IAOS

International Association for Obsidian Studies

Bulletin

ISSN: 2310-5097

Number 65 **Winter 2020**

CONTENTS

NEWS AND INFORMATION

NEWS AND NOTES

Have news or announcements to share? Send them to IAOS.Editor@gmail.com for the next issue of the *IAOS Bulletin.*

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!

International Obsidian Conference 2021 now VIRTUAL!

Due to the current COVID-19 pandemic, the IOC 2021 conference will be held virtually from April 30-May 2 and is now free! The conference is hosted by the Archaeological Research Facility at the University of California, Berkeley, the International Association for Obsidian Studies, and Far Western Anthropological Research Group, Inc.

Please see the announcement in this issue of the *IAOS Bulletin* for more information.

NOTES FROM THE PRESIDENT

Hello IAOS members, we are finally nearing the end of 2020! This year has changed many lives and I'm hopeful that 2021 will be much better. Please stay safe, practice good hygiene, and avoid large crowds.

The IAOS would like to congratulate Craig Skinner on his 25 years of service as the IAOS Webmaster! He is retiring at the end of this year, and the IAOS needs someone for this position. If you are familiar with webpage development, HTML coding, and design, please email Craig at obsidianlab@gmail.com.

I was very much looking forward to meeting everyone in Berkeley at the 2021 International Obsidian Conference (IOC). For the safety of all participants due to the Covid-19 pandemic, the conference will now be held virtually on April 30-May 2, 2021. The IOC is hosted by the Archaeological Research Facility at the University of California, Berkeley, the IAOS, and Far Western Anthropological Research Group, Inc. Because the conference will be online, the organizers have waived fees to attendees and participants, but the IOC organizers ask that you become a member of the IAOS or renew your membership. The deadline for submitting an abstract to present at the IOC is March 1, 2021. See the third circular for additional information.

Also, the Society for American Archaeology meeting will be in San Francisco on April 14-18, 2021. The IAOS reserved a time and space for our annual board meeting, but at this time we do not know the date. However, the IAOS may have another online board meeting similar to 2020 because the SAA is unsure if the meeting will be held in person, online, or a combination of the two. Hopefully, the SAA will decide early in 2021 so students, faculty, and archaeological professionals can make travel plans or get ready to record their paper/posters to present online. Keep in mind that universities and companies may discourage conference travel or may not reimburse funds due to the pandemic. I'll present a paper, but I won't be there in person. The pandemic has made many people weigh the pros and cons of conference travel. I have not participated in an online conference, but I think more organizations will adopt them in the future, especially for international participants.

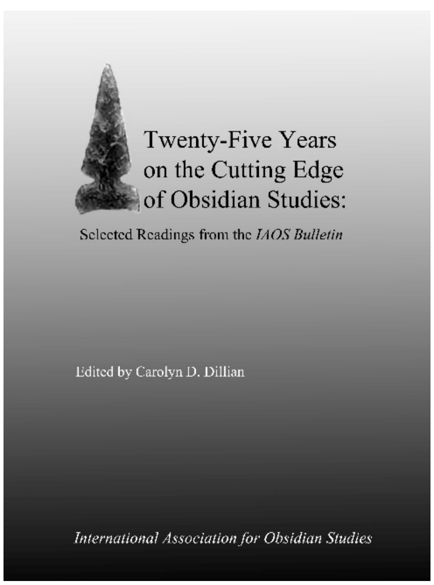
Please consider submitting an article, research update, news, or lab report projects to the *IAOS Bulletin*. You can submit your work to Carolyn Dillian at IAOS.Editor@gmail.com. Finally, please renew your IAOS membership dues in 2021.

Stay safe!

Sean Dolan, IAOS President
sgdolan@gmail.com

New SAA Awards for Collections Research

The Society for American Archaeology (SAA) Awards for Excellence in Curation, Collections Management, and Collections-Based Research and Education have been updated. Rather than a rotating category, the committee is soliciting nominations for two standing awards: the Award for Excellence in **Curation and Collections Management** https://www.saa.org/career-practice/awards/awards-detail/award-for-excellence-in-curation-and-collections-management and the Award for Excellence in **Collections-Based Research and Education:** https://www.saa.org/career-practice/awards/awards-detail/award-for-excellence-in-collections-based-research-and-education. These awards are presented in special recognition of excellence by an archaeologist or group of archaeologists whose innovative work, or repeated and enduring contributions, have contributed significantly to archaeology and the preservation, documentation, and use of the collections recovered from archaeological investigations. **The deadline for 2020 has already passed, but watch for next year's deadline to submit!**



Twenty-Five Years on the Cutting Edge of Obsidian Studies: Selected Readings from the IAOS Bulletin

Edited volume available for purchase online!

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. The volume is now available for sale on the IAOS website for $10 (plus $4 shipping to U.S. addresses). http://www.deschutesmeridian.com/IAOS/iaos_publications.html

International addresses, please contact us directly at IAOS.Editor@gmail.com for shipping information.

International Obsidian Conference 2021

3rd Circular – IOC 2021

April 30 - May 2, 2021

Venue: Virtual conference

Hosted by the *Archaeological Research Facility* (ARF), the *International Association for Obsidian Studies* (IAOS), and *Far Western Anthropological Research Group, Inc*.

Dear Friends and Colleagues,

We invite you to participate in the updated International Obsidian Conference (IOC 2021) to be held virtually from April 30 – May 2, 2021.

Our aim is to invite specialists on all aspects of obsidian studies extending from natural sciences to anthropology. Following prior meetings, we intend for the conference to remain global in scope and encourage contributions from any geographical region, yet highlight obsidian studies in the Americas. Because the geologies of North America are so diverse, we also aim to include semi-glassy fine-grained volcanics (FGV) used by Amerindians in the Great Basin and other regions in the Americas.

<u>Suggestions for conference sessions and themes:</u>

- Formation and geology of obsidian and FGV
- Sources, their characterization, and archaeological distributions
- Analytical and methodological aspects
- Archaeological obsidian and FGV by chronological periods
- Lithic technology and use-wear studies
- Theoretical and cultural concerns (e.g., materiality, itineraries, tool stone resource management or control strategies)

Conference Updates

With the consistent threat of COVID-19 in combination with changes to university safety guidelines, we are compelled to change the date of the conference and its overall format. Our main reason for doing so is the result of new rules at UC Berkeley that have cancelled all in-person gatherings like ours into early 2021; our venue will therefore not be available. The dates of the conference are now April 30 – May 2 to mitigate overlap with the Annual Meeting of the Society for American Archaeology (SAA) and allow participants to spread out their conference activities and obligations. The conference will follow a virtual format to be announced soon. Other relevant changes and updates include:

1) The conference is now **free** for participants and attendees. We do ask that you become a member of the International Association of Obsidian Studies (IAOS) as a courtesy for IAOS helping to organize and subsidize the conference. You can become a member by clicking here. By joining IAOS, you will become part of an international network of obsidian researchers that offers a variety of resources to support your research. Your membership dues will also assist in sponsoring future conferences.
2) There is a location for submitting registration and abstract information on the recently updated IOC homepage through the UC Berkeley Archaeological Research Facility (see below). Submissions should be made by the revised deadline of March 1st, 2021.
3) The conference will offer an option to present live or to submit a pre-recorded presentation that will be streamed at a set time. We will also set aside time to showcase poster presentations and make them available to conference participants.
4) Dr. Steven Shackley has accepted our invitation to give a Keynote speech during the conference.
5) The Archaeological Research Facility (ARF) at UC Berkeley plans to publish the conference proceedings pending review and approval in their publication series that began in 1960. This publication series has seen many seminal works on obsidian studies, and we anticipate our conference proceedings to be an important addition to this legacy.
6) Our excursion to Napa Valley is canceled.

Local Organizing Committee

- Nicholas Tripcevich – University of California Berkeley, Archaeological Research Facility
- Lisa Maher – University of California Berkeley, Anthropology
- Lucas R. M. Johnson – Far Western Anthropological Research Group, Inc.
- Kyle Freund – Far Western Anthropological Research Group, Inc.
- Tom Origer – Origer and Associates

Scientific Committee

- Biró, Katalin - Hungarian National Museum, Budapest, Hungary

- Glascock, Michael - University of Missouri, Columbia, MO, USA
- Kuzmin, Yaroslav - Institute of Geology & Mineralogy, Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia
- Le Bourdonnec, François-Xavier - Université Bordeaux Montaigne, Pessac, France
- Lexa, Jaroslav - Earth Sciences Institute of the Slovak Academy of Sciences, Bratislava, Slovakia
- Markó, András - Hungarian National Museum, Budapest, Hungary
- Ono, Akira - Meiji University, Tokyo, Japan
- Torrence, Robin - Australian Museum, Sydney, Australia
- Tykot, Robert - University of South Florida, Tampa, FL, USA
- Vianello, Andrea - University of South Florida, Tampa, FL, USA

Partnering Institutions

UC Berkeley

Contact Persons

The conference email address is obsidian2021@gmail.com. Please direct questions to this address.

Kyle Freund, Ph.D.; Lucas R. M. Johnson, Ph.D.; Nicholas (Nico) Tripcevich, Ph.D.

Technical Information

Duration and Dates: 3 days, April 30 – May 2, 2021

Location: Online, to be held from 9am-5pm Pacific Standard Time

Keynote Speech: Dr. Steven Shackley, Professor Emeritus, UC Berkeley

Presentation Logistics: Because our conference is international, those participants in other time zones beyond Pacific Standard Time may wish to submit a pre-recorded asynchronous presentation to be viewed during the conference.

Oral Contributions: Oral contributions will be 15 minutes, followed by a 5-minute discussion. Please prepare them in common presentation format (e.g., PowerPoint).

Poster Presentations: The posters should be planned as standing (portrait) orientation and their size must not exceed A0 (841 x 1189 mm). Submitted posters will be hosted online for view during the conference (website location to be announced).

Abstracts: must not exceed 300 words

Language: The official language of the conference is English.

