KECK GEOLOGY CONSORTIUM

PROCEEDINGS OF THE TWENTY-FOURTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

April 2011
Union College, Schenectady, NY

Dr. Robert J. Varga, Editor
Director, Keck Geology Consortium
Pomona College

Dr. Holli Frey
Symposium Convenor
Union College

Carol Morgan
Keck Geology Consortium Administrative Assistant

Diane Kadyk
Symposium Proceedings Layout & Design
Department of Earth & Environment
Franklin & Marshall College

Keck Geology Consortium
Geology Department, Pomona College
185 E. 6th St., Claremont, CA 91711
(909) 607-0651, keckgeology@pomona.edu, keckgeology.org

ISSN# 1528-7491

The Consortium Colleges   The National Science Foundation   ExxonMobil Corporation

KECK GEOLOGY CONSORTIUM
PROCEEDINGS OF THE TWENTY-FOURTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

ISSN# 1528-7491

April 2011

Robert J. Varga
Editor and Keck Director
Pomona College

Keck Geology Consortium
Pomona College
185 E 6th St., Claremont, CA 91711

Diane Kadyk
Proceedings Layout & Design
Franklin & Marshall College

Keck Geology Consortium Member Institutions:
Amherst College, Beloit College, Carleton College, Colgate University, The College of Wooster, The Colorado College, Franklin & Marshall College, Macalester College, Mt Holyoke College, Oberlin College, Pomona College, Smith College, Trinity University, Union College, Washington & Lee University, Wesleyan University, Whitman College, Williams College

2010-2011 PROJECTS

FORMATION OF BASEMENT-INVOLVED FORELAND ARCHES: INTEGRATED STRUCTURAL AND SEISMOLOGICAL RESEARCH IN THE BIGHORN MOUNTAINS, WYOMING
Faculty: *CHRISTINE SIDDOWAY*, *MEGAN ANDERSON*, Colorado College, *ERIC ERSLEV*, University of Wyoming
Students: *MOLLY CHAMBERLIN*, Texas A&M University, *ELIZABETH DALLEY*, Oberlin College, JOHN *SPENCE HORNBUCKLE III*, Washington and Lee University, *BRYAN MCATEE*, Lafayette College, *DAVID OAKLEY*, Williams College, *DREW C. THAYER*, Colorado College, *CHAD TREXLER*, Whitman College, *TRIANA N. UFRET*, University of Puerto Rico, *BRENNAN YOUNG*, Utah State University.

EXPLORING THE PROTEROZOIC BIG SKY OROGENY IN SOUTHWEST MONTANA
Faculty: *TEKLA A. HARMS*, *JOHN T. CHENEY*, Amherst College, *JOHN BRADY*, Smith College
Students: *JESSE DAVENPORT*, College of Wooster, *KRISTINA DOYLE*, Amherst College, *B. PARKER HAYNES*, University of North Carolina - Chapel Hill, *DANIELLE LERNER*, Mount Holyoke College, *CALEB O. LUCY*, Williams College, *ALIANORA WALKER*, Smith College.

INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, COLORADO
Faculty: *DAVID P. DETHIER*, Williams College, *WILL OUIMET*. University of Connecticut
Students: *ERIN CAMP*, Amherst College, *EVAN N. DETHIER*, Williams College, *HAYLEY CORSON-RIKERT*, Wesleyan University, *KEITH M. KANTACK*, Williams College, *ELLEN M. MALEY*, Smith College, *JAMES A. MCCARTHY*, Williams College, *COREY SHIRCLIFF*, Beloit College, *KATHLEEN WARRELL*, Georgia Tech University, *CIANNA E. WYSHNYSZKY*, Amherst College.

SEDIMENT DYNAMICS & ENVIRONMENTS IN THE LOWER CONNECTICUT RIVER
Faculty: *SUZANNE O'CONNELL*, Wesleyan University
Students: LYNN M. GEIGER, Wellesley College, KARA JACOBACCI, University of Massachusetts (Amherst), GABRIEL ROMERO, Pomona College.

