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

April 2014
Mt. Holyoke College, South Hadley, MA

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

Dr. Michelle Markley
Symposium Convener
Mt. Holyoke College

Carol Morgan
Keck Geology Consortium Administrative Assistant

Christina Kelly
Symposium Proceedings Layout & Design
Office of Communication & Marketing
Scripps 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-SEVENTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

ISSN# 1528-7491

April 2014

Robert J. Varga
Editor and Keck Director
Pomona College

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

Christina Kelly
Proceedings Layout & Design
Scripps 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

2013-2014 PROJECTS

MAGNETIC AND GEOCHEMICAL CHARACTERIZATION OF IN SITU OBSIDIAN, NEW MEXICO*:*
Faculty: *ROB STERNBERG*, Franklin & Marshall College, *JOSHUA FEINBERG*, Univ. Minnesota, *STEVEN SHACKLEY,* Univ. California, Berkeley, *ANASTASIA STEFFEN*, Valles Caldera Trust, and Dept. of Anthropology, University of New Mexico
Students: *ALEXANDRA FREEMAN*, Colorado College, *ANDREW GREGOVICH*, Colorado College, *CAROLINE HACKETT*, Smith College, *MICHAEL HARRISON,* California State Univ.-Chico, *MICHAELA KIM*, Mt. Holyoke College, *ZACHARY OSBORNE*, St. Norbert College, *AUDRUANNA POLLEN*, Occidental College, *MARGO REGIER*, Beloit College, *KAREN ROTH*, Washington & Lee University

TECTONIC EVOLUTION OF THE FLYSCH OF THE CHUGACH TERRANE ON BARANOF ISLAND, ALASKA*:*
Faculty: *JOHN GARVER*, Union College, *CAMERON DAVIDSON*, Carleton College
Students: *BRIAN FRETT*, Carleton College, *KATE KAMINSKI*, Union College, *BRIANNA RICK*, Carleton College, *MEGHAN RIEHL*, Union College, *CLAUDIA ROIG*, Univ. of Puerto Rico, Mayagüez Campus, *ADRIAN WACKETT*, Trinity University,

EVALUATING EXTREME WEATHER RESPONSE IN CONNECTICUT RIVER FLOODPLAIN ENVIRONMENT*:*
Faculty: *ROBERT NEWTON*, Smith College, *ANNA MARTINI*, Amherst College, *JON WOODRUFF*, Univ. Massachusetts, Amherst, BRIAN YELLEN, University of Massachusetts
Students: *LUCY ANDREWS*, Macalester College, *AMY DELBECQ*, Beloit College, *SAMANTHA DOW*, Univ. Connecticut, *CATHERINE DUNN*, Oberlin College, *WESLEY JOHNSON*, Univ. Massachusetts, *RACHEL JOHNSON,* Carleton College, *SCOTT KUGEL*, The College of Wooster, *AIDA OROZCO*, Amherst College, *JULIA SEIDENSTEIN,* Lafayette College

Funding Provided by:
Keck Geology Consortium Member Institutions
The National Science Foundation Grant NSF-REU 1062720
ExxonMobil Corporation

A GEOBIOLOGICAL APPROACH TO UNDERSTANDING DOLOMITE FORMATION AT DEEP SPRINGS LAKE, CA

Faculty: *DAVID JONES*, Amherst College, *JASON TOR*, Hampshire College,
Students: *KYRA BRISSON*, Hampshire College, *KYLE METCALFE*, Pomona College, *MICHELLE PARDIS*, Williams College, *CECILIA PESSOA*, Amherst College, *HANNAH PLON*, Wesleyan Univ., *KERRY STREIFF*, Whitman College

POTENTIAL EFFECTS OF WATER-LEVEL CHANGES ON ON ISLAND ECOSYSTEMS: A GIS SPATIOTEMPORAL ANALYSIS OF SHORELINE CONFIGURATION

Faculty: *KIM DIVER*, Wesleyan Univ.
Students: *RYAN EDGLEY*, California State Polytecnical University-Pomona, *EMILIE SINKLER*, Wesleyan University

