IAOS

International Association for Obsidian Studies

Bulletin

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CONTENTS

NEWS AND INFORMATION

IAOS Annual Meeting

The 2012 annual meeting of the International Association for Obsidian Studies will be held during the Society for American Archaeology meetings in Memphis, Tennessee, in April. Please see your SAA program for time and location.

CONSIDER PUBLISHING IN THE IAOS *BULLETIN*

The *Bulletin* is a twice-yearly publication that reaches a wide audience in the obsidian community. Please review your research notes and consider submitting an article, research update, news, or lab report for publication in the IAOS *Bulletin*. Articles and inquiries can be sent to cdillian@coastal.edu Thank you for your help and support!

PXRF Shootout at the 2012 SAA Meetings

Widespread availability in portable XRF instrumentation has resulted in a major paradigmatic shift in how obsidian source studies are conducted. This has resulted in concerns by some about the potential misuse of this emerging technology as well as a host of questions regarding accuracy, precision, and reproducibility. Following Shackley's recent essay in the SAA Archaeological Record, we will hold a PXRF "shootout" at the 2012 SAA Meeting in Memphis. The purpose of this round robin exercise will be to evaluate the current state of inter-laboratory reproducibility when conducting quantitative portable XRF analyses of obsidian. Preregistration for this event is required and participation is limited. Contact Jeff Speakman archsci@uga.edu to reserve your spot.

NOTES FROM THE PRESIDENT

Belated New Year's greetings to you all! Already in week two of classes with the first major conference under my belt (annual meeting of the *Archaeological Institute of America*, the panel chaired by our very own Rob Tykot) and thoughts turning to this year's IAOS gathering at the Memphis SAA's (18-20th April). This is also my final note to you in my role as President. I have been hugely honoured to have been accorded this role and have enjoyed it immensely. There is always more that you wish you could have done, such as organise a conference on some wondrous obsidian-bearing island, an idea I am still working on, albeit for a time beyond my presidential responsibilities. I, and many others, are also very keen to have a greater presence at non-US based conferences, something we again continue to look at via such venues as the *European Association of Archaeologists* annual meetings (well once they have moved beyond the nose-bleedingly expensive Scandaweigian venues), plus the *International Society of Archaeometry* bi-annual conferences, *GMPCA* and others.

The past two years have made me realise even more keenly what a dynamic group of scholars our *Association* and field more generally represents. The SAA's for the past couple of years – and the upcoming meeting is no exception – have had dedicated *IAOS* panels, while there have been a plethora of other obsidian oriented papers and posters scattered throughout these proceedings. This dynamism and growth we can also happily view being reflected in academic end-product, with a ten-fold increase in obsidian related papers in the major archaeological and geo-archaeological journals over the past decade, with over 36 articles published last year on *obsidian sourcing alone* in *Journal of Archaeological Science*, *Archaeometry*, *American Antiquity*, *Latin American Antiquity* and others (Kyle Freund pers. comm.). While the sourcing contingent of our membership can be justifiably proud of their productivity, this of course only represents a part of our scientific engagement with obsidian. A number of our members continue to be involved in hydration dating, an area of research that is in the midst of critical reflection and dynamic methodological debates (as many will have appreciated with the talks of Steffen & Rogers / Anovitz *et al* last year at the SAA's), while others on the material science end of our academic spectrum pursue studies on the materials' physical properties (as celebrated in a *GSA* panel organised by our President-elect a couple of years back in Portland). While we can be justifiably proud of our achievements and research diversity, there is one group I believe that is yet to be fully represented in the membership of the *IAOS*, namely those working primarily on techno-typological issues, i.e. the specifics of how past cultures consumed these materials once they gained access to the quarries and/or the products of exchange. Prior to my own engagement in characterisation studies my primary research focus was technological; following on Robin Torrence in the Aegean, the region's Bronze Age focus on pressure-flaked blade production immediately led one to a wealth of literature from Mesoamerica, the Near East and beyond. This work has been generated by a large number of scholars who alas do not tend to be members of the *IAOS* and tend to present within their own regional panels at the SAA's. It would certainly be a desire of mine to see a closer integration in the *IAOS* between the technologists and those working on sourcing (at Çatalhöyük we have long stressed the importance of integrating these variant means of studying obsidian tools [cf. Carter *et al JAS* 2006), something I shall be attempting to part-rectify this February in Barcelona at the 7th workshop on Pre-Pottery Neolithic lithics, a gathering that brings together numerous Eastern Mediterranean lithic specialists, many of whom are working with obsidian assemblages. With a stack of membership forms in one hand, and a sharp stick in the other... that should do the trick, ole!

The SAA's may still be a few months off, but there is a lot to look forward to. Mike Glascock and Ana Steffen have stepped up to the plate to organise not one, but *two* panels under the *IAOS* banner on Friday 20th April (see the announcements in this *Bulletin*). In the morning we have the poster session *Obsidian Studies Across the Americas: Alaska to Argentina and Beyond*, followed in the afternoon by a symposium entitled *World of Obsidian: Sourcing, Dating and Beyond*. We also have our annual *Association* meeting (please see your SAA program for meeting time and location), where we hope to see as many of you as possible. Last and by no means least, we have the *IAOS* sponsored *PXRF Shootout*! This gathering of pXRF users is to be held in one of the suites of the official conference hotel (though it is not part of the official SAA programme), the exact time and place to be circulated in due course. I, along with many others, am very excited at not only what this shootout will produce, but also what it *represents*.

The *PXRF Shootout* is the brainchild of Jeff Speakman, Steve Shackley, Mike Glascock and Arlen Heginbotham. Its origin lays in an acknowledgement of the enormous interest in and application of portable XRF instruments over the past few years (indeed the technique can be seen as a prime factor in the aforementioned increase in obsidian sourcing publications over the past decade). With new techniques come the need of a careful understanding of these instruments' capabilities and exactly how they are being employed (standards, analytical protocols etc, anything one would expect to be informed upon with a desktop XRF, or any other instrument for that matter). Hence our colleague's desire to run this workshop as a "round robin exercise... to evaluate the current state of inter-laboratory reproducibility when conducting quantitative portable XRF analyses of obsidian". It will involve a group of users bringing their own pXRFs to the gathering, where they will then be asked to detail their "experimental setup, calibration routine, and values they determined from the analyses", the latter being run on 10-12 obsidian samples whose values are known to the organisers but not to the analysts. Ultimately this workshop represents a direct follow-up to the inter-laboratory comparison project organised by Mike Glascock in 1999, when sub-samples of the same piece of obsidian were analysed by a number of different labs / techniques around the world (published as a special report in the *IAOS Bulletin* 23: 13-25). While the users' data – and hopefully critical commentary thereof – will be the main point of interest for our community, I am also thrilled by what this gathering represents. I feel very strongly that our membership is taking a lead in critically reflecting upon our methodological bases and analytical applications, an extremely healthy state of affairs for a scientific community and something we can be justifiably be proud of. Indeed, aside from the Glascock 1999 paper, our members have also recently published other papers on inter-lab / technique comparability (e.g. Hancock & Carter *JAS* 2010; Poupeau *et al JAS* 2010), not least Steve Shackley's timely reflections on the proliferation of pXRF use in the *SAA Archaeological Record* (November 2010).

Finally, might I be allowed a small indulgence, in bringing you up to date with my own work, with the *McMaster Archaeological XRF Lab* [MAX Lab], now fully operational, thanks to a grant from the Canadian Foundation for Innovation (**Figure 1**). This small facility is Canada's first lab dedicated to the elemental characterisation of archaeological and related materials, with a current focus – surprise, surprise – on obsidian studies. Central to our work is the ThermoScientific Quant'X EDXRF spectrometer, the same instrument employed so successfully by Steve Shackley over the past few years – indeed it was largely his inspiration,

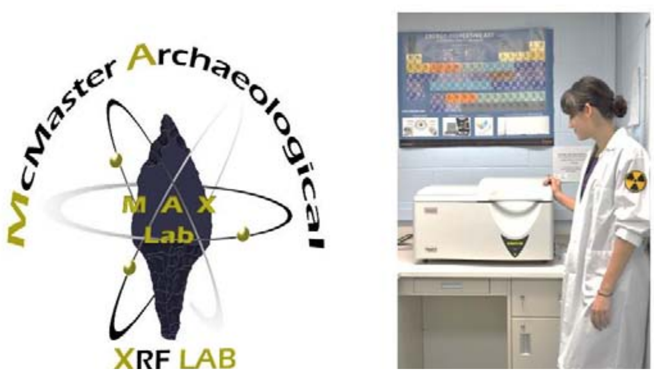

Figure 1. Left: MAX Lab logo. Right: Sarah Grant operating EDXRF.

help and friendship that got us where we are today with the new lab. Thanks to another award from the Social Sciences and Humanities I have been able to collect geological samples from a great many obsidian sources throughout the Aegean and Anatolia, accompanied by Daniel Contreras, Kyle Freund and my dedicated undergrad RA's, the latter – under careful supervision – generating the vast majority of the elemental data over the past couple of months (**Figure 2**). It has been a wonderful period of productivity and generating projects and collaborations anew, working on various Neolithic assemblages from Anatolia (Çatalhöyük, Kortik Tepe and Göbekli Tepe amongst others), Syria (Abu Hureyra, in collaboration with the Royal Ontario Museum), and Iraq (Tell Nader), plus Mayan artefacts from Minanha and Buenavista del Cayo (in collaboration with scholars from Trent and Calgary universities). The lab is providing a wonderful opportunity for student training, both at the undergraduate and graduate level, all of whom enjoy a research profile and co-authorship of academic papers alongside the general maintenance and running of the lab. We have our first – minor – report published in the 2011 issue of *Anatolian Studies*, while other projects have been presented at last year's SAA's and the annual meetings of the *American Schools of Oriental Research*. I am now actively looking for graduate students to develop their own projects here with us in Ontario, so please pass the word and please come and visit should you be in the area.