GEOMORPHIC AND PALEOENVIRONMENTAL CHANGE IN GLACIER NATIONAL PARK, MONTANA, U.S.A.
Faculty: *KELLY MACGREGOR*, Macalester College, *CATHERINE RIIHIMAKI*, Drew University, *AMY MYRBO*, LacCore Lab, University of Minnesota, *KRISTINA BRADY*, LacCore Lab, University of Minnesota

Students: *HANNAH BOURNE*, Wesleyan University, *JONATHAN GRIFFITH*, Union College, *JACQUELINE KUTVIRT*, Macalester College, *EMMA LOCATELLI*, Macalester College, *SARAH MATTESON*, Bryn Mawr College, *PERRY ODDO*, Franklin and Marshall College, *CLARK BRUNSON SIMCOE*, Washington and Lee University.

GEOLOGIC, GEOMORPHIC, AND ENVIRONMENTAL CHANGE AT THE NORTHERN TERMINATION OF THE LAKE HÖVSGÖL RIFT, MONGOLIA
Faculty: *KARL W. WEGMANN*, North Carolina State University, *TSALMAN AMGAA*, Mongolian University of Science and Technology, *KURT L. FRANKEL*, Georgia Institute of Technology, *ANDREW P. deWET*, Franklin & Marshall College, *AMGALAN BAYASAGALN*, Mongolian University of Science and Technology.
Students: *BRIANA BERKOWITZ*, Beloit College, *DAENA CHARLES*, Union College, *MELLISSA CROSS*, Colgate University, *JOHN MICHAELS*, North Carolina State University, *ERDENEBAYAR TSAGAANNARAN*, Mongolian University of Science and Technology, *BATTOGTOH DAMDINSUREN*, Mongolian University of Science and Technology, *DANIEL ROTHBERG*, Colorado College, *ESUGEI GANBOLD, ARANZAL ERDENE*, Mongolian University of Science and Technology, *AFSHAN SHAIKH*, Georgia Institute of Technology, *KRISTIN TADDEI*, Franklin and Marshall College, *GABRIELLE VANCE*, Whitman College, *ANDREW ZUZA*, Cornell University.

LATE PLEISTOCENE EDIFICE FAILURE AND SECTOR COLLAPSE OF VOLCÁN BARÚ, PANAMA
Faculty: *THOMAS GARDNER*, Trinity University, *KRISTIN MORELL*, Penn State University
Students: *SHANNON BRADY*, Union College. *LOGAN SCHUMACHER*, Pomona College, *HANNAH ZELLNER*, Trinity University.

KECK SIERRA: MAGMA-WALLROCK INTERACTIONS IN THE SEQUOIA REGION
Faculty: *JADE STAR LACKEY*, Pomona College, *STACI L. LOEWY*, California State University-Bakersfield
Students: *MARY BADAME*, Oberlin College, *MEGAN D'ERRICO*, Trinity University, *STANLEY HENSLEY*, California State University, Bakersfield, *JULIA HOLLAND*, Trinity University, *JESSLYN STARNES*, Denison University, *JULIANNE M. WALLAN*, Colgate University.

EOCENE TECTONIC EVOLUTION OF THE TETONS-ABSAROKA RANGES, WYOMING
Faculty: *JOHN CRADDOCK*, Macalester College, *DAVE MALONE*, Illinois State University
Students: *JESSE GEARY*, Macalester College, *KATHERINE KRAVITZ*, Smith College, *RAY MCGAUGHEY*, Carleton College.

Funding Provided by:
Keck Geology Consortium Member Institutions
The National Science Foundation Grant NSF-REU 1005122
ExxonMobil Corporation

Keck Geology Consortium: Projects 2010-2011
Short Contributions— Teton Range, Wyoming

Keck Geology Consortium
Pomona College
185 E. 6th St., Claremont, CA 91711
Keckgeology.org

U-PB DETRITAL ZIRCON GEOCHRONOLOGY OF HOMINY PEAK, WYOMING AND CORRELATION TO THE HEART MOUNTAIN DETACHMENT

RAY MCGAUGHEY, Carleton College
Research Advisor: Cameron Davidson

INTRODUCTION

Despite the active controversy surrounding the volcanic components of the Heart Mountain Detachment (HMD) in the Absaroka Range (Anders et al., 2010), little attention has been paid to Eocene volcanic deposits on the west side of the Teton Range such as the Hominy Peak Formation (Love et al., 2003). K-Ar dating of a small outcrop on the East side of the Teton Range yielded an age of 48.6±0.7 Ma for the Hominy Peak Formation (Love et al., 1978) but this date has not been interpreted within a wider context for the area. In this study, I use U/Pb zircon dates from Eocene volcaniclatic rocks located at Hominy Peak—the only major location of early Tertiary-age volcanic-derived rocks on the west side of the Teton Range—in order to evaluate the potential for correlation with the HMD (Figure 1).

