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Author
Dillian, Carolyn D., cdillian@coastal.edu

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NEWS AND INFORMATION

IAOS Bulletin ISSN

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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 IAOS.Editor@gmail.com Thank you for your help and support!

CALL FOR PAPERS: IAOS SPONSORED SESSION FOR SAA 2015
Exotic, Lustrous and Colorful: Obsidian in Symbol, Society and Ceremony

The long distance movement of obsidian in many parts of the world is well documented in the archaeological science literature, but few scholars have seriously considered why this particular raw material was so popular in the past. Although its physical properties, particularly excellent conchoidal fracturing and extremely sharp cutting edges, must have played a role, the widespread popularity and variety of uses for obsidian demand additional explanations. The papers in this session will explore a broad range of factors, such as performance, symbolism, ritual, and exchange value that significantly extend our understanding of the role of this black, shiny rock within past societies.

To participate or for more information, please contact the organizers:
Robin Torrence (Robin.Torrence@austmus.gov.au)
Carolyn Dillian (cdillian@coastal.edu).

NOTES FROM THE PRESIDENT

After serving as Vice President for a year under Ellery, I am excited to begin my term as IAOS President and am looking forward to making Ellery perform the all-important coffee-making duties as Past/Vice President for the next year. The IOAS has had a great run of capable Presidents since I first joined the society more than 10 years ago, and I hope to continue this tradition. But the real thanks go to the individuals who do all the real work: Carolyn Dillian (*Bulletin* Editor), Kyle Freund (Secretary/Treasurer), and Ana Steffen (not really sure if she has an official title), who manage most of the regular working of the society and have done a remarkable job.

Our recent efforts to increase the profile of the IAOS at the 2014 Society for American Archaeology Meetings in Austin were well-received. We had a booth in the exhibit hall where we provided past IAOS Bulletins, information on membership, displayed examples of obsidian from around the world, and sold copies of the new IAOS publication "*Twenty-Five Years on the Cutting Edge of Obsidian Studies: Selected Readings from the IAOS Bulletin*". If you missed your chance to purchase the volume in person, it will be available for the bargain price of $10 (plus $3.50 shipping) soon through the IAOS website. I was fortunate to have this volume with me on the return trip from Austin when I was stuck in the Dallas Airport for 10 hours. The time just flew by reading these great articles.

The IAOS and the Society for Archaeological Sciences co-sponsored an ambitious session in Austin honoring the initial obsidian compositional provenance research titled "The Gold Anniversary of Obsidian Sourcing: 50 Years of Research Around the World". The session drew such interest that it was split into two sessions and included 25 papers and four discussants. The honored guest in attendance was none other than one of the pioneering obsidian researchers himself – Colin Renfrew. He presented the opening paper (co-authored with Johnson Cann) and also served as the sole discussant for the opening session. The presenters included speakers from at least four continents and many papers involved intensive international collaboration. Rob Tykot did a commendable job of organizing the session and for hosting the post-session dinner.

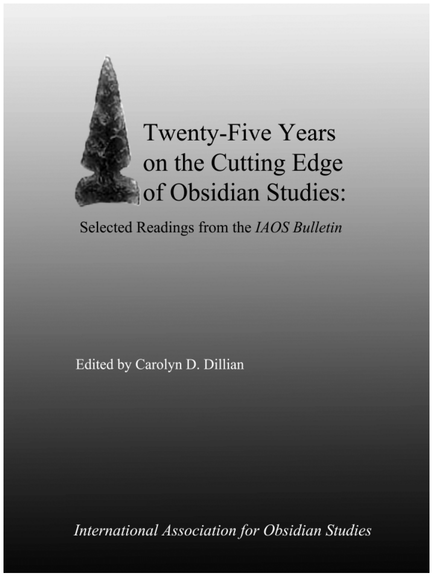
The annual IAOS meeting also took place in Austin and was well-attended with about 20 members and officers. Among the usual business, I suggested an IAOS-sponsored session for the 2015 SAA meeting in San Francisco that would highlight the role of CRM obsidian studies in our understand of the prehistory of California, Oregon, and Washington. The IAOS started in California and it would be a great opportunity for the society to showcase the importance of sourcing and hydration studies in the region where it has remained standard practice for decades. In addition, I am really hoping to guilt our elusive webmaster, Craig Skinner, into making a personal appearance. I don't have high hopes, but if it is ever going to happen, this is the year.

I am looking forward to hearing about the upcoming bi-annual symposium of the *International Society of Archaeometry* later this month in Los Angeles. At the meeting they will be selecting the location for the 2016 meeting somewhere in Europe. There are plans in the works for an international obsidian symposium in Italy to be organized by Mike Glascock, Slava Kuzmin, and Rob Tykot that will probably take place just before or just after the Archaeometry meeting.

I am looking forward to an active two years as IAOS President and hope to continue to increase the membership and participation of the society. Please feel free to contact me with any questions or suggestions.

Thanks,
Jeff Ferguson
fergusonje@missouri.edu
President IAOS
Research Assistant Professor
Archaeometry Group
University of Missouri Research Reactor Center

NEWS AND NOTES: Have announcements or research updates to share? Send news or notes to the *Bulletin* Editor at IAOS.Editor@gmail.com with the subject line "IAOS news.



Twenty-Five Years on the Cutting Edge of Obsidian Studies: Selected Readings from the IAOS Bulletin
Edited volume now available!

As part of our celebration of the 25th anniversary of the IAOS, we published an edited volume highlighting important contributions from the *IAOS Bulletin.* Articles were selected that trace the history of the IAOS, present new or innovative methods of analysis, and cover a range of geographic areas and topics. If you did not have a chance to purchase your copy at the 2014 Society for American Archaeology conference, you may purchase it online soon on the IAOS website for $10 (plus $3.50 shipping to U.S. addresses). International addresses, please contact us directly at IAOS.Editor@gmail.com for shipping information.

CALL FOR NOMINATIONS

Jeff Ferguson has just begun his responsibilities as IAOS President, and Ellery Frahm has stepped into the position of Past President for the coming year. That means that it's now time for nominations for our next IAOS President. Elections will be held this winter and the winner announced at the 2015 IAOS meeting at the SAAs in San Francisco. The winner will then serve as President-Elect for one year and begin the term of President in 2016. If you, or someone you know, would be interested in serving as IAOS President, please send a nomination to Jeff Ferguson at fergusonje@missouri.edu.

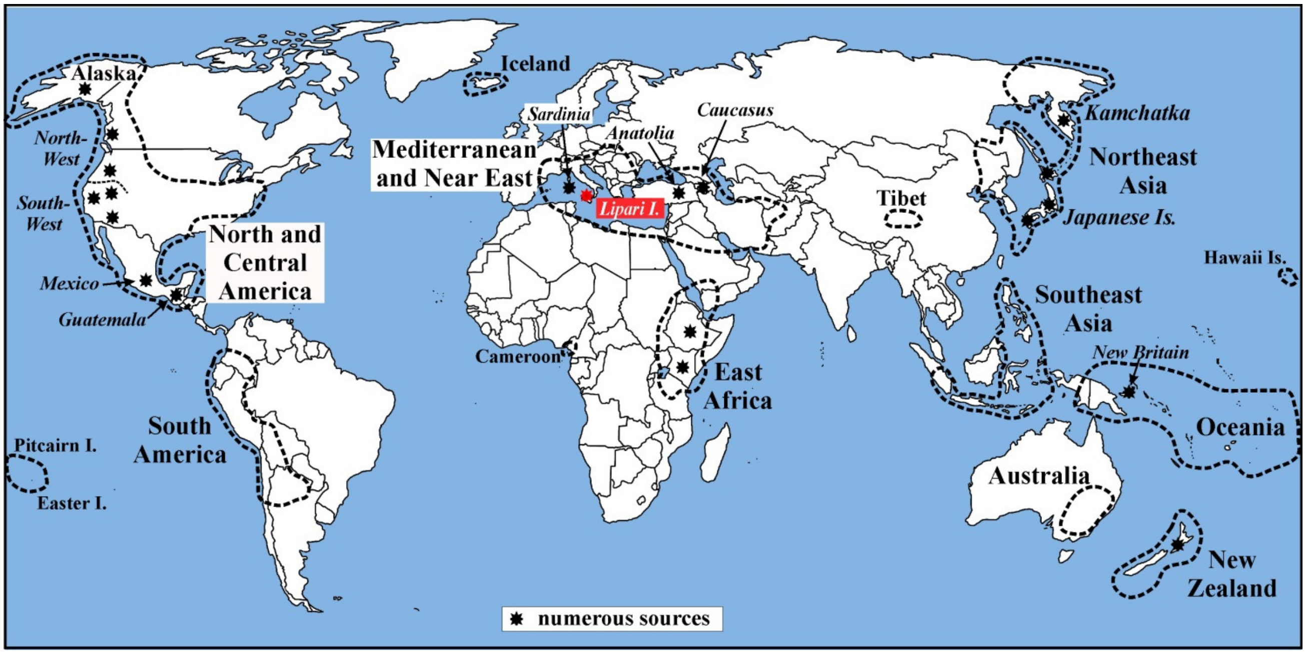
OBSIDIAN QUARRY EXCAVATION OPPORTUNITY

The Valles Caldera Trust is partnering with Earthwatch Institute to excavate an obsidian quarry inside the Valles Caldera National Preserve in the heart of the Jemez Mountains of north-central New Mexico. We are excavating in Obsidian Valley on the north side of Cerro del Medio near the center of the caldera. If you are interested in joining the volunteer crew, sign up through the Earthwatch website (below). The sessions this year are the final two to wrap up the project and will run September 6 – 16 and October 4 - 14. Our housing this season will be inside the Preserve at the scenic Lodge on the edge of the Valle Grande. Nice digs for a fun dig!

For more information:
http://earthwatch.org/expeditions/encountering-the-prehistoric-people-of-new-mexico
http://earthwatch.org/news-media/a-thousand-year-old-social-network-revealed
http://earthwatch.org/events/2013/05/16/why-emotion-matters-in-conservation-science
http://www.vallescaldera.gov/
https://www.facebook.com/VallesCaldera
http://www.santafenewmexican.com/magazines/bienvenidos/valles-caldera-has-rich-human-history/article_c3d7eb14-d4af-11e3-a882-0017a43b2370.html

Project Principal Investigator: Ana Steffen, Cultural Resources Coordinator, Valles Caldera Trust, PO Box 359, Jemez Springs, NM 87501; asteffen@vallescaldera.gov

International Obsidian Conference in summer 2016 — a proposal



Distribution of obsidian sources (including Lipari) and artifacts worldwide [compiled by Y. Kuzmin]

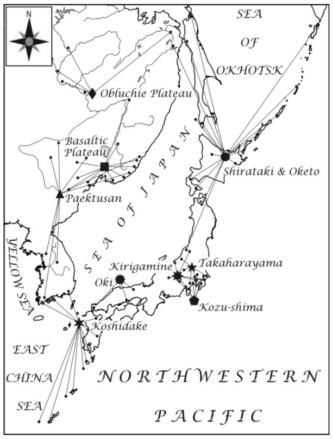
Scholars from the USA, Italy, Russia, and Japan are working to organize the **International Conference** on various aspects of **obsidian studies** (*archaeology, anthropology, geology, geochemistry, archaeometry, etc.*) worldwide, in **summer 2016** (presumably **June**) on the Mediterranean island of **Lipari (Italy)**, at the Regional Aeolian Archeological Museum "Luigi Bernabò Brea".