Deadline for submitting abstracts: March 1, 2021

Deadline for registration: March 1, 2021 for presenters (April 15, 2021 for attendees not presenting a poster or paper)

Submission location: *https://forms.gle/JnaWkzRuuxQMV4ZQ6*

Registration Fee: None

The conference is **free** for participants and attendees. We do ask that you become a member of the International Association of Obsidian Studies (IAOS) as a courtesy for IAOS helping to organize the conference and pay for any incidental costs.

PLEASE BECOME A MEMBER OF THE IAOS HERE

Four membership tiers are available:

IAOS Student Registration	$10 USD
IAOS Regular Membership	$20 USD
IAOS Institutional Membership	$50 USD
IAOS Lifetime Membership	$200 USD

Publication of Proceedings

Contributions of the Archaeological Research Facility, Berkeley
https://arf.berkeley.edu/publications/contribution-series

Conference Homepage

http://arf.berkeley.edu/projects/ioc2021

Please forward this circular to anybody who may be interested.
We look forward to seeing you in 2021!

Lucas, Kyle, and Nico

NEW INSIGHTS INTO THE USE OF OBSIDIAN AT COTTONWOOD SPRINGS PUEBLO (LA 175), DOÑA ANA COUNTY, NEW MEXICO

Sean Dolan,[a] Judy Berryman,[b] and M. Steven Shackley[c]

[a] Environment, Safety, and Health (ES&H), N3B Los Alamos, Los Alamos, New Mexico, USA
[b] Department of Anthropology, New Mexico State University, Las Cruces, New Mexico, USA
[c] Geoarchaeological XRF Laboratory, Albuquerque, New Mexico, USA

Abstract

Cottonwood Springs Pueblo (LA 175) is a multicomponent site in southern New Mexico that was occupied from A.D. 1000–1450. In an earlier paper, Dolan et al. (2017) analyzed 40 obsidian artifacts from area A of the site using EDXRF spectrometry to evaluate regional and long-distance social interaction, and how people in the Jornada Mogollon region organized their lithic technology. In this paper, we report on an additional 24 obsidian artifacts from areas A and E of the site. The obsidian is from similar sources found in the earlier study, including Cerro Toledo Rhyolite, Antelope Creek, Grants Ridge, and Nutt Mountain, as well as one new source (Cow Canyon). With these new data, we provide further insights into obsidian procurement at Cottonwood Springs including differences in source use at the site, and how the residents maintained connections to outside social groups by acquiring nonlocal obsidian, while at the same time using the locally available obsidian.

Introduction

Located in Doña Ana County, New Mexico, Cottonwood Springs Pueblo (LA 175) is a large multicomponent site that Jornada Mogollon groups occupied from A.D. 1000–1450. In 2012, the Department of Anthropology at New Mexico State University (NMSU) began a field school at Cottonwood Springs focusing on area A. Because the site has surface-visible adobe architecture and surface artifacts, the site has been the subject of looting and uncontrolled artifact collection for many years, and some areas of the site have even been leveled with mechanical equipment. Despite some destruction, there are still intact cultural deposits and archaeologists can learn much about Jornada Mogollon lifeways through studying the entire complex. For example, how did the pueblo village change through time? Who were the residents? How did they connect to other groups in the region?

The past inhabitants of Cottonwood Springs used many types of raw materials to manufacture formal and informal chipped stone tools. Obsidian is but one of the raw materials used, and this volcanic glass is more amenable to geochemical sourcing than other lithic raw materials because each obsidian source on the landscape has its own unique geochemical fingerprint. Using energy-dispersive X-ray fluorescence (EDXRF) spectrometry to determine the source provenance, archaeologists can use this information to evaluate regional and long-distance social interaction, and how people organized their lithic technology. Obsidian is relatively rare on the surface and in excavated contexts at Cottonwood Springs, but the field school collected 40 obsidian artifacts at area A during the first three field seasons (2012–2014). In recent years, the field school has excavated area E of the site. In this paper, we report on an additional 24 obsidian artifacts from areas A and E. With these new data, we provide further insights into obsidian procurement at Cottonwood Springs. We discuss differences in source use at the site, and how the residents maintained connections to outside social groups by acquiring nonlocal obsidian, while at the same time using the locally available obsidian.

The Jornada Mogollon

The Mogollon, Ancestral Pueblo, and Hohokam are the three primary prehispanic archaeological traditions in the U.S. Southwest and Mexican Northwest. The Mogollon lived in the semi-arid lowland deserts and upland environments of parts of Arizona, New Mexico, Texas, and Chihuahua, Mexico. There are several cultural branches within the Mogollon that archaeologists have defined over the years based on differences in location, chronology, architecture, and ceramics (Diehl 2007; Wilcox and Gregory 2007: Figure 1.2; Wheat 1955).

As first defined by Lehmer (1948), the Jornada is the eastern-most branch of the Mogollon in south-central and southeastern New Mexico, the western Trans-Pecos of Texas, and northern Chihuahua. We do not provide a detailed discussion of Jornada cultural developments in this paper but see recent works by Miller (2005, 2018a, 2018b, 2019; Miller and Kenmotsu 2004), Wiseman (2019), and chapters in Rocek and Kenmotsu (2018). But in general, beginning around A.D. 400, people in the Jornada region lived in semi-subterranean pithouse structures and made brownware pottery. Around the same time, they began growing maize but still processed wild plants using manos and metates and hunted small and large game. During the Late Doña Ana phase (A.D. 1150–1300) and into the El Paso phase (A.D. 1300–1450), Jornada groups relied more on agriculture, and their ceramic technology included black-on-white and polychrome painted wares. While Mimbres Mogollon groups in southwestern New Mexico built and lived in above-ground masonry pueblos beginning around A.D. 1000, those living in the Jornada region adopted pueblo architecture a few centuries later. Furthermore, Jornada groups were relatively more mobile than other groups, and they occupied many of their pueblo villages for shorter periods.

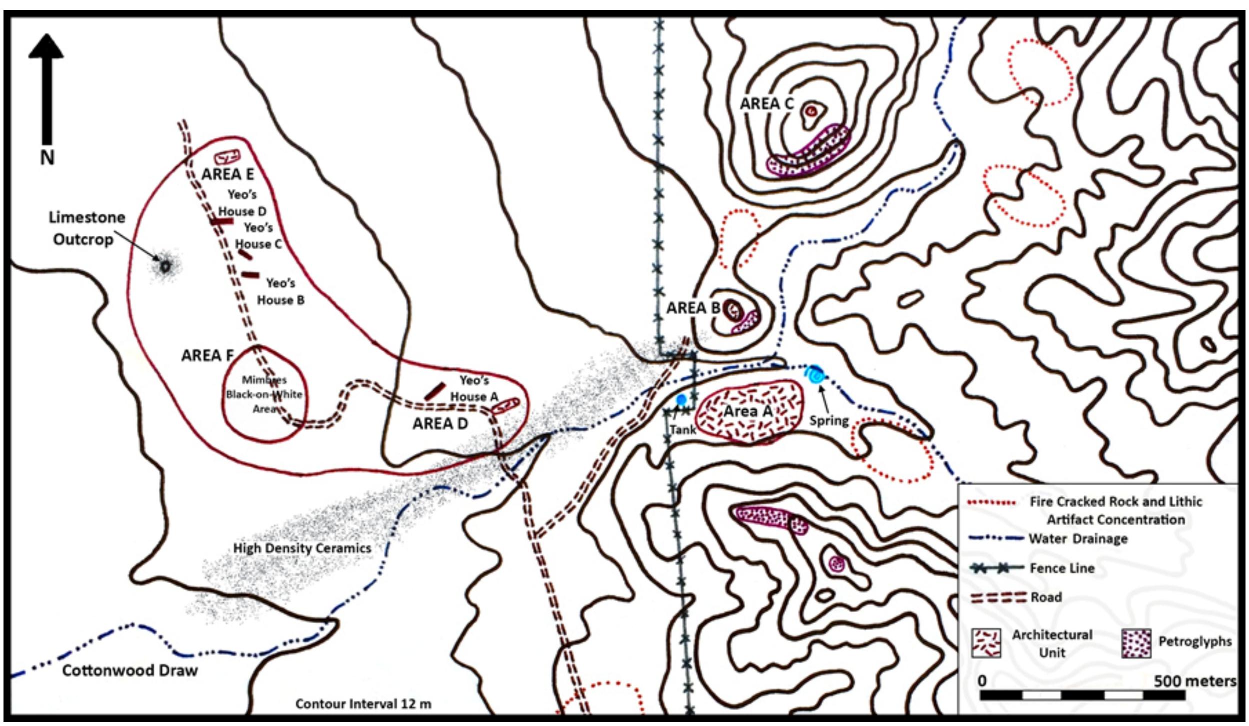


Figure 1. Site map of Cottonwood Springs Pueblo.

Cottonwood Springs Areas A and E

Cottonwood Springs Pueblo is divided into six areas (Figure 1). Areas A and B are two El Paso phase pueblos, area C is a possible shrine, area D is a El Paso phase pueblo, area E consists of a cluster of El Paso phase pueblos, and area F is an artifact scatter primarily of Mimbres Classic Black-on-white sherds indicative of the Early Doña phase, A.D. 1000-1150 (Lekson and Rorex 1995). The NMSU field school first excavated area A in 2012 because it is a substantial El Paso phase L- or (more likely) F-shaped pueblo with visible architecture that define plaza areas. The field school has collected over 15,000 ceramics from area A from five loci representing 17 rooms, two extramural spaces, and a limited surface collection. Based on tree-ring samples, people lived at the area A pueblo during the mid- to late-1300s.