PĀHOEHOE LAVA ON MARS AND THE EARTH: A COMPARATIVE STUDY OF INFLATED AND DISRUPTED FLOWS

Faculty: *ANDREW DE WET*, Franklin & Marshall College, *CHRIS HAMILTON*. Univ. Maryland, *JACOB BLEACHER*, NASA, GSFC, *BRENT GARRY*, NASA-GSFC
Students: *SUSAN KONKOL*, Univ. Nevada-Reno, *JESSICA MCHALE*, Mt. Holyoke College, *RYAN SAMUELS,* Franklin & Marshall College, *MEGAN SWITZER*, Colgate University, *HESTER VON MEERSCHEIDT*, Boise State University, *CHARLES WISE*, Vassar College

THE GEOMORPHIC FOOTPRINT OF MEGATHRUST EARTHQUAKES: A FIELD INVESTIGATION OF CONVERGENT MARGIN MORPHOTECTONICS, NICOYA PENINSULA, COSTA RICA

Faculty: *JEFF MARSHALL*, Cal Poly Pomona, *TOM GARDNER*, Trinity University, *MARINO PROTTI, OVSICORI-UNA, SHAWN MORRISH*, Cal Poly Pomona
Students: *RICHARD ALFARO-DIAZ*, Univ. of Texas-El Paso, *GREGORY BRENN*, Union College, *PAULA BURGI*, Smith College, *CLAYTON FREIMUTH*, Trinity University, *SHANNON FASOLA*, St. Norbert College, *CLAIRE MARTINI*, Whitman College, *ELIZABETH OLSON*, Washington & Lee University, *CAROLYN PRESCOTT*, Macalester College, *DUSTIN STEWART*, California State Polytechnic University-Pomona, *ANTHONY MURILLO GUTIÉRREZ*, Universidad Nacional de Costa Rica (UNA)

HOLOCENE AND MODERN CLIMATE CHANGE IN THE HIGH ARCTIC, SVALBARD NORWAY

Faculty: *AL WERNER*, Mt. Holyoke College, *STEVE ROOF,* Hampshire College, *MIKE RETELLE*, Bates College
Students: *JOHANNA EIDMANN*, Williams College, *DANA REUTER*, Mt. Holyoke College, *NATASHA SIMPSON*, Pomona (Pitzer) College, *JOSHUA SOLOMON*, Colgate University

Funding Provided by:
Keck Geology Consortium Member Institutions
The National Science Foundation Grant NSF-REU 1062720
ExxonMobil Corporation

Keck Geology Consortium: Projects 2013-2014
Short Contributions— Obsidian Provenance, New Mexico Project

MAGNETIC AND GEOCHEMICAL CHARACTERIZATION OF GEOREFERENCED OBSIDIAN SAMPLES FROM FOUR SOURCE AREAS IN NEW MEXICO
Faculty: ROB STERNBERG, Franklin & Marshall College
M. STEVEN SHACKLEY, Geoarchaeological XRF Laboratory, Albuquerque, NM,
JOSHUA M. FEINBERG, Institute for Rock Magnetism, University of Minnesota
ANASTASIA STEFFEN, Valles Caldera Trust, and Dept. of Anthropology, University of New Mexico

OBSIDIAN ARTIFACT PROVENANCE STUDY OF THE PIEDRAS MARCADAS PUEBLO, ALBUQUERQUE, NEW MEXICO
ALEXANDRA FREEMAN, The Colorado College
Research Advisor: Christian M. Schrader, The Colorado College

MAGNETIC PROPERTIES OF CERRO TOLEDO OBSIDIAN
ANDREW GREGOVICH, Colorado College
Research Advisors: Christian M. Schroder, Colorado College and Joshua M. Feinberg, University of Minnesota

GEOCHEMICAL CHARACTERIZATION OF THE MULE CREEK OBSIDIAN, NEW MEXICO
CAROLINE HACKETT, Smith College
Research Advisor: Mark Brandriss