It would be the first meeting of this kind since the 2004 Obsidian Summit in Tokyo (Japan).

Your interest & participation are very welcome!

Please contact us about details and updates by email:

Robert Tykot (rtykot@usf.edu)
Yaroslav Kuzmin (kuzmin@fulbrightmail.org)
Akira Ono (onoak@meiji.ac.jp)
Michael Glascock (glascockm@missouri.edu)



Obsidian Source Studies in Northeast Asia

New book from *Archaeopress* (Oxford, UK) — dedicated to 50 years of obsidian provenance studies worldwide, with *Foreword* by Colin Renfrew

BAR International Series S2620 (2014). ***Methodological Issues for Characterisation and Provenance Studies of Obsidian in Northeast Asia***. Edited by Akira Ono, Michael D. Glascock, Yaroslav V. Kuzmin, and Yoshimitsu Suda. Oxford: Archaeopress. ISBN 978-1-4073-1255-2. Price: £34 ($57), plus shipping & handling. xviii+183 pages, with 89 b/w figures and 40 tables.

Résumé
This volume is a collection of papers related to geology, geochemistry, and archaeology of obsidian in Northeast Asia. Special focus of this book is on methodological aspects of acquisition and comparison of geochemical data for obsidian sources generated by different analytical methods (NAA, XRF, ICP–MS, and EPMA), conducted in this region for the first time. The updated situation with obsidian source studies in Japan, Russian Far East, and Korean Peninsula is presented.

Content

To order: Hadrian Books, 122 Banbury Road, Oxford OX2 7BP, UK. Tel +44 (0) 1865 310431, Fax +44 (0) 1865 316916; e-mail: bar@hadrianbooks.co.uk (http://www.archaeopress.com).

INTERPRETING OBSIDIAN USE IN THE NEAR EAST: A PERSONAL PERSPECTIVE

Elizabeth Healey
School of Arts, Languages and Cultures, University of Manchester

Introduction

Obsidian studies in the Near East are at a watershed. More and more compositional analyses are being undertaken and developments in technological analysis are bringing new understandings about how the raw material was transformed into artifacts. However, with a few notable exceptions, we do not seem to be paying much attention to obsidian as a material, or to how it was obtained, what it was used for, let alone what it might have meant to the people who acquired and worked and used it, or how it related to other things in their lives. To a certain extent this is because we are hide-bound by previous understandings. In the past, studies of obsidian artifacts have tended, with a few recent exceptions, to privilege geo-chemical analysis over techno-typological and functional studies, and context and meaning. Indeed provenance studies of obsidian have been called a success story (Williams-Thorpe 1995). The data generated, despite the fact that it was often based on scant and possibly unrepresentative material, was then used not only to indicate trade and exchange but also to explain how people might have been organized (for example Earle and Ericson 1977; Ericson and Earle 1982; Renfrew *et al*. 1966, 1968; Renfrew 1975; Wright 1969*; inter alia*). Even now, although more data and new approaches to the study of obsidian artifacts indicate that the picture is far more complex and nuanced, this original general understanding all too often still seems to pervade our interpretations. Some of the underlying issues and some other possible approaches will be explored in this paper.

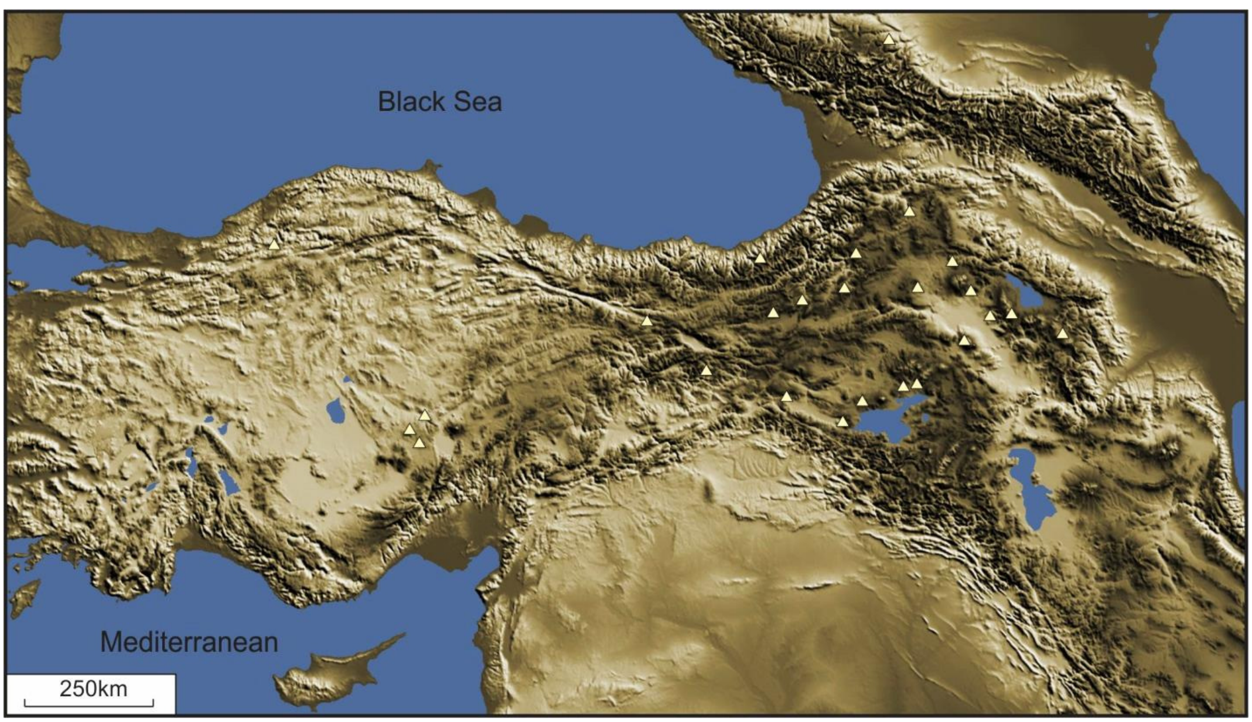


Figure 1. Main Obsidian Sources in Anatolia and Armenia. Map courtesy of Stuart Campbell.

The Status Quo

Archaeologists working in the Near East often pay a lot of attention to obsidian, although in many instances it forms a minor component of the raw materials used to make chipped stone tools. Generally it is worked and used alongside flint and similar raw materials in everyday contexts, but at other times it is reduced differently from flint, or it is made into special objects such as items of jewelry, vessels, mirrors and so on, in a way that flint is not. Our interest in it seems to be stimulated by its relative rarity, its visual appeal and the fact that it is often an exotic material, whereas flint is usually local or regional. We tend to look at the occurrence of obsidian artifacts as dots on maps and from them postulate networks of exchange without actually thinking about the prehistoric peoples who interacted with it as they acquired and worked it.

Attention was drawn to its exotic nature at sites in the 1880s (de Morgan 1927; see also Frahm 2012a; Wainwright 1927) but Renfrew et al. in the 1960s were among the first to apply scientific techniques to characterize sources and artifacts of obsidian in the Near East and Mediterranean and to match up the two (Cann and Renfrew 1964). They also used the data to explore wider questions of acquisition and to generate patterns of exchange. This work was, however, based on a small data set (approximately 160 artifacts from 53 sites - an average of roughly three artifacts per site. Now there are ten times more data - Frahm estimated c.1600 in 2012 and now perhaps there are as many as 2000) and a realization that techno-typological and functional attributes also inform our understanding of the use of obsidian (Binder 2008; Carter *et al*. 2006, 2008; Freund 2013 *inter alia*). This suggests that a much more holistic approach is needed (cf. Gebel 2013). The emphasis on acquisition by exchange has meant that little attention has been paid to the people who exploited the sources, quarries and workshops, or made and used the artifacts (cf. Özdoğan 1994). So when we look for ways to interpret how and why prehistoric people engaged with obsidian, it is important to examine not only the data but how, as archaeologists, we have responded to those data.

In what follows I will briefly review what I see as some of our present understandings relating to the analytical methods used for Near Eastern obsidian studies, the known sources of obsidian in the Near East, the extent to which they were exploited and by whom, and then consider some other ways that might be valuable in elucidating the use of obsidian.

Discriminating Between Sources

Instrumental Methods

The use of geochemical analysis to characterize obsidian was initiated by Renfrew and Cann in the 1960s. They used OES which is now largely obsolete (Cann and Renfrew 1964; Renfrew et al. 1966, 1968); this was followed by neutron activation analysis (Wright 1969). Since then, a variety of methods have been used to characterize Near Eastern obsidians (Gratuze 1998; see also Frahm 2012b; Pollard et al. 2012) some of which seem to be as much about testing the efficacy of the technique as the results, and not all are directly comparable (Frahm 2010; Hancock and Carter 2010). The methods now most commonly used, and the associated laboratories,[1] include INAA (MURR), LA-ICP-MS (Bordeaux and Orleans), PIXE (Bordeaux and Paris) and EDXRF (Berkeley and MAX Lab McMaster) SEM-EDS (Bordeaux) and most recently pXRF (Shackley 2011; Frahm and Doonan 2013; Frahm 2013a; and related papers). EMPA (Missouri) is also used (Frahm 2012b). Fission track dating is also used (Poupeau et al. 1998;

[1] This list includes only the most commonly used laboratories and is not intended to exclude other laboratories carrying out similar procedures.

Oddone et al. 2003) and has proved useful in distinguishing sources otherwise difficult to separate (Poidevin 1998). Rock magnetism is also increasingly being used to identify the precise point of a flow from which the obsidian was obtained (Binder et al. 2011; Frahm and Feinberg 2013b), offering exciting possibilities for understanding how obsidian was exploited at a particular source.

Each of the panoply of techniques available have their strengths and weaknesses; some are better suited to analyzing certain elements than others, others are non or minimally destructive, some are speedier than others, some produce elemental concentrations while others intensities which then need to be converted to concentrations using various standards. There are question marks over each method and some answer certain questions better than others (Shackley 2008; Frahm 2012c). Most of these issues can be addressed in one way or another.

Visual Characterization

As well as geochemical analyses there have been a number of attempts to distinguish different obsidians on the basis of their physical characteristics, with varying degrees of success (Cann and Renfrew 1964; Braswell et al. 2000 *inter alia*). When carried out on a site-by-site basis, particularly where large assemblages make wholesale geochemical analysis impractical, in controlled conditions (including the use of blind tests) in conjunction with geochemical analysis, it has proved with a 75 to 99% degree of confidence to be a useful discriminator. It thus enables discussions of the techno-typological, chronological and spatial distribution of obsidian throughout an assemblage (Healey and Campbell 2009; Milić et al. 2014), which would not otherwise have been possible.