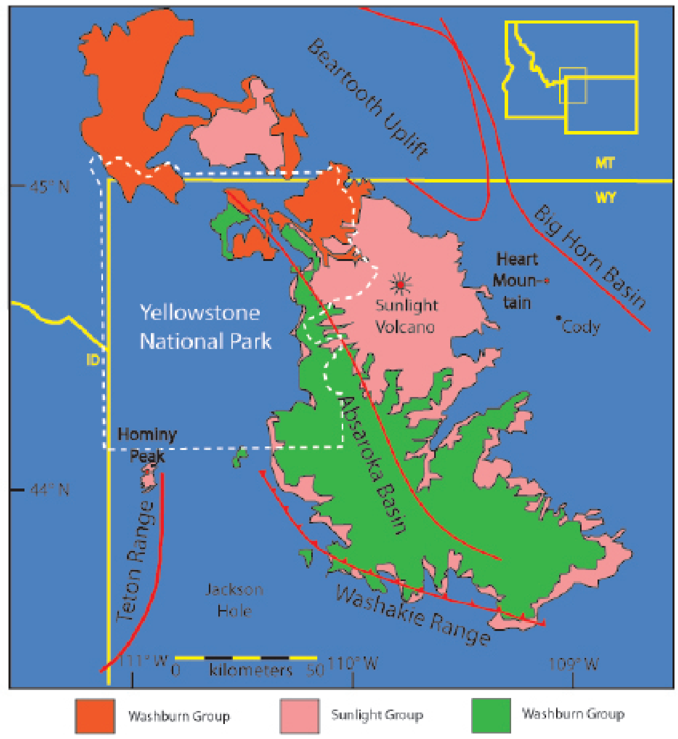

Figure 1. Map of the Absaroka volcanic province showing the three stratigraphic units of Smedes and Proska (1972). Groups decrease in age from left to right. Dashed line is the boundary of Yellowstone national Park. Note Hominy Peak, Sunlight Volcano and Heart Mountain. Modified from Smedes and Proska (1972), Sundell (1993) and Malone (1995), and Feeley and Cosca (2003).

GEOLOGIC SETTING

Hominy Peak Formation

The Hominy Peak Formation (HPF) is a mafic volcaniclastic deposit that reaches 600 m in its thickest sections near Hominy Peak (Love et al., 1978). The HPF is exposed in about 50 Km^2 in the Northern Teton Range, but is heavily eroded and does not crop out in any one area representing more than 25 Km^2. While erosional remnants are found in various locations in the northern Tetons, thick deposits (> 300 m) are found only at Hominy Peak and the Grand Targhee Resort. Love et al. (1978) assigned the HPF to the Absaroka Volcanic Supergroup (Smedes and Prostka, 1972) but no further work has been done to narrow the geographic origin or classify the HPF as part of a specific subgroup. The HPF represents the only early Tertiary volcanic deposit on the west side of the Tetons.

The majority of the Hominy Peak Formation is a volcanic breccia. The clast composition of the formation include: Paleozoic carbonates (up to 10 m in diam eter), Mesozoic conglomeratic sandstones (up to 7-10 m in diameter) and Precambrian quartzite cobbles as well as various Wyoming Province volcanic rocks (Love et al., 1978). The basal unit of the formation is a white tuff representing the bottom ~90 m of the formation (Fig. 2).

The HPF rests unconformably above the Paleocene Pinyon Conglomerate. The clasts in the Pinyon Conglomerate are Precambrian quartzite cobbles, presumably of similar origin as the HPF quartzite clasts (Love et al., 1978). Above the HPF unconformably lie Pliocene and Pleistocene tuffs.

Absaroka Range and Heart Mountain Detachment
Volcanism within the Absarokas is distributed into three distinct groups (from oldest to youngest): the Washburn, Sunlight and Thorofare (Fig. 1). The Heart Mountain detachment (HMD) are characterized by more than 230 m of Paleozoic carbonate rocks blanketed by early Eocene volcanic rock of the Sunlight Group, including the Wapiti and other formations (Malone, 2000).