MAGNETIC CHARACTERISTICS OF OBSIDIANS IN MULE CREEK, NM
MICHAEL BABATUNDE HARRISON, California State University, Chico
Research Advisor: Todd J. Greene

BASIC PALEOMAGNETIC PROPERTIES OF OBSIDIAN FROM THE MOUNT TAYLOR REGION OF NEW MEXICO
MICHAELA KIM, Mount Holyoke College
Research Advisor: Michelle Markley

HYSTERESIS AND LOW-TEMPERATURE MAGNETIC PROPERTIES OF MOUNT TAYLOR OBSIDIAN
ZACH OSBORNE, St. Norbert College
Research Advisor: Joshua M. Feinberg, University of Minnesota - IRM

EFFECTS OF WILDFIRE ON FLOAT OBSIDIAN CLASTS FROM THE VALLES CALDERA, NEW MEXICO
AUDRIANNA POLLEN, Occidental College
Research Advisor: Dr. Scott Bogue

INTRA AND INTER-SOURCE MAGNETIC PROVENANCING OF MULE CREEK REGIONAL SOURCE OBSIDIAN
MARGO REGIER, Beloit College
Research Advisors: James Rougvie, Beloit College and Joshua M. Feinberg, University of Minnesota

Funding Provided by:
Keck Geology Consortium Member Institutions
The National Science Foundation Grant NSF-REU 1062720
ExxonMobil Corporation

GEOCHEMICAL VARIABILITY OF OBSIDIAN IN WESTERN NEW MEXICO WITH LABORATORY-BASED PXRF

KAREN ROTH,Washington and Lee University
Research Advisor: Jeffrey Rahl

Funding Provided by:
Keck Geology Consortium Member Institutions
The National Science Foundation Grant NSF-REU 1062720
ExxonMobil Corporation

Learning Science Through Research
Published by Keck Geology Consortium

Short Contributions
27th Annual Keck Symposium Volume
26 April, 2014
ISBN: 1528-7491

MAGNETIC CHARACTERISTICS OF OBSIDIANS IN MULE CREEK, NM

MICHAEL BABATUNDE HARRISON, California State University, Chico
Research Advisor: Todd J. Greene

INTRODUCTION

Rhyolitic glass (obsidian) is an important archeological material because it can easily be fractured into a sharp edge tool. Archeologists and geoarcheologists have commonly used geochemical methods to characterize obsidian in order to trace the geographic pathways from its geological source. To adequately determine the source of archaeological obsidian artifacts, it is essential to characterize unambiguous properties of the source to compare with the properties of the artifact. This study focuses on the magnetic characteristics of obsidians located at N. Sawmill Creek, Antelope Creek, and west Antelope Creek site within the Mule Creek locality, New Mexico.

BACKGROUND

The Mule Creek eruptive vent is located within the Mogollon-Datil volcanic field. The vent is approximately 11 km north of the settlement of Mule Creek and approximately 8 km east of the Arizona border (Ratté 2004). The rhyolite of Mule Creek dates between 17.7 and 19.0 Ma.

Obsidian is a disordered and aphyric volcanic rock associated with rhyolitic deposits and is defined by its holohyaline texture. Iron and magnesium make obsidian black and are key elements in microscopic grains of magnetite and hematite found in obsidian. Submillimeter hematite and magnetite grains are largely responsible for magnetic properties and can reflect the net result of the grain sizes, concentrations, compositions, morphologies, and spatial arrangement of magnetic minerals (Feinberg and Frahm 2013).

METHODS

In this study, low-field magnetic susceptibility, natural remanent magnetization, and alternating-field demagnetization are measured from 64 samples. Seventeen spatially distributed samples were measured from N. Sawmill Creek, thirty-three spatially distributed samples were measured from Antelope Creek, and fourteen samples were measured from west Antelope Creek site.