Well that will have to be my final few words, or Carolyn – who has been waiting all too patiently for me to finish this – will have my guts for garters. Next time you will be hearing from Ellery Frahm who takes over this position in April at the SAA's; congratulations to him for his new post-doc and exciting new life in Sheffield. I look forward to seeing many of you in Memphis, thank you once again for voting me into this honoured position and wish you all the very best for 2012!

Tristan Carter
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President IAOS
Associate Professor, Dept. Anthropology, McMaster University / Director MAX Lab

Figure 2 – Sarah Grant, undergrad Research Assistant (and IAOS member) working with the new ThermoScientific Quant'X EDXRF spectrometer in the MAX Lab. Lower left: Renee Ford.

NEWS AND NOTES: Have announcements or research updates to share? Send news or notes to the *Bulletin* editor at cdillian@coastal.edu with the subject line "IAOS news."

IAOS Sponsored Symposium at the 2012 Society for American Archaeology meeting:

A World of Obsidian: Sourcing, Dating and Beyond
Michael D. Glascock, Organizer

Session Abstract:
One of the greatest success stories in archaeology is the ability to trace obsidian artifacts back to their original source through the use of chemistry. This was first accomplished in the mid-1960's by Colin Renfrew and colleagues who studied the trade and exchange of obsidian artifacts in Anatolia. However, the success of obsidian as an analytical archaeological material is not limited to its potential for sourcing. Other applications for obsidian include dating, technology, use-ware, ritual-symbolism, etc. In addition to sourcing studies, the obsidian researchers in this symposium will compare and contrast various aspects of their obsidian research both regionally and on a world scale.

Speakers:
1. Ellery Frahm, University of Minnesota
2. Sarah Grant, McMaster University
3. Mark Golitko, Field Museum
4. David Williams, University of Colorado
5. Charles Knight, University of Vermont
6. Martin Giesso, Northeastern Illinois University
7. Raven Garvey, University of California-Davis
8. Sean Dolan, New Mexico State University
9. Colby Phillips, University of Washington
10. Jeff Rasic, National Park Service-Alaska

Discussants:
11. Robert Cobean - INAH-Mexico
12. Robert Tykot - University of South Florida

From the IAOS Webmaster:

NEW IAOS ONLINE LIBRARY AVAILABLE FOR A SNEAK PREVIEW

Please see the IAOS Home Page for news about our new online PDF library at http://members.peak.org/~obsidian/library_index.html. We're assembling a rapidly-growing collection of obsidian-related literature and have so far put together a fairly random group of articles, papers, monographs, theses, and dissertations. If you have Adobe Acrobat versions of any of the above to contribute to the library, please contact me, Craig Skinner, at cskinner@obsidianlab.com (or simply attach the PDF's to the email) and I'll get them posted promptly.

IAOS Sponsored Poster Session at the 2012 Society for American Archaeology meeting:

Obsidian Studies Across the Americas: Alaska to Argentina and Beyond

Anastasia Steffen, Organizer
Thomas Hanson, Chair

Session Abstract:

Obsidian analyses can inform on transport, trade, temporality, and transformations of the archaeological record. The assembled posters span this range of inquiry and provide a diverse set of studies representing prehistoric records in North, Central, and South America. Also included are investigations that provide productive comparisons to these New World contexts. Topics include obsidian geochemical sourcing and hydration chronometry, as well as studies of reduction technology, site formation processes, and artifact utilization.

Posters:

1. *Freshmen Sourcing Obsidian? Using PXRF in the Introductory Archaeology Classroom*
   Bonnie J. Clark
2. *Ten years of analysis in obsidian procurement from the Early to the Late Holocene on both sides of the temperate Andes*
   Valeria Cortegoso, Martin Giesso, Victor Durán, Lorena Sanhueza, and Michael D. Glascock
3. *Indirect Effects of the Las Conchas Wildfire on Obsidian Lithic Reduction Sites*
   Thomas Hanson and Michaela Grillo
4. *pXRF Sourcing of Obsidian Artifacts from Pepperwood Preserve, Sonoma County, California*
   Michelle Hughes Markovics, Robert H. Tykot, and Benjamin Benson
5. *Identification of Thermally Altered Obsidian Toward Understanding Site Formation Processes in Prehistoric Hunter-Gatherer Sites*
   Yuichi Nakazawa
6. *Obsidian Acquisition Strategies in a High Elevation Desert in NW Argentina.*
   Elizabeth Pintar, Jorge Martinez, and Michael Glascock
7. *The Secondary Distribution of Archaeological Obsidian in Rio Grande Quaternary Sediments, Jemez Mountains to San Antonito, New Mexico: Inferences for Prehistoric Procurement and the Age of Sediments*
   M. Steven Shackley
8. *Obsidian in the Aleutians Islands and Alaska Peninsula*
   Robert J. Speakman, R. Game McGimsey, Richard Davis, Michael Yarborough, and Jeff Rasic
9. *Shattered: Direct Effects of the Las Conchas Fire at Jemez Obsidian Quarries*
   Anastasia Steffen
10. *Obsidian Hydration Dating by Infrared Photoacoustic Spectroscopy*
    Christopher Stevenson
11. *Using PXRF and NAA to Reveal Prehistoric Mobility and Trade Patterns in Central California*
    Carly S. Whelan, Jeffrey R. Ferguson, Jeffrey S. Rosenthal, and Scott R. Jackson
12. *Relatively Useful: Applications of Obsidian Hydration in the Northern Rio Grande*
    F. Scott Worman and Patrick Hogan

2012 International Association for Obsidian Studies
PXRF Shootout

Society for American Archaeology Meeting, Memphis, TN
April 18, 2012 from 8:00am–6:00pm (exact location TBD)

Organizers:

Jeff Speakman, Center for Applied Isotope Studies,
University of Georgia, Athens, GA
M. Steven Shackley, Archaeological XRF Laboratory,
Albuquerque, NM
Michael D. Glascock, Archaeometry Laboratory, University of Missouri
Research Reactor, Columbia, MO
Arlen Heginbotham, J. Paul Getty Museum, Los Angeles, CA

Over the past 10 years, widespread availability in portable XRF instrumentation has resulted in a major paradigmatic shift in how obsidian source studies are conducted. This has resulted in concerns by some about the potential misuse of this emerging technology as well as a host of questions regarding accuracy, precision, and reproducibility. Following Shackley's recent essay in the SAA Archaeological Record (see http://www.saa.org/Portals/0/SAA/Publications/thesaaarchrec/Nov2010.pdf), we will hold a PXRF "shootout" at the 2012 SAA Meeting in Memphis. The purpose of this round robin exercise will be to evaluate the current state of inter-laboratory reproducibility when conducting quantitative portable XRF analyses of obsidian.

The round robin will occur from 8:00am–6:00pm on Wednesday April 18, 2012. Participants will be asked to analyze 10-12 obsidian samples (and optionally 4 ceramics) using their portable instrument and preferred calibration routine. Upon completion of the measurement, participants will complete a worksheet that describes their experimental setup, calibration routine, and values they determined from the analyses. Participants will receive 2–3 pieces of obsidian (and ceramics) that were included in the round robin to take with them. Results from this study will be tabulated and published in an appropriate venue.

If you own a portable XRF instrument and have analyzed or are contemplating the analysis of obsidian, this is something you will not want to miss!

Preregistration for this event is required and participation is limited. Contact Jeff Speakman archsci@uga.edu to reserve your spot.

Announcement: Fieldwork Opportunity, Quispisisa Obsidian Source, Peru

We are conducting several months of fieldwork at the Quispisisa obsidian source in southern Ayacucho (Peru) and may have space for a few more participants. The research background is described in a recent publication available here: **Quarrying Evidence at the Quispisisa Obsidian Source, Arequipa, Peru** *Latin American Antiquity* (2011).

This is not a field school and participants must have archaeological field experience (e.g., a field school or comparable training). The project is focused on lithic technology as we'll be studying the material remains of obsidian quarrying and production in source area and at nearby workshops, and will also include preliminary investigation of the anthropogenic landscape as we extensively survey the surrounding area. The project will be making considerable use of emerging digital methods, GPS technology, and GIS in both the field and the lab.