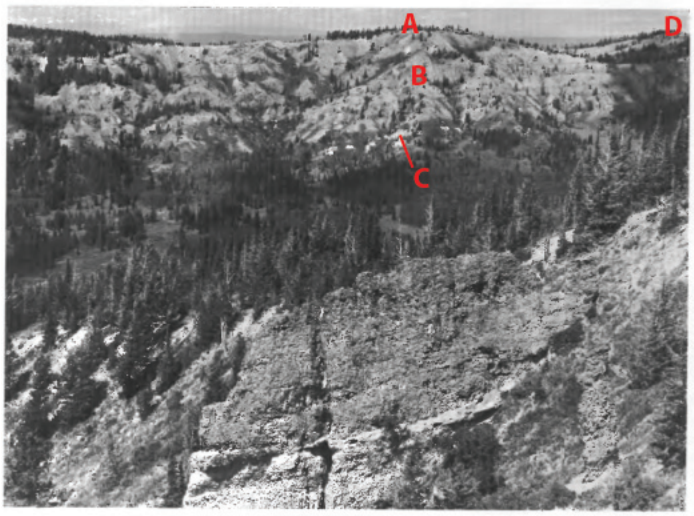

Figure 2. View of Hominy Peak Formation from west edge of Carrot Knoll. (A) Hill 8373 capped by rhyolitic Conant Creek Tuff; (B) Upper Hominy Peak Formation and approximate location of matrix sample; (C) White marker tuff comprising basal unit of Hominy Peak Formation and approximate location of ash sample; (D) Hominy Peak. Photograph by J. D. Love, 1965. From Love et al., 1978.

U/PB GEOCHRONOLOGY

Samples of the Hominy Peak Formation volcanic matrix and basal tuff were collected at Hill 8373 just SW of Hominy Peak (Fig. 2). Samples were processed at Macalester and Carleton Colleges using standard techniques (crushing, Wilfley table, heavy liquids and Franz magnet separation). U/Pb geochronology of zircons took place at the LaserChron Lab at the University of Arizona. Once the samples were mounted they underwent laser ablation ICPMS analyses. A beam diameter of ~30 µm was used, resulting in a pit depth of ~12 µm. Sri Lankan zircons of known age were used as a standard and checked periodically to ensure accuracy.

Precambrian detrital zircons and zircon cores are present in both samples. In order to minimize uncertainty, an age of 900 Ma served as the cutoff between 206Pb/238U and 206Pb/207Pb calculated ages (Gehrels et al., 2008). The change in levels of precision is a result of the low intensity of the 207Pb signal. Isotopic data were analyzed and plotted using Isoplot 3.0 (Ludwig, 2003).

RESULTS

Hominy Peak Formation – Volcanic Matrix

Of the 100 grains analyzed from the Hominy Peak Formation (HPF) volcanic matrix, 85 yielded reliable concordant to slightly discordant ages. Twenty-one zircons (25%) yielded Eocene ages, seven (8%) yielded Paleozoic ages, 50 (59%) yielded Proterozoic ages and seven (8%) yielded Archean ages. The age distribution and the associated relative probability distribution of these data are plotted in Figure 3. The most pronounced peak is in the lower Eocene and is quite narrow. A much smaller and broader peak is visible in the Proterozoic.

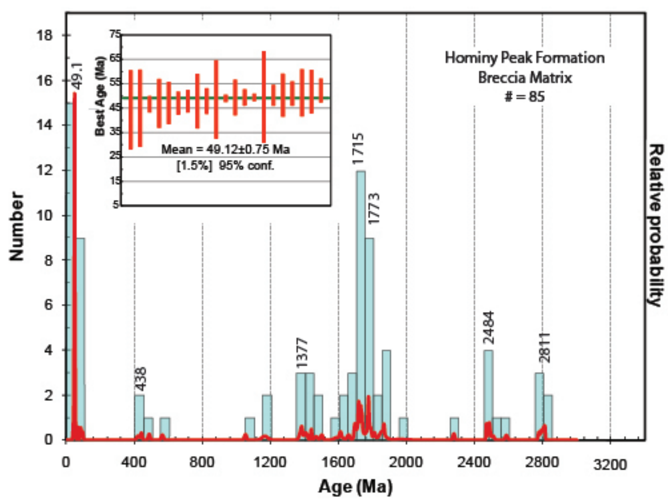

Figure 3. Relative probability distribution of Hominy Peak Formation breccia matrix. Blue rectangles represent 50-Ma bins of analyses. Red curve is relative-probability. Number of zircons analyzed and maximum depositional age of Eocene population listed (Gehrels et al., 2008). Insert: Best Ages of zircons. Green line represents mean age of population.

