

KECK GEOLOGY CONSORTIUM

**PROCEEDINGS OF THE TWENTY-FIFTH
ANNUAL KECK RESEARCH SYMPOSIUM IN
GEOLOGY**

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Keck Geology Consortium: Projects 2011-2012
Short Contributions—Teton-Absaroka Ranges, Wyoming Project

EOCENE TECTONIC EVOLUTION OF THE TETON-ABSAROKA RANGES, WYOMING

Project Faculty: JOHN P. CRADDOCK, Macalester College & DAVE MALONE, Illinois State University

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ANDREW L. KELLY, Amherst College

Research Advisors: Tekla A. Harms & Peter D. Crowley

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STUART KENDERES, Western Kentucky University

Research Advisor: Andrew Wulff

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BENJAMIN KRAUSHAAR, Fort Lewis College

Research Advisor: John P. Craddock

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KAT HRYN SCHROEDER, Illinois State University

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BENJAMIN KRAUSHAAR, Fort Lewis College
Research Advisor: Kim Hannula

ABSTRACT

The Heart Mountain Detachment is preserved over an area of 3400 km² and occurred from a lateral volcanic eruption similar to the 1980 eruption of Mount Saint Helens. At White Mountain, carbonate ultracataclasite (CUC) dikes have been injected vertically (~120 m) from the bedding plane detachment CUC into the overlying Mississippian Madison and Bighorn formations, and another vertical CUC injectite is located at Silvergate closer to the break-away portion of the detachment. These injectites are the first evidence of forceful upward motion of fault gouge material during the emplacement of the Heart Mountain detachment and are anomalous to all fault systems as they have a disproportional relationship between fault offset and cataclasite vertical injection (Scholz, 1989). At White Mountain the CUC is injected ~40 times farther into the hanging wall than would be expected for a normal fault with one episode of motion. In order to further understand the timing and emplacement of the Heart Mountain detachment we analyzed the anisotropy of magnetic susceptibility (AMS) and the age of zircons within the vertical CUC injectites.

AMS analysis of the injectites show high variability in K_{\max} and K_{\min} values, suggesting a chaotic and violent intrusion of fault gouge material. AMS samples were collected at the bottom, middle and top of CUC-3 and the resultant magnetic fabric changes from chaotic AMS orientations to orientations consistent with a vertical flow direction from bottom to top. Near the top, K_{\max} values become more parallel to the injectite, suggesting a greater time and distance for the carrier mineral (magnetite) to align itself.

Laser ablation multicollector inductively coupled plasma mass spectrometry (LA-MC-ICPMS) analysis of detrital zircons from the CUC injectites and igneous dike intrusion at White Mountain provide similar ages of 48.8 ± 0.9 Ma which are within error of ash deposit ages at Jim Mountain (49.8 ± 1.1 Ma) and Hominy Peak (49.1 ± 0.75). These corresponding ages mark the timing of the eruption that liberated the HMD upper plate Paleozoic rocks to 48.8 Ma. The data reported in this paper further support the hypothesis of volcanic landslide induced, catastrophic emplacement of upper plate rocks as opposed to slow moving allochthon models.

INTRODUCTION

Location

The Heart Mount Mountain detachment is located in northwestern Wyoming on the northeast flank of the Absaroka Mountains. Fault generated CUC samples were analyzed from two locations; White Mountain and Silvergate. White Mountain is located 16.6 miles south of the Wyoming/ Montana boarder and 27 miles northwest of Cody, Wyoming. The Silvergate samples were collected 0.5 miles south of Silvergate, Montana just inside of the Wyoming/Montana boarder (Fig. 1).