In the 1950s, Herbert Yeo mapped four distinct pueblo roomblocks that make up the western portion of Cottonwood Springs in areas D, E, and F. Three of the four linear roomblocks were grouped in the north, and Lekson and Rorex (1995) assigned them to area E. The NMSU field school excavated area E on the east side of the road where Yeo recorded three of the four roomblocks (Figure 2). Ceramics, chipped stone, and ground stone are common on the surface. Based on the ceramics, people occupied area E during the El Paso phase, and they had contacts with other groups in southern New Mexico and the Casas Grandes region of northwestern Chihuahua. The field school did not find obsidian from intact subsurface cultural contexts, but they did collect obsidian debitage from the looter's piles in area E. Before analyzing the area E obsidian with EDXRF spectrometry, we suspected that the area A and area E obsidians would belong to different sources because the area E obsidian is noticeably larger and has more dorsal cortex compared to the area A obsidian.

Obsidian Use in the Jornada Region

The lithic landscape of the Jornada Mogollon region includes coarse-grained and fine-grained materials, including chert, chalcedony, rhyolite, basalt, and obsidian (Camilli 1988; Church 2000; Church et al. 1996). Procurement of these materials involved decision making, planning, and preference because lithic materials can be unevenly

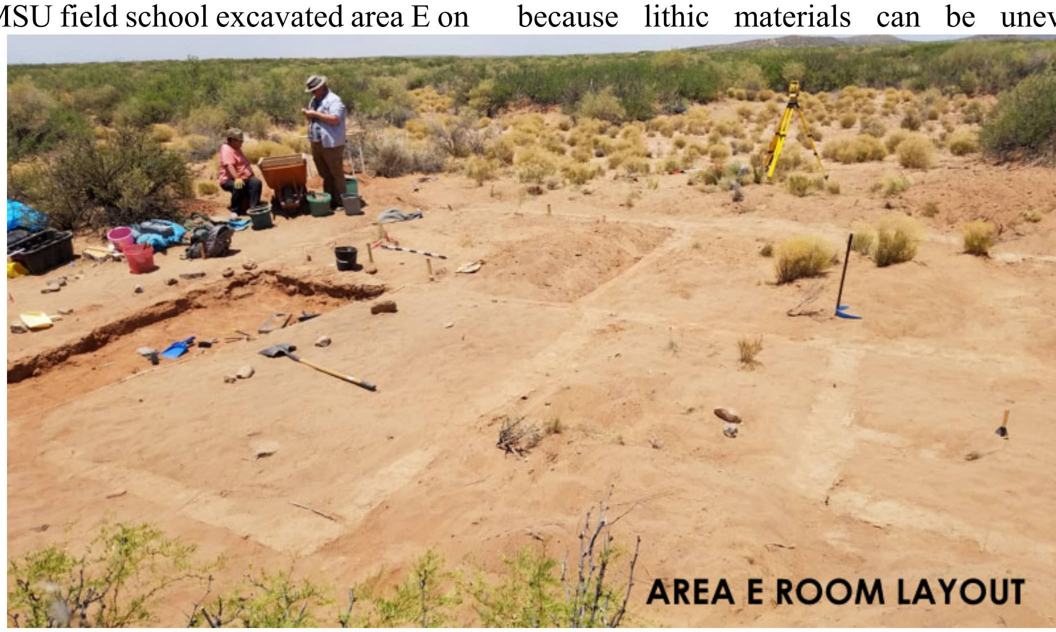


Figure 2. Area E pueblo at Cottonwood Springs Pueblo.

dispersed in localized deposits in bedrock outcrops and river gravels along the Rio Grande. Additionally, lithic materials come in various sizes, shapes, and colors, and some materials are best suited for performing specialized tasks. For example, people use obsidian because it cuts and pierces flesh more so than coarse-grained materials.

Our knowledge of which obsidian sources people used in southern New Mexico has improved in recent years (Dolan 2016, 2019; Dolan et al. 2017; Ferguson et al. 2016; Mills et al. 2013; Roth et al. 2019; Taliaferro et al. 2010; VanPool et al. 2013). We also have a better understanding of the geographic location of primary and secondary obsidian deposits and dating of obsidian sources (Church 2000; Shackley 2005; Shackley et al. 2018). However, archaeologists have largely focused on the Mimbres Mogollon with far fewer published studies on obsidian use in the Jornada Mogollon region.

People in the Jornada region could have acquired obsidian from several sources in Arizona, New Mexico, Chihuahua, and Sonora either directly from the primary source or secondary deposits, or through trade. Sources include (but are not limited to) Cow Canyon, Mule Creek, Antelope Wells, Nutt Mountain, and Sierra Fresnal (Figure 3). One additional source area is the Rio Grande. Although the primary source for Cerro Toledo Rhyolite obsidian, El Rechuelos, Canovas Canyon Rhyolite, and Bearhead Rhyolite obsidian is the Jemez Mountains in northern New Mexico, these obsidians can also be found hundreds of miles south in the Rio Grande Quaternary alluvium (Church 2000; Glascock et al. 1999; Shackley 2005, 2013; Shackley et al. 2016). Cerro del Medio, also known as Valles Rhyolite, is another obsidian associated with the Jemez Mountains, but it does not erode into the Rio Grande Quaternary alluvium like the other Jemez obsidians (Church 2000; Shackley

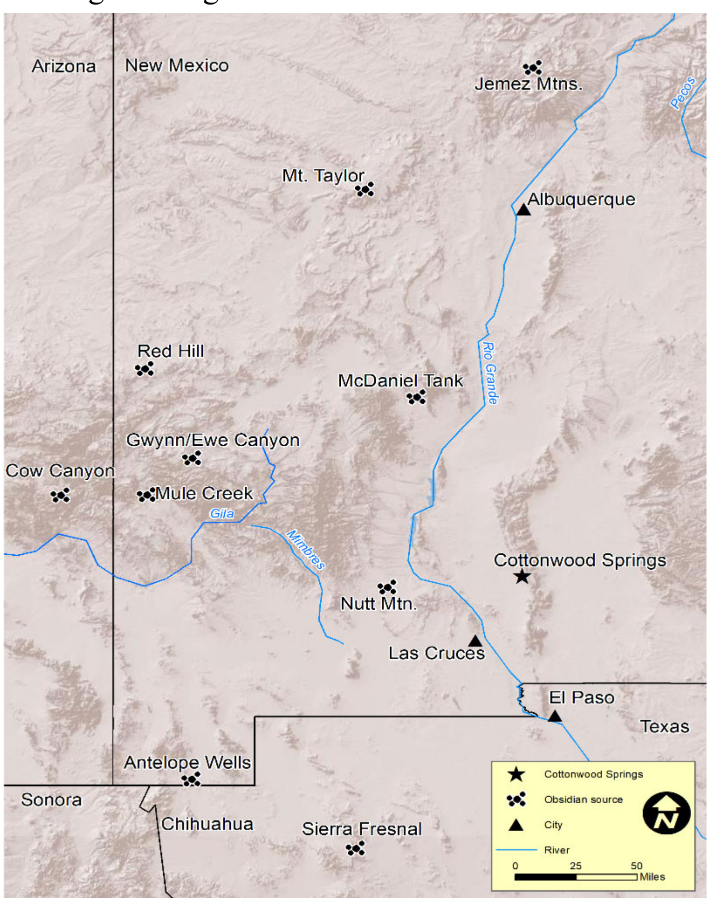


Figure 3. Location of obsidian sources in New Mexico, Arizona, and Chihuahua.

2005, 2013). Additionally, the primary source for Grants Ridge obsidian and Horace Mesa obsidian is at Mount Taylor, but these obsidians are also found in the Rio Grande Quaternary alluvium (Church 2000; Shackley 1998, 2005).

If tools or debitage made from Jemez or Mount Taylor obsidian are present at Jornada Mogollon sites, archaeologists can have a difficult task in determining whether the artifact was made from obsidian acquired from the Rio Grande gravels, from material procured at the primary source, or obtained through trade. However, lithic materials collected from the Rio Grande gravels are usually smaller in diameter because they have been tumbled by water. Therefore, archaeologists can potentially determine whether the tool or debitage came from secondary deposits or the primary source based on the size and presence of dorsal cortex. However, obsidian from Rio Grande gravels retain some cortex. The small nodule sizes mean that some cortex is often present on flakes and sometimes even on arrow points or tools. Although, in some cases, waterworn (Rio Grande gravel) cortex can be differentiated from weathered (primary outcrop Jemez sources) cortex.

Many factors influenced how people organized their stone tool technology and how they made their stone tools, including nodule or core size, and availability (Andrefsky 1994). Most obsidian in southern New Mexico is smaller in size compared to other local coarse-grained and fine-grained lithic raw materials. The small size of obsidian restricted projectile point manufacture until about A.D. 500 when people in the Mimbres Valley began using the bow and arrow (Roth et al. 2011). However, by examining collections of radiocarbon dates associated with early arrow point forms, Miller and Graves (2019) argue for the use of the bow and arrow earlier at 1630-1550 B.P. (A.D. 320-400) due to the presence of Scallorn Goup arrow points in the Jornada region. Before the bow and arrow, people used the atlatl with stone dart and spear projectiles. Darts and spears are larger than arrow points and were made primarily of non-obsidian materials, but Paleoindian and Archaic hunter-gatherers did make dart and spear points from Jemez obsidian because cores of Jemez obsidian at the primary source can be very large (Dolan et al. 2016; LeTourneau and Shackley 2009; Shackley 2005, 2013; Vierra et al. 2012). Bow and arrow technology allowed Mogollon groups to exploit new lithic resources, including obsidian from the Mule Creek area and the Rio Grande gravels. Obsidian use peaks in the Jornada Mogollon region when projectile point forms changed to small, triangular arrow points during the Late Doña Ana phase and into the El Paso phase (Miller and Kenmotsu 2004).

Due to the presence of obsidian in the Rio Grande Quaternary alluvium, archaeologists have wondered if Jornada Mogollon groups primarily used the locally available obsidian or if they used obsidian from other sources. Dolan, Miller, Shackley, and Corl (2017) answered this question by studying 24 pieces of debitage, 12 projectile points, 2 bifaces, 1 core, and 1 drill from Cottonwood Springs area A. People at Cottonwood Springs area A primarily used Cerro Toledo Rhyolite obsidian and other Rio Grande gravel obsidians, but they also had Antelope Creek (Mule Creek) and Sierra Fresnal arrow points. Because no debitage from area A came from Antelope Creek or Sierra Fresnal, Dolan et al. (2017) argued that the Antelope Creek and Sierra Fresnal arrow points came into the site already finished.