Ideally participants will have a strong background in at least two of the following three areas:

1. Experience with technical analysis of lithics: we'll be focusing primarily on core reduction and flake morphology as there are few finished tools at the source area.
2. Strong proficiency in Spanish: we'll be predominantly working Spanish both in the lab and the field).
3. Experience and ability with digital methods in archaeological fieldwork: we'll be managing project data including imagery as well as GPS and total station spatial data in a GIS.

The fieldwork will run from the beginning of July through the end of August 2012, and a month of lab work in Ayacucho, Peru will follow through the end of September. We ask that participants commit to a minimum of five weeks of involvement in the project and preference will be given to people who can stay longer and/or through the September lab period. The project will cover room and board while working with us. Travel expenses to the vicinity of the project are the responsibility of the participants. In different phases of the project we'll be based in a small village at 3600m above sea level with electricity but otherwise few modern amenities and camping at the obsidian source itself, a 2 hour moderately strenuous hike in at an elevation of 4000m.

A webpage further describing our project can be seen at
http://mapaspects.org/projects/quispisisa

For further information please contact Nico Tripcevich and Daniel Contreras at the following project email address: quispi@MapAspects.org. Thank you for taking an interest in our research and please send this notice along to other interested parties.

EXPANDING THE RANGE OF PXRF TO ETHNOGRAPHIC COLLECTIONS

Robin Torrence[1, 2], Peter White[2] and Sarah Kelloway[2]
[1]Anthropology, Australian Museum, 6 College Street, Sydney, NSW 2010, Australia
[2]Archaeology, SOPHI, University of Sydney, NSW 2006, Australia

Abstract

By developing new methods for presenting the samples to the PXRF instrument, a pilot project on obsidian-tipped spears from the Admiralty Islands, Papua New Guinea has expanded the range of artifacts analysed by portable x-ray fluorescence (PXRF) to include large, fragile artifacts housed in ethnographic collections. The characterization study demonstrated a lack of correlation between obsidian source and the method of hafting suggesting spear production was independent of obsidian quarrying.

Introduction

Portable x-ray fluorescence (PXRF) has made a significant contribution to archaeological characterization studies largely because it has substantially reduced the cost of the necessary large numbers of non-destructive analyses required to achieve representative samples (e.g., Sheppard *et al.* 2010; Nazaroff *et al.* 2010). A major advantage of this new technology-- portability –is essential for access to museum and private collections, but has only just begun to be realised (e.g., Tykot 2010; Freund and Tykot 2011). The analysis of ethnographic objects housed in museum collections, however, can pose new problems because the artifacts are often quite fragile. This study developed a useful method for mounting the instrument to reduce the risk of damage to museum specimens of hafted obsidian-tipped spears and daggers from Papua New Guinea.

Obsidian from various sources in the Admiralty Islands of Papua New Guinea (Figure 1) was widely traded throughout prehistory beginning in the Pleistocene (Fredericksen 1997; Summerhayes 2004). At the time of European contact in the late 19th century, obsidian-tipped spears and daggers were widely used in the Admiralty Islands, but very little is known about the trading mechanisms responsible for the movement of obsidian from the sources. Over 50 years later Mead (1930) described an intra-regional pattern of exchange in which local communities specialised in the production and exchange of particular products. Given the rapid speed of cultural change in the region (cf. Torrence 1993; 2000; 2002), earlier trading patterns may have been quite different. To evaluate whether an archaeological study of ethnographic material can help reconstruct historic trade patterns, we conducted a pilot chemical characterization study of obsidian spears held in museum collections.

Two very different techniques were used to bind obsidian tips to the Admiralty spears and daggers. In one case, a loose bundle of sago fibres was used to join the stone point to the wooden spear. This was then covered by a putty-like substance made from the Atuna (*parinarium*) nut. Patterns were often incised into the putty before it hardened and the completed haft was painted (Figure 2). The second technique used a wooden collar to bind the blade to the shaft. Next twine was wound around the haft creating a series of intricate patterns (e.g. Moseley 1877: pl. XX). Paint was used to highlight the resulting designs and the base of the wooden collar was also painted and often carved (Figure 3). Early travelers described obsidian point production by specialist knappers resident at the well-known obsidian sources on Lou and Pam Lin islands (Parkinson 1905; 1999: 158 [1907: 373], Mikloucho-Maclay in Nevermann 1934: 234), but since we lack a pre-1970s account of how the hafts were constructed and decorated, it is not known whether the two different hafting techniques relate to function, cultural practices, or manufacturing centres. As a first step in investigating whether the difference in the handles is correlated with various obsidian sources, we conducted a characterization study of the obsidian tips. The analysis of a reasonable sample size of large, fragile objects housed in museum collections demanded the use of an instrument that could be moved to the artifacts. Portable EDXRF was selected because previous studies have demonstrated that, although the ppm data may not be as accurate as other techniques, the data captured provide excellent discrimination among obsidian sources in the Pacific region (Sheppard *et al.* 2010; cf. Nazaroff *et al.* 2010).

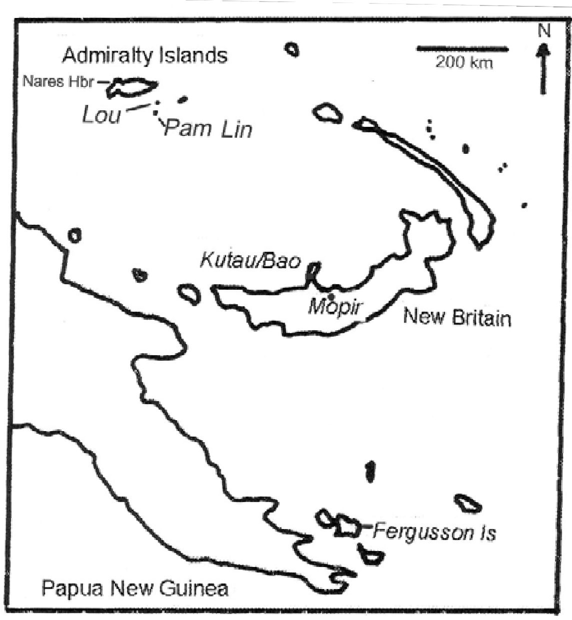

Figure 1. Map showing Nares Harbour on Manus where obsidian-tipped artifacts were traded to *HMS Challenger* crew and the major obsidian sources in Papua New Guinea.

Methods

The particular sample of spears chosen for the study was collected by various crew members from the *HMS Challenger* expedition, which visited Nares Harbour on Manus Island (Figure 1) between March 3-10, 1875 (e.g. Moseley 1877; 1892; Spry 1877). These are among the earliest collections of Admiralty obsidian artifacts in museum collections; their provenience is secure, and the assemblages contain obsidian-tipped spears and daggers with both forms of haft. Since the spears were obtained from communities situated at the opposite end of the island from the obsidian sources on Lou and Pam Lin (Figure 1), they are assumed to represent a broad sample of material that was circulating within the Admiralty-wide trading system operating at that time. The study sample comprised 54 spears and daggers, of which 32 are currently housed in the British Museum and 22 are from the Pitt Rivers Museum, Oxford.

A Bruker Tracer III-IV portable EDXRF analyzer with a rhodium tube x-ray source and a peltier-cooled, silicon PIN diode detector, equipped with a filter consisting of 6 mil copper (Cu), 1 mil titanium (Ti) and 12 mil aluminum (Al) and operating at 40kV and 20μA for 180 seconds, was used to characterize the obsidian spear tips. Elements shown by previous studies to be good discriminators for obsidian were used: Fe, Rb, Sr, Y, Zr, and Nb (e.g. Nazaroff *et al.* 2010). Stability of the instrument was monitored by running two standards of well-characterized obsidian (AD 2000 Wekwok [Bird *et al.* 1997; Ambrose *et al.* 2008] and the Pachuca source from Hidalgo, Mexico [Glascock 1999]) at the beginning and end of each round of analyses. Measurements were taken from least four different locations on each artifact and the results averaged.

To capture the maximum number of x-rays, the x-ray emission window of the instrument should be in direct contact with the obsidian

Figure 2. A typical obsidian-tipped blade with an incised gum haft (PR 1884.19.31) under analysis by PXRF at the Pitt Rivers Museum (photo by Robin Torrence by courtesy and copyright Pitt Rivers Museum, University of Oxford).

Figure 3. A spear haft with a wrapped and painted design. BM +700 was characterized to the Wekwok source on Lou Island (photo courtesy of the British Museum).

artifact with the beam path fully covered. The Bruker instrument was designed to be hand-held and placed securely against the material to be measured, but it is difficult to maintain a stable instrument position for the relatively long times required by obsidian analysis (in this case 180 seconds). A common practice is to mount the instrument on a stand with the x-ray emission window facing upward and then place samples on top of it (cf. Nazaroff *et al.* 2010: 889). However, the sample stage provided by the manufacturer is not adequate to balance large retouched artifacts in place for measurement. Additionally, radiation safety issues prohibit manually holding the artifact in place while x-rays are being emitted. To solve the problem of measuring large and irregular samples, we trialed two techniques that either (1) increase the size of the platform for supporting the artefact or (2) the normally upright direction of the instrument was reversed to point down on an object held in place on a flexible pillow. These methods were developed due to demands by museum curators and conservators that the risk of damage to artifacts be minimal, but were also found to improve the ease of measurement.