Heart Mountain Detachment

The Eocene Heart Mountain detachment (HMD) is a rootless low angle normal fault that transported upper plate Paleozoic rocks up to 50km southeastward from the tectonically active, northern Absaroka Mountains into the western margin of the Bighorn Basin. Some

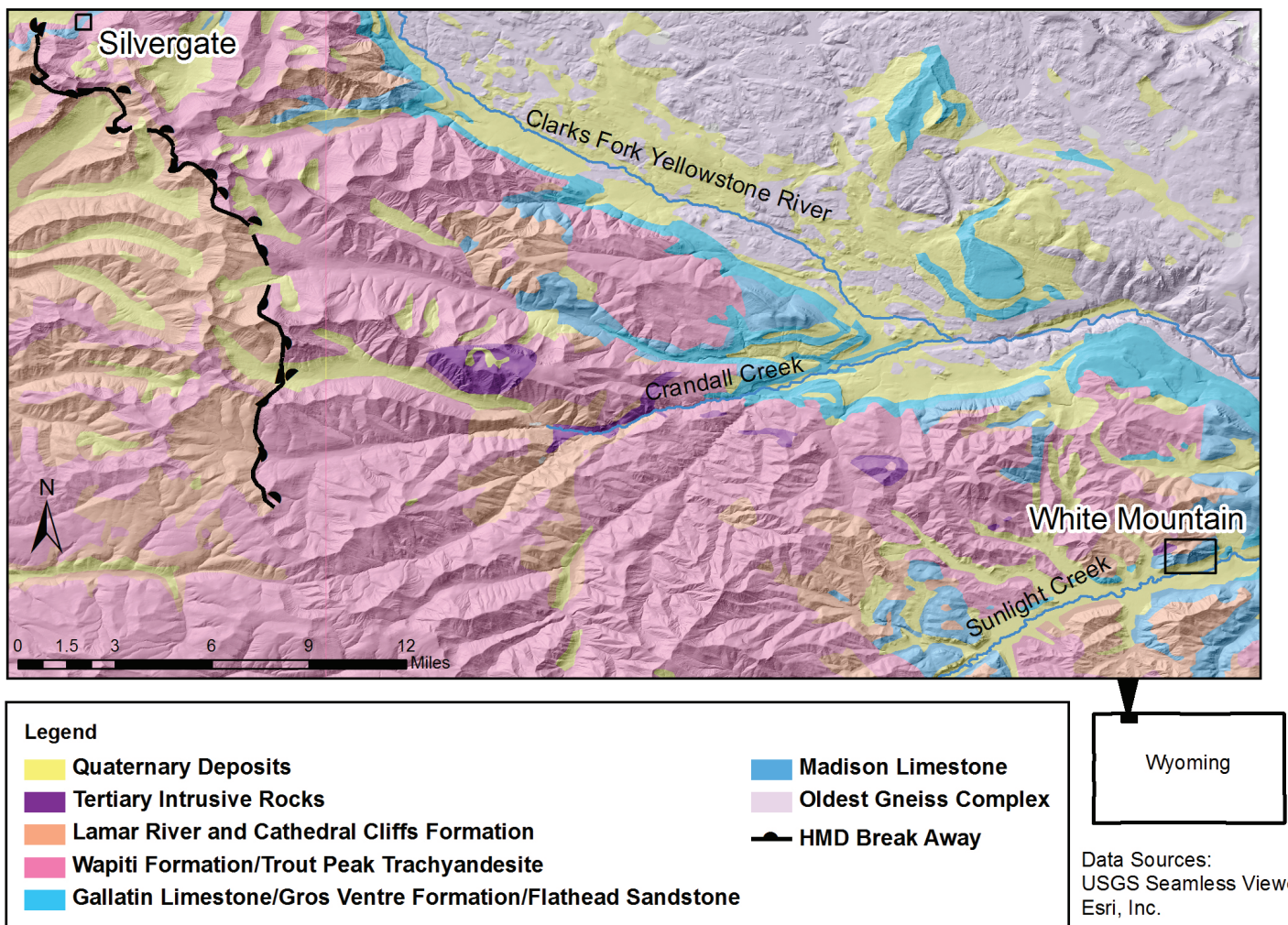


Figure 1: Generalized geologic map of the Heart Mountain Detachment. Silvergate and White Mountain Study areas shown.

