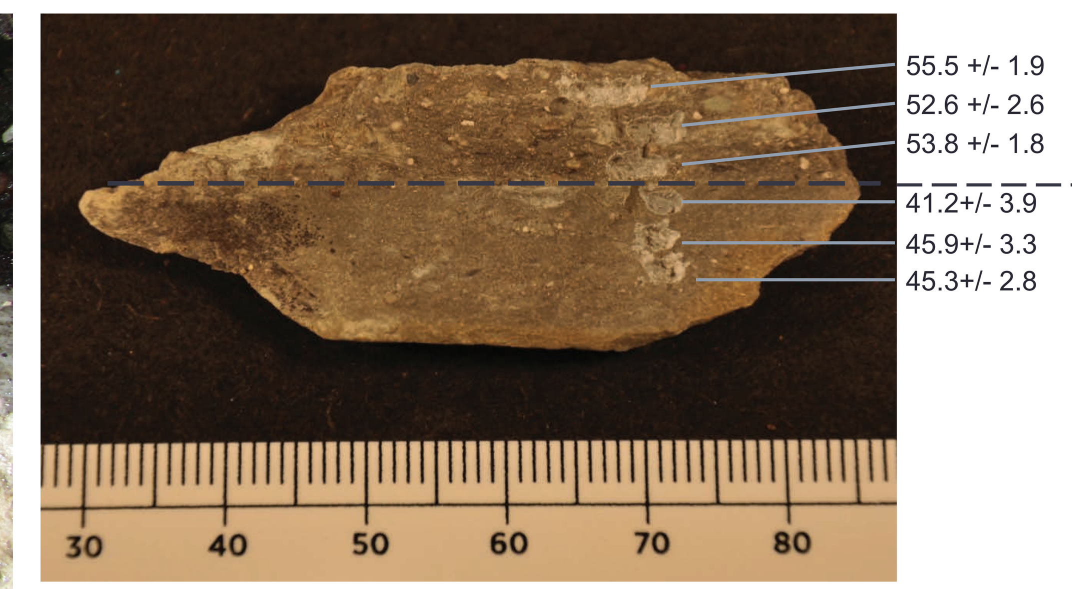


Figure 5. Map and schematic cross-section of the Heart Mountain detachment. (A) Map, showing line of section for (B). HM: Henderson Mountain, WM: White Mountain, CP: Colter Pass, JS: Jim Smith Creek, PC: Pilot Creek. (B) Schematic cross-section, showing the distribution of units in hanging wall and footwall of the detachment. Lighter shades indicate rocks are in the hanging wall. Dotted line represents modern erosion surface. Ts: Tertiary sedimentary rocks, Tv: Tertiary volcanic rocks, Absaroka Supergroup; C-M: Cambrian through Mississippian carbonates; pC: pre-Cambrian basement rocks