In the first case we built a large perspex stage (20 cm x 20 cm) cut to fit over and sit slightly below the machine head and supported by legs screwed into mounting holes on the sides of the instrument (Figure 4). The large stage provides good support for large fragile obsidian objects and satisfies the reasonable concerns of museum curators, but despite placing multiple props under various parts of the artifact (we use rubber erasers), it is often difficult to balance retouched objects so that a flat surface has a tight contact with the x-ray emitter.

In the case of obsidian-tipped artifacts hafted on shafts up to 2 meters in length, it was necessary to design a different method. After some experimentation, we found the most satisfactory approach is to mount the instrument on a tripod with a reversible head so that the x-ray emission window faces downward (Figure 2). After the instrument is secured (which needs two screw holes per side and a bar to prevent it swinging), the artefact is placed on an elastic cushion (e.g. sponge) and together the artifact and pillow are gently pushed down and positioned under the instrument. Once the artifact is in situ, the pillow will rebound and press the selected flat surface so that it fits snugly against the emitter. By maneuvering the artifact on the pillow, it is possible to take measurements on flat areas that would be very difficult to balance on a stage, such as the blade scar shown in Figure 2 which required the spear to be tilted on its side. When firmer support was required to bring an area into tight contact with the instrument, we placed an eraser between the cushion and the artifact. This method increases the number of areas on the artifact that can be measured to such a large degree that we have now adopted it to measure all large obsidian artifacts, whether they are hafted or not. Setting the instrument in place first and then moving the object up to it also minimizes risk of breakage.

Figure 4. A large obsidian artefact placed on a large stage purpose-built for the Bruker Tracer III-IV PXRF (photo by Peter White)

Results and Conclusions

The spectra obtained from the Admiralty Island artifacts were characterized to geochemical groups by comparison with an extensive reference collection of 244 samples from the four major source regions in Papua New Guinea: Admiralty Islands (63) West New Britain (150); Fergusson Islands (20); Vanuatu (11) (cf. Sheppard *et al.* 2010) (Figure 1). Discriminant analysis classified all the artifacts as belonging to the Admiralty sources (cf. a plot of the first three discriminant functions in Figure 5) and the majority were further classified into the Umrei/Umleang source on Lou Island (cf. the discriminant plot in Figure 6). Only two spears [one from the British Museum (Figure 3] and another from the Pitt Rivers) were shown by discriminant analysis to most closely match samples collected by Ambrose (Ambrose *et al*. 1981: 7) at Wekwok, situated on the northwest side of Lou Island. There is nothing unusual or distinctive about the two Wekwok spears. The wrapped designs are relatively common and the obsidian blades fall within the overall range of shapes and sizes of the samples as a whole, although the surface of the Pitt Rivers Museum blade is slightly irregular due to a flaw in the obsidian.

Archaeological and ethnographic studies have documented the extensive use of the Umrei/Umleang outcrops throughout prehistory and up to the modern day (e.g. Ambrose *et al.* 1981; Fullagar and Torrence 1991; Fredericksen 2000), but the Wekwok source has rarely been found in archaeological assemblages (Fredericksen 1997) and there is no historic data concerning the use of this location for blade production, although Ambrose *et al.* (1981: 7) and Richard Fullagar (personal communication) did observe lithic debitage at that locality. The absence of spear and dagger tips in the *HMS Challenger* assemblage made with obsidian from Pam Lin is also unexpected since there are early 20th

century accounts of knappers on the island (Parkinson 1905; 1999: 158 [1907: 373]).

Although the pilot study should be expanded to explore variation through time and across space, the results obtained already provide a glimpse of trading patterns in the Admiralty Islands during the late 19^{th} century. The obsidian characterization supports Mead's (1930) account of communities specializing in certain commodities, but the findings show that the situation was much more complex since raw material obtained from one place could be converted by a range of methods into objects that were possibly traded on. Given the predominance of the Umrei/Umleang obsidian in all the types and decorations of spear and dagger hafts studied, it seems clear that there was not a one-to-one correlation between the source of the obsidian and the place where the decorated artifact was manufactured. Although during the past thirty years, (De'Ath 1989; Ambrose personal communication) spears were made at the Umrei/Umleang quarry and village using the incised gum handles, in the past obsidian was probably also traded in the form of nodules and/or blades to producers of the very different wrapped style handles. Given the great variety in forms and decoration of spears and daggers among the communities in Nares Harbour when the *HMS Challenger* visited, the artifacts had possibly passed through a number of exchange links stretching across the entire island group.

Finally, the study underlines the substantial potential of PXRF instrumentation for expanding archaeological research on obsidian trade to include both large and fragile artifacts and material housed in museum collections. We have suggested two ways in which a PXRF spectrometer can be adapted for analyzing museum materials. In the cases when it would be impossible to analyse a significant sample of material with more sophisticated technology, PXRF has a critical role to play in research.

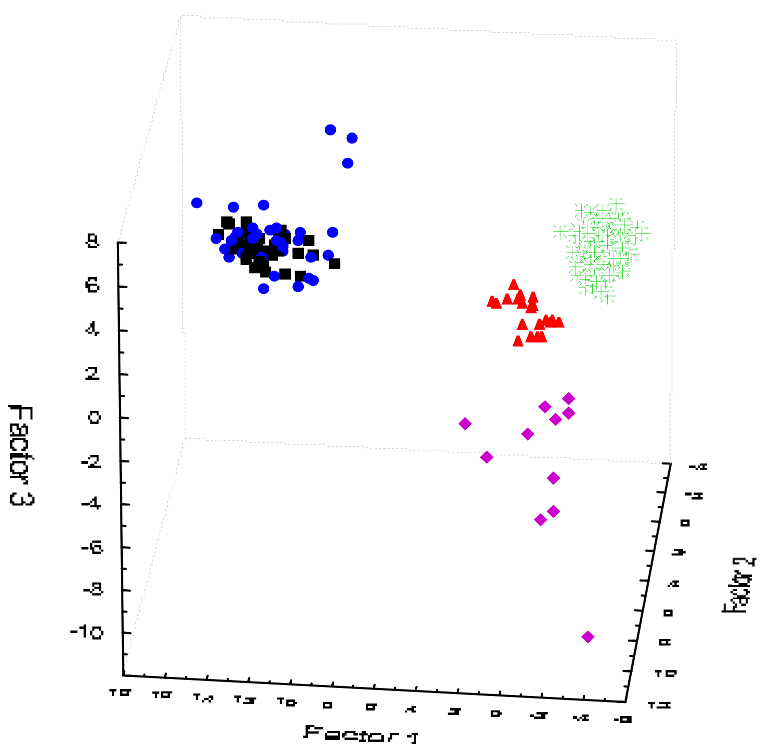

Figure 5. Plot showing the separation of the major Papua New Guinea obsidian sources using the first three factors resulting from discriminant analysis, with all artefacts plotting with the Admiralty source group. Black solid squares represent artefacts; blue solid circles Admiralty sources; green stars West New Britain sources; red solid triangles Vanuatu sources and purple solid diamonds East and West Fergusson Island sources.

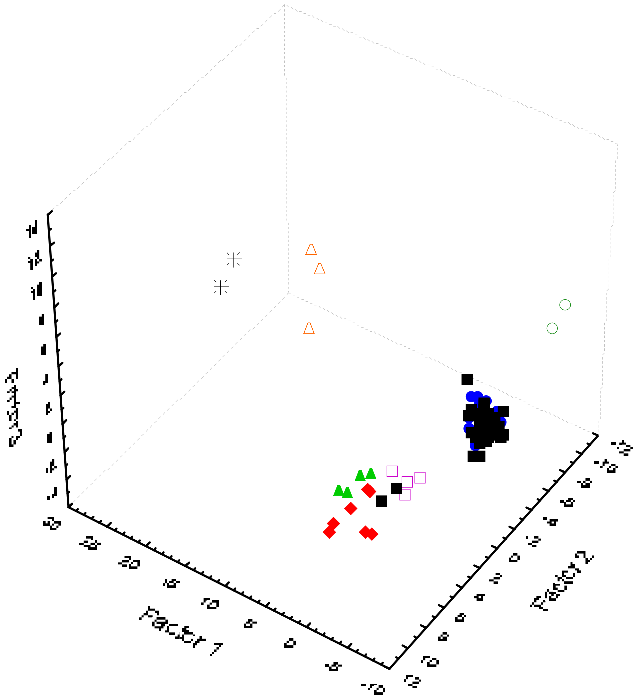

Figure 6. Plot showing the distribution of the obsidian spears in relation to the Manus (Admiralty) obsidian sources using the first three factors resulting from discriminant analyses. All but two artefacts (assigned to Wekwok) are associated with the Umrei/Umleang source group. Black solid squares represent artefacts; blue solid circles Umrei/Umleang sources; green solid triangles Pam Mandian sources; red solid diamonds Pam Lin sources; dark green open circles Lakou sources; purple open squares Wekwok samples; orange open triangles Manus Island samples and black stars Hahie obsidian.