In addition to the Dolan, Miller, Shackley, and Corl (2017) study, Dolan, Berryman, and Shackley (2017) studied 16 obsidian artifacts from six sites near the Las Cruces area. Their results are similar to the Cottonwood Springs assemblage in that most of the obsidian derives from sources that are found in the Rio Grande Quaternary alluvium, including Cerro Toledo Rhyolite, El Rechuelos, Bearhead Rhyolite, and Canovas Canyon. However, one artifact is from an unknown source, and one Armijo projectile point is from the Gwynn/Ewe Canyon source.

The Office of Contract Archeology at the University of New Mexico has also studied the source provenance of obsidian artifacts from sites on the White Sands Missile Range (Shackley 2018). Using EDXRF spectrometry, they analyzed 102 pieces of obsidian from 21 sites and two isolated occurrences. Twelve obsidian sources were found and Cerro Toledo Rhyolite obsidian was used the most (n = 72), with smaller amounts of Grants Ridge (n = 11), and El Rechuelos (n = 7). The other sources include Canovas Canyon Rhyolite (n = 3), Horace Mesa (n = 2), Antelope Wells (n = 1), Cerro del Medio (n = 1), Sierra Fresnal (n = 1), Bearhead Rhyolite (n = 1), Gwynn/Ewe Canyon (n = 1), Antelope Creek (n = 1), and Mule Mountains (n = 1). These data corroborate the other Jornada obsidian studies as there is a high frequency of Rio Grande Quaternary alluvium obsidian, but people also used nonlocal sources like Cerro del Medio, Sierra Fresnal, Gwyn/Ewe Canyon, and Mule Creek (Antelope Creek and Mule Mountains).

Figure 4. Arrow point from Cottonwood Springs area A.

EDXRF Analysis

Shackley (2020) analyzed the 24 obsidian artifacts from Cottonwood Springs area A and E using a benchtop ThermoScientific *Quant'X* EDXRF spectrometer at the Geoarchaeological XRF Spectrometry Laboratory in Albuquerque, New Mexico. Six of the artifacts including one arrow point is from area A (Figure 4) and the remaining 18 are from area E. EDXRF spectrometry is an established method to characterize the trace elements of obsidian accurately and reliably without destroying the sample. The trace elements titanium (Ti), manganese (Mn), iron (Fe), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), niobium (Nb), barium (Ba), cerium (Ce), lead (Pb), and thorium (Th) were measured and converted to concentration estimates that were then converted in table form in parts per million (ppm). Shackley (2020) compared the trace elemental values for each of the Cottonwood Springs artifacts with those from known baseline source samples reported in Shackley (1995, 2005; Shackley et al. 2018). The proportions of Mn, Fe, Rb, Sr, Y, Zr, and Nb are commonly used to discriminate individual obsidian source groups using bivariate plots to separate the sources visually. See Shackley (2005, 2011) and http://swxrflab.net/analysis.htm for a more detailed discussion of EDXRF instrumentation, methods, and procedures.

Results

As shown in Figure 5 and Table 1, there are five geochemically distinct obsidian sources. The trace elemental concentrations for all

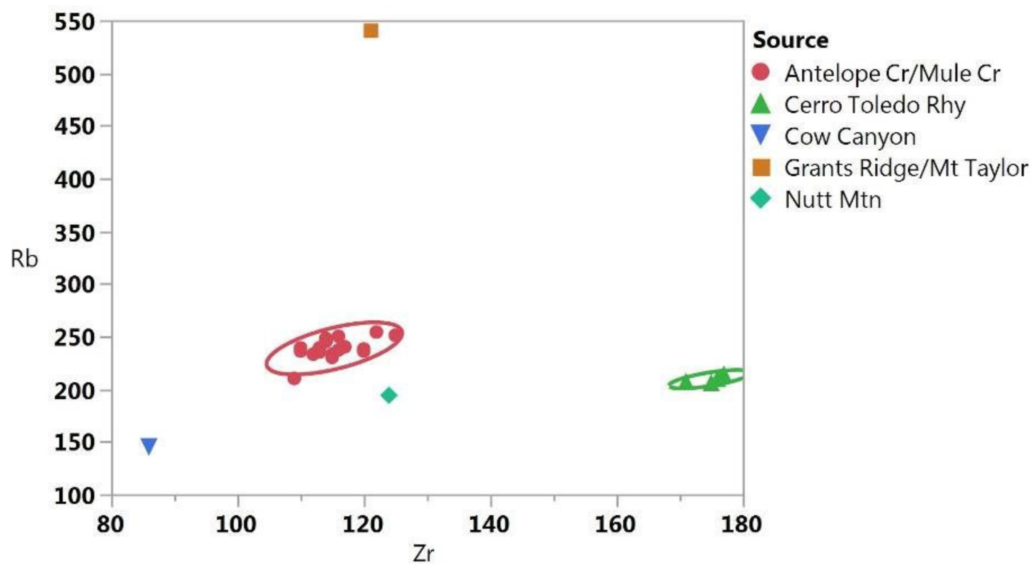


Figure 5. Bivariate plot comparing Rb/Zr of the archaeological samples in areas A and E.

sampled artifacts, including four artifacts that are not obsidian, are included in Table 2. The area A obsidian is from Cerro Toledo Rhyolite, Grants Ridge, and Nutt Mountain, while the area E obsidian is from Antelope Creek and Cow Canyon. These data corroborate our hypothesis. The area A and area E obsidians belong to different sources. However, it is difficult to determine what these differences mean because excavations at area E are ongoing, although we discuss potential explanations.

Five of the six artifacts from area A derive from Cerro Toledo Rhyolite obsidian and Grants Ridge obsidian. Cerro Toledo Rhyolite obsidian and Grants Ridge obsidian can be collected from the Rio Grande Quaternary alluvium which is approximately 35 to 40 km east of the site. The other area A artifact is from Nutt Mountain. The Nutt Mountain primary outcrop is likely in Sierra County, New Mexico, and $^{40}Ar/^{39}Ar$ dating indicates that this obsidian is 31 million years old (Shackley et al. 2018). Nutt Mountain obsidian is not present in the Rio Grande gravels, so people at Cottonwood Springs had to obtain this obsidian from the primary source or through trade. Nutt Mountain obsidian is relatively rare in most Mimbres and Jornada lithic assemblages, most likely because of its small nodule size due to its geologic age. One piece of Nutt Mountain debitage was found in the earlier study.

Obsidian Source	Area A	Area E
Cerro Toledo Rhyolite	4	-
Grants Ridge	1	-
Antelope Creek	-	17
Nutt Mountain	1	-
Cow Canyon	-	1
Total	6	18

Table 1. Obsidian artifacts analyzed for this study.

All 18 obsidian artifacts from area E were produced from the Mogollon-Datil sources of Antelope Creek and Cow Canyon. Antelope Creek obsidian belongs to the Mule Creek source group in west-central New Mexico that also contains Mule Mountains, North Sawmill Creek, and San Francisco/Blue Rivers (Shackley 1992, 1995, 2005; Shackley et al. 2018). Antelope Creek nodules are found in secondary deposits elsewhere, but not in the Rio Grande Quaternary alluvium. Antelope Creek obsidian dates to over 27 million years ago and nodules over 10 cm in diameter are not

Field Specimen	Area	Artifact Type	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	Th	Source
21A	E	Flake	583	385	11684	245	23	43	114	26			30	32	Antelope Cr
21B	E	Flake	696	367	11652	239	21	43	113	22			83	37	Antelope Cr
21C	E	-	393	157	8972	3	48	5	19	5			0	5	not obsidian
21D	E	Flake	565	358	11299	237	23	41	116	31			25	33	Antelope Cr
21E	E	Flake	669	371	11762	248	20	44	114	29			28	34	Antelope Cr
21F	E	Flake	1053	420	8333	145	90	26	86	20	1108	61	21	17	Cow Canyon
21G	E	Flake	575	367	11452	240	21	48	117	27			28	39	Antelope Cr
21H	E	Flake	546	365	11460	250	21	45	116	27			26	34	Antelope Cr
21I	E	Flake	607	403	11537	238	22	48	120	29			27	38	Antelope Cr
21J	E	Flake	465	313	11067	210	20	41	109	22			17	29	Antelope Cr
21K	E	Flake	585	381	11594	236	25	40	120	25			28	32	Antelope Cr
21L	E	-	1348	459	10995	193	46	39	214	27	728	126	19	20	unknown vitrophyre
21M	E	Flake	540	364	11208	235	22	39	113	26			26	44	Antelope Cr
21N	E	Flake	573	417	11799	254	24	44	122	26			27	37	Antelope Cr
21O	E	Flake	586	391	11349	239	23	40	110	30			27	35	Antelope Cr
21P	E	Flake	612	379	11390	233	21	41	112	23			27	38	Antelope Cr
21Q	E	Flake	549	378	11559	233	24	43	115	24			30	36	Antelope Cr
21R	E	Flake	701	386	11818	251	20	41	125	24			29	40	Antelope Cr
21S	E	Flake	568	343	11220	230	20	44	115	23			29	33	Antelope Cr
21T	E	Flake	663	367	11529	236	20	43	110	24			24	38	Antelope Cr
PD 155/FS 22	A	Point	680	463	12144	206	10	65	175	89			34	27	Cerro Toledo Rhy
203	A	-	437	147	8611	0	54	4	24	1			1	6	not obsidian
PD 207-1 FS 12	A	Flake	493	495	11929	214	10	63	177	95			32	31	Cerro Toledo Rhy
207-2	A	-	295	153	8515	0	13	34	17	1			3	11	not obsidian
PD 207-3 FS 2	A	Flake	938	441	8735	194	27	30	124	19	130	52	24	22	Nutt Mtn
PD 209	A	Tool?	430	720	10907	541	11	78	121	195			65	32	Grants Ridge/Mt Taylor
PD 210/FS 2	A	Flake	554	460	11988	210	9	65	176	98			35	21	Cerro Toledo Rhy
PD 225 FS 34	A	Biface	591	502	12108	207	27	62	171	91			35	30	Cerro Toledo Rhy
RGM1-S4	-	-	1556	304	13098	153	108	25	221	5	840	41	18	19	standard

Table 2. Elemental concentrations and source assignments for the archaeological specimens and analysis of USGS RGM-1 obsidian standard. All measurements are in parts per million (ppm).

uncommon at the primary source (Shackley et al. 2018). While the Jemez obsidian played a vital role in lithic technology for people living in northern New Mexico, Antelope Creek obsidian was particularly important to those living in southwestern New Mexico. Antelope Creek obsidian is relatively rare at Jornada Mogollon sites, but when present, they are often arrow points. Also, two Antelope Creek obsidian artifacts from area E are brownish/mahogany in color (FS 21D and FS 21H). Mahogany obsidian is a reddish-brown color and is relatively rare in the U.S. Southwest and Mexican Northwest, but outcrops of Cerro del Medio and Agua Fria in Sonora can be mahogany (Dolan and Shackley 2017; LeTourneau and Steffen 2002).