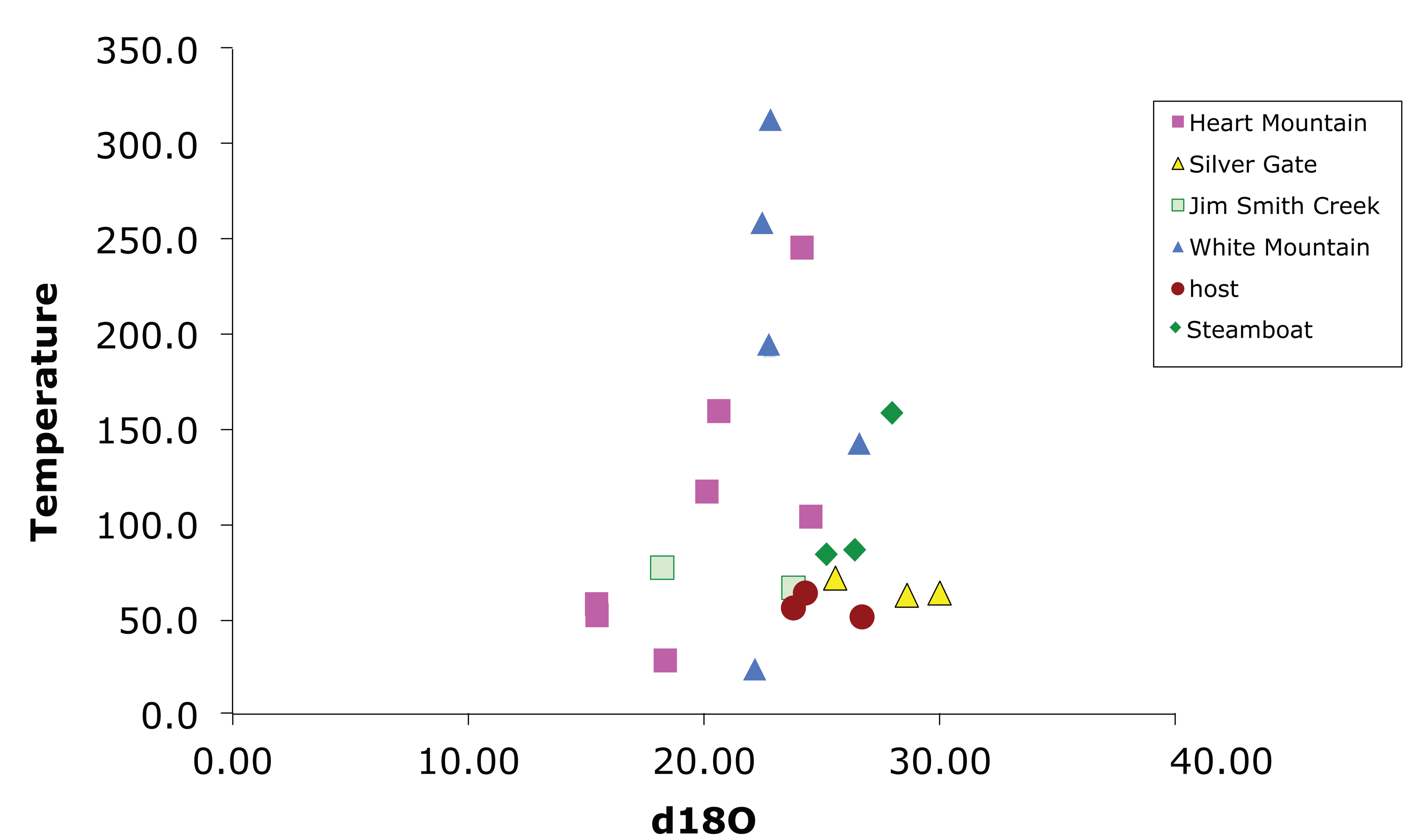
Clastic dikes above Heart Mountain detachment



Clastic dikes contain material that is compositionally and texturally very similar to that of fault gouges, but they occur in fractures that have little to no slip along them. They are thought to inject into tensile fractures that open up near a fault during the slip event, due to the reduction in pressure within the fracture relative to that along the slip surface, As such, they can be used to infer information about the stress conditions during slip.