blocks we transported over the Rattlesnake Mountains (~500 m tall) and detachment is preserved over an area of over an area of 3400 km² (Craddock, 2009). The timing of the detachment has been narrowed to 49.7 and 49.5 Ma (Rhodes et al., 2007; Smith et al., 2003) a time contemporaneous to igneous activity in the Absarokas including the eruptive Sunlight Volcano which is 49.6 Ma - 48.1 Ma (Feeley and Cosa, 2003). Allochthonous HMD rocks are primarily Eocene age andesite from the Absaroka Volcanic Supergroup as well as Paleozoic cratonic strata (Craddock, 2009). Ordovician to Lower-Middle Eocene rocks were also transported by the HMD.

White Mountain/Silvergate

White Mountain is an allochthonous upper plate block that was transported down dip by the Heart Mountain

detachment (~15 km). It consists of pre-detachment dikes a trachandesite stock as well as Madison Limestone and Bighorn Dolomite that was metamorphosed into marble prior to the detachment. Recent thermodynamic calculations at White Mountain suggest an initial upper plate emplacement of 126-340 m/sec, too fast to develop detachment related calcite twin overprint in upper and lower plate carbonates (Craddock, 2009).

White Mountain rests on the thickest CUC (1m) within the HMD. Nine CUC dikes are present at White Mountain. Five vertical CUC intrusions are located to the West of the trachandesite stock while four are located to the East (Fig 2). The tallest injectite is located to the west and is ~120 m above the detachment. Previous field observations, XRF analysis, and stable isotope analysis confirm that the injectite CUC

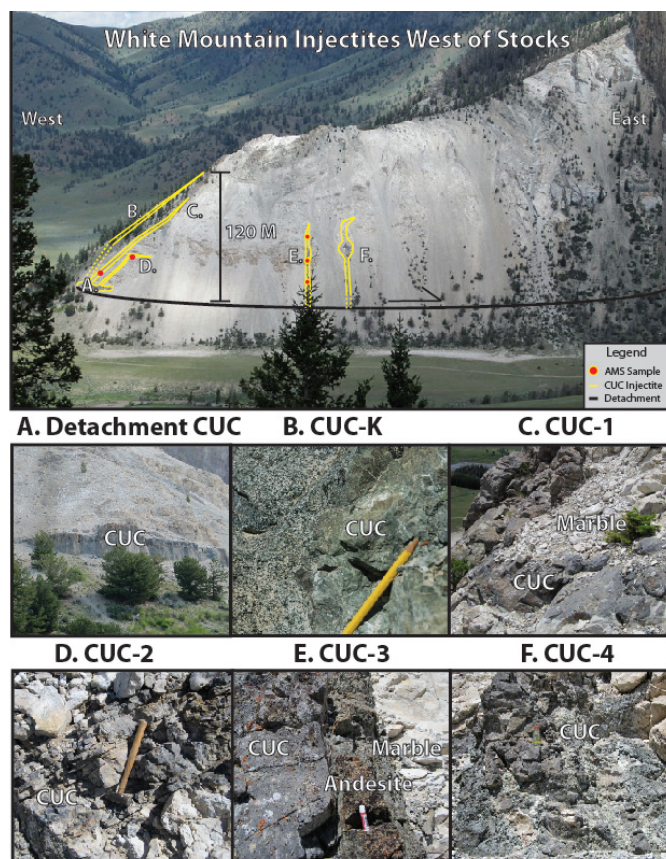


Figure 2: Detachment and injectite CUC west of stock. Field photographs of detachment CUC (A), CUC-k (B), CUC-1 (C), CUC-2 (D), CUC-3 (E), and CUC-4 (F) shown. Also shown is the location of AMS samples collected at White Mountain.

is identical to the detachment CUC (Geary, 2011). AMS analysis of the basal CUC indicates a flow fabric in which K_{\max} is parallel to the detachment slip direction (Craddock, 2009). At Silvergate, one CUC injectite protrudes vertically from a thin basal CUC that marks the detachment. The Silvergate CUC is between volcanic rocks and Mississippian Madison Limestone.