In addition to the Antelope Creek obsidian from area E, one obsidian artifact is from Cow Canyon. The primary Cow Canyon source is in eastern Arizona, but it can also be found in secondary deposits in other parts of Arizona and New Mexico, but not in the Rio Grande Quaternary alluvium (Shackley 1992, 2005). The Cow Canyon primary source is relatively close to Mule Creek, but Cow Canyon obsidian was rarely used in southwestern and south-central New Mexico. For example, of the over 900 obsidian artifacts from sites in southwestern New Mexico that Taliaferro et al. (2010) report, only 19 are from Cow Canyon. Cow Canyon obsidian is uncommon in Jornada assemblages, but archaeologists did recover three Cow Canyon artifacts at Madera Quemada Pueblo, including a projectile point and a core (Dolan et al. 2017).

Discussion

If Jornada groups during the El Paso phase were more residentially mobile than other groups, we might expect their obsidian to be from nonlocal sources throughout the region. At the same time, however, if Cottonwood Springs represents a settled pueblo village that depended on agriculture, then we would expect the obsidian to be local. Taking all Cottonwood Springs obsidian data into account to date, the obsidian primarily derives from Cerro Toledo Rhyolite (n = 29) and Antelope Creek (n = 22), with lesser amounts of Grants Ridge, Nutt Mountain, El Rechuelos, Canovas Canyon, Horace Mesa, Cow Canyon, and Sierra Fresnal (Table 3). Also, the obsidian that can be found in the Rio Grande gravels makes up 59 percent of the total assemblage (n = 38) with the remaining 41 percent coming from non-Rio Grande gravels, or nonlocal obsidian (n = 26). Based on the presence of these sources, it seems that both of the above statements are true, people at Cottonwood Springs used both local and nonlocal obsidian.

Obsidian Source	Area A	Area E	Total
Cerro Toledo Rhyolite	29	-	29
El Rechuelos	1	-	1
Canovas Canyon	1	-	1
Horace Mesa	1	-	1
Grants Ridge	6	-	6
Antelope Creek	5	17	22
Nutt Mountain	2	-	2
Cow Canyon	-	1	1
Sierra Fresnal	1	-	1
Total	46	18	64

Table 3. Total obsidian artifacts analyzed from Cottonwood Springs Pueblo.

The high frequency of Cerro Toledo Rhyolite obsidian and other obsidians found in the Rio Grande Quaternary alluvium demonstrates that people at Cottonwood Springs area A did not use high-energy costs to procure large quantities of nonlocal obsidian. Instead, they organized their obsidian resources informally and reduced the local obsidian expediently because it was nearby and easy to acquire. Also, because Cerro del Medio obsidian can only be obtained from the Valles Caldera or through exchange, the absence of Cerro del Medio obsidian supports the conclusion that people did not acquire the other Jemez obsidians from the primary source in northern New Mexico. If Cerro del Medio was present in the assemblage, an argument could be made that during the trip to the Jemez Mountains in which they acquired Cerro del Medio obsidian, they could have also acquired Cerro Toledo Rhyolite, El Rechuelos, Canovas Canyon Rhyolite, and Bearhead Rhyolite obsidian.

The amount of Antelope Creek debitage from area E is surprising. Dolan, Miller, Shackley, and Corl (2017) found no Antelope Creek debitage at area A, and suggested that Antelope Creek arrow points came into the site already finished. The presence of Antelope Creek debitage with dorsal cortex at area E allows for new questions regarding obsidian procurement at Cottonwood Springs. It is possible that people at area A acquired Antelope Creek points from those occupying area E if the two pueblos are contemporaneous. Another possibility is that a single person collected several Antelope Creek obsidian marekanites during a trip to the Mule Creek area and brought them to Cottonwood Springs, or it could represent a single exchange episode.

Why would people at Cottonwood Springs areas A and E want and/or need obsidian from sources other than what was locally available in the Rio Grande Quaternary alluvium? The nonlocal obsidian at Cottonwood Springs includes Antelope Creek, Nutt Mountain, Cow Canyon, and Sierra Fresnal. Small scale middle-range societies, like the Jornada Mogollon, exchanged obsidian and other goods through complementarity and reciprocal processes (Braun and Plog 1982; Ford 1972). During crop failure or times of environmental stress, local and nonlocal exchange networks would have provided a structural context through which groups could have gained access to resources (Borck et al. 2015; Rautman 1993). Long-distance social networks helped to create stability during unsettling times, and people at Cottonwood Springs could have accounted for the differential value placed on obsidian, even though obsidian is relatively rare in most Jornada lithic assemblages. The presence of nonlocal obsidian arrow points in area A and Antelope Creek debitage in area E suggests that people relied on long-distance exchange networks, but they also used the locally available obsidian for stone tool manufacture.

Conclusion

In conclusion, obsidian did not play a major role in chipped stone technology at Cottonwood Springs Pueblo, but to date, we have analyzed 64 obsidian artifacts from areas A and E. Based on the available obsidian data, there are clear differences in obsidian procurement between areas A and E. Area A obsidian largely derives from sources that can be found locally along the Rio Grande Quaternary alluvium, including Cerro Toledo Rhyolite, El Rechuelos, Canovas Canyon, Grants Ridge, and Horace Mesa. However, many of the obsidian arrow points from area A are from nonlocal sources, like Antelope Creek and Sierra Fresnal. The area E obsidian, on the other hand, derives from Antelope Creek and Cow Canyon. Also, keep in mind that the area E obsidian came from disturbed contexts in a looters' pile.

When obsidian artifacts are present in Jornada Mogollon lithic assemblages, the obsidian is most likely Cerro Toledo Rhyolite or another obsidian from the Rio Grande gravels. However, you should not always assume that all obsidian artifacts were made from sources present in the Rio Grande gravels, as some arrow points could be from Antelope Creek, Sierra Fresnal, or another nonlocal source. We hope the addition of these new obsidian data from Cottonwood Springs will help archaeologists better understand the parameters governing lithic manufacture and obsidian procurement in the Jornada region. Continuing to examine Jornada Mogollon obsidian will contribute to a more complete understanding of the relationship between people and their stone tools through maintenance, technology, exchange, and movement.

Acknowledgments

We thank William Walker and Myles Miller who provided comments on an earlier draft, and Alex Kurota for providing the White Sands Missile Range reports.

References

Andrefsky, W. (1994) Raw-Material Availability and the Organization of Technology. *American Antiquity* 59: 21–34.

Borck, L., B. J. Mills, M. A. Peeples, and J. J. Clark (2015) Are Social Networks Survival Networks? An Example from the Late Pre-Hispanic US Southwest. *Journal of Archaeological Method and Theory* 22: 33-57.

Braun, D. P., and S. Plog (1982) Evolution of "Tribal" Social Networks: Theory and Prehistoric North American Evidence. *American Antiquity* 47: 504-525.

Camilli, E. L. (1988) Lithic Raw Material Selection and Use in the Desert Basins of South-Central New Mexico. *Kiva* 53: 147–163.

Church, T. (2000) Distribution and Sources of Obsidian in the Rio Grande Gravels of New Mexico. *Geoarchaeology* 15: 649–678.

Church, T., C. Caraveo, R. Jones, and J. Sirianni (1996) *Mountains and Basins: The Lithic Landscape of the Jornada Mogollon*. Archaeological Technical Reports 8. Anthropology Research Center, University of Texas, El Paso.

Diehl, M. W. (2007) Mogollon Trajectories and Divergences. In *Zuni Origins: Toward a New Synthesis of Southwestern Archaeology*, edited by D. A. Gregory and D. R. Wilcox, pp. 146–162. University of Arizona Press, Tucson.

Dolan, S. G. (2016) *Black Rocks in the Borderlands: Obsidian Procurement in Southwestern New Mexico and Northwestern Chihuahua, Mexico, A.D. 1000 to 1450*. Unpublished Ph.D. Dissertation, University of Oklahoma, Norman.

Dolan, S. G. (2019) Stone Tool and EDXRF Analysis of Obsidian Tools from Elk Ridge Ruin (LA 78963). In *Collected Papers from the 20th Biennial Mogollon Archaeology Conference*, edited by L. C. Ludeman, pp. 45–55. Friends of Mogollon Archaeology, Las Cruces, New Mexico.

Dolan, S. G., J. Berryman, and M. S. Shackley (2016) The Source Provenance of an Obsidian Eden Point from Sierra County, New Mexico. *PaleoAmerica* 2: 48–51.

Dolan, S. G., J. Berryman, and M. S. Shackley (2017) Source Characterization of Obsidian Artifacts from Six Sites in the Jornada Mogollon Region of Southern New Mexico. *International Association for Obsidian Studies Bulletin* 58: 38–44.