Low-field magnetic susceptibility measures the induced magnetization in response to a magnetic field. These measurements are commonly interpreted as reflecting the magnetic mineral concentration of a sample. The applied magnetic field in these measurements are weak and do not permanently affect the magnetization of the sample. Measurements were recorded with an MS2 Bartington susceptibility meter at California State University, Chico and at the University of California, Davis, Paleomagnetism Laboratory. Measurements take approximately 1-2 minutes per sample.

Natural remanent magnetization (NRM) refers to a permanent magnetic moment within the mineral grains given through natural processes. These moments are primarily due to the thermal remanent magnetization (TRM) acquired as the obsidian originally cooled from a lava flow. NRM is subjected to partial erasing by dissolution and alteration. Alterations are due to reheating by secondary lava flows, fire, lightning, etc. Full demagnetization measurements were recorded with a superconducting rock magnetometer (u-channel magnetometer) at the UC Davis Paleomagnetism

Laboratory, and take approximately 40-50 minutes per set of samples (up to 7).

Alternating-field demagnetization is usually effective in removing secondary NRM. Using stepwise demagnetization we can reveal the median destructive field (MDF), which is the strength of the applied field needed to decrease the initial remanent magnetization by a half. In this study, the demagnetization followed the steps of 0, 10, 20, 30, 40, 50, 60, 80,100, and 120 mT. Measurements were recorded with a superconducting rock magnetometer at the UC Davis Paleomagnetism Laboratory and take approximately 50-60 minutes per set.

RESULTS

Low-field magnetic susceptibility has some minor variability between the three sites. The mean value of samples from N. Sawmill Creek is 23.8 x 10^{-8} m^3kg^{-1}. The mean value of samples from Antelope Creek is 52.7 x 10^{-8} m^3kg^{-1}. The mean value of samples from the west Antelope Creek site is 14.9 x 10^{-8} m^3kg^{-1}. Antelope Creek can be distinguished by its relatively high mean value in susceptibility. The standard deviation between samples from N. Sawmill Creek is 21.2 x 10^{-8} m^3kg^{-1}. The standard deviation between samples from Antelope Creek is 25.6 x 1010^{-8} m^3kg^{-1}. The standard deviation between samples from the west Antelope Creek site is 8.6 x 1010^{-8} m^3kg^{-1}. The west Antelope Creek site can be distinguished by its relatively low variation in susceptibility values.

The original NRM of the three sites have some variability. The mean value of samples from N. Sawmill Creek is 1.53 x 10^{-3} Am^2 kg^{-1}. The mean value of samples from Antelope Creek is 3.46 x 10^{-4} Am^2 kg^{-1}. The mean value of samples from the west Antelope Creek site is 1.57 x 10^{-4} Am^2 kg^{-1}. N. Sawmill Creek can be distinguished by its relatively high mean value in NRM. The standard deviation between samples from N. Sawmill Creek is 1.43 x 10^{-3} Am^2 kg^{-1}. The standard deviation between samples from Antelope Creek is 2.90 x 10^{-4} Am^2 kg^{-1}. The standard deviation between samples from the west Antelope Creek site is 1.27 x 10^{-4} Am^2 kg^{-1}. N. Sawmill Creek can be distinguished by its relatively high values and variation in NRM. Figure 1 displays variability between the three sites with an NRM intensity vs. low-field susceptibility chart, in which the three sites are distinguished by N. Sawmill Creek's relatively high values in NRM and Antelope Creek's relatively high values in susceptibility.

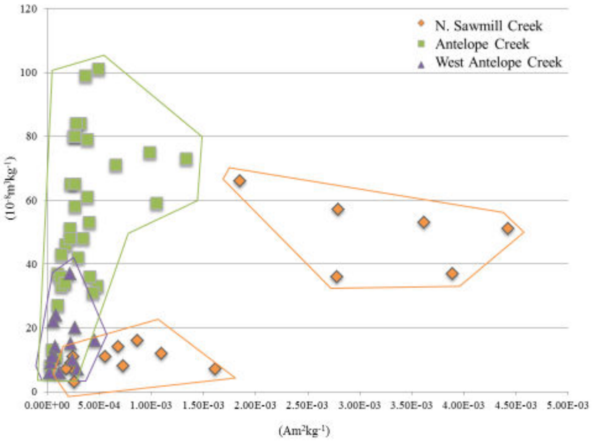

Figure 1. NRM intensity vs. low-field susceptibility. Samples on the scatter plot are boxed to display trends between the three sites.