Hominy Peak Formation – Basal Tuff

Twenty-seven zircons were analyzed from the Hominy Peak Formation basal tuff yielding 32 U-Pb isotopic ages; seven grains were analyzed on both the rim and core and therefore yielded multiple ages (Fig. 4). The vast majority of the grains (77%) yielded Eocene ages. The remainder of the ages are Proterozoic and Archean. The age distribution and relative probability curve of these data is plotted in Figure 5. As with the Hominy volcanic matrix, the most pronounced peak is in the Eocene. Other peaks of relative probability were small and insignificant as they represented only 1-2 grains in the group.

About half of the Proterozoic ages displayed in the relative probability diagram are cores, the other half are rims. Almost all (86%) of the zircons analyzed in rim and core yielded Eocene rim ages and Proterozoic core ages. This is typical of igneous zircons with inherited cores as found in volcanic ashes (Gehrels et al., 2008). All zircons analyzed were concordant to slightly discordant.

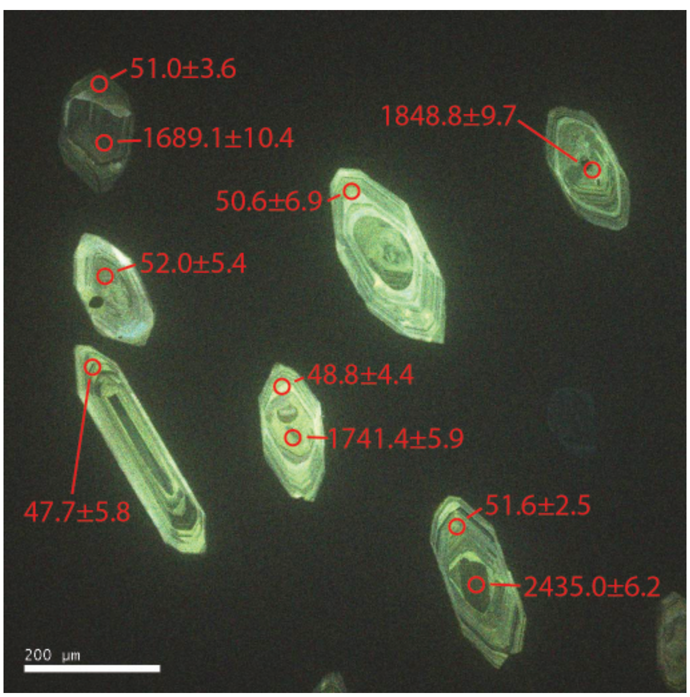

Figure 4. Select zircons under cathodoluminescence (SEM-CL) imaging and associated rim/core ages and ranges of error (Ma). Inherited cores are clearly visible in most of the grains. Many of the cores have lost their original shape but the rims display classic zircon euhedral shape.

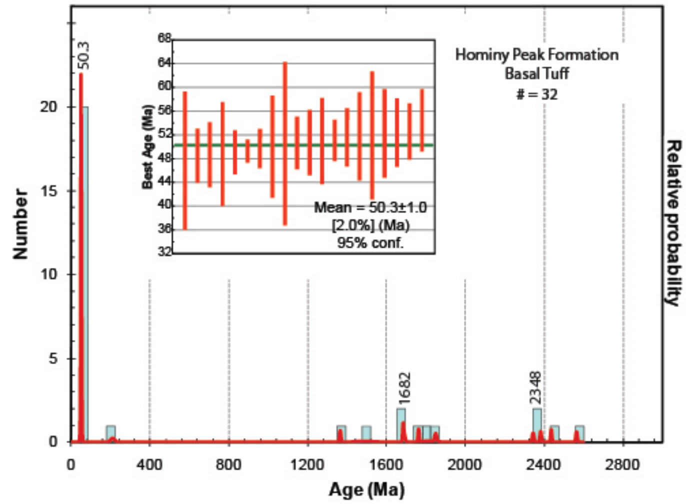

Figure 5. Relative probability distribution of Hominy Peak Formation basal tuff. Blue rectangles represent 40-Ma bins of analyses. Red curve is relative-probability. Number of zircons analyzed and crystallization age of Eocene population listed (Gehrels et al., 2008). Insert: Best Ages of zircons. Green line represents mean age of population.