Inter-Comparability of Data

Comparison of concentrations of elements between methods is mostly reasonably successful (Hancock and Carter 2010; Milić 2014, Table 4; Poupeau et al. 2010) though the issue of legacy data remains (although see Frahm 2014a). The main contention is still a small number of artifacts geochemically analyzed from each assemblage, placing any overall interpretation of obsidian use on a precarious footing (Shackley 2008).

The Data Set

This is partly because laboratories with suitable equipment and good comparative material are situated outside the country of excavation, which means that the artifacts have to be exported for analysis. Unfortunately there are often quite stringent restrictions on the number and types of artifacts permitted for export, and certainly forbid objects of ‘museum quality.’ Also, until recently, analytical methods tended to be expensive and partially destructive, making permissions even harder to obtain (*cf.* Orange et al. 2013). It is often not clear why excavators chose particular artifacts for characterization or how representative they are of the entire assemblage. Perhaps, too, the lack of understanding by archaeologists of the need to comprehensively analyze an assemblage, or at the very least to devise meaningful sampling strategies, has been a factor.

The result of all this is that in most, if not all, cases we fall short of the recommendation that at least 60% of an assemblage needs to be characterized in order to apportion the obsidian to the sources at a 95% level of confidence (Blackman *et al*. 1993; see also Shackley 2008). However, where obsidian specialists are involved in selecting artifacts, it is becoming more usual to analyze more artifacts (Carter 2011; Healey and Campbell 2014; Maeda 2003; Milič 2014; Orange et al. 2013). For the future, the increasing confidence in the suitability of pXRF equipment for use in field laboratories (Frahm 2013a; Frahm et al. 2014) will enable more artifacts (ideally the whole assemblage) to be analyzed at the excavation, but in the meantime, it is still often difficult to assess the relative importance of the obsidian from each source at a particular site.

Something else which we do not consider when attempting to understand and reconstruct networks (if that is what we want to do) is the range and location of excavated sites and how this might affect the data. A particular site may have been chosen for excavation in order to investigate specific (often non-obsidian related) questions or may sometimes be governed by modern political demands with the result that a lot of obsidian-related questions have had to go unexplored and unanswered (and at times unasked). Lacunae in the distribution of obsidian also may be as much a factor of location of excavations as real absences. With these limitations in mind, we will now briefly consider our present understanding of the use of obsidian.

The Sources

In the Near East obsidian occurs naturally in Anatolia, the Mediterranean, SW Arabia, Ethiopia, Armenia, Iran (probably) and Afghanistan. Here we are concerned primarily with the Anatolian and, to a lesser extent, the Armenian sources. There are at least 20 known potential source areas (Figure 1) although not all provided 'tool-quality' obsidian or were exploited simultaneously or to the same extent. Even what we mean by a source can be ambiguous (Frahm 2012d).

The focus on geochemical analysis means that the majority of sources,[2] and often individual flows, can largely be distinguished by their geochemical composition even though with one exception we have little detailed knowledge of individual sources (cf Özdoğan1994)[3]. Only in rare instances can we document the elemental variability of a particular source with any confidence, nor do we understand the geomorphology or even know the number of flows and outcrops at a particular volcano, or the variation in their physical nature and geochemical composition (Binder et al. 2011; Chataigner and Gratuze 2014a and b). Studies involving geo-morphology show too that outcrops can become accessible or disappear due to tectonic movement and fluvial events (cf Binder et al. 2011), so we cannot assume that all outcrops known to us were available to prehistoric peoples and *vice versa*.

Geographical and Chronological Extent of the Use of Different Sources

Most of our information about how and when sources were used in fact comes from the data generated by artifact analysis. This suggests that some sources are dominant through time, namely Göllüdağ east in central Anatolia and to a lesser extent Nenezi Dağ, and in eastern Anatolia the peralkaline sources of Nemrut Dağ and Bingöl A, as well as the calcalkaline sources labelled Bingöl B. Others played a supplementary role at various times (Carter et al. 2013; Frahm 2012a) though their role may be distorted by the small numbers of artifacts analyzed overall (Orange et al. 2013; see too McKillop 1996; Shackley 2008 on the limitations imposed by small samples). As well as a measure of the popularity of each source, albeit a crude one because it depends on how the artifacts were selected for analysis, these data are also the basis for the distribution of obsidian from the various sources. For the most part it indicates that Central Anatolian obsidians (mainly from Göllüdağ east, Nenezi Dağ and more rarely Acigöl) are found at settlements in central and

[2] It has only recently been possible to distinguish between the two peralkaline sources of Nemrut Dag and Bingöl A (150km apart (Carter et al. 2013; Frahm 2010, 2012c; Orange et al. 2013; Poidevin 1998). It is still not possible to distinguish the two in much of the older data (but see Frahm 2014). There is also on occasion some ambiguity between some sources (Frahm 2013d).

[3] Hopefully this will be greatly improved by recent surveys such as those of Chataigner and Gratuze (2014a and b).

western Anatolia, and the Levant as far as the Euphrates, whereas obsidians from southeast Anatolia, mainly Nemrut Dağ and Bingöl but also Muş, Meydan Dağ, Suphan Dağ, Tendurek and an unlocated source (Renfrew's 3d) are found at settlements in eastern Anatolia and Northern Mesopotamia. Obsidians from both source areas are regularly found at settlements in northern Mesopotamia (mainly Syrian Euphrates) and the Levant. This highly generalized understanding has formed the 'template' for the majority of discussions of obsidian distribution (see map in Frahm 2014, Figure 1). Increasingly though, as more artifacts are analyzed, we are seeing this trend bucked, for example by the presence of east Anatolian obsidians at Çatalhöyük (Carter et al. 2008) and the presence of central Anatolian obsidians in the Early Bronze Age at Tell Mozan (Frahm and Feinberg 2013b and c) and with Armenian obsidian being used in the Northern Levant (Frahm et al. forthcoming). We should note here too that people were aware of the origins of their obsidian in that there is evidence of an acceptance of how the obsidian from each source should be worked and used (Healey 2000; Maeda 2007; Nishiaki 1993).

Chronologically and geographically there is great variation in the way obsidian was used, and here we can only highlight a few points. In the lower Paleolithic it seems to be only found at sites near to sources (Slimak et al. 2008; Yalçinkaya 1998); obsidian has been recovered from Palaeolithic settlements away from these areas but it is unusual and unfortunately not from reliable contexts (Moutsious 2010; Renfrew et al. 1966, but see Carter 2014 for a wider picture). The earliest indication we have so far of movement of obsidian away from source in the Near East is at Shanidar in Northern Iraq, from a context dated to c. 30,000BC, where two artifacts of peralkaline obsidian were identified (Renfrew et al. 1966), the source of which is some 250-300km to the north. The next evidence is from more than ten thousand years later (c. 18,000 cal. BC) in south-western Anatolia from the early levels in Öküzini cave where a flake of Nenezi Dağ obsidian was recovered (Carter et al. 2011). Throughout this time, obsidian was used widely though it is scarce (Cauvin and Chataigner 1998, 329). For the following period (PPNA/PPNB) there are more data, and artifacts made of obsidian both from Göllüdağ and Nenezi Dağ are found at various sites in western Anatolia and the Levant but still in minute quantities (Cauvin and Chataigner 1998, Periods 0, 1 and 2).

So far, the earliest evidence of relatively intense use of obsidian comes from the Upper Tigris region at the late epi-Paleolithic site at Hallan Çemi where obsidian comprises 56% of the lithic tool kit - some 2500 artifacts. Analysis of 16 artifacts show that obsidians from both Bingöl B and Bingöl A and Nemrut Dağ are present (Rosenberg 1994), the source being some 100-130km distant. Carter et al.'s recent analysis of 120 samples from the contemporary and nearby site of Körtik Tepe refines our understanding of the use of the two sources in that Bingöl obsidians were used earlier than the Nemrut Dağ obsidian; it also revealed the earliest use of obsidian from Muş located between the two source areas. Techno-typological analysis also allowed them to suggest that Bingöl calcalkaline obsidians appear to have reached Körtik Tepe as decorticated nodules whereas the peralkaline obsidians came as corticated nodules. Techno-typological studies have also demonstrated different knapping traditions in Upper Tigris region compared to contemporary practices in northern Mesopotamia and the Levant suggesting localized 'communities of practice' (Carter et al. 2013, Figure 10).

By the late PPNA/EPPNB (ASPRO Period 3) obsidian is generally found in larger quantities and at a wider range of sites, and it is at this point that it has been used in wider archaeological narratives as evidence of networks of exchange (Asouti 2006; Watkins

2008), although detailed studies of obsidian show that the picture is much more nuanced. For example, there are a number of different pressure blade technologies: in central Anatolia, there is distinctive and very particular blade technology (naviform) associated with the Kaletepe P workshop on Göllüdağ which is different from that practiced at other workshops on Göllüdağ and has a different distribution (Balci 2014). Different blade techniques again are present in northern Mesopotamia (Binder 2007, 2008; Maeda 2009).

By the later Neolithic and Ubaid there seems to be some sort of realignment in source usage (though this may also reflect the geographic location of settlements and excavated sites), and new sources also begin to be exploited (see for example Healey and Campbell 2009; Maeda 2003; Renfrew et al. 1966: 48). At about this time, we also begin to see obsidian increasingly used for making things other than tools (Healey 2013).[4] Although there is a general decline in the use of stone for tool manufacture from the Chalcolithic (Rosen 1997), obsidian use continues regularly, albeit in small quantities, though one or two sites have exceptionally large amounts as for example at Khirbat al Fakar (al Quntar et al. 2011).

The reasons for the choice of obsidian from a particular source or combination of sources are probably many and varied and not always obvious (Chataigner and Barge 2008). Distance from source is likely to have been a factor, though not necessarily an overriding one (Barge and Chataigner 2003; Chataigner and Barge 2008; Healey and Campbell 2009; Ortega et al. 2013; cf Frahm's maximal efficiency 2014). Abundance and accessibility of the obsidian at source is likely to have been a major factor, as is its quality (Freund 2013, 781). For example, the size and quality of the obsidian at Kaletepe P on east Göllüdağ seems to have been the enabling factor for the production of a particular type of blade specific to this workshop (Balci 2013; Balkan-Atlı and der Aprahamian 1998; Binder 2001; Binder et al. 2011). Conversely, on Nemrut Dağ we may note the avoidance of some flows of obsidians with feldspar phenocrysts and thus of poor flaking quality. Cultural affinities and social and ritual perceptions are also likely to have had a major role (see below).