METHODS

Anisotropy of Magnetic Susceptibility (AMS)

For a rock specimen, the dependence of magnetic properties on a preferred direction is referred to as magnetic anisotropy and the ratio of induced magnetism to the intensity of the inducing magnetic field referred to magnetic susceptibility. The anisotropy of magnetic susceptibility (AMS) of orientated carbonate ultra cataclasite (CUC) samples was analyzed

using the “Roly-Poly” instrument at the Institute of Rock Magnetism in Twin Cities Minnesota. The “Roly-Poly” is an alternating-current (AC) susceptibility bridge that determines the anisotropy of low-field magnetic susceptibility at room temperature. An AC in the external “drive” coils produces an alternating magnetic field in the sample space with a frequency of 680 Hz and amplitude of up to 1 mT. The induced magnetization of a sample is detected by a pair of “pickup” coils, with a sensitivity of 1.2×10^{-6} SI (International System of Units) volume units. The Anisotropy component of AMS is determined by rotating a sample about three orthogonal axes, and the susceptibility is measured at 1.8° intervals in each of the three measurement planes. The susceptibility tensor is computed by least squares from the resulting 600 directional measurements and K_{\max} , K_{int} , and K_{\min} directions are determined (Craddock, 2009). K_{\max} refers to the contoured maxima of the long axis of the magnetic ellipsoid while K_{\min} refers to the contoured minima.

Laser ablation multicollector inductively coupled plasma mass spectrometry (LA-MC-ICPMS)

Bulk CUC Samples were collected at White Mountain and Silvergate for detrital zircon analysis. Samples were processed and prepared at Macalster College using crushing, Wilfley table, heavy liquids and Franz magnet separation techniques. Zircons were analyzed using laser ablation multicollector inductively coupled plasma mass spectrometry (LA-MC-ICPMS) at the Arizona LaserChron in Tucson.

The LA-MC-ICPMS instrument uses a Photon Machines Analyte G2 excimer laser with a spot diameter of 30 microns to ablate a pit of ~15 microns in the zircon grain. The ablated material is carried in helium into the plasma source of a Nu HR ICPMS, which is equipped with a flight tube of sufficient width that U, Th, and Pb isotopes are measured simultaneously. Each analysis consists of one 15-second integration on peaks with the laser off (for backgrounds), 15 one-second integrations with the laser firing, and a 30 second delay to purge the previous sample and prepare for the next analysis. (Gehrels et al, 2006, 2008).