DISCUSSION

Zircon Age Interpretation

The group of youngest zircons in both samples appear to form a single population and will be interpreted as representing the crystallization age of a population of zircons formed during Eocene volcanism. Interpreted this way, the maximum depositional age of the Hominy Peak Formation (HPF) matrix and the crystallization age of the basal tuff are 49.1 ± 0.75 and 50.3 ± 1.4 Ma, respectively. These dates appear to coincide with the Absaroka volcanism that was going on to the northeast and confirm the assertion that the HPF is part of the Absaroka Volcanic Supergroup. Specifically, they can be correlated to the Sunlight Group, the group largely associated with eruptions of the Sunlight Volcano in the middle Eocene:

1) Feely and Cosca (2003) constrained the period of activity of Sunlight Volcano to 49.6-48.1 Ma. They mark three distinct stages of major Sunlight volcanism at 49.4, 48.4 and 48.1 Ma. These dates coincide with the maximum depositional age of the HPF volcaniclastic matrix and crystallization age of the HPF basal tuff.

2) The Sunlight volcano was the biggest and most eruptive edifice of the Middle Eocene (Feeley and

Cosca, 2003). This is based on the extent of its radial dike swarm (over 400 Km^2) and the abundance of vent facies rocks.

3) The volcanic matrix and the composition of clasts in the Hominy Peak formation best matches that of the Sunlight Group. Feely and Cosca (2003) described the Sunlight volcano as erupting onto a surface of Mesozoic and Paleozoic sedimentary rocks as well as older regional volcanic rocks. This matches with the clast composition of the HPF, specifically the Paleozoic Madison limestone clasts, Cretaceous sandstones and assorted types of volcanic rock. Furthermore, the Sunlight Group is the most mafic in composition, similar to the mafic HPF breccia matrix.

Hominy Peak Analogy: Mt. St. Helens

The location of Hominy Peak relative to Sunlight volcano is puzzling, given this correlation. The majority of the rocks of the Sunlight group are emplaced downhill to the southeast and Hominy Peak would be one of the few areas of deposition to the southwest (Fig. 1). This is potentially explained by studying the emplacement of lahars at contemporary stratovolcanos such as Mt. St. Helens.

While the areas directly affected by the 1980 Mt. St. Helens eruption were predominantly downhill to the north, lahars and debris slides mostly traveled to the west (Pierson, 1985). Lahars move in all directions from a volcano, following drainage basins. Thus, by treating Hominy Peak as a Sunlight volcano lahar, the fact that the Hominy Peak Formation is the sole deposit of Absaroka volcanism to the southwest of Sunlight Peak does not preclude Sunlight as its source.

The cause for the extreme distance from Sunlight Volcano to Hominy Peak (110 km) is still open to discussion. This is much greater than the ~30 km distance from Mt. St. Helens to the emplacement of the furthest lahars (Tilling et al., 1984). However, it is clear that the Sunlight volcanic collapse occurred on a much greater scale than that of Mt. St. Helens making the distance less surprising (Feeley and Cosca, 2003).

Interpretation within the Heart Mountain Controversy
The zircon ages determined in this study for the Hominy Peak Formation are within error of the 49.7-49.5 Ma ages for the Heart Mountain Detachment (HMD) (Malone and Craddock, 2008).

The relatively large distance (110 km) between Sunlight volcano and Hominy Peak suggest an Eocene eruption of huge proportions and adds credence to the catastrophic emplacement model. A volcanic collapse that could displace the upper plate of the Heart Mountain Detachment as far as 50 km at rapid speeds would surely deposit distant lahars. In short, it is possible that the Hominy Peak Formation is a result of the same volcanic collapse that initiated the Heart Mountain Detachment.

Another interpretation (and one that is not necessarily mutually exclusive with the first) is that the Hominy Peak Formation correlates with the Wapiti Formation, the decidedly volcanic rock that overlies the Heart Mountain Detachment. The two formations are almost identical in composition given that both are Sunlight Group mafic volcanic rock containing large Madison Limestone clasts (Torres and Gingerich, 1983). However, a precise geochronological date is needed on the Wapiti atop Heart Mountain in order to test this hypothesis.