The Amount of Obsidian Involved

So far I have focused on the origins of the obsidian obtained by communities. It is also useful to have some idea of how much obsidian was involved before I continue the discussion of how it was acquired, its meaning and so on, because amount present has been used as a factor in explaining its distribution. The quantity of obsidian consumed at each site is usually given as a percentage of the flint (weight being only occasionally recorded). This is a very blunt instrument because it lumps all obsidian together and does not allow an assessment of relative importance of each source (Healey and Campbell 2009; Milić 2014). Cessford and Carter have suggested that density in grams per cubic meter of occupation debris might be a more reliable and repeatable measurement (2005; see also Torrence 1986, Table 6. 126-7). Using this method, they calculate that between 116 and 318kg per annum was acquired by the inhabitants of Çatalhöyük who depended on obsidian as a raw material for tool manufacture, although they were 190 km from its source. Others report obsidian in terms of weight, for example at Aratashen, in the Ararat plain (Armenia) relatively near to source, had about 90kg or 18,000 obsidian artifacts (Chataigner and Barge 2008); from the Burnt House at Tell Arpachiyah where obsidian was reported to be about 50% a

[4] It is interesting that at times of change and/or developing social complexity, lithics are used in unusual and often highly elaborate ways (Apel 2001; Carter et al. 2008) and are perhaps a way of expressing social distinction (Conolly 1999).

sample of 2300 artifacts weighed 9000g (Campbell and Healey 2013) and at Domuztepe, a large site with 2000 or more inhabitants, where obsidian forms only about 18% of the toolstone used, consumption of obsidian (assuming equal use across the site) is estimated at 202kg of obsidian per generation (Healey 2000, 141-2). From these data, it is difficult to make comparisons.

Weight and quantity of course are only one measure and do not necessarily tell us its relative importance to the inhabitants, nor indeed why they wanted to use it. In settlements where obsidian is not the dominant raw material, the reasons for acquiring and using obsidian blades might be the same for those who made their blades on site as those who preferred to acquire their blades ready-made (analogous to cooking from scratch or eating ready-made meals) although there would be considerably more obsidian present in the form of debris at the former.

The form in which obsidian was obtained varies from community to community. At Çatalhöyük, it has been demonstrated that obsidian from Göllüdağ was often obtained in the form of large quarry flakes and implies direct access, though other ways were likely involved too (Carter 2011; Cessford and Carter 2005). The presence of unmodified raw materials is rare on sites: the nodules at Arqa, in the Lebanon, being highly unusual; amongst them there is a large block of obsidian weighing 22kg though it is some 250km from its source at Göllüdağ (Thalmann 2006). Most of our information is deduced from the type of debitage present. For example, in the upper Tigris, Carter et al. (2013) suggested that Bingöl B obsidian was obtained in the form of semi-prepared cores whereas peralkaline obsidian was unprepared, cf too Domuztepe and Arpachiyah (Healey 2000, 140 and 148; but see too Frahm 2014; Kuhn 2004). Elsewhere attention has been drawn to some unusually large cores including one found with a large mirror at Kabri in Israel (Stekelis 1958), a core from Hagoshrim (4kg) (Schechter et al. 2013) and one from 'Ain el Kerk in the Rouj basin (715g) (Maeda 2002) All these sites are over 200km distant from the source. There is also a large core from Tell Halaf in the Khabur and several from Tilke Tepe (which is relatively near to the source area), one of which weighs 11kg (Korfmann 1982: 44). In contrast, at Sabi Abyad in the Balikh Valley also some 250km from the source, obsidian seems to have been acquired as ready-made blades. Here a parcel of 21 blades, with a total weight of 70g that were likely struck from the same nodule of peralkaline obsidian, was recovered. This has been interpreted as belonging to an individual and contrasted with another possible reserve of 300 blades from the burnt house at Bouqras, which seem to have been for communal consumption (Astruc et al. 2007; Roodenberg 1986). It seems then that there is no universal way of transporting obsidian, and suggests that our analyses should be sensitive to reduction stages present to help elucidate this, and also needs to be factored in to any discussion on exchange.

Most explanations for the distribution of obsidian are concerned with the how rather than the why. Most still, at least to some extent, hark back to Renfrew's models of exchange, and obsidian still seems to be seen as some sort of commodity, though not to the extent implied by Mellaart (1964, 1967, 176-7). It is almost always conceived as part of a network in which someone or some community is the driving force - any change in quantities or use of different sources is seen as a change in control of sources or exchange partners (Biçakçi *et al.* 2011; Erim Özdoğan 2011). Alternative more flexible models have been suggested by Ortega et al. using agent based models in which small world networks allow some villages to establish links with others up to 800km distant (2013).

The possibility of regional redistribution centers near sources (Mellaart 1964; Renfrew 1975) has recently been reopened with the excavation of Tepecik-Çiflik, but as they note, much more research is needed (Biçakçi et al. 2011: 101). Further from source and where obsidian is present in substantially larger quantities than in the surrounding areas and where blades in excess of what would be required for local consumption were produced, as at Khirbat al Fakar (Hammoukar) (Al-Quntar et al. 2011), it has been suggested that it was distributed along the lines of the Mesoamerican gateway communities (Carter et al. 2013; Frahm 2010, 721ff.; Heath-Anderson and Hirth 2009; Hirth 1978; Hirth and Castanzo 2006). This model may also be applicable to communities with large amounts of obsidian such as Magzaliyah and Arpachiyah. Other sites like Domuztepe appear to have a central role among sites in the surrounding area (Healey and Campbell 2014), but in almost every case we lack the supporting regional data. We should note though, that despite the dependence on obsidian and the vast amounts present at Çatalhöyük, the inhabitants seem to have acquired obsidian independently of other communities (Carter 2011).

I suspect that the answer to how people obtained obsidian is inevitably and inextricably bound up with their particular perception and understanding of obsidian, and its significance within their particular society, so that there may be several responses.

Hunting and gathering communities almost certainly viewed the acquisition of raw materials rather differently from people in more sedentary situations. Both archaeological and ethnographic data suggest that mobile communities mostly seem to use materials which originate within their territories rather than exchange raw materials or tools in any significant quantity, acquiring the material directly for themselves, though there has been some discussion of the significance of distance. Whatever the case, it seems that there is no evidence for sustained or systematic exchange (see for example Fèblot-Augustins 1993; Kuhn 2004; Pèrles 2013a: 540; Shackley 1986; Whallon 2006; but see also Carter 2014; Carter et al. 2011). This does not mean that the origins of the raw material was not without meaning to the people using it, as Pirie has suggested in the case of Pinarbaşi where the different uses of obsidian and flint may link peoples to a particular part of the landscape (Pirie 2011).

Once communities become more sedentary (even though a transhumant pastoral or semi-nomadic way of life probably continued), it seems to have been rather uncritically assumed that obsidian was distributed through exchange networks along with ideas and other materials as part of a sort of package (Asouti 2006; Watkins 2008), and that it must have had a social significance simply because it was exotic. While this might turn out to be the case, each community seems to have made its own response to obsidian use, and so we need to look much more closely at individual data sets and deconstruct just how much obsidian was consumed and used, and for what purposes.

As complex and urban societies emerge or develop, some probably did acquire at least some obsidian via more formalized trade and exchange networks, as suggested by the store of nodules obsidian at Kültepe and the quantities of obsidian involved at the vase-making workshop at Uruk-Warka (Lindermeyer and Martin 1993) or Atchana (Woolley 1955), and/or at least piggy-backed on trade networks of other materials. The intriguing suggestion made by Frahm and Feinberg (2013a) that artifacts of Göllüdağ obsidian found at Tell Mozan (well outside its expected distribution range) were part of a personal diplomatic gift, again suggests that we need to be looking much more closely at the material, its context and chronology.

The Role of Nomads

It has long been thought that pastoral nomads might have been involved in obsidian diffusion (Chataigner 1994; Crawford 1978; Hole 1968; Wright 1969 *inter alia;* but see too, Cribb 1991: 14 re their involvement in trade), and Chataigner and Barge (2008) have put up a compelling model showing the possible role of transhumant nomads in some cases. One of the difficulties with pinning down this suggestion is that relations between nomads and sedentary groups varies over time (see Rosen 2008: 119, 131) and another is recognizing them archaeologically, as for example in the Hibermerdon survey (Ur and Hammer 2009). The frequently quoted historical example of the Alikan tribe, whose summer pastures were within the obsidian source area of Nemrut Dağ but who over-wintered further south, some as far as the Sinjar and headwaters of the Khabur where the settlements are (Cauvin and Chataigner 1998: 338; Cribb 1991; Frahm and Feinberg 2013a and b), is used to support the argument that nomads were instrumental in the dispersal of obsidian, and it is a beguiling idea. However, extrapolating back to a different world and some millennia earlier is difficult. We also need to have a better understanding of how nomads might have engaged with obsidian themselves before assuming that they passed it on. It also does not account for the presence of obsidian beyond nomads' territories, though Crawford (1978) has offered explanations as to how it might have been forwarded outside territorial limits. While the question must remain unresolved pending better archaeological documentation, it is possible that nomads were responsible for what Rosen calls the 'trinket trade' in the Bronze Age (Rosen *et al* 2005; and cf Frahm and Feinberg 2013a and b). On the other hand, we should not ignore or discount the possibility of a special expedition to acquire obsidian, either (Kador 2007).

Other Ways of Tracing People's Engagement with Obsidian

There are other ways too, by which we might shape our thinking about why and how people understood, acquired, and used obsidian (cf Gebel 2014; Maeda 2009). Conneller is explicit that "materials are meaningful and these meanings are reciprocally generated in varied processes of people's engagement with them. Tracing these connections reveals past worlds" (Conneller 2011: 9). Thus it is through the 'material-ness' of obsidian and its origins that we might discover how and why people used it (cf Cooney 2005: 15; Geertz 2000: 16; van Gjin 2010: 164, 166). As archaeologists, we accept almost without question that the act of making stone tools is inextricably bound up with an appreciation of their physical nature and cultural norms (Dobres 2000).

It is often said that obsidian had both a utilitarian and a symbolic function, but these are values put on it by us. While we can relatively easily and 'scientifically' identify and explain the utilitarian side, just what we mean by symbolic aspects is rarely defined (cf. Goring Morris and Belfer-Cohen 2001; Sedit 2014). Two approaches to get behind these ideas suggest themselves (as well, of course, as a detailed study of the artifacts and their context): ethnographic analogy and contemporary evidence. Ethnographic data largely comes from very different situations (see for example Berleant 2007; Boivin and Owoc 2004; Gould 1980; Parry 2001; Pètrequin *et al*. 2011: 58-9; Saunders 2001) but one used quite extensively by archaeologists. In the Near East, we also have more or less contemporary textual references to obsidian and flint in Akkadian texts dating from c.3000BC onwards, a time when obsidian was still in use (summarised in CAD 1962, Vol 16/5 *ṣurru,* and see too

Coqueugniot 1998; Postgate 1997).[5] Quite apart from references to the specific use of obsidian, these textual descriptions are interesting because they document a world of beliefs not usually observable in archaeology alone, and show that obsidian (and other stone) continued to have a significance to people at a later date than the archaeological material alone might lead us to believe.

In some respects, obsidian as a material is relatively well understood and appreciated both by us and by past peoples. It is hard and glassy (5-6 on the Mohs scale), and like flint, fractures in a predictable way with a sharp edge - a property noted in cuneiform lexical texts (CAD 16/6, 257). As we have seen, these characteristics have been exploited in different ways throughout prehistory.