Dolan, S. G., M. R. Miller, M. S. Shackley, and K. Corl (2017) El Paso Phase Obsidian Procurement in Southern New Mexico: Implications for Jornada Mogollon Regional Interaction and Exchange. *Kiva* 83:267–291.

Dolan, S. G., and M. S. Shackley (2017) Is there Mahogany Obsidian in Northeastern Sonora, Mexico? *International Association for Obsidian Studies Bulletin* 56: 11-17.

Ferguson, J. R., K. W. Laumbach, S. H. Lekson, M. C. Nelson, K. G. Schollmeyer, T. S. Laumbach, and M. R. Miller (2016) Implications for Migration and Social

Connections in South-Central New Mexico Through Chemical Characterization of Carbon-Painted Ceramics and Obsidian. *Kiva* 82: 22–50.

Ford, R. I. (1972) Barter, Gift, or Violence: An Analysis of Tewa Intertribal Exchange. In *Social Exchange and Interaction*, edited by E. N. Wilmsen, pp. 21-45. Anthropological Papers, No. 36, Museum of Anthropology, University of Michigan, Ann Arbor.

Glascock, M. D., R. Kunselman, and D. Wolfman (1999) Intrasource Chemical Differentiation of Obsidian in the Jemez Mountains and Taos Plateau, New Mexico. *Journal of Archaeological Science* 26: 861–868.

Lehmer, D. J. (1948) *The Jornada Branch of the Mogollon*. University of Arizona Social Science Bulletin 17, Tucson.

Lekson, S. H., and A. S. Rorex (1995) The Cottonwood Springs and Indian Tanks Sites. *Artifact* 33: 9–36.

LeTourneau, P. D., and M. S. Shackley (2009) Geochemistry of Paleoindian and Early-Archaic Obsidian Artifacts from New Mexico and Colorado. *Current Research in the Pleistocene* 26: 81–84.

LeTourneau, P. D., and A. Steffen (2002) Field Investigations at a Likely Source for New Mexico Obsidian Folsom Artifacts. *Current Research in the Pleistocene* 19: 57-59.

Miller, M. R. (2005) Revision of the Jornada Mogollon Ceramic Period Sequence and Alignment with the Greater Southwest. In *Archaeology between the Borders: Papers from the 13th Biennial Jornada Mogollon Conference*, edited by M. Thompson, J. Jurgena, and L. Jackson, pp. 59–88. El Paso Museum of Archaeology, El Paso, Texas.

Miller, M. R. (2018a) A Millennium of Identity Formation and Maintenance in the Jornada Mogollon Region. In *Life Beyond the Boundaries: Constructing Identity in Edge Regions of the North American Southwest*, edited by K. G. Harry and S. A. Herr, pp. 239–272. University Press of Colorado, Boulder.

Miller, M. R. (2018b) Archaic Transitions and Transformations in the Jornada Mogollon Region of Southern New Mexico and Western Texas. In *The Archaic Southwest: Foragers in an Arid Land*, edited by B. J. Vierra, pp. 119–144. University of Utah Press, Salt Lake City.

Miller, M. R. (2019) Integrating Households and Communities at Jornada Mogollon Pueblos. In *Communities and Households in the Greater American Southwest: New Perspectives and Case Studies*, edited by R. J. Stokes, pp. 229-253. University Press of Colorado.

Miller, M. R., and T. Graves (2019) Chronological Trends among Jornada Projectile Points. In *Recent Research in Jornada Mogollon Archaeology: Proceedings from the 20th Jornada Mogollon Conference*, edited by G. O. Maloof, pp. 205-251. El Paso Museum of Archaeology, El Paso, Texas.

Miller, M. R., and N. A. Kenmotsu (2004) Prehistory of the Jornada Mogollon and Eastern Trans-Pecos Regions of West Texas. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 205–265. Texas A&M University Press, College Station.

Mills, B. J., J. J. Clark, M. A. Peeples, W. R. Haas Jr., J. M. Roberts Jr., J. B. Hill, D. L. Huntley, L. Borck, R. L. Breiger, A. Clauset, and M. S. Shackley (2013) Transformation of Social Networks in the Late Pre-Hispanic US Southwest. *Proceedings of the National Academy of Science* 110: 5785–5790.

Rautman, A. E. (1993) Resource Variability, Risk, and the Structure of Social Networks: An Example from the Prehistoric Southwest. *American Antiquity* 58: 403-424.

Rocek, T. R., and N. A. Kenmotsu (editors) (2018) *Late Prehistoric Hunter-Gatherers and Farmers of the Jornada Mogollon*. University Press of Colorado, Boulder.

Roth, B. J., K. E. DiBenedetto, and J. R. Ferguson (2019) Obsidian Procurement and Social Interaction at the Harris Site, Mimbres River Valley, New Mexico. *Journal of Archaeological Science: Reports*, DOI: https://doi.org/10.1016/j.jasrep.2019.102008

Roth, B. J., E. Toney, and L. Lorentzen (2011) The Advent of Bow and Arrow Technology in the Mimbres Mogollon Region. *Kiva* 77: 87–109.

Shackley, M. S. (1992) The Upper Gila River Gravels as an Archaeological Obsidian Source Region: Implications for Models of Exchange and Interaction. *Geoarchaeology* 4: 315–326.

Shackley, M. S. (1995) Sources of Archaeological Obsidian in the Greater American Southwest: An Update and Quantitative Analysis. *American Antiquity* 60: 531–551.

Shackley, M. S. (1998) Geochemical Differentiation and Prehistoric Procurement of Obsidian in the Mount Taylor Volcanic Field, Northwest New Mexico. *Journal of Archaeological Science* 25: 1073–1082.

Shackley, M. S. (2005) *Obsidian: Geology and Archaeology in the North American Southwest*. University of Arizona Press, Tucson.

Shackley, M. S. (2011) An Introduction to X-Ray Fluorescence (XRF) Analysis in Archaeology. In *X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology*, edited by M. S. Shackley, pp. 7–44. Springer, New York.

Shackley, M. S. (2013) The Geochemistry and Archaeological Petrology of Volcanic Raw Materials in Northern New Mexico: Obsidian and Dacite Sources in Upland and Lowland Contexts. In *From Mountain Top to Valley Bottom: Understanding Past Land Use in the Northern Rio Grande Valley, New Mexico*, edited by B. J. Vierra, pp. 17–32. University of Utah Press, Salt Lake City.

Shackley, M. S. (2018) Source Provenance of Obsidian Artifacts from White Sands Missile Range, Southern New Mexico. In *Archaeology of White Sands Missile Range: Evaluation of 36 Sites and Implementation of Site Protective Measures Between Highway 70 and Nike Avenue, Otero and Doña Ana Counties, New Mexico: Volume 3: Analyses and Appendices*, compiled by A. Kurota, E. Sternberg, and R. Dello-Russo, pp. 50-1-50-8.

Shackley, M. S., F. Goff, and S. G. Dolan (2016) Geologic Origin of the Source of Bearhead Rhyolite (Paliza Canyon)

Obsidian, Jemez Mountains, Northern New Mexico. *New Mexico Geology* 38: 52–65.

Shackley, M. S., L. Morgan, and D. Pyle (2018) Elemental, Isotopic, and Geochronological Variability in Mogollon-Datil Volcanic Province Archaeological Obsidian, Southwestern USA: Solving Issues of Intersource Discrimination. *Geoarchaeology* 33: 486–497.

Taliaferro, M. S., B. A. Schriever, and M. Steven Shackley (2010) Obsidian Procurement, Least Cost Pathway Analysis, and Social Interaction in the Mimbres Area of Southwestern New Mexico. *Journal of Archaeological Science* 37: 536–548.

VanPool, T. L., C. M. Oswald, J. A. Christy, J. R. Ferguson, G. F. M. Rakita, and C. S. VanPool (2013) Provenance Studies of Obsidian at 76 Draw. In *Advances in Jornada Mogollon Archaeology: Proceedings from the 17th Jornada Mogollon Conference*, edited by T. L. VanPool, E. M. McCarthy, and C. S. VanPool, pp. 163–184. El Paso Museum of Archaeology, El Paso, Texas.

Vierra, B. J., M. A. Jodry, M. S. Shackley, and M. J. Dilley (2012). Late Paleoindian and Early Archaic Foragers in the Northern Southwest. In *From the Pleistocene to the Holocene: Human Organization and Cultural Transformations in Prehistoric North* America, edited by C. Britt Bousman and B. J. Vierra, pp. 171–195. Texas A&M University Press, College Station, Texas.

Wheat, J. B. (1955) *Mogollon Culture Prior to A.D. 1000*. Memoires of the Society for American Archaeology 10. Society for American Archaeology, Salt Lake City.

Wilcox, D. R., and D. A. Gregory (2007) Introduction: The Structure of Anthropological Inquiry into Zuni Origins. In *Zuni Origins: Toward a New Synthesis of Southwestern Archaeology*, edited by D. A. Gregory and D. R. Wilcox, pp. 3–13. University of Arizona Press, Tucson.

Wiseman, R. N. (2019) *Pruning the Jornada Branch Mogollon: Changing Perspectives Prehistory Southeastern New Mexico*. Second Books, Albuquerque.

WHAT IS (AND ISN'T) THE "MOONSTONE OBSIDIAN" FROM SEVAN, ARMENIA?

Ellery Frahm

Council on Archaeological Studies, Department of Anthropology, Yale University, USA

Should you ever find yourself in Armenia – specifically its capital city, Yerevan, during the weekend – be sure to visit the open-air market known as Vernissage. Its name derives from the French term for a sneak preview of an artistic exhibition because the market began in the 1980s when artists displayed their works in a public square. Today, paintings, wood carvings, and other *objets d'art* are still on display (Figure 1), but there is also much more for sale: tools, books, coins, jewelry, carpets, records, chemicals, games, and clothing, to name just a few things. Despite this variety, students enrolled in the University of Connecticut's field school seem to buy the same items as souvenirs every year. Hand-painted silk scarves are popular gifts for their mothers, and someone always buys a replica dagger made for tourists or a vintage gas mask. For the obsidian enthusiast, however, Vernissage is a veritable cornucopia of delights. There are hundreds, likely thousands, of obsidian items, ranging from paperweights and keychains to elaborate sculptures and complete chess sets. Occasionally there are obsidian knives that have, by the looks of them, been pressured-flaked from preform slabs. I have used portable XRF to analyze several obsidian trinkets from Vernissage over the years, and all of them chemically matched a source in western Armenia known as Pokr Arteni (Figure 2). Use of this obsidian source dates back more than 325 thousand years, as I showed at the site of Nor Geghi 1 (Adler et al. 2014).