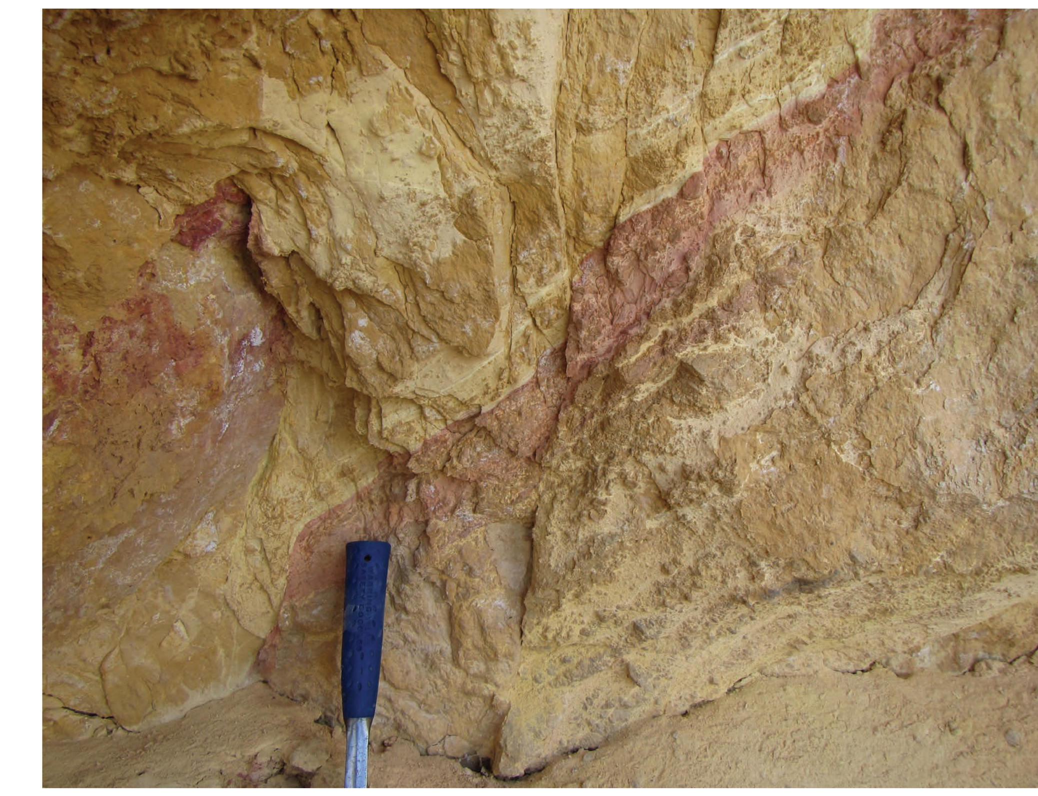
Here, en echelon clastic dikes (top left) indicate a shear component to the tension, here top to the SE. There is also plenty of evidence for multiple clastic dike injection events. Two-toned clastic dikes are present (right 2 photographs), and temperatures from clumped-isotope thermometry indicate 2 discrete events, with no gradation between them. In addition, there are cross-cutting clastic dikes (shown in the bottom left photo), again indicating multiple clastic dike injection events, separated by suffient time to lithify the clastic dike material.

Temperatures from Clumped-Isotope Thermometry



The temperatures of crystallization as measured from clumped-isotope thermometry indicate a large range of temperatures. However, the hottest temperatures are only found in two places: White Mountain and Heart Mountain. White Mountain is heavily metamorphosed from nearby volcanism, and the host rock here is hotter than in other areas, obscuring further interpretation of the hot samples. Heart Mountain, however, contains no indication of volcanics, and still preserves very hot temperatures along a clastic dike found there.

Offsets in Gouge Layers



Several sites show evidence of gouge layers being offset by further faulting. This suggests multiple episodes of deformation, at least one to create the gouge layer, and another to deform it. The top photo is from a hanging-wall fault within the Heart Mountain allochthon on the west side of Heart Mountain. The bottom photo is of a clasts of gouge within a clastic dike on the east side of Heart Mountain

Discussion

The preliminary results presented here are not consistent with a single, catastrophic slip event that is responsible for all of the observed displacement. This is contrary to most current researchers' interpretations. Slip with multiple events, such as that triggered by earthquakes, is favored here. However, there is also much evidence suggesting high-energy events. This includes the presence of clastic dikes and accreted grains (as found by most other researchers, and will likely be found in my samples after thin-section work), and the high temperatures of crystallization measured from clumped-isotope thermometry presented here. This strongly suggest high-energy slip events rather than slow creep, which makes slip along the e Heart Mountain detachment even more enigmatic, as slip must be initiate d and stopped multiple times.

Current models of the Heart Mountain detachment tend to be over simplified, and the complexities that are overlooked may have significant importance with regards to interpreting slip. Future work will focus on the departures from the simple model, iand the insight they may give us on the slip kinematics.

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