Its sensual features, such as shininess, reflectivity, translucence, and sometimes deep blackness give it a mysterious, almost ethereal, appearance. It is also smooth, almost silky to touch, and produces a tinkling sound when struck. There is also a distinctive smell associated with stone knapping which may not have gone unremarked. These sorts of attributes, though less definable, are known to have engaged various pre-modern people in a number of ways. Shiny and bright materials are often considered potent and to be infused with life-force (Gould's 'righteous rocks' 1980: 134; see too Gaydarksa and Chapman 2008; Saunders 2002), or to reflect ancestral power (Brumm 2004: 147; Taçon 1991) and so to be closely linked to mythological understandings of the landscape (Brumm 2004, 2011; Robinson 2004: 98), something not immediately recognized or experienced or appreciated by most present-day archaeologists (Hurcombe 2007; Jones 2004).

[5] There are also references to rocks and minerals throughout the Egyptian and classical world (see for example Aufrère 1991; Decourt 1998; Graves-Brown 2010). Stone, often flint, knives are mentioned in various places in the Hebrew Bible (ḥallamīš, Koehler and Baumgartner translated by Richardson 1994: 32).

Color may also have had meanings that are not immediately apparent to us, an aspect which some suggest is often underestimated (Jones and MacGregor 2002, and papers therein). Obsidian is found in a variety of colors: black (opaque), green, grey, and red-brown; sometimes it is mottled or striped (flow banding), features which are most easily visible in transmitted light. Indeed Carter suggests that the distinctive visual and tactile properties of the 'exotic' artifacts made from east Anatolian obsidians at Çatalhöyük would not have gone unnoticed by the inhabitants (Carter et al. 2008). The Mesopotamians too were aware of the different colors of obsidian and described it as black, green, and white, and sometimes as being without 'lines'. Different colors were specified for different purposes. For example black obsidian is specified in statuary and for medicinal[6] and ritual purposes (CAD 1962 vol. 16/5: 25). Glazed bricks are also described as being the color of obsidian (CAD 1962 vol.16/5: 25; Tawil 2002) and Babylon is described as a 'mountain of obsidian' (CAD 1962 vol 16/5), perhaps indicating its splendor.

The texts (CAD ṣ) also inform us that obsidian had a value. For example a Neo-Assyrian king from Kouyunjik noted in a letter that it had become expensive (Harper 1896, ABL 404; 17, 422). In Middle Babylonian texts it is regarded as a precious stone alongside gold, lapis lazuli, and carnelian; note for example a description of a necklace of 34 beads of obsidian, 33 golden beads, a center-piece of genuine lapis lazuli

[6] Assyrian medical texts specify that black obsidian be powdered in mountain oil and used for medicinal purposes (CAD 1962: 258; Coqueugniot 1998: 352-3). Apparently medicinal use was a widely recognized feature as Saunders' description of 16th century Aztec understanding of obsidian indicates: 'The powder of this stone [obsidian], mixed with quartz crystal equally pulverized, removes cataracts and leucomas and clears up the vision' (Saunders 2001: 224 quoting Francisco Hérnandez quoted by Clark 1989: 315).

set in gold in a list of gifts of Tušratta, a Mittanian king of the 14th BC (CAD 1962 16/5). Indeed, just such a necklace was found in the grave of a Neo-Assyrian princess at Assur (now in the Vorderaisiatiche Museum, Berlin). As an aside, we might also note that the *Epic of Giglamesh* it is listed, along with other precious materials as a gift suitable for Shamhat, a harlot -'…obsidian shall he give you, lapis and gold.' (Gilgamesh VII line 157)! It is also regarded as a suitable offering to the gods: Tiglath-Pileser 1st (1114-1076BC) records how he brought obsidian and other rocks and minerals "from the Mountains of the lands of Na'iri, which I conquered with the support of the god Ashur my lord. I deposited them forever in the HAMRU temple [which he had restored] of the god Adad, my lord forever" (CAD 11962, 16/5; Arnold and Beyer 2002: 143). So too, obsidian is listed among the rocks dedicated by Sargon to the god Marduk (Winckler Sar. Pl. 35, no. 74, 142).

Not all the attributes of obsidian are good.[7] In a Sumerian poem describing the god Ninurta's dramatic battle with Asag and the rocks, Ninurta passes judgement on the rocks, cursing or blessing them depending on how they acquitted themselves in the battle – obsidian/flint was cursed whereas other precious rocks like lapis lazuli were blessed. The poem also provides an explanation of how each rock got its physical properties, its technological use and cultural associations (Black et al. 2004/2006: 341) and so presumably shaped and reflected peoples' understanding of the different rocks and influenced how and when they were used.

We know that for pre-modern peoples sources of certain rock were regarded as sacred. This means that rights of access may have been restricted and certain rituals performed before any expedition could be mounted.[8] Various examples have been described and discussed and need not be rehearsed here (see *inter alia* Brumm 2011; Burton 1980; Edmonds 1995; Stout 2002; Taçon 1991, 2004; and papers in Boivin and Owoc 2004). These sorts of data are often used as an aid to interpretation by archaeologists when questioning why particular sources of rock were exploited by Neolithic peoples in Europe (Bradley and Edmonds 1995; Cooney 1998, 2005; Edmonds 1999; Pétrequin *et al*. 2011) though rarely specifically to obsidian (but see Dillian 2002; Frahm 2012d).

Obsidian sources in the Near East, as in many of the situations above, are in inaccessible mountainous terrain, usually far from any known settlements and very different from the lived landscape (cf Frahm 2010; Maeda 2009), a feature which may well have impacted people's perception and appreciation of it as something unusual and outside of their daily experiences.

Ethnography shows too that landscapes had supernatural power and complex cultural significance (Brumm 2011). The exploitation of sources of rock went far beyond being the supply of raw material. The special nature of the rock from a specific source may be transferred to the stone worker and user (Tacon 1991; 1999), and so too a journey to obtain exotic goods by individuals is believed to give power to the traveler as well as a special aspect to any goods which they may acquire (cf Helms 1988). We need to remember too that every time obsidian (raw or crafted) passes through different hands and is worked and used, it accrues meaning (Gosden and Marshall 1990).

[7] So too, the Owens Valley Paiute (Steward 1933 quoted by Eerkens et al. 2008) regarded obsidian and /or the sources as poisonous or as having toxic qualities (Robinson 2004: 97).

[8] Rituals are often performed before a quarrying or mining expedition sets off, to ensure a good and a safe harvest and to placate the spirits (see for example Robinson 2004: 97; Stout 2002).

In our explanations of how things got from a to b, we tend to be obsessed by finding the most cost-efficient route, but objects, materials, time, and distance had different meanings in pre-modern societies (Helms 1988). Our estimates of distance between source and consumer using terrain modelling, GIS, and carrying capacity (Astruc et al. 2007: 336f; Barge and Chataigner 2003; Chataigner and Barge 2008) may serve to put some geographic perspective and are testable, but do not take into account (un)familiarity with the route, the pleasure of journeying for its own sake, or the rituals, taboos and social obligations that might be encountered on the way. Rather, the action of moving materials and objects from place to place suggests that materials and journeys are "…socially meaningful and historically constituted practices that respond to and transform their cultural context. They are embodied experiences, real and mythical, that constitutes a person's identity and condition" (Cummins and Johnston 2007 passim; see too Gero 1989: 103). So too, the act of moving through the landscape is a fundamental part of the experience of and engagement with places (Edmonds 1999; Ingold 2004, 2011: 148; Tilley 1994: 29-30) not just a means to an end. Indeed, "…. the identity of person would have become inextricably bound with the locality of her place in the settlement or on the landscape" (Steadman 2005: 296; cf Ingold 2006; Verhoven 2013) – important if we consider that the origins of obsidian may have been significant to the people using it (cf Helms 1988). It is more like Ingold's suggestion of wayfaring or "meshwork's of entangled lines involving all aspects of people and things" (Ingold 2011: 143; cf Hodder's entanglement 2012) rather than a network, and provides different ways of looking at dots on maps and apparent connections.

Discussion and Conclusion

This brief survey has highlighted aspects of the use of obsidian over thousands of years and hundreds of kilometers. The area I am considering is vast, and the sites and artifacts widely and unevenly distributed with the result that, to borrow a phrase from Felix Riede and ultimately Tolkein, the data has been "stretched thin, like butter on too much bread...." (Riede 2007).

Such data should not really be used to make general assumptions. This should not be a cause for despair, but it does mean that we need to find different, more integrated ways of looking at what is behind the distribution, and not impose models on the data which have been constructed to suit our understanding of the world, concepts which for pre-modern peoples may have had no meaning.

It is clear that for many peoples, artifacts and materials are significant for reasons other than the obviously functional. Appreciating how certain minerals and rocks bridge the symbolic and material world may be a difficult concept for us because, as post-modernists, our interpretation of our own world is different (Thomas 2004), but also perhaps in part because we do not need stone for our own survival, we regard it as a means to an end and so we do not directly engage with it. For Mesopotamians though substance was not separated from function, nor was there a hard and fast dividing line between the natural and supernatural (Postgate 1997: 220).

To rise to this challenge, our analyses need to balance prosaic technical descriptions and geochemical analyses with observations and understandings of the material qualities of obsidian, and to be more adventurous in exploring accounts of people's engagement with materials, sources, and landscapes. We also need to contextualize the use of obsidian within the wider society (Baysal 2013; Gebel 2014). This contextualizing is important because we need to be careful not to impose our own understandings and interpretations on to the past (Berleant 2007).

It is hoped that integrated studies will eventually allow us to address questions as to why obsidian was selected as a raw material and worked and used in particular ways; why obsidian from particular sources were chosen; why some sources were preferred above others; and why this changed through time.

The way we problematize the study of obsidian and the framework in which we choose to interpret it, whether on an economic, political, processual, post-processual, agentive, or phenomenological basis will affect our perceptions of how and why obsidian was used. Rather than try to explain and generalize using inadequate data, it is perhaps time to observe and record systematically on a case-by-case basis.

Afterword and Acknowledgements

This paper has been a long time in gestation and is a personal view with many things worthy of further discussion curtailed or omitted. It arose from frustration with what appeared to me to be the staidness of approaches to obsidian studies in much of the literature. Of course there are colleagues who are breaking this mold as is obvious from the references in this paper. My thinking is not original, but has been formed, colored, and modified through the papers of and discussions with numerous colleagues who wittingly and unwittingly have contributed in various ways to my thoughts. Invidious though it is to name individuals, I really do want to thank Stuart Campbell, Osamu Maeda, Tristan Carter, Ellery Frahm, and Laurence Astruc, even if they do not necessarily share my views.

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ESTIMATING OBSIDIAN HYDRATION RATES FROM TEMPORALLY-SENSITIVE ARTIFACTS: METHOD AND ARCHAEOLOGICAL EXAMPLES

Alexander K. Rogers, MA, MS, RPA
Maturango Museum

Daron Duke, PhD, RPA
Far Western Anthropological Research Group

Abstract

This paper describes a rigorous method for estimating an obsidian hydration rate based on temporally-sensitive artifacts, using a weighted linear least-squares best fit. The individual data points are weighted by a factor which reflects the level of confidence in the ages. The mathematics for the technique are developed and a rate example is computed for Meadow Valley Mountains obsidian from Lincoln County, Nevada. The rate is applied to an archaeological example for site 26CK8411 in the Moapa Valley, Nevada, and shows the rate gives archaeologically reasonable ages. The method is generally applicable in estimating hydration rates from temporally-sensitive artifacts, and is an efficient employment of often-sparse data.