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WHAT CONSTITUTES AN OBSIDIAN "SOURCE"?: LANDSCAPE AND GEOCHEMICAL CONSIDERATIONS AND THEIR ARCHAEOLOGICAL IMPLICATIONS

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Introduction

In his chapter titled "Tracing to Source" in *Science and the Past,* Hughes (1991) draws an analogy between the chemical analyses of artifacts for sourcing and the classification of objects based on visual characteristics. He argues that a particular "object's appearance is the first way we recognise where it comes from: a Volkswagen 'Beetle' is an instantly recognisable shape even if the VW badge has fallen off the car; likewise we recognise a Rolls Royce" (99). The analogy is not carried through, though, to an underlying issue in sourcing research: what is the definition of a "source"? The "sources" of Volkswagen and Rolls Royce automobiles are complex. Should the Beetle's source be considered the Volkswagen Corporation, or would a specific factory be the source? Volkswagen is a German company; however, Beetles were also manufactured in Ireland, South Africa, Brazil, Australia, and Mexico. To clutter the issue further, Rolls Royce Motors was sold to Volkswagen in 1998. Depending on the definition, a 1963 Volkswagen Beetle and a 2010 Rolls Royce sedan may have identical "sources." Hughes' analogy inadvertently accentuates the importance of a clear conceptualization of "source." In addition, there will be varied definitions for different archaeological materials (i.e., the definition for the "source" for a multi-component artificial material like pottery will differ from that for obsidian).

Indeed, what constitutes an obsidian "source" has been in flux for as long as the volcanic glass has been recognized as an exotic raw material moved by people. In *Incidents of Travel in Yucatan*, John Lloyd Stephens, appointed Special Ambassador to Central America by Martin Van Buren, wrote one of the first published observations of exchange evidenced by obsidian:

> At the head of the skeletons were two large vases of terra cotta, with covers of the same material. In one of these was a large collection of Indian ornaments, beads, stones, and two carved shells... The other vase was filled nearly to the top with arrow-heads, not of flint, but of obsidian; and as there are no volcanoes in Yucatan from which obsidian can be produced, the discovery of these proves intercourse with the volcanic regions of Mexico. (1843:341-343)

For Stephens, the source of these artifacts was no more specific than Mexico's volcanic regions. Over a century later, Colin Renfrew and colleagues John Dixon and Joseph Cann (Renfrew et al. 1965, 1966, *inter alia*) recognized a handful of obsidian sources in the Near East. For example, the maps in Dixon et al. (1968) reveal only two obsidian sources in central Anatolia: Acigöl and Çiftlik (i.e., Göllü Dağ) are marked by closed and open circles, respectively. These early studies often referred to *the* Açigöl source and *the* Çiftlik source, but this reflected neither the realities in the geochemical data nor on the landscape:

> Rapp and his colleagues have defined eight separate signatures, not simply one for Açigol and one for Çiftlik. In the eastern part of the Açigöl caldera three separate flow signatures can be defined. In the western part of the caldera there is only one distinct signature -- from the youngest of the obsidians in central Anatolia. In the Çiftlik area three separate sources can be distinguished. The eighth source is from the obsidians at Nenezi Dağ, about halfway between Açigöl and Çiftlik. (Rapp and Hill 1998:138)

Today, obsidian sources are typically defined using multivariate data-analysis techniques or GPS coordinates in Google Earth or a GIS map, but there are still large variances in conceptualization and terminology. This was noted, for example, by Roger Green (1998) in his concluding review chapter in *Archaeological Obsidian Studies*. In particular, he observed "a fair degree of variation in the terminology... when describing different levels of 'source' discrimination" (226-227). Just within the same volume, Green noted an assortment of terms and concepts:

> Summerhayes et al. are very explicit about what they mean by geographic regions with a number of sources, and source localities as specific sampling loci where naturally occurring obsidian specimens were collected. All source localities within a geographic region are for them a regional group, within which similarities in chemical composition make it possible to distinguish subgroups or "chemical groups." Other authors, such as Glascock et al. also speak of geographic regions, but they also talk of subregions, source areas and complex source areas, and chemical or compositional subgroups for these, while Shackley speaks of four distinct chemical groups for a named source region. (227)

That same year, Richard Hughes (1998) also discussed the conceptualization of obsidian sources in an essay reprinted in this bulletin (volume 22, pages 3-6).

Although the issues discussed by Green (1998) and Hughes (1998) have since remained within the obsidian sourcing *zeitgeist*, discussions regarding the nature of obsidian sources have begun to reappear in the literature (e.g., Nazaroff et al. 2010:886-887). This paper is an effort to further the discussion and to introduce other issues for consideration, primarily inspired by recent fieldwork as well as landscape archaeology and phenomenology. Regarding the former approach to archaeological research, Branton (2009) writes:

> Although resource exploitation, class, and power are frequent topics of landscape archaeology, landscape approaches are concerned with spatial, not necessarily ecological or economic, relationships. While similar to settlement archaeology and ecological archaeology, landscape approaches model places and spaces as dynamic participants in past behavior, not merely setting (affecting human action) or artifact (affected by human action). Landscape archaeology can be said to be the archaeology of "place." (51)

Regarding the latter, Tilley (2004) explains that phenomenology "attempts to reveal the world as it is actually experienced directly by a subject [and] describe that world as precisely as possible in the manner in which human beings experience it" (1). When merged, the goal is to learn how people in antiquity interacted with and conceived of the places around them. To begin, though, I briefly consider the terminology issue of "provenancing" versus "sourcing."

"Sourcing" versus "Provenancing"

"Provenancing" is often used as a synonym for archaeological sourcing, and I suspect this is due, at least in part, to hesitation regarding the concept of "source." One objection to the term "sourcing" is the argument that one does not ever conclusively identify the source of an artifact. Instead, one statistically assigns an artifact to the most probable source, but this does not ensure that it came from that source. For example, the artifact may have originated from a source not included in the database, or two sources may have compositions so similar that an artifact could potentially be attributed to both. Harbottle (1982) contends that

> with a very few exceptions, you cannot unequivocally source anything. What you can do is characterize the object… and also characterize the equivalent source materials, if they are available, and look for similarities to generate attributions. A careful job of chemical characterization, plus a little numerical taxonomy and some auxiliary archaeological and/or stylistic information… will produce groupings of artefacts that make archaeological sense. This, rather than absolute proof of origin, will often necessarily be the goal. (15)

Wilson and Pollard (2001) go further and argue "only mis-matches between source material and test object can be conclusively demonstrated... provenancing proceeds by systematic elimination of possible sources, rather than by positive attribution" (510).

Unfortunately, "provenance" is also commonly used interchangeably with "provenience." Both terms come from the French *provenir*, "to come from," referring to the origin of something. Rapp and Hill (1998) argue for the following distinction between these terms:

> *Provenience* is a common archaeological term referring to the precise location at which an artifact was recovered (from a survey or excavation). Without provenience data, artifacts have little archaeological value. By *provenance*, however, geoarchaeologists mean something quite different. The provenance of an artifact is the location, site, mine that is the origin of the artifact *material*. (134)

Adherence to this distinction, though, is far from universal. Various authors, including those of many archaeological dictionaries, equate the two terms and even treat them as alternate spellings (e.g., "The term *provenance,* or *provenience*, as the word is often also spelled," Goffer 2007:42; also see Mignon 1993:88, Kipfer 2000:458, Bahn 2001:369, Wilson and Pollard 2001:507, and Darvill 2008:367 for examples of treating the words as synonyms). Harbottle (1982) suggests a hypothesis about the usage of two terms:

> Provenience (= provenance). It *ought* to mean *only* where something is found... But among art historians it generally means *presumed origin*... Some archaeometry papers have also used the term to mean *source* or *origin* (Wilson 1978). One suspects that we are seeing here an Old World-New World bias, the art-historical usage being common among Old World archaeologists. (16)

Pollard et al. (2007) likewise attribute the ambiguity to differences between the United

States and Great Britain as well as art history and archaeology:

> … relating to *provenance* (or, in the US, *provenience*…). The term here is used to describe the observation of a systematic relationship between the chemical composition of an artifact… and the chemical characteristic of one or more of the raw materials involved in its manufacture. This contrasts sharply with the use of the same term in art history, where it is taken to mean the find spot of an object, or more generally its whole curatorial history. (5)

Regarding the distinctions proposed by Rapp and Hill (1998), Pollard et al. (2007) write:

> In fact, a recent North American textbook on geoarchaeology has used the term *provenience* for find spot, and *provenance* for the process of discovering the source of raw materials... Although this is an elegant solution to a terminological inexactitude, it has not yet been universally adopted, at least in Europe. (5)

Because the distinction between the terms is not widely accepted and has caused confusion (e.g., Millet and Catling 1966), "sourcing" is a preferable term, whereas "provenancing" seems largely a euphemism that reflects uncertainty about attribution to sources.