Alternating field demagnetization data displays the direction of inclination and declination of NRM at each demagnetization step (Fig. 2a). The fraction of the original NRM remaining at each demagnetization step is also displayed (Fig. 2b). Samples typically tend to increasingly lose NRM intensity between each step (Figure 2b). A few samples that have high NRMs and dramatically lose NRM intensity between the first steps (low MDFs) probably display a recent isothermal remanent magnetization due to lightning strikes (Fig. 3). Sample MH061813-1-2-1 has the highest original NRM of its location (Fig. 3). Some samples may increase NRM between demagnetization steps. This is a result of two components of magnetization that are at high angles with each other. If the older component has a coercivity of remanence higher than the younger component, the NRM will appear to increase as the younger component is removed.

The median destructive field displays the approximate demagnetization step level in which more than 50% of the original NRM is removed. The median destructive field between samples has no real variability. The

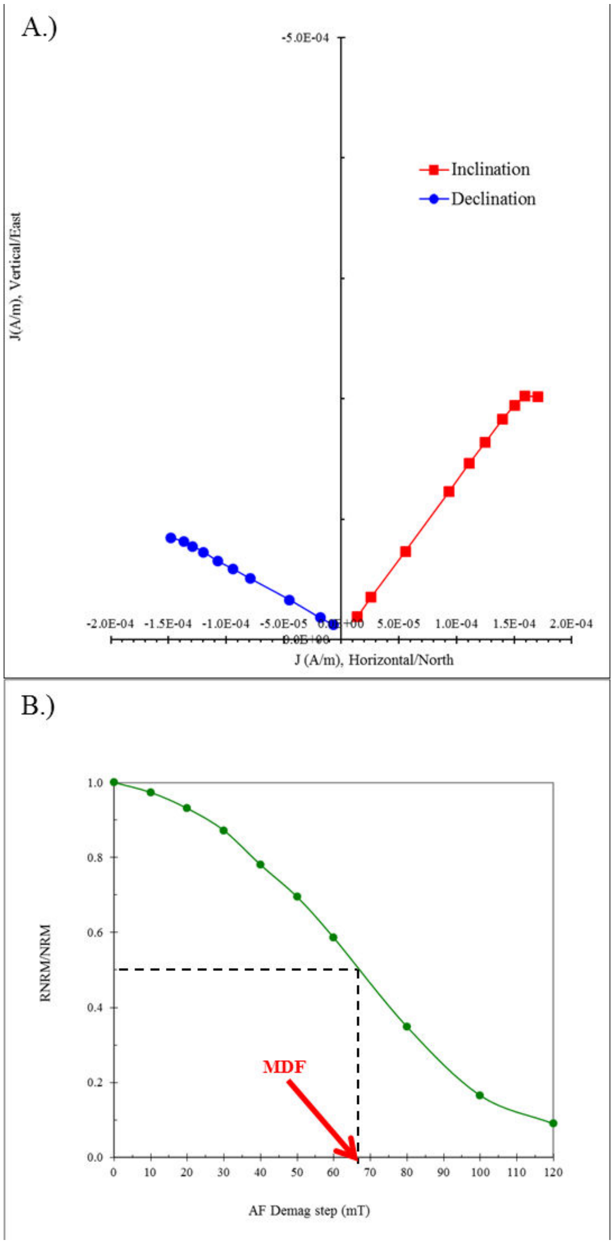

Figure 2. Alternate-field demagnetization data of sample MH062013-2-11 (west Antelope Creek). A.) Vector diagram of inclination and declination between each demagnetization step. B.) The fraction of the original NRM and the NRM during each demagnetization step.