Introduction

This paper describes a rigorous and consistent method for developing a hydration rate estimate based on temporally-sensitive artifacts, employing a weighted linear least-squares best fit. Use of temporally-sensitive artifacts such as projectile points is not new (e.g. Pearson 1995), but the process is fraught with peril. Should the analyst use the median age for each point type, or try to determine "hinge points" between types? Is the use of either the median or the hinge points applicable for very long-lived types such as Elko? Does including such point types improve or degrade the rate estimate?

The method described here addresses these issues by including a confidence-based weighting factor for each data point. The weighting factors are not arbitrary but are based on the inverse of the known span of persistence of the artifact type; the longer the span, the lower the confidence in the artifact's age. The analysis assumes the hydration rim data have been corrected for effective hydration temperature (EHT) using the method of Rogers (2007), including the effects of site elevation, burial depth of the artifact, and site formation processes.

The mathematics for the technique are developed from least-squares best fit theory and applied to obsidian hydration. It is shown that errors are minimized if the hydration rim value is chosen as the independent variable in the analysis, and the square root of time as the dependent variable. A specific mathematical form for the weighting factors is developed, which is applicable in all cases. An example is presented based on Meadow Valley Mountains obsidian, from Lincoln County, Nevada, with a summary of the method. An application to obsidian debitage from site 26CK8411 in the Moapa Valley, Nevada, shows that the rate yields archaeologically reasonable ages.

Least-Squares Best Fit Theory

It is well known that the growth of the hydration rim in obsidian proceeds as

$$r^2 = kt \qquad (1)$$

where r is the EHT-corrected hydration rim (typically in microns), t is the age (typically in years), and k is the hydration rate (in μ^2/yr or μ^2/1000 yrs) (Crank 1975; Doremus 2002). Thus, the rate is a slope, and can be computed by least-squares best fit methods. The physics of the situation (zero rim at zero time) dictates that the best fit line passes through the origin.

Consider a general data set of N pairs $\{x_i, y_i\}$, in which the y_i values are assumed to include random errors and the x_i values are assumed error-free (Cvetanovic et al. 1979; Meyer 1975). Assume further that a theoretical model suggests a linear relationship between the two, and that the best fit line is constrained to pass through the origin as in equation (1). The least-squares best fit method then yields a slope of

$$S = \sum w_i x_i y_i / \sum w_i x_i^2 \quad (2)$$

(Cvetanovic et al. 1979: 52, eq. 6), which minimizes the mean-square errors in y. Here the sums are taken over all N data points, and w_i is a weighting factor, typically chosen to be $1/\sigma_i^2$, where σ_i is the standard deviation of the errors in y associated with the i^{th} data point Note that σ_i is the statistically expected error for the i^{th} point, not the difference between the i^{th} data point and the best fit line.

In applying equation (2), it is possible to choose either t, r, or r^2 as the independent variable x. In each case the resulting slope S is related to hydration rate k shown in Table 1.

Independent variable	Dependent variable	**Hydration rate**
t	r^2	k = S
r^2	t	k = 1/S
r	sqrt(t)	$k = 1/S^2$

Table 1. Choices of independent variable in analysis.

An obvious first choice is to use t as the independent variable, since then the slope yields the rate directly. However, the best fit procedure is based on the assumption that the independent variable is error free, which is clearly not the case here since there are errors (i.e. uncertainties) in both the hydration rim value and the assumed age. Furthermore, the uncertainties in t are much greater than in r, so t is not a good choice for independent variable.

Choosing between r and r^2 as independent variable depends on propagation-of-error theory (Taylor 1982). It can be shown that the error coefficient of variation (CV) for r^2 is twice that of r. Thus, choice of r as the independent variable and sqrt(t) as the dependent variable more closely approximates the assumed error-free condition for the independent variable. For this case the mean value of the hydration rate is

$$k = 1/S^2 \quad (3)$$

Once S has been computed, the next step is to compute the standard deviation of the slope, based on errors resulting from the best-fit solution. The best-fit value of y_i (designated $\hat{y}_i$) is then given by

$$\hat{y}_i = Sx_i \quad (4)$$

and the error between the best fit and the measured data is then

$$\delta_i = \hat{y}_i - y_i \quad (5)$$

Finally, the standard deviation of the slope value S is (Cvetanovic et al. 1979: 52, eq. 6e)

$$\sigma_S = \text{sqrt}\{\sum w_i \delta_i^2 / [(N-1) \sum w_i x_i^2\} \quad (6)$$

and the CV_s of the slope is σ_S/S. The CV of the rate is $CV_k = 2 \times CV_s$, and the standard deviation of the rate is then

$$\sigma_k = CV_k \times k \quad (7a)$$

or

$$\sigma_k = 2 \times CV_s \times k \quad (7b)$$

Appropriate values for the weighting factors w_i must also be defined. The present case involves temporally-sensitive artifacts such as projectile points, in which the age assigned to a point is typically the median age for the type. For example, the Rose Spring point type is generally considered to have been employed between approximately 1600 cal BP (Yohe 1994) and 650 cal BP (Justice 2002: 321); by contrast, the Elko point type was exceptionally long-lived, from approximately 7800 cal BP to 1800 cal BP (Smith et al. 2013: 588, Fig. 3). Thus the Rose Spring type would be assigned an age of 1125 cal BP, and the Elko 4800 cal BP.

However, the confidence associated with these ages differs, since the Rose Spring type was manufactured over a span of only 950 years, while the Elko span was 6000 years; the shorter the span, the higher the confidence, so the weighting factor should be inversely related to the time span. For ages uniformly distributed between where t_b (the beginning age) and t_e (the ending age), the standard deviation of the age is $(t_b - t_e)/\text{sqrt}(12)$. A simple form for the weighting factors is then

$$w_i = 1/(t_b - t_e)^2 \qquad (8)$$

The factor by sqrt(12) is omitted since it cancels out of equations (2) and (6).

Thus, given a set of data points and a model of the physical process, the mean and standard deviation of the hydration rate can be computed.

Application to Obsidian Hydration

Hydration Rate Example:

A data set from Lincoln County, Nevada, geochemically sourced to the Meadow Valley Mountains, is shown in Table 2 (Daron Duke, personal communication). The artifacts were recovered from a number of sites in Lincoln County, and all have been corrected to an EHT of 20°C. Here R_{meas} is the measured value of the hydration rim and R_{20} is the rim corrected to EHT of 20°C, both in microns. All were recovered from surface contexts.

Cat. No.	Site	Elev, ft amsl	R_{meas}, μ	R_{20}, μ	Type
5	26LN5669	3259	2.90	2.81	Desert Series
18	26LN3736	3126	2.50	2.38	Desert Series
19	26LN3736	3128	2.70	2.57	Desert Series
3	26LN5669	3259	3.20	3.10	Rosegate Series
6	26LN5669	3259	4.10	3.97	Rosegate Series
21	26LN5580	4543	7.50	8.65	Elko Series
26	26LN5586	5299	6.60	8.45	Elko Series
12	ISO	4641	8.80	10.29	Humboldt Series
9	ISO	5099	4.70	5.85	Gatecliff Series
56	26LN0251	3823	9.00	9.40	Western Fluted

Table 2. Meadow Valley Mountains obsidian artifacts.

Temporal values were assigned based on Justice (2002), modified as appropriate by Yohe (1994) and Smith et al. (2013) (Table 3). The weight factors are computed from equation (8), and normalized by dividing each factor by the value for artifact Cat. No. 5; the normalization is for convenience, and does not affect the resulting values of rate.

Note that the weighting factors have the effect of emphasizing data points corresponding to types whose age can be estimated more closely (Desert Series and Rosegate Series), and de-emphasizing those point types which were long-lived (Elko, Humboldt, Gatecliff). However, the long-lived point types are not entirely excluded, and still contribute to the solution.

Using the hydration rim data from Table 2 and the mean age and weight factor data from Table 3, hydration rates were computed for each of the three choices of independent variable in Table 1. Table 4 shows results.

Cat. No.	Type	Beginning age (t_b), cal BP	Ending age, (t_e) cal BP	Mean age, cal BP	Span, yrs	Weight factor (w_i)
5	Desert Series	950	150	550	800	1.0000
18	Desert Series	950	150	550	800	1.0000
19	Desert Series	950	150	550	800	1.0000
3	Rosegate Series	1600	650	1125	950	0.7091
6	Rosegate Series	1600	650	1125	950	0.7091
21	Elko Series	7800	1800	4800	6000	0.0178
26	Elko Series	7800	1800	4800	6000	0.0178
12	Humboldt Series	8000	1400	4700	6600	0.0147
9	Gatecliff Series	7000	3300	5150	3700	0.0467
56	Western Fluted	14000	11000	12500	3000	0.0711

Table 3. Temporal parameters for Lincoln County, Nevada, artifacts.

The hydration rates as determined by the three different methods (choices of independent variable) and summarized in Table 4 are not statistically independent, and thus an analyst would be justified in using any of them. However, the associated standard deviations vary considerably, and thus the analyst would have higher confidence in the rate determined by using r as the independent variable.

As a caveat, it is preferable to treat each artifact as an individual data point; it can be shown that aggregating the artifacts of a particular type and using a mean hydration rim is less accurate. There are cases in which the individual values are no longer extant and only means and standard deviations are available. In such cases each data point should be weighted by the number of specimens represented as well as by the weight factors in equation (8) above.

Hydration rate, μ^2/1000 yrs	r is independent variable	r^2 is independent variable	**t is independent variable**
Mean	11.10	9.74	8.51
Standard deviation	1.11	2.47	2.83
CV	0.10	0.25	0.33

Table 4. Hydration rate summary, Meadow Valley Mountains obsidian, EHT = 20°C

Summary of the Method

The procedure above is best applied in a series of steps.

1. Sort the artifacts by geochemical source – artifacts from different geochemical sources should never be mixed. Verify the source by XRF, LA-ICP-MS, or INAA if possible.
2. Identify the artifacts as temporally-sensitive types for which ages are known.
3. Get hydration rim measurements made on the artifacts.
4. Correct the hydration rims to a standard EHT by the methods of Rogers (2007). An EHT of 20°C is used here.
5. Assign median ages and age spans to the artifacts, using published references appropriate to the area from which the artifacts were recovered.
6. Compute the mean slope from equation (2), using r as the independent variable and sqrt(t) as the dependent variable. Table 5 shows an implementation in MS Excel. The mean slope is then 475.4733/50.0939 = 9.49 $yrs^{0.5}/\mu$. The mean rate is computed from equation (3) as $1/(9.49)^2 = 11.10 \times 10^{-3}\ \mu^2/yr$ or 11.10 μ^2/1000 yrs.
7. Using the slope determined above, compute the values of $\hat{y}_i$ from equation (4), then compute δ_i from equation (5) and compute $w_i\delta_i^2$. Table 6 shows an implementation in MS Excel.
8. The standard deviation of slope can now be computed from equation (6). The term $\sum w_i\delta_i^2$ = 101.9113 from Table 6; since there are 10 data points, N - 1 = 9; and the term $\sum w_i x_i^2$ = 50.0939 from Table 5. Equation (6) then yields σ_S = 0.4754 and CV_s = 0.0501.
9. Finally, the CV of rate (CV_k) is 2 × 0.0501 or 0.1002, or 0.10 after rounding to two decimal places. The standard deviation of the rate is then computed from equation (7) to be 1.11 μ^2/1000 yrs.
10. When quoting results, always include both mean and standard deviation, and cite the EHT for which the rate applies; for example "The hydration rate for Meadow Valley Mountains obsidian computed from these ten artifacts is 11.10 ± 1.11 μ^2/1000 yrs at EHT = 20°C".