During the summer of 2019, my colleagues and I took a day trip to Sevanavank (which is Armenian for "Sevan monastery"), an apt name for a monastery complex on the shores of Lake Sevan (Figure 3). Both the lake itself and the monastery are highly popular destinations for local Armenians as well as foreign tourists.

Figure 1. The paintings section at Vernissage market in Yerevan.

Figure 2. The Pokr Arteni obsidian source in western Armenia.

Unsurprisingly, there is an open-air market, similar to but smaller than Vernissage, between the monastery and parking lots for abundant minibuses. As I perused the items for sale, most of them similar to what I have come to expect at Vernissage, I stopped to inspect a collection of glassy chunks. They varied from clear with an iridescence that shifted among yellows, greens, and blues to translucent and milky white, sometimes within the same fragment (Figure 4). When I picked up a piece to examine it, the vendor told me that it was obsidian. I expressed my doubt in reply. He insisted, however, that the assortment of glassy pieces was indeed obsidian from nearby, somewhere close to Lake Sevan. I chose not to argue with him further, and after walking away, I noticed similar chunks at other vendors' tables as well. At each table, the proprietors insisted that the fragments, which have an appearance not unlike the gem known as "moonstone," were obsidian. At one point, a colleague walking beside me asked, "Are those really obsidian?" "No," I replied without hesitation.

My colleagues on the Pleistocene Archaeology, Geochronology, and Environment of the Southern Caucasus (PAGES) Project have just finished three years' worth of geological mapping between Lake Sevan and Yerevan (see Sherriff et al. 2019), and their findings corroborate that obsidian should not be expected to occur naturally near Lake Sevan. The nearest mountains are Miocene-Cretaceous in age and are composed of marine sediments and igneous intrusions. The closest felsic Quaternary flows are kilometers away and are not known to have obsidian. To the best of my knowledge, the closest source of any sort of aphanitic or glassy

Figure 3. Sevanavank monastery in the foreground, Lake Sevan in the background.

Figure 4. Fragment of "moonstone obsidian" purported from the Sevan region.

material is a volcanic vent called Menaksar, almost 20 km from Sevan. Volcanic ejecta around the scoria cone include rare sub-centimeter glassy trachydacite pebbles, but that is all. Otherwise, the nearest source of true obsidian is the Gutansar volcanic complex, about 30 km to the southwest.

Confusingly, mentions of an obsidian source in the Sevan area can be found in literature from the 1980s and 1990s (e.g., Gratuze et al. 1993, Hall and Shackley 1994). A map in Williams-Thorpe (1995) illustrates the limited Western knowledge of Armenian obsidian at the time: she erroneously placed an obsidian source near the shore of Lake Sevan. This inaccurate location was based on erroneous descriptions in the literature, especially Blackman (1984), who described "a source between the city of [H]razdan and the northwestern tip of Lake Sevan" (23). Eventually it was realized that the purported "Sevan" obsidian source was an anthropogenic context (i.e., an archaeological site) with artifacts rather than a geological deposit (Blackman et al. 1998, Frahm et al. 2016). Such problems have been common in the region. For example, supposed geological specimens of obsidian from Mount Ararat in London's National History Museum (BM.1955,309) are actually artifacts from the Gutansar complex (personal observation).

Ideally, of course, one can speak to what something is, instead of merely stating what it is not. Back at the University of Minnesota when I oversaw the Electron Microprobe Lab, I often interacted with members of the public who brought suspected meteorites to the Department of Earth and Environmental Sciences. Except for the very last one that I tested, none of the objects were meteorites. For most of them, a simple visual inspection ruled out the objects as potential meteorites, but my colleagues and I sought to give these individuals, who took the time to bring us these objects, answers to what they really were. People tended to be less disappointed with their "meteor-wrongs" if we could identify their mysteries. Many were slag. Two or three were pyrite concretions. One was even a cannon ball embedded in a tree trunk.

To confirm my suspicions and to attempt to identify the "moonstone obsidian," I bought a chunk from a vendor so that I could analyze it using portable XRF. I also sought specimens of artificial glass for comparison, but where to start? Dishware? Bottles? Ultimately, a small set of Soviet-era glass electrical insulators caught my attention. Their hues and iridescence reminded me of the purported obsidian (Fig. 5), and I recalled the use of such glass insulators by historical and modern knappers as a raw material for flaked points. Specifically, I purchased four greenish insulators plus a greyish one, and those with legible stamps dated to the 1970s. I should stress that there is no reason to believe that these insulators were made locally. Under Soviet control, Sevan became an important center of manufacturing, but I did not find

Figure 5. Example of a Soviet-era electrical insulator analyzed for comparison.

anything related to glass production in particular. In 1962, a fiberglass manufacturing plant opened in the city of Sevan, but the process was based on basalt fibers – essentially melting crushed basalt powder and then extruding the melt through miniscule nozzles – instead of glass fibers. Therefore, it is unclear, at present, what type of glass manufacturing occurred in the vicinity of Sevan.

Table 1 shows the chemical data for the Sevan "obsidian" specimen, the glass insulators, and four obsidian sources. These four obsidian sources – Gutansar in Armenia, Meydan Dağ and Sarıkamiş in eastern Turkey, and Chikiani (a.k.a. Paravani Lake) in Georgia – are included in the Peabody–Yale Reference Obsidian (PYRO) calibration sets (Frahm 2019). The instrument was an Olympus Vanta VMR, which is equipped with a Rh anode, a 4-W X-ray tube, and a large-area (40 mm^2) silicon drift detector with excellent spectral resolution even at high count rates ($\lesssim$140 eV at $\gtrsim$100,000 X-ray counts/second). In the "GeoChem" mode, the tube's current and its voltage change in sync with built-in beam filters to better fluoresce the heavier and lighter portions of the periodic table. These measurements were calibrated using (1) electron microprobe analysis (EMPA) values in Frahm (2010) for the major elements and (2) recommended inter-laboratory, inter-technique values reported in Frahm (2019) for the trace elements.

The data illustrate that the Sevan "moonstone obsidian" is indeed an artificial glass, not a volcanic one. For example, the measured Ca concentration is almost two orders of magnitude greater than that in the obsidian specimens, and it is indicative of a soda-lime glass, which is the most common type of artificial glass. The amount of Zn is low (24 ± 2 ppm), but art glasses tend to have considerably higher Zn contents in order to improve their workability. It is not a leaded glass either (Pb: 10 ± 1 ppm). The best clue regarding the specimen's purpose is a relatively high As content (0.14%). Arsenic oxide is used at such concentrations as a fining agent – that is, it is used to remove bubbles from the melt, and the As becomes incorporated into the glassy matrix in the process. As one can see from the glass insulator data, this is not a ubiquitous practice. It is typically reserved for optical-grade glasses that must remain bubble-free.

Consequently, the "moonstone obsidian" from the Sevan region is not volcanic in origin. Instead, it is appears to be waste from the production of optical-grade soda-lime glass, perhaps the outcome of a bad batch. It is not possible to be any more specific than that without delving deeper into the history of manufacturing around Sevan. There is, of course, no shortage of fake obsidian for sale, whether on the internet or in stores, flea markets, and gift shops around the world – one could spend considerable time and effort trying to debunk all of it. In this instance, however, I am glad to be able to lay the ghost of "Sevan obsidian" to rest.

	Purported "moonstone obsidian"	Electrical Insulators		Obsidian Specimens			
		Green Glass n=4	Grey Glass n=1	Gutansar PYRO Cal-02	Meydan Dağ PYRO Cal-06	Sarıkamış PYRO Cal-08	Chikiani PYRO Cal-05
Al (%)	7.13 ± 0.54	9.06 ± 0.23		7.30 ± 0.26	6.75 ± 0.19	6.74 ± 0.05	7.20 ± 0.11
Si (%)	21.74 ± 0.79	32.32 ± 0.40	37.73 ± 4.20	34.89 ± 0.09	35.00 ± 0.20	36.09 ± 0.06	35.49 ± 0.13
P (%)			0.17 ± 0.08				
S (%)			0.17 ± 0.03				
K (%)			0.54 ± 0.02	3.48 ± 0.01	3.66 ± 0.02	3.85 ± 0.02	3.98 ± 0.01
Ca (%)	13.45 ± 0.12	9.92 ± 0.40	5.30 ± 0.64	0.71 ± 0.01	0.30 ± 0.01	0.34 ± 0.01	0.50 ± 0.01
Ti (ppm)	403 ± 48	467 ± 64	508 ± 107	877 ± 111	423 ± 91	656 ± 20	749 ± 54
V (ppm)	37 ± 7	41 ± 6	56 ± 7	46 ± 14	18 ± 17	60 ± 3	78 ± 2
Cr (ppm)	46 ± 3	42 ± 3	39 ± 2				
Mn (ppm)	73 ± 8	45 ± 7	71 ± 12	619 ± 11	517 ± 9	361 ± 6	457 ± 8
Fe (ppm)	1154 ± 21	890 ± 95	886 ± 215	7982 ± 28	9371 ± 52	5731 ± 21	5529 ± 10
Ni (ppm)	15 ± 3	19 ± 1	17 ± 3	13 ± 2	15 ± 4	12 ± 3	11 ± 1
Cu (ppm)	31 ± 3	9 ± 1					
Zn (ppm)	24 ± 2	23 ± 3	38 ± 7	44 ± 3	79 ± 3	35 ± 1	44 ± 4
As (ppm)	1414 ± 19	8 1	11 ± 2				
Rb (ppm)	2 ± 0	2 ± 1	3 ± 1	138 ± 1	198 ± 4	126 ± 2	124 ± 1
Sr (ppm)	113 ± 1	55 ± 4	143 ± 2	123 ± 2	17 ± 1	24 ± 1	88 ± 2
Y (ppm)	3 ± 1	5 ± 1	3 ± 1	23 ± 1	55 ± 2	24 ± 1	13 ± 1
Zr (ppm)	419 ± 17	222 ± 50	30 ± 1	164 ± 3	272 ± 3	104 ± 1	94 ± 2
Nb (ppm)				38 ± 1	32 ± 1	13 ± 1	20 ± 1
Pb (ppm)	10 ± 1	38 ± 15	83 ± 9	23 ± 1	32 ± 1	25 ± 1	24 ± 2
Th (ppm)				19 ± 2	29 ± 4	18 ± 6	18 ± 1
U (ppm)				11 ± 1	10 ± 1	8 ± 1	7 ± 1

Table 1. Analytical data.