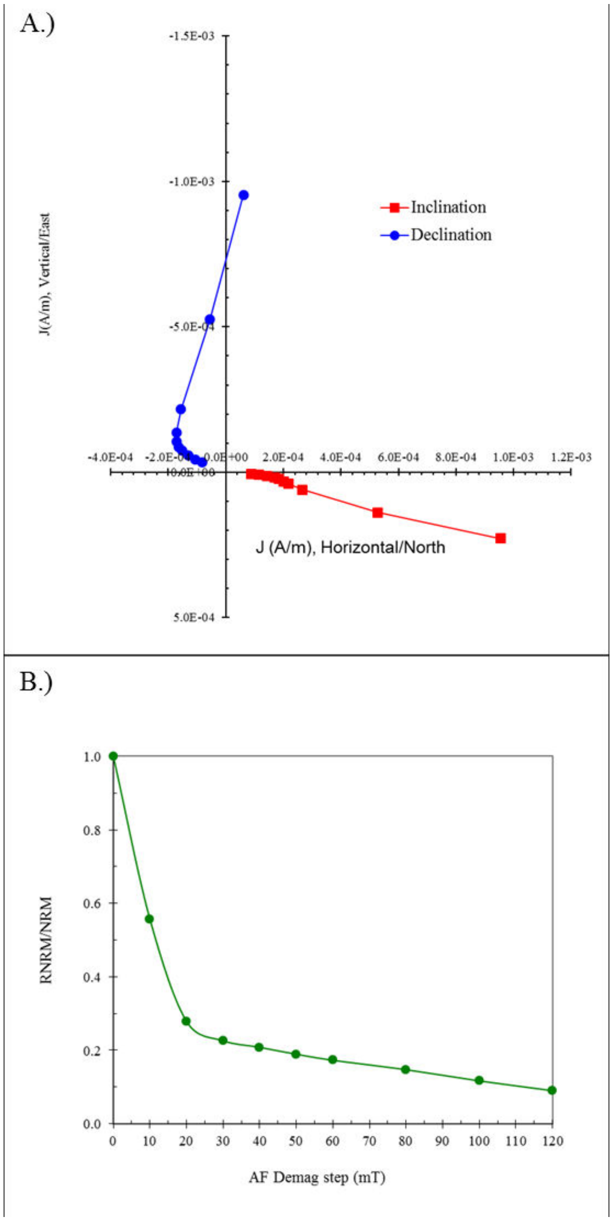

Figure 3. Alternate-field demagnetization data of sample MH061813-1-2-1 (Antelope Creek).

mean value of samples from N. Sawmill Creek is 89 mT. The mean value of samples from Antelope Creek is 97 mT. The mean value of samples from the west Antelope Creek site is 68 mT. The west Antelope Creek site can be distinguished by its relatively low mean value in MDF. The standard deviation between samples from N. Sawmill Creek is 10 mT. The standard deviation between samples from Antelope Creek is 26 mT. The standard deviation between samples from the west Antelope Creek site is 20 mT. N. Sawmill Creek can be distinguished by its relatively low variation in MDF values. Some variability between sites can be illustrated with a NRM vs. MDF chart (Fig. 4). west Antelope Creek is distinguished by its low MDF values while N. Sawmill Creek is distinguished with high NRM values.

DISCUSSION

In a related study, 33 additional samples from Antelope Creek and the west Antelope Creek site

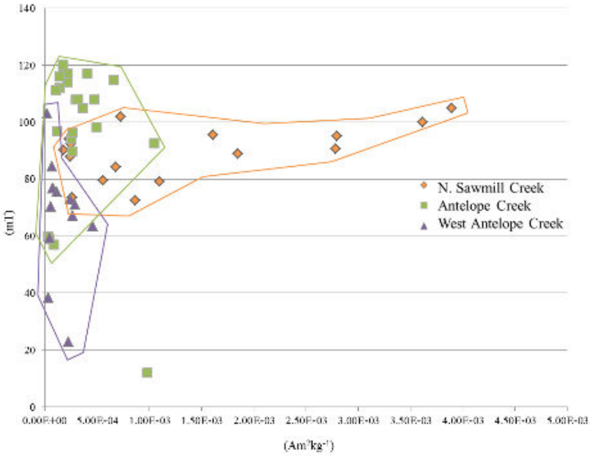

Figure 4. NRM vs. MDF. Samples on the scatter plot are bordered to display trends between the three sites.