X=r	Y = sqrt(t)	w	wXY	wX^2
2.81	23	1.0000	65.7948	7.8708
2.38	23	1.0000	55.7081	5.6425
2.57	23	1.0000	60.1827	6.5854
3.10	34	0.7091	73.6346	6.7964
3.97	34	0.7091	94.3421	11.1564
8.65	69	0.0178	10.6526	1.3298
8.45	69	0.0178	10.4131	1.2707
10.29	69	0.0147	10.3611	1.5546
5.85	72	0.0467	19.6420	1.6025
9.40	112	0.0711	74.7423	6.2847
Sum terms:			475.4733	50.0939

Table 5. Computation of mean slope.

X=r	Y = sqrt(t)	w	$\hat{y}_i$	δ_i	$w\delta_i^2$
2.81	23.45	1.0000	26.63	3.18	10.0917
2.38	23.45	1.0000	22.55	-0.91	0.8201
2.57	23.45	1.0000	24.36	0.91	0.8197
3.10	33.54	0.7091	29.38	-4.16	12.2531
3.97	33.54	0.7091	37.65	4.11	11.9594
8.65	69.28	0.0178	82.09	12.81	2.9170
8.45	69.28	0.0178	80.25	10.96	2.1371
10.29	68.56	0.0147	97.63	29.08	12.4232
5.85	71.76	0.0467	55.57	-16.19	12.2579
9.40	111.80	0.0711	89.23	-22.57	36.2321
Sum = $\sum w_i\delta_i^2$					101.9113

Table 6. Computation of standard deviation of slope.

An Archaeological Test Case

As a test case, the rate determined above is applied to obsidian debitage data from 26CK8411 (House 46), in the Moapa Valley of southern Nevada. The site was initially excavated by Mark Raymond Harrington in 1925-26. It was covered by Lake Mead beginning in 1937, and was exposed with the retreat of the lake level in 2001. In 2009 the site was re-excavated by a field school from the University of Nevada, Las Vegas, directed by Karen Harry (Harry 2013). The site was found to be a multi-component site, with a substantial Pueblo II occupation (AD 1050 – 1100), followed by Paiute occupation in the proto-historic period (AD 1663 and subsequent). The Pueblo II occupation was dated by pottery typology, and the Paiute occupation by radiocarbon and projectile points (Desert series). The elevation of the site is 1203ft above mean sea level.

Ten obsidian specimens from the site were sourced to the Meadow Valley Mountains and hydration rims were measured (Table 7) (Daron Duke, personal communication).

Specimen ID No.	Description	R_{meas}
35	Thinning flake	2.30
36	Thinning flake	3.60
37	Flake core	2.60
40	Retouched flake	2.60
41	Retouched flake	2.30
42	General flake	2.50
43	Biface tip	1.50
44	General flake	2.70
45	General flake	2.60
47	General flake	2.30

Table 7. Obsidian specimens from CK268411.

Computing age requires first computing EHT, which is a function of local temperature conditions and burial depth of the artifact (assumed to be zero here). Temperature parameters were computed by regional scaling from meteorological data from the Western Regional Climate Center from data from 1980-2010 for stations at Overton, Mesquite, Pahranagat Wildlife Refuge, Tempiute, Caliente, and Pioche. The model yields an annual average temperature of 20.28°C, an annual variation (hot month mean minus cold month mean) of 21.16°C, and a mean diurnal variation of 19.48°C.

Effective hydration temperature for the specimen (EHT) was computed by numerical integration of the hydration rate over a modeled temperature profile based on these parameters, resulting in an EHT of 25.37°C (Rogers 2007, 2012). After EHT was obtained, a rim correction factor (RCF) was computed as

$$RCF = \exp\{[10000/(EHT + 273.15) - 10000/(EHT_r + 273.15)]/2\} \quad (10)$$

where EHT_r is the EHT for the hydration rate, 20°C in this case. Finally, the hydration rim value corrected to 20°C (R_{20}) is

$$R_{20} = RCF \times R_{meas} \quad (11)$$

where R_{meas} is the measured value of the hydration rim, and age is

$$t = R_{20}^2/k \quad (12)$$

where k is the rate (1.1 μ^2/1000 yrs at 20°C).

There are always errors, or uncertainties, in the parameters used for age computation, the primary sources of error being obsidian rim measurement, errors in the hydration rate ascribed to a source, intra-source rate variability due to uncontrolled intrinsic water in the obsidian (Ambrose and Stevenson 2004; Stevenson et al. 1993; Zhang et al. 1991; Zhang and Behrens 2000), errors in reconstructing the temperature history (Rogers 2007), and association errors caused by site formation processes (Schiffer 1987). The standard deviation of the age estimate, σ_t, can be shown to be (Rogers 2010)

$$\sigma_t = 2 \times t \times \mathrm{sqrt}[(\sigma_r/r)^2 + (0.06\sigma_{EHT})^2 + (CV_{ks}/2)^2 + CV_{ke}^2] \quad (13)$$

where the variables are defined as follows: σ_r is the standard deviation of the hydration rim measurement, and is ~0.1μ; r is the mean hydration rim; σ_{EHT} is the uncertainty in EHT post-correction, and is ~1.0°C; CV_{ke} is the coefficient of variation of the hydration rate ascribed to the obsidian source, and is assumed to be 0.10 (Table 4); and CV_{ks} is the coefficient of variation of the intra-source rate variations, assumed to be ~0.15.

Table 8 shows the resulting ages and standard deviations.

Spec. ID No.	Description	R_{mea} μ	R_{20} μ	Mean age, cal BP	Std. dev. age, yrs
35	Thinning flake	2.30	1.69	262	76
36	Thinning flake	3.60	2.65	654	185
37	Flake core	2.60	1.91	337	97
40	Retouched flake	2.60	1.91	337	97
41	Retouched flake	2.30	1.69	262	76
42	General flake	2.50	1.84	312	90
43	Biface tip	1.50	1.10	108	33
44	General flake	2.70	1.99	364	105
45	General flake	2.60	1.91	337	97
47	General flake	2.30	1.69	262	76

Table 8. OHD ages for debitage from 26CK8411

Figure 1 shows a plot of the ages converted to dates AD. Specimen 36 falls close to the Pueblo II dates derived from pottery, but is nonetheless later. The remaining specimens fall within the Paiute period and agree with the radiocarbon dates reported by Harry (2013). Thus, it appears that the rate yields ages which are consistent with other dating methods. It also appears that the primary period of obsidian use post-dates the Puebloan occupation.

Conclusions

The method of weighted least-squares described here is generally applicable in estimating hydration rates from temporally-sensitive artifacts such as projectile points. It places heavier weights on projectile point types whose age is well defined, and has the great advantage that all dated point types can be used, rather than ignoring artifacts which have a long time span associated with them. It can be employed consistently with different point types and does not require arbitrary inclusion/exclusion judgments. It is thus an efficient method of employing the data, and the archaeological example presented shows that the rates thus derived give archaeologically reasonable results.

Acknowledgements

This work has been previously published in a cultural resource management report for the Bureau of Land Management, Ely, Nevada, Field Office (Rogers and Duke 2014). It is republished here to make the technique more generally available to the archaeological field.

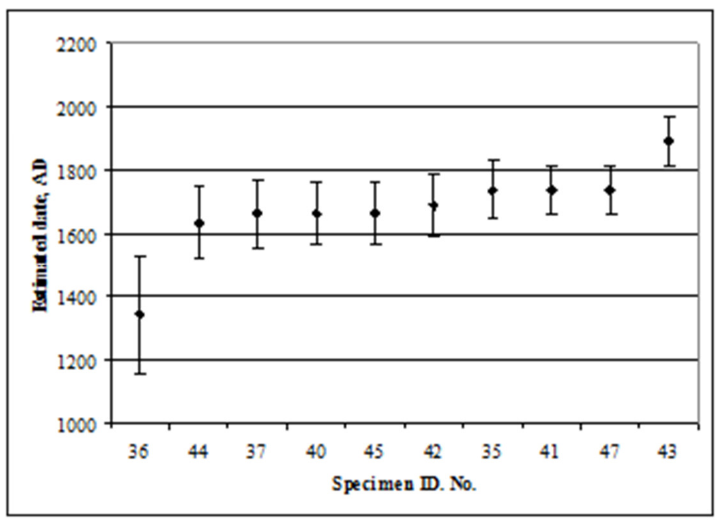

Figure 1. Obsidian ages on debitage from site 26CK8411, Moapa Valley, Nevada.

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OBSIDIAN USED IN ART:
A BAROQUE PAINTING SHOWING THE MARTYRDOM OF SAINT CATHERINE

Michael D. Glascock and Jeffrey R. Ferguson
Archaeometry Laboratory, Missouri University Research Reactor

It is well known that the predominant use for obsidian was the production of sharp-edged tools for cutting, scraping, piercing, etc. Some less common uses for obsidian include jewelry, lip plugs, mirrors, and surgical scalpel blades. However, an even more rare use of obsidian occurs in the field of art. This article describes work we did to identify the medium used for a painting being studied by an art historian at the University of Missouri-Columbia (MU).

In the fall of 2012, we were contacted by Dr. Mary Pixley, a postdoc in the Department of Art History and Archaeology at MU. Dr. Pixley was studying a painting on stone that MU acquired several years earlier from a dealer in Europe. A color photo of the painting is shown in Figure 1. The painting tells the story of the beheading of Saint Catherine of Alexandria in 305 AD on the orders of the Roman Emperor Galerius Maxentius. The mahogany stone, with its mottled black and red pattern, forms an integral part of the composition. In addition to being painted on an unusual medium, another notable feature of the painting is the display of milk pouring from the neck of Saint Catherine at the moment of her execution. This flow of milk is interpreted to indicate her innocence and purity. The stone painting, which has dimensions of about 20x20cm and 2cm thickness, is encased in a carved and gilded seventeenth century French wooden frame.

Before contacting us, Dr. Pixley asked some colleagues in geology what type of stone might have been used for the painting. One person suggested that it might be jasper, while another suggested obsidian. She was encouraged to contact the Archaeometry Laboratory at MURR to identify the type of stone. Because we were intrigued, we took our portable XRF spectrometer (Bruker III-V) to the museum where we performed a non-destructive analysis of the stone. Our analysis proved that the stone was obsidian – which was also evident by observing several small, shiny, conchoidal fractures on the back side of the stone. Once we determined that the stone was obsidian, we compared the measured elemental information to the Archaeometry Laboratory's database of previously analyzed sources, and we were able to find a highly-probable match to the well-known Mexican source located at Ucareo in the State of Michoacan. Our data are presented in Table 1.