Mathematical versus Geographical Sources

The quotation from Green (1998) in the Introduction alludes to one important divide in how a "source" is conceptualized: the geographical concept (i.e., a place on the landscape where the obsidian flow or secondary deposit occurs and where humans collected the raw material) and the mathematical concept (i.e., a cluster in the geochemical data). These two conceptions do not necessarily yield identical results. Harbottle (1982) points out: "One must never assume that the physical and mathematical source have to coincide" (31).

Wilson and Pollard (2001) offer a representative mathematical definition, explaining that chemically similar specimens "can be agglomerated into chemically coherent 'groups' which will 'characterize' a single 'source'" and, in turn, that "'sources' can then be distinguished as discrete clouds of points in multivariate space" (509). Similarly, Hughes (1998) explains that obsidian "sources are defined, geochemically speaking, on the basis of chemical composition -- not spatial distribution" (104). Such mathematical definitions place obsidian sources in multi-dimensional space in statistical software, not "real" space on the landscape.

Neff (1998) follows a geographical definition, arguing "the theoretical concept of interest here is 'source,' defined as a location or set of locations in geographic space" (116). A source, in his terminology, can be defined by coordinates on a map or plotted in Google Earth. Similarly, Harbottle (1982) considers it "the ultimate starting point -- the clay bed, obsidian flow, mine of flint or copper or marble quarry, which is the natural deposit of a material" (16). Rapp and Hill (1998) give a virtually identical definition for a source (134). To them, a source is where people collected raw material and started the distribution process. Other researchers implicitly define a source geographically, referring to them having particular locations (e.g., a volcano), being a set distance from an archaeological site, or having a series of coordinates.

Geographical conceptions of "source" seem to prevail in the recent literature. Terms like "chemical fingerprint" and "chemical type" are, in turn, often used to describe the mathematical source concept. In some respects, the former is a rather apt nickname for a diagnostic pattern of elements. Fingerprints are, of course, used as a means of identification. Siblings frequently have similar ridge patterns, and geological materials with the same "parentage" have similar chemical fingerprints. Fingerprints are classified by pattern types, pattern sizes, and their locations on the fingers. Similarly, materials are characterized by the elements present, their quantities, and their distributions. When an individual touches a dime, though, there are sufficient ridge patterns left behind for a positive identification to the exclusion of any other person. This, regrettably, is not true of geochemical "fingerprints," which are not nearly so characteristic.

Of the alternatives, including such terms as "chemical group" and "geochemical variety," "chemical type" best recognizes that mathematical sources are analogous to other archaeological typologies. Typologies are artificial constructs, essentially idealized classifications, used to sort, for example, ceramics by time and place. Ceramic types are empirically derived from a series of sherds and vessels. Some traits are diagnostic while others are not. Consider, for example, two ceramic types in Northern Mesopotamia: Khabur Ware and Nuzi Ware. Khabur ware has painted red-brown horizontal lines with geometric, usually triangular, patterns of the same color whereas Nuzi Ware has white curled or wavy lines on a brown or black background. Both types, though, are wheel-made. It is the overall pattern of traits that characterizes the type. Furthermore, there are variations within a type. Patterns on Khabur vessels can be either hatched or cross-hatched, and "there are no two examples of Nuzi Ware with exactly the same white painted design" (Stein 1984:27). There are also very similar types, and sherds will be discovered that can be sorted into more than one type. The same can occur in obsidian "chemical types."

Following the geographical concept, a "source" of obsidian can be represented on a map with a dot, but this raises the issue of, as Green (1998) put it, "the size of the dot which pinpoints [an artifact's] supposed origin" and a plethora of terms to describe it (227).

Sources, Subsources, and Source Areas, Oh My!

Varied nomenclatures are found in the literature to describe hierarchies within the origins of obsidian: sources and subsources, sources areas and sources, source systems and subsystems, localities and locality complexes, source localities and sample loci, and more. It is often unclear how these terms relate to one another or why different researchers apply different schemes to the same obsidian-bearing region. For example, Glass Buttes in central Oregon, which has obsidian with nine different chemical compositions, has been described in a variety of ways: an "obsidian source" (Godfrey-Smith et al. 1993), a "source locality" (Hughes 1986), a "source area" (Skinner 2010), a "source complex" (Skinner et al. 1999), a "multi-component obsidian source" (Ambroz et al. 2001) and, a "complex" comprised of multiple "subsources" (Ambroz et al. 2001). Thus, I visited Glass Buttes -- and Newberry Volcano, roughly 100 km west, for comparison -- in part to explore source concepts, terminology, and landscape manifestations.

Glass Buttes versus Newberry Volcano

Glass Buttes is a lava dome complex that covers about 10 x 20 km, and the obsidians are between 4 and 6.5 million years old (Godfrey-Smith et al. 1993). This complex is highly eroded and dissected by channels from small streams and springs. Ma et al. (2007) explained that the "surface obsidian flows have long since been eroded away" at Glass Buttes (552), and Russell (1905) described the complex as the "remnants of ancient... volcanoes, now deeply dissected by erosion" (49). Waters (1927) observed that obsidian, which occurs as sizable chunks "in the dry stream channels and as loose blocks... is rarely found in place" (451).

Newberry Volcano, a shield volcano in Newberry National Volcanic Monument, suffered a caldera collapse about half a million years ago. The caldera is 7 x 8 km and 400 m deep, and it has two large lakes (Paulina and Eastern Lakes) as well as several younger obsidian-bearing lava domes. In particular, I explored Big Obsidian Flow (1300 years old), East Lake Obsidian Flows (3500 years old), and Interlake Obsidian Flow (7300 years old).

The experiences of seeking obsidian at Newberry Volcano and Glass Buttes are strikingly different. At Newberry Volcano, one enters along a narrow channel where the caldera wall has been nearly eroded away, cut by a stream that drains Paulina Lake. From this vantage point, one is surrounded by the caldera walls, hundreds of meters tall, which encircle huge obsidian flows hidden by evergreens. If one instead hikes a trail around the caldera rim, one looks down into a deep depression several kilometers across, and three massive, gray, rocky lava flows are apparent as discrete features among the trees and rises of reddish-yellowish ash. From atop one lava flow, the other two are usually visible. For example, when standing on the East Lake Obsidian Flows and looking west, one sees Big Obsidian Flow (BOF) on the left and Interlake Obsidian Flow on the right. From either the caldera edge or atop a flow, the flows look similar, but they are clearly separate features and could easily be considered different obsidian "sources." One does not need to resort to chemical analyses to regard them as distinct.

Walking up to the edge of one of the Newberry flows, one has the distinct impression of encountering a rubble wall in the middle of the forest. BOF, for example, is 20 m tall and covers over 2.7 km^2. Large obsidian chunks, over a meter in diameter, can be found at the bottom of the slope. If one ascends the slope of sharp pumice blocks, about two-thirds of the way up, one can gather high-quality obsidian from an inner shell exposed along the periphery. These shiny, black rocks occur in any size and are easy to identify among dull, gray pumice.

The top of BOF presents a different experience. Its upper surface is composed of a series of ridges, and when standing between the ridges, the gray, rocky, nearly lifeless surface is all one can see other than sky. It is little exaggeration to say the BOF surface seems otherworldly. Atop BOF in 1964, Apollo 7 astronaut R. Walter Cunningham tested a spacesuit for use on the Moon, and over the next two years, dozens of astronauts trained for lunar missions there and on similar lava fields. Atop the flow, spires of obsidian protrude from the pumice, and some of these spires have collapsed, creating a pile of obsidian useful for tool production. One cannot move from one of these quasi-lunar surfaces to another without walking at least 2 km through dense forest. Thus one can only find obsidian at one of these lava flows within the caldera, and the imposing flows can even surround one with bizarre, even transcendental, scenery.

In comparison, collecting obsidian at Glass Buttes is quite a distinct experience. The two low, eroded mountains of Glass Buttes -- termed Glass Butte and Little Glass Butte -- are typical of the region known as the High Desert or High Lava Plains in central and southeastern Oregon. This region has had many names over the years. The Great Sandy Desert and Rolling Sage Plain were popular terms in the nineteenth century, and locals today call it the Oregon Outback. Low shrubs, particularly sagebrush, and occasional juniper trees grow on this semi-arid plateau. The mountains in this region were created by volcanism between 2 and 15 million years ago, and the Glass Buttes obsidians formed between 4 and 6.5 million years ago. Since then, weathering and erosion have worn down the ancient mountains. There are no conspicuous lava domes, massive obsidian outcrops, or steep slopes of pumice blocks. The only outcrops are basalt from eruptions during the same period. The remaining low mountains of Glass Butte and Little Glass Butte, at first glance, seem completely unremarkable on the landscape.

Eventually, though, one observes small black pebbles, just a few millimeters in diameter, scattered across the ground. At some spots, rounded obsidian cobbles, up to 40 cm or so, can be found emerging from the clayey soil, often in dry rills and gullies. One also finds, in spots where larger cobbles occur near the surface, many obsidian flakes. The flakes at Glass Buttes, though, are not only the products of ancient obsidian workspaces. Instead, they are the waste of modern rock collectors and knapping hobbyists. Thus, one must either dig or search for cobbles recently eroded out of the soil to discover any sizable obsidian pieces.