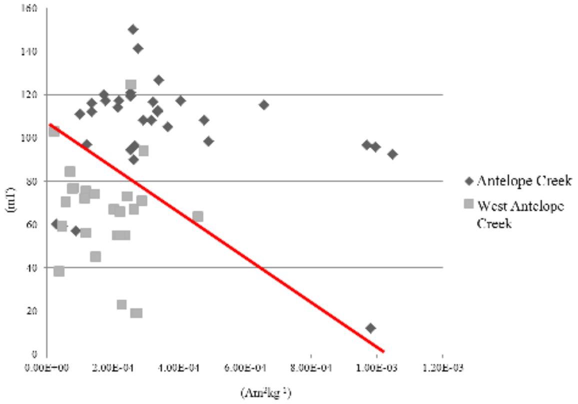

Figure 5. NRM vs. MDF. Samples on the scatter plot are separated with a line to distinguish Antelope Creek and west Antelope Creek.

were measured (Sternberg et al., 2013). When those additional data are compared with the current data, distinct similarities are exhibited. Samples from the west Antelope Creek site exhibit a generally low range in MDF. This low range helps distinguish west Antelope Creek from Antelope Creek when comparing on an NRM vs. MDF chart (Figure 5).

CONCLUSIONS

Magnetic analysis has been capable of distinguishing obsidian from N. Sawmill Creek, Antelope Creek, and the west Antelope Creek site. Although sample magnetic properties are generally similar, sites can be distinguished with the magnetic properties used in this study. The magnetic characteristic features found in this study appear to be promising for sourcing. Further study using more samples along with different methods is required for adequately characterizing obsidian in Mule Creek.

This portion of the project will not only contribute to the database but can be used for further research. Further work may include using isothermal remanent magnetization testing, multivariate statistical analysis of various magnetic parameters, along with comparing magnetic data to Mount Taylor and Valles Caldera sites in compiling magnetic characteristics throughout New Mexico.

ACKNOWLEDGEMENTS

I want to thank everyone behind the Keck Geology Consortium along with ExxonMobil for providing additional funding for the project. I want to thank for Rob Sternberg, Joshua Feinberg, Steven Shackley along with my teammates Alexandra Freeman, Andrew Gregovich, Caroline Hackett, Michaela Kim, Zach Osborne, Audrianna Pollen, Margo Regier, and Karen Roth and additional participating faculty Tim Flood, Christian Shrader, Ana Steffen, and Ryan Samuels. I am very grateful for all Chico State geology faculty especially Terry Kato, Ann Bykerk-Kauffman, and Todd Greene. Finally, I would immensely like to thank Ken Verosub for access to the UC Davis Paleomagnetism Laboratory and for taking excess time to help me with the project – without his aid; this project would not be possible.

REFERENCES

Feinberg, J.M., Frahm, E., 2013, From flow to quarry: magnetic properties of obsidian and changing the scale of archaeological sourcing: Journal of Archaeological Science, v. 40, p. 3706-3721.

Ratté, J.C., 2004, A guide to the Mule Creek volcanic vent, the rhyolite of Potholes Country, and obsidian ledges, Gila National Forest, southwestern New Mexico: New Mexico Geology, v. 26, no. 4, p. 111-122.

Sternberg, R.S., Samuels, R., Feinberg, J.M., Shackley, M.S., (2013), Magnetic properties of a new obsidian source, west Antelope Creek, Grant County, New Mexico, Abstract GP53B-1136 presented at 2013 Fall Meeting, AGU, San Francisco, Calif., 9-13 Dec.