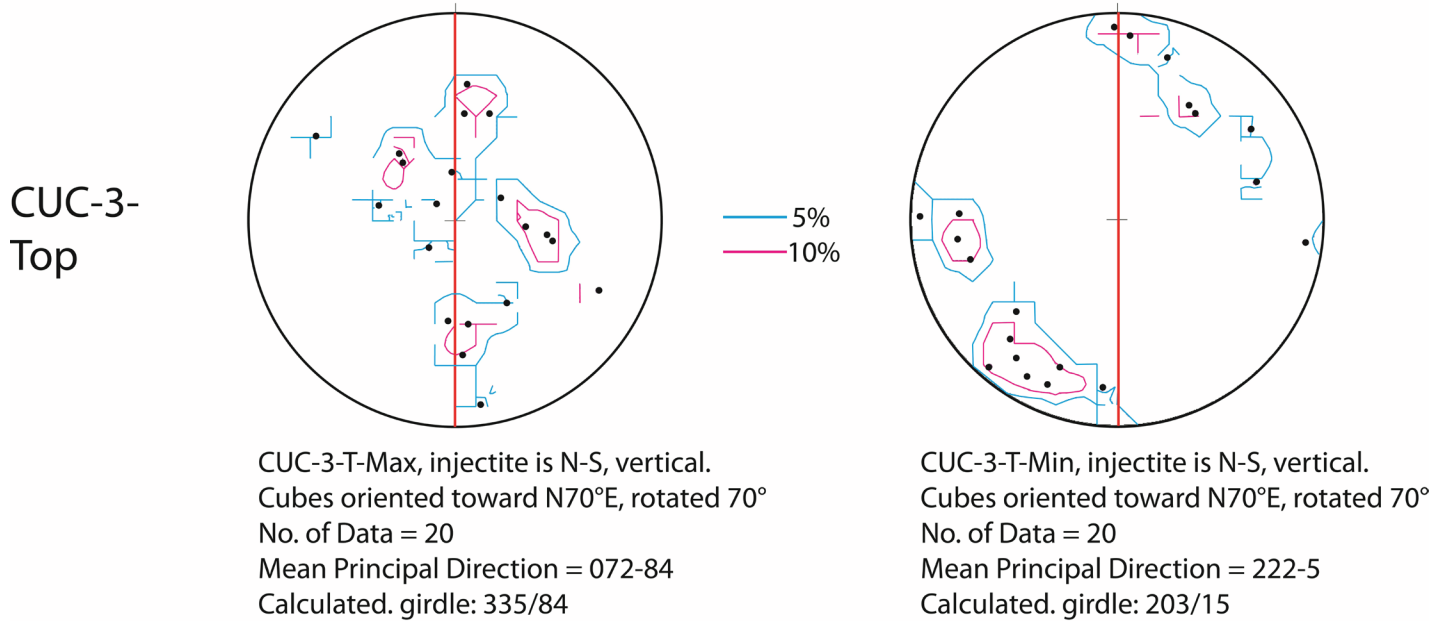


Figure 3: AMS K_{max} and K_{min} values for CUC-3-Top

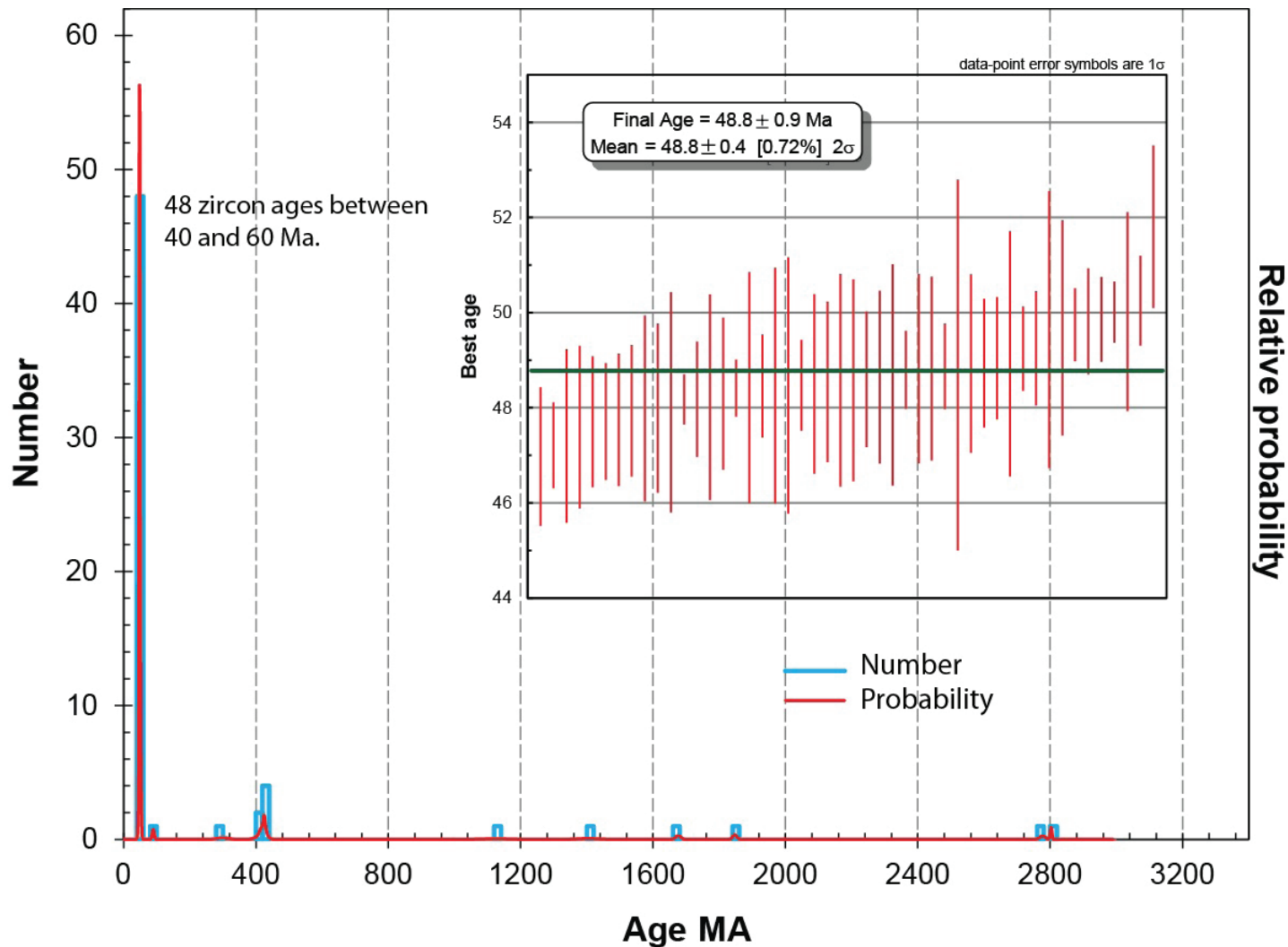


Figure 4: Zircon ages for CUC samples from White Mountain and Silvergate. Final age is 48.8 ± 0.9 Ma

RESULTS

Anisotropy of Magnetic Susceptibility

At White Mountain 102 samples from CUC-1, CUC-2, and CUC-3 injectites (Fig 2.) were analyzed for AMS. For CUC-3, AMS was done at the bottom, middle, and top of the injectite. Twenty oriented AMS samples were analyzed from the CUC-Silvergate injectite. The only clear AMS signature was observed at CUC-3. Here the orientation of K_{\max} becomes more vertical further up the injectite while K_{\min} becomes more horizontally orientated (Fig. 3). At CUC-1, CUC-2, AMS orientations appear chaotic and randomly orientated.

Zircon Ages

LA-MC-ICPMS analysis was conducted on 60 detrital zircons from White Mountain and Silvergate CUC. The age distribution and relative probability of the CUC zircon data is shown in Figure 4. The most prominent peak is Eocene and the final best age is 48.8 ± 0.9 M.

DISCUSSION