Ambroz et al. (2001) produced a map of the spatial distributions of seven chemical types of obsidian at Glass Buttes. Even with the map and a GPS unit in hand, a visitor to Glass Buttes would be hard-pressed to identify the spatial boundaries of these different chemical types. On the western slope of the larger Glass Butte, obsidian collected from the rises are one particular type (Group B) while that from the channels between them are another (Group G), and almost immediately to the northeast and southeast is Group A. Other than the occasional barbed-wire fence, there are no clear boundaries or demarcations. One can wander within the Group A area or from Group A to Group B with little change of the landscape to indicate that there was ever a series of distinct domes, very different from the situation at Newberry.

Recent fieldwork and analyses have even shown that multiple chemical types of obsidian may be obtained from various locations at Glass Buttes (Skinner 2010, 2011). For example, at a natural basin where water collects, a few kilometers from these mountains, Skinner (2010) found obsidian nodules of five chemical types. His discovery necessitated XRF analysis conducted in a laboratory to establish, not just visual inspection. Equally as important, he reported that, around this water source, abundant obsidian flakes were scattered across the ground, so it "was clearly a prehistoric place of interest" (Skinner 2010). There are at least two interpretations for this result. First, erosion could have carried obsidian from five different eruptions to a single water basin at the foot of Glass Butte. This suggests people may have gathered obsidian from one location that also served as a water source; however, the cobbles present there originated from five flows and correspond to five distinct chemical types. A second possibility is that people collected obsidian nodules from the mountain, gathered at the water source, and discarded unwanted nodules (from five chemical types) in the basin while working there. Other secondary deposits, either artificial or natural and with mixed chemical types, almost certainly exist nearby.

The research of Ambroz et al. (2001) also offers a possible clue to ancient conceptions of obsidian "sources" at Glass Buttes. Their chemical analyses of artifacts from an archaeological site -- the Robins Springs site -- on the western slope of Glass Butte revealed the use of obsidian from five chemical types but none from the other two. Although not noted in the article, there is an interesting trend in their results. The five chemical types identified at the site all, according to their map, occur on the larger Glass Butte mountain, and the two unrepresented types are the two on the smaller Little Glass Butte mountain to the southeast. Additionally, one artifact was traced to Yreka Butte, more than 5 kilometers west of Glass Butte, farther than Little Glass Butte. The fact that all Glass Butte chemical types are represented at the

Robins Spring, in numbers roughly corresponding to distance from this site, whereas no Little Glass Butte types were found, might suggest that the larger mountain was considered a viable or acceptable obsidian "source" but the smaller mountain was not. Other factors, such as material quality or nodule size, may have been important influences; however, differences in quality or size between the seven Glass Butte types and the two Little Glass Butte types seem slight if present at all.

To summarize, at Newberry Volcano, the individual lava flows are identifiable as such, so one can easily identify them as discrete "sources" of obsidian. Laidley and McKay (1971) found that BOF and other flows in the caldera are geochemically similar, due to the same host rock and magma chamber, yet still distinguishable. Thus, at Newberry Volcano, the obsidian "sources" on the landscape, as perceived by an observer standing in the caldera or along its edge, are identical to the chemical "sources." At Glass Buttes, however, the distributions of the chemical "sources" are indistinguishable on the ground. It seems likely that, on the landscape, a "source" would be perceived as a local geographical feature (like the water basin), an entire mountain (as suggested by the findings of Ambroz et al. 2001), or just a dense cluster of nodules (as rock collectors and knapping hobbyists mark with Xs on their maps). These perceived landscape "sources" are not the same as the chemical "sources" at Glass Buttes. In addition, the perceived "sources" might, in comparison to the distribution of the chemical "sources," be higher resolution (e.g., a basin or nodule cluster) or lower resolution (e.g., one mountain versus another). The spatial distributions of the chemical "sources" is known only from laboratory-based analyses of specimens collected from precisely recorded locations, not from observations on the ground.

Nomenclature in the Field and the Lab

Based on my experiences at Newberry Volcano and Glass Buttes, I concluded that linking chemical "source" types to "sources" on the landscape -- either explicitly or implicitly -- when it came to labeling specimens for analysis required critical consideration.

Rarely in obsidian sourcing do researchers have the luxury of personally collecting all the geological reference specimens. Often such specimens were collected over time by a number of individuals. Rapp et al. (2000) identify this as a cause of variability in their native-copper source database, and it is likely also the case in most sourcing studies. Renfrew and his colleagues, for example, had five obsidian specimens from the "Açigöl source" for reference: Giorgio Pasquaré of the University of Milan collected two of these specimens, and Herb Wright of the University of Minnesota collected three (Renfrew et al. 1966:62). Today, though, we know of five different flows and chemical types at Açigöl (Rapp and Hill 1998). This was obscured, at least in part, by the label "Açigöl" used for all the specimens they received (i.e., lumping).

For every specimen collected, particularly before the use of GPS, there is imprecision in its location description. "Açigöl" is an inexact description for a specimen location or chemical "source" type due to the presence of multiple obsidian-bearing flows there. It might, though, be adequate as a "source" for archaeological studies on a sufficient scale, when it might not matter that the obsidian came from one of three eastern flows or from only a few kilometers to the west. Gordus et al. (1971) argues for giving specimens with imprecise locations a broad geographical name, such as "Yellowstone" (226). This would be acceptable only if such specimens were not attributed to one "Yellowstone source" because over a dozen different flows occur there. Again specimens should not be uncritically "lumped" into "sources."

What, then, is an acceptable term or concept for geological obsidian specimens collected at some specific location? At Glass Buttes, for example, one should hesitate to label a scatter of nodules as all having the same "source." Those nodules may have all originated from one flow, or they may be a secondary deposit from a complex *milieu* of origins. Nevertheless, their spatial coherence when collected should be recognized. Other researchers have considered a variety of terms to describe such a concept. "Locality" is commonly used by geoscientists to define a small geographical area where a specific composition of mineral or rock occurs (e.g., olivine from San Carlos, Arizona). The term, though, has already been used inconsistently to describe sources of greatly varied scales, from "subsources" to "source areas" (Baugh and Nelson 1987, Wada et al. 2003, Izuho and Sato 2007, Park 2010). Terms like "outcrop" do not accurately describe sites of secondary deposition. "Mine" or "quarry" implies that the location was a site of ancient human activity, which is not necessarily the case for all specimens.

For my research, I settled on "collection areas." This term reflects their nature: a place, of any scale, that the specimens' original collector considered to be a single area where obsidian occurs. It is not necessarily equal to either a geographically defined source or a chemical type of obsidian. Its size can vary from collector to collector. For one person, a "collection area" might be one or two meters in diameter, and for another person, it might be an entire volcano or dome complex. What constitutes one "collection area" is determined by each collector. Thus they are emic, not etic, descriptions. Consequently, reporting the "source" of obsidian artifacts involves relevant collection area as well as the volcano and, if available, geographical descriptions known in the literature (e.g., Kömürcü village at Göllü Dağ volcano).

The Importance of Place

Shackley (1998) has proposed that "stone tool makers are often not concerned with the location from which they procure raw material, only that it be easily procurable" (6; Shackley 2005:26 includes a more definitive statement). Perhaps this is true in the American Southwest; however, ethnographic accounts and archaeological data indicate that the locations where raw materials, such as obsidian and chert, are collected can have important meanings or symbolism that affect collectors' choices. Regarding obsidian in Mesoamerica, Saunders (2001) notes that "mines appear to have been an important physical and metaphysical component of a landscape where individual features were given cosmological significance" (229). Similarly Dillian (2002) concluded that obsidian from the Glass Mountain lava dome in California was used for different functions than obsidian from other locations. For the Australian Aborigines of Arnhem Land, reports Taçon (1991), a quartzite quarry is "often given heightened significance by associating it with powerful, dangerous forces" of the Ancestral Beings (199). Therefore the selection of lithic materials may have important symbolic and cultural meanings.

Other times there may be simpler factors involved in the selection of a quarry site, such as a workspace with a view. Bradley (2000) examined the acquisition of raw materials for stone axes in Great Britain. He found that high-quality materials in accessible locations went unused and "inaccessible exposures with the same physical characteristics were employed instead" (86). Bradley proposed that the "character of the place seemed at least as important as the qualities of the material" and that such inaccessible locations were preferentially exploited because the work sites "commanded enormous views" of the surrounding landscapes (86-87).

The proverb "getting there is half the fun" offers another issue to consider. For example, Hodgson (2007) contends that, for the Wintu tribe of California, quarrying obsidian had religious components, and that this sacrality also applied to the journey itself to Glass Mountain: "In the summer, two or three men would make a two- to three-day trip NE to the quarry. The men fasted throughout the journey as the act of obtaining obsidian was seen as a semi-religious quest" (307). This implies that journeys to and from the sources, as well as the experiences along the way, can also be significant factors in exploiting particular raw-material sources.