CONCLUSIONS

While the Hominy Peak Formation (HPF) is an accepted product of Eocene Absaroka volcanism, the zircon ages presented in this study help to pinpoint the source to the northeast. Smedes and Prosca (1972) mapped the HPF as part of the Absaroka Volcanic Supergroup (AVS) but did not correlate it regionally to one of the three AVS groups: the Thorofare, Washburn and Sunlight. By correlating the crystallization age of the HPF tuff and maximum depositional age of the HPF matrix, and by comparing matrix and clast composition, the Hominy Peak Formation is here assigned to the Sunlight Group of the AVS.

Treating the Hominy Peak Formation as a lahar has important consequences for the Heart Mountain Detachment (HMD). The great distance between Sunlight Volcano and Hominy Peak suggest a volcanic collapse of immense proportions, consistent with estimates for the size needed to displace the HMD such great distances. Similarities in dates between the deposition of the HPF and the Heart Mountain detachment suggest a correlation and support the catastrophic emplacement model. Further radiometric dating is necessary to better understand the relationship between the Hominy Peak Formation and the allochthonous Wapiti Formation that overlies the Heart Mountain Detachment.

ACKNOWLEDGEMENTS

I thank the Keck Geology Consortium and the Carleton College Geology Department for funding my research. John Craddock and Dave Malone shared limitless knowledge in the field and ongoing insight and support as my thesis developed. Cameron Davidson's familiarity with the detrital zircon processes and advice on the organization and content of my thesis were vital. I thank my fellow undergraduates who shared the burden of the sample processing and zircon analysis and proved great companions in the field. Finally, thanks to all my family and friends who supported me in long but ultimately rewarding this process.

REFERENCES CITED

Anders, M.H., Fouke, B.W., Zerkle, A.L., Tavarnelli, E., Alvarez, W., and Harlow, G.E., 2010, The role of calcining and basal fluidization in the long runout of carbonate slides; an example from the Heart Mountain slide block, Wyoming and Montana, U.S.A: Journal of Geology, v. 118, p. 577-599.

Feeley, T.C., and Cosca, M.A., 2003, Time vs. composition trends of magmatism at Sunlight Volcano, Absaroka volcanic province, Wyoming: Geological Society of America Bulletin, v. 115, p. 714-728.

Gehrels, G.E., Valencia, V.A., and Ruiz, J., 2008, Enhanced precision, accuracy, efficiency, and spatial resolution of U-Pb ages by laser ablation–multicollector–inductively coupled plasma–mass spectrometry Geochemistry, Geophysics, Geosystems, v. 9.

Love, J.D., Leopold, E.B., and Love, D.W., 1978, Eocene Rocks, Fossils, and Geologic History, Teton Range, Northwestern Wyoming. U.S. Geological Survey Professional Paper 932-B. 40pp. .

Love, J.D., Reed, J.C., Jr., and Pierce, K.L., 2003, Creation of the Teton Landscape: A Geological Chronical of Jackson Hole & The Teton Range: Moose, WY, Grand Teton Natural History Association.

Ludwig, K.R., 2003, Isoplot 3.00: Berkeley Geochronology Center, Special Publication No. 4, 70 p.

Malone, D.H., 1995, Very large debris-avalanche deposit within the Eocene volcanic succession of the northeastern Absaroka Range, Wyoming: Geology (Boulder), v. 23, p. 661-664.

—, 2000, Structure and stratigraphy of Eocene volcanic rocks in the proximal areas of the Heart Mountain Detachment: Guidebook - Wyoming Geological Association, v. 51, p. 29-50.

Pierson, T.C., 1985, Initiation and flow behavior of the 1980 Pine Creek and Muddy River lahars, Mount St. Helens, Washington: Geological Society of America Bulletin, v. 96, p. 1056-1069.

Smedes, H.W., and Prostka, H.J., 1972, Stratigraphic framework of the Absaroka Volcanic Supergroup in the Yellowstone National Park region.

Sundell, K.A., 1993, A geologic overview of the Absaroka volcanic province: Memoir - Geological Survey of Wyoming, v. 5, p. 480-506.

Tilling, R.I., Topinka, L.J., and Swanson, D.A., 1984, Eruptions of Mount St. Helens; past, present, and future, p. General Interest Publication, 57.

Torres, V., and Gingerich, P.D., 1983, Summary of Eocene stratigraphy at the base of Jim Mountain, north fork of the Shoshone River, northwestern Wyoming: Guidebook - Wyoming Geological Association, v. 34, p. 205-208.