The high variability and scatter in K_{\max} and K_{\min} values suggest a chaotic and violent intrusion of fault gouge material into the hanging wall. This is consistent with a catastrophic emplacement model. At CUC-3 the magnetic fabric changes from chaotic AMS orientations to orientations consistent with a vertical flow direction from bottom to top. Near the top, K_{\max} values become more parallel to the injectite, suggesting a greater time and distance for the carrier mineral (magnetite) to align itself. A slow moving allochthon would not see this violent gouge intrusion. The CUC ages of 48.8 ± 0.9 Ma are within error of ash deposit ages at Jim Mountain (49.8 ± 1.1 Ma) and Hominy Peak (49.1 ± 0.75) (McGaughe, 2011) as well the age of the eruptive Sunlight Volcano (49.6 Ma - 48.1 Ma) (Cosa et al; 2003). These corresponding ages mark the timing of the eruption that liberated the HMD.

CONCLUSION

While there has been significant debate on the timing and emplacement of the HMD, the data presented in this paper further strengthen the argument for volcanic landslide induced catastrophic emplacement. The chaotic AMS signature supports catastrophic emplacement and the zircon ages narrow the timing of the detachment to a time of eruptive volcanism in the Absarokas. A final question: How do you get 1.8 and 2.6 Ga zircons in the detachment CUC but not in the injectite CUC?

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