Hodgson's account indicates a potential for phenomenological approaches, such as those advocated by Tilley (1994, 2004) to interpret natural and cultural landscapes. As quoted in the Introduction, Tilley explains that phenomenology "attempts to reveal the world as it is actually experienced directly by a subject [as well as] to describe that world as precisely as possible in the manner in which human beings experience it" (2004:1). This approach may reveal how people in antiquity interacted with and conceived of the landscapes around them. It asks us to enter into the physical landscapes and experience them using our own senses. For the Wintu tribe, Glass Mountain is an element of their cultural landscape, that is, as "a set of relational places linked by paths, movements, and narratives… It is invested with powers… and is always sedimented with human significances" (Tilley 1994:34). Hence we must consider symbolism of the landscape as well as the sights, sounds, and smells experienced by those who collected obsidian. Such factors can affect source selection and how materials were subsequently used.

Potentials for Symbolism and Meaning

The fieldwork at Glass Buttes and Newberry Volcano not only affected my perception of what constitutes an obsidian "source," but I also sought the experiences of acquiring obsidian at these places so I could better comprehend the experiences of people doing the same in antiquity. My experiences of seeking obsidian at the two locations were quite distinct. Almost every sight, sound, and smell was different. For instance, after a little afternoon drizzle at both places, Glass Buttes was filled by the pungent odor of sagebrush while Newberry Volcano had pine and earthy scents. Bald eagles, to which many Americans ascribe special meaning, may be seen and heard from atop the obsidian-bearing flows at Newberry Volcano while there are none at Glass Buttes. Because bald eagles are symbolic of the United States (e.g., a bald eagle is incorporated in most official seals, including the Great Seal of the United States, the Seal of the President, and those of numerous federal executive departments), perhaps one could consider it more "American" to collect obsidian at Newberry. Today, though, one cannot gather obsidian at Newberry because it is ascribed "national significance" and "exceptional value" as a national monument (NPS 2003), whereas Glass Buttes is merely public land on which cows freely graze and from which one can scavenge as much obsidian as desired. Part of Newberry Volcano's value, no doubt, derives from spectacular views from the caldera edge, particularly the portion known as Paulina Peak, which reaches an elevation over 2400 m. In contrast, I have only half-jokingly called Glass Buttes "the landscape of the banal." Even the body processes of collecting obsidian at the two locations are markedly different. These and other differences between Glass Buttes and Newberry afford great possibilities for distinct meanings and symbolism ascribed to them.

The Future

This paper is an attempt to continue the discussion about the nature of sources started by Green (1998) and Hughes (1998) and to consider approaches from landscape archaeology (e.g., Branton 2009) and phenomenology (e.g., Tilley 2004). It is easy, in obsidian sourcing research, to spend considerable time and effort developing the instrumentation and data analysis. Debates regarding, for example, choice of clustering algorithms or the statistical benefits of normalizing versus standardizing data are important. These are the basic tools by which we can measure the chemical attributes of obsidian artifacts and validly attribute them to a particular volcano. At the same time, though, we should strive to keep developing what is best described as the "theory of source." Just as fundamental anthropological concepts are revisited and redefined to reflect new scholarly trends in the field (e.g., ecological, cognitive, and postmodernist definitions of culture), we should consider the concept of "source" in light of these same intellectual developments. By exploring new ways to conceive of obsidian sources, we are reminded that our ultimate goal is to translate patterns within geochemical data into human behaviors and perhaps even the immaterial aspects of culture like values, beliefs, and perceptions of the world.

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ACCURACY OF OHD IS NOT LIMITED BY MICROSCOPE RESOLUTION

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Abstract

It is frequently repeated that the accuracy achievable in measuring the position of the hydration front in obsidian is limited by the resolution of the microscope employed for the measurement. This resolution is frequently cited as ~0.25µ. In this paper I show that this is incorrect, and is based on a misunderstanding of the physics of the measurement process. The optical accuracy limit is actually defined by a parameter known as vernier acuity; numerous measurements on optical systems have shown this to be approximately one to two orders of magnitude *smaller* than resolution. Thus, given good laboratory technique, accuracy is not limited by resolution of the microscope, but is more likely limited by the material properties of the obsidian. I suggest actual measurement accuracies lie in the range of 0.05 - 0.1µ, which is consistent with data reported by laboratories. The accuracy of rim measurement is not a large contributor to the error in computed age in obsidian hydration dating (OHD).

Introduction

This short paper discusses the issue of resolution and accuracy in optical measurements for obsidian hydration dating (OHD). In the past it has been argued that resolution of the eye-microscope system is the limiting factor in the achievable accuracy in measuring hydration rims (e.g. Scheetz and Stevenson 1988). Scheetz and Stevenson (1988) also computed the resolution limit for a typical filar microscope system to be approximately 0.25µ. This limit is frequently cited as a reason for poor accuracy of OHD (e.g. Anovitz et al. 1999; Riciputti et al. 2002; Stevenson and Novack 2011).

Contra this view, I argue here that resolution is the incorrect parameter for OHD accuracy, and is, in fact, irrelevant. Resolution measures the ability to *separate* or *distinguish* two images; however, the problem in hydration measurements is the accuracy with which two images can be *merged*. This process is known in optical engineering as "coincidence measurement"; the parameter which quantifies coincidence measurement is known as "vernier acuity" (Jacobs 1943).

Discussion

Resolution is a measure of the ability to distinguish two nearby objects in the field of view. Because of the wave nature of light, a point object is seen as having finite width, which displays the familiar diffraction pattern of physical optics. The diffraction pattern limits the ability of the observer to separate, or resolve, two images. Images which are as close as they can be and still be resolved are at what is known as the Rayleigh limit. When "resolution" is evaluated, the quantity actually calculated is the Rayleigh limit, and a high-quality telescope or microscope achieves resolution very close to this value. Resolution is especially important to microscope manufacturers because it depends solely on the optics of the microscope and not on the observer's skill, and hence is a useful figure of quality for the instrument. Resolution is discussed in all physics textbooks that deal with optics (e.g. Born and Wolf 1980; Sears and Zemansky 1970; Shortley and Williams 1950).

Scheetz and Stevenson (1988) presented a valid analysis of the resolution of a microscope system. However, resolution is not the relevant parameter in optical measurements of obsidian hydration. Such a measurement entails aligning the image of a filar with the image of the hydration front; accuracy is determined by how well the operator can bring the two images into coincidence, not how well they can be separated. The accuracy with which the two lines can be brought into coincidence, or vernier acuity, has been extensively studied because it forms the basis of operation of optical range-finders, which have great importance to the military. Similar rangefinders used to be standard on good quality 35mm cameras, and are still used today by golfers and hunters.

Obsidian measurements are made by a coincidence process, and thus the key criterion for accuracy is the vernier acuity achievable by the operator of the microscope. Both the filar and the image of the hydration front are subject to the limitations of physical optics, and the measurement is performed by bringing the two images into coincidence. Good instrument technique, as taught by the military in range-finder operation, is to bring the two images together until they just merge and note the position, continue to move the filar until the images just separate, and then bring the filar back half-way. A similar technique is taught in microbiology.

Jacobs (1943) provides quantitative data on vernier acuity, based on a series of tests on coincidence rangefinders prior to World War II:

> …under favorable conditions coincidence settings could be repeated so closely that the departure of an observation from the mean of a series was only about half a second of arc, or *less than a hundredth part of the displacement necessary for resolution of the two lines* (Jacobs 143:86, emphasis added).

He later states that the probable error for an observer making a coincidence setting is about two seconds of arc. This is on the order of one fiftieth of the Rayleigh criterion for resolution; in other words, the vernier acuity, or accuracy, is a factor of about fifty *better* than the resolution limit. If the resolution of the microscope system is 0.25µ, the vernier acuity should be approximately 0.005µ.

Obsidian laboratories consistently report measurement accuracies of 0.01 - 0.1µ, based on multiple measurements on a single sample. These are strictly measures of repeatability, which may be better than absolute accuracy. However, a detailed calculation of measurement accuracy, based on laboratory hydration measurements, found a standard deviation of 0.08µ for Topaz Mountain obsidian (Rogers and Duke 2011), so an accuracy of 0.05 - 0.1µ is not unreasonable.

Obsidian is a natural material and typically exhibits non-uniformities. Furthermore, the hydration front has a finite thickness, and the operator is trying to measure the center of it. Thus, the accuracy limit is probably being caused by material properties, not by the optical system. A measurement accuracy in the 0.05 - 0.1µ range is entirely reasonable given a vernier acuity of ~0.005µ and normal obsidian quality.

Finally, I have shown elsewhere (Rogers 2010) that the accuracy of optical measurement is a very minor contributor to the accuracy of a rate estimate or age estimate. Even with the best corrections possible today, uncertainties in temperature history and intrinsic water content dominate the accuracy of any age computation.

Conclusion

Resolution of the microscope optical system is irrelevant to the accuracy of hydration measurement. The limiting performance of the optical system, or vernier acuity of the system, is on the order of 0.005µ, and hence does not limit practical accuracy. Accuracy of hydration rim measurement is in the range of 0.05 - 0.1µ and is probably limited by material properties. In any case, the accuracy of rim measurement is not a large contributor to the error in computed age.

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