Figure 1. Painting on obsidian of the beheading of Saint Catherine of Alexandria.

The use of Ucareo obsidian as a medium for paintings has been reported previously by Calligaro et al. (2005) who used PIXE to analyze two works housed in the Louvre Museum painted by the Spanish Baroque artist Bartolome Esteban Murillo (1617-1682). Both of the Louvre paintings were traced to the

Element (ppm)	Results for Obsidian Painting	Ucareo (n = 34) Mean	Std. dev.
Fe	8286	8402	± 671
Rb	140	152	± 6
Sr	13	11	± 2
Y	22	21	± 2
Zr	111	113	± 6
Nb	10	12	± 2

Table 1. Comparison between obsidian in the Missouri painting and Ucareo source material.

Ucareo source. A third Murillo painting on obsidian (still untested) is located in the Museum of Fine Arts in Houston. The obsidian used in the Louvre paintings was compared to several Mesoamerican obsidian "smoking mirrors" held in Paris at the Musée de l'Homme and Musée National d'Histoire Naturelle, with all pieces apparently coming from the obsidian source in Ucareo. This information suggests that the obsidian stones used to produce the paintings were probably transported across the ocean to Spain following the conquest of Mexico by Hernán Cortes in the sixteenth or early seventeenth century and eventually used as medium for paintings.

According to an article by Pixley (2012), the idea to use stone as a medium for paintings evolved from the works of Sebastiano del Piombo (1485-1547), who conducted experiments with stone in the 1530s as a way to preserve his paintings. A number of other artists learned this method and produced paintings on a variety of types of stones. The most prolific of these was the French painter Jacques Stella (1596-1657), who learned the technique in Florence and influenced a number of his students to paint on stone. Although the Missouri painting is not typical of Stella, it is quite possible that one of his students created the painting.

An old piece of paper on the wooden backing board of the painting states the painting was in possession of the Capuchin Monastery in Martigues in 1793. The portrayal of the execution of Saint Catherine suggests that it was inspired by an Italian friar named Girolamo Zonca, who in 1631 composed a widely cited article dedicated to St. Catherine of Alexandria as both a virgin and martyr. The style of wooden frame is also characteristic of the seventeenth century. Thus, it is believed that the painting dates to the first half of the seventeenth century, although the name of the painter remains unknown.

Acknowledgements

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PITFALLS AND PXRF

Ruth Fauman-Fichman
University of Pittsburgh

At this point it is clear that portable x-ray fluorescence (pXRF) is a low cost form of non-destructive analysis of samples needing minimal or no preparation, and that produces rapid results and is easy to use. It is less clear to the average user how to do this correctly. In my initial attempts to use pXRF, the points I make below were not understood or followed. After the generous support, explanations, and advice from Jeffrey Ferguson and Michael Glascock at the University of Missouri Research Reactor, Archaeometry Laboratory, I was able to perform the pXRF correctly using a Bruker Tracer III-V handheld unit. It was operated at 40KeV (voltage) and about 15 microamps using a filter made of layered copper, titanium and aluminum and a SiPIN diode detector. All samples were analyzed for 180 seconds. The instrument was calibrated with a set of 40 calibration standards that included specially chosen obsidian samples from MURR with well-known concentrations from around the world. Each standard has been analyzed by different XRF labs, NAA and two types of ICP-MS.

Using the above protocol I was able to successfully analyze all 206 obsidian pieces from the surface collection and 18 from excavations in the small rural settlement of Calcahuas in Tlaxcala, Mexico. The results were startling to me. The surface collection resulted in secure identification of nine sources of obsidian. The limited excavation from the Postclassic period (AD 1350-1521) had four sources of obsidian, some from areas thought to have not been accessible to Calcahuas at that time.

Below are suggestions for beginners in the use of pXRF:

1. Know how to "shoot" the gun or…

Since pXRF instruments are available for purchase on eBay and other venues, sometimes there is little documentation about the instrument. Other times the documentation is highly technical and not user-friendly to those without a background in physics. As a result, the neophyte pXRF-er will not know how to "shoot" and what "ammunition" they are using.

2. Truly understand what calibration is and means to the user.

It needs to be clear to the lay user that calibration does not refer to something inherent within the measuring device itself, but rather refers to a process that must be undertaken before using the instrument on the obsidian to be studied. As you experts know, this process entails using the device to take a "picture" of the chemical composition of known obsidian samples from a laboratory (such as the Missouri University Research Reactor Archaeometry Laboratory) and verifying that this picture of elements and their concentrations matches the known characterization by that laboratory. Many do not understand this meaning of calibration.

3. Understand the mechanics of excitation.

Once that is done, one is still not quite ready to begin. The field technician, student, or archaeologist needs to understand the correct way to take the measurement and the correct duration of the measurement. The device can be handheld, but that doesn't really mean that is the best way to use it! Users do not understand how the atoms become excited or absorption phenomena. They need to know it is best to use the instrument in a stand that immobilizes it, with a method (either jury-rigged or formal) that activates the trigger and maintains it in an active state for the duration required. While it is easy to see that the area of excitation in the instrument is very small, many do not know that the device will measure (fluoresce) right through a thin piece of obsidian to the material it is resting upon, or miss the obsidian altogether and measure something else entirely! So even in a field environment it is best to place the sample (which may be a very small obsidian fragment) directly above or on the opening, with nothing but air on the other side of it. That way you will not inadvertently measure the wrong thing. It is also important to recognize that one wants to get the samples shot squarely within the very small beam of the instrument.

4. What elements are you looking for in obsidian (or other material being analyzed)?

The lay user needs to know what elements are analyzed to source the obsidian. Many are not aware that in order to analyze the elements of interest (typically Rb through Nb and sometimes Fe) the incoming x-rays should come through an instrument filter. For example, 6 mil of copper, 2 mil of titanium and 12 mil of aluminum to decrease the lower spectrum x-rays and produce a better analysis. The instrument should use a voltage well above that of the highest energy K-alpha line for Nb. For example, I used 40 kV. (They need to have Jeff Ferguson talking in their ear to tell them the elements of interest will be swamped by the more common elements in obsidian such as iron and that x-rays above 17keV taper off at much higher energies and are better for obsidian source analysis.) The data should probably be normalized using the rhodium Compton peak and the user needs to be aware that the iron spectra will overcorrect and be huge. So analysis will entail selecting a region of the spectrum where the elements of interest do not have peaks for normalization.

5. Review two-dimensional scatterplots of the data

When these above-mentioned steps are correctly accomplished, the average archaeologist can do the data analyses needed to produce provenance information on their obsidian.

It is my hope that any one of the expert readers here will improve my list, keeping it as simple as possible so that more archaeologists will correctly use this terrific technique. This, together with a technical analysis of the tools and debitage provides a completely new and different picture of obsidian procurement for this area. All thanks to a pXRF analysis – done correctly!

Calcahuas Obsidian Sources	Surface		Excavated	
	n	%	*n*	%
Paredon	116	56.90%	11	61.10%
Otumba	29	14.20%	2	11.10%
Zaragoza-Oyameles	28	13.70%	1	5.60%
Pachuca	22	10.80%	4	22.20%
Pico de Orizaba	4	2.00%		
Malpais	2	1.00%		
Tulancingo	1	0.50%		
Ucareo?	1	0.50%		
Zacualtipan	1	0.50%		
Total	**204**	**100%**	**18**	**100%**

Table 1. Calcahuas obsidian sources

ABOUT OUR WEB SITE

The IAOS maintains a website at http://members.peak.org/~obsidian/
The site has some great resources available to the public, and our webmaster, Craig Skinner, continues to update the list of publications and must-have volumes.

You can now become a member online or renew your current IAOS membership using PayPal. Please take advantage of this opportunity to continue your support of the IAOS.

Other items on our website include:

- World obsidian source catalog
- Back issues of the *Bulletin.*
- An obsidian bibliography
- An obsidian laboratory directory
- Photos and maps of some source locations
- Links

Thanks to Craig Skinner for maintaining the website. Please check it out!

From the *Bulletin* Editor:

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Please use the following email address: IAOS.Editor@gmail.com for future submissions to the *IAOS Bulletin.* This email address was created as a permanent contact for the *IAOS Bulletin* Editor and will be passed on to future Editors as well, to ensure that submissions are always received by the proper point of contact. The old email address is still valid, but I hope to transition all *IAOS Bulletin* correspondence to the new email address over the next year. Thanks! (and send along your submissions!), Carolyn Dillian, *IAOS Bulletin,* Editor.

CALL FOR ARTICLES

Submissions of articles, short reports, abstracts, or announcements for inclusion in the *Bulletin* are always welcome. We accept electronic media on CD in MS Word. Tables should be submitted as Excel files and images as .jpg files. Please use the *American Antiquity* style guide for formatting references and bibliographies.
www.saa.org/publications/StyleGuide/styFrame.html

Submissions can also be emailed to the *Bulletin* at IAOS.Editor@gmail.com Please include the phrase "IAOS Bulletin" in the subject line. An acknowledgement email will be sent in reply, so if you do not hear from us, please email again and inquire.

Deadline for Issue #52 is December 1, 2014.

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Dr. Carolyn Dillian
IAOS Bulletin, Editor
Department of History
Coastal Carolina University
P.O. Box 261954
Conway, SC 29528
U.S.A.

Inquiries, suggestions, and comments about the *Bulletin* can be sent to IAOS.Editor@gmail.com Please send updated address information to Kyle Freund at freundkp@mcmaster.ca

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The IAOS needs membership to ensure success of the organization. To be included as a member and receive all of the benefits thereof, you may apply for membership in one of the following categories:

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Kyle Freund
IAOS
c/o McMaster University
Department of Anthropology
Chester New Hall Rm. 524
1280 Main Street West
Hamilton, Ontario, Canada
L8S 4L9
freundkp@mcmaster.ca

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ABOUT THE IAOS

The International Association for Obsidian Studies (IAOS) was formed in 1989 to provide a forum for obsidian researchers throughout the world. Major interest areas include: obsidian hydration dating, obsidian and materials characterization ("sourcing"), geoarchaeological obsidian studies, obsidian and lithic technology, and the prehistoric procurement and utilization of obsidian. In addition to disseminating information about advances in obsidian research to archaeologists and other interested parties, the IAOS was also established to:

1. Develop standards for analytic procedures and ensure inter-laboratory comparability.
2. Develop standards for recording and reporting obsidian hydration and characterization results
3. Provide technical support in the form of training and workshops for those wanting to develop their expertise in the field
4. Provide a central source of information regarding the advances in obsidian studies and the analytic capabilities of various laboratories and institutions.

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IAOS
c/o McMaster University
Department of Anthropology
Chester New Hall Rm. 524
1280 Main Street West
Hamilton, Ontario, Canada
L8S 4L9