References

Adler, D. S., K. N. Wilkinson, S. Blockley, D. Mark, R. Pinhasi, B. A. Schmidt-Magee, S. Nahapetyan, C. Mallol, F. Berna, P. J. Glauberman, Y. Raczynski-Henk, N. Wales, E. Frahm, O. Jöris, A. MacLeod, V. Smith, V. Cullen, B. Gasparyan (2014) Early Levallois Technology and the Transition from the Lower to Middle Palaeolithic in the Southern Caucasus. *Science* 345(6204): 1609-1613.

Blackman, M. J. (1984) Provenance Studies of Middle Eastern Obsidian from Sites in Highland Iran. In *Archaeological Chemistry III*, edited by J. B. Lambert, pp. 19-50. American Chemical Society, Washington, DC.

Blackman, M. J., R. Badalian, Z. Kikodze, P. Kohl (1998) Chemical Characterization of Caucasian Obsidian Geological Sources. In *L'obsidienne au Proche et Moyen-Orient: Du Volcan à l'Outil,* edited by M.-C. Cauvin, A. Gourgaud, B. Gratuze, N. Arnaud, G. Poupeau, J.-L. Poidevin, and C. Chataigner, pp. 205-231. BAR International Series 738, Oxford.

Frahm, E. (2010) The Bronze-age Obsidian Industry at Tell Mozan (ancient Urkesh), Syria. Ph.D. dissertation. Department of Anthropology, University of Minnesota. Available online through the University of Minnesota's Digital Conservancy: http://purl.umn.edu/99753.

Frahm, E. (2019) Introducing the Peabody-Yale Reference Obsidians (PYRO) Sets: Open-source Calibration and Evaluation Standards for Quantitative X-ray Fluorescence Analysis, *Journal of Archaeological Science: Reports* 27: 101957.

Frahm, E., S. Campbell, E. Healey (2016) Caucasus Connections? New Data and Interpretations for Armenian Obsidian in Northern Mesopotamia. *Journal of Archaeological Science: Reports* 9: 543-564.

Gratuze, B., J. Barrandon, K. Al Isa, M.-C. Cauvin (1993) Non-destructive Analysis of Obsidian Artefacts Using Nuclear Techniques: Investigation of Provenance of Near Eastern Artefacts. *Archaeometry* 35(1): 11-21.

Hall, M. E. and M. S. Shackley (1994) An Energy Dispersive X-Ray Fluorescence Study of Some Near Eastern Obsidians. *Al-Rafidan* 15: 25-32.

Sherriff, J. E., K. N. Wilkinson, D. S. Adler, D. Arakelyan, E. J. Beverly, S. P. E. Blockley, B. Gasparyan, D. F. Mark, K. Meliksetian, S. Nahapetyan, K. J. Preece, R. G. O. Timms (2019) Pleistocene Volcanism and the Geomorphological Record of the Hrazdan Valley, Central Armenia: Linking Landscape Dynamics and the Palaeolithic Record. *Quaternary Science Reviews* 226: 105994.

Williams-Thorpe, O. (1995) Obsidian in the Mediterranean and the Near East: A Provenancing Success Story. *Archaeometry* 37: 217-248.

GROUP 3d OBSIDIAN FROM TELL ZIDAYEH, NE SYRIA, STUDIED BY XRF AND NAA

Yukiko Tonoike[a] and Michael D. Glascock[b]

[a] Department of Anthropology, Yale University, New Haven, CT 06511, USA
[b] Research Reactor Center, University of Missouri, Columbia, MO 65211, USA

Abstract

A study of 73 obsidian artifacts recovered from the site of Tell Ziyadeh in northeast Syria using X-ray fluorescence finds that twenty of the artifacts came from the unknown Group 3d source. To date, the site of Kenan Tepe is the only other site reporting a greater number of 3d artifacts. Neutron activation analysis (NAA) was performed to obtain a more complete compositional profile of Group 3d obsidian.

Introduction

The site of Tell Ziyadeh (Figure 1) is located along the middle Khabur River about 12.5 km southeast of the modern city of Al-Hasakah (Hasseke). The site was discovered in the early 1980s by Monchambert (1983, 1984). Initially, Frank Hole considered the excavation potential of Tell Ziyadeh as part of the larger Khabur Basin Project (KBP), but he chose to work elsewhere. As a result, the first excavations at the site were conducted from 1988 to 1990 by the International Institute of Mesopotamian Area Studies (Buccellati et al. 1991). In the mid-1990s, after reviewing the history of appearance and disappearance of contemporaneous sites in the Khabur Basin, Hole decided that additional research at Tell Ziyadeh might be productive. The Yale University team under Hole's direction conducted excavations from 1995 through 1997 (Hole and Tonoike 2016).

The presence of a small number of Halaf period painted ceramics suggests a limited occupation of Tell Zidayeh occurred during the Halaf period (sixth millennium BCE). The primary occupation occurred during two other periods, the Ubaid and post-Ubaid/Kuranian (fifth millennium BCE) and early Al-Jazirah

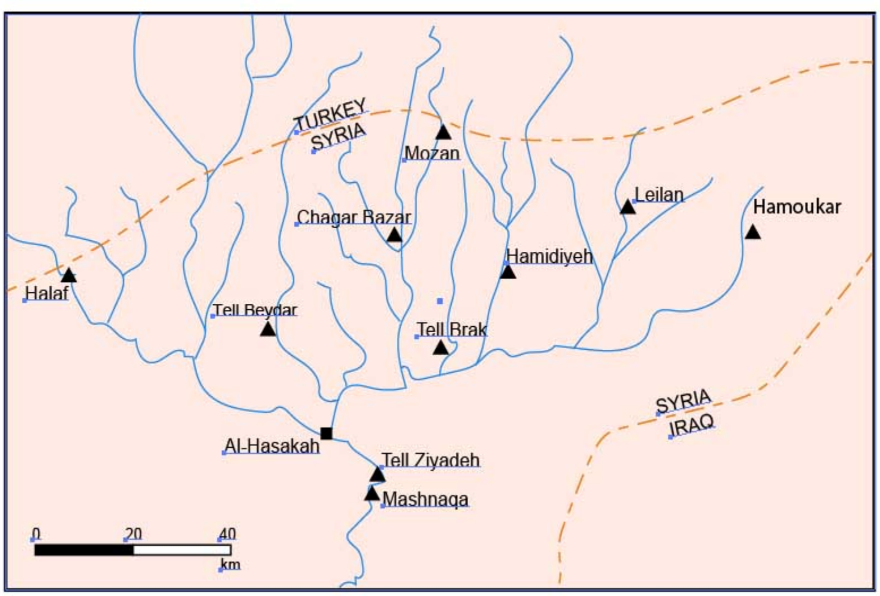


Figure 1. Map showing Tell Ziyadeh and other sites in the Khabur Basin. The straight-line distance to sources at Lake Van and Bingol from Tell Ziyadeh is approximately 125km.

(third millennium BCE). The excavations at Tell Ziyadeh along with those from contemporary sites within the Khabur basin, including Tell Kuran and Tell Mashnaqa, found that immigrants from southern Mesopotamia moved into the sparsely occupied region at the beginning of the fifth millennium BC bringing with them their Ubaid-derived culture. The immigrants built a network of small homesteads consisting of a few house compounds and storage structures throughout northern Mesopotamia. Their modest existence was based on agro-pastoralism supplemented by wild food resources for approximately one thousand years. After a short flourish of local traditions at the beginning of the fourth millennium BCE (Kuranian phase), it was replaced by Uruk influence. Shortly thereafter, likely as a result of changes in the environment, the site was abandoned for a thousand years until beginning of the third millennium BCE. However, by the middle of the third millennium BCE, a serious drought brought about a second episode of abandonment. Thereafter, the site was not occupied to the same degree again until modern times (Hole and Tonoike 2016).

The lithic artifacts recovered from excavations at Tell Ziyadeh were limited in number and types when compared to sites from earlier periods. The number of lithic artifacts found by the Yale team were 3,976 flint and 389 obsidian pieces. The tools made from flint were produced from local materials, except for a few third-millennium Canaanean blades that were made of non-local flint using superior workmanship. The presence of finely-chipped obsidian blades along with an absence of obsidian cores, suggest that the obsidian blades were not produced at the site. Instead, the obsidian may have been worked at larger contemporaneous sites such as Tell Brak where there is evidence of obsidian manufacture (Khalidi et al. 2009).

Although the percentage of obsidian in the lithic assemblage at Tell Ziyadeh is low, its relative abundance in the third millennium (69% of all blades) was greater than during the fifth millennium (38% of all blades). This pattern is similar to all other third and fifth millennium occupations in the Khabur Basin, but contrasts with sites located along the Euphrates River to the west. The disparity suggests that differences between the regions were due to distance or ease of access between sites and sources.

Analysis and Results

A total of 73 obsidian artifacts from Ubaid contexts at Tell Ziyadeh were analyzed by a portable XRF at Yale and previously reported by Tonoike (2016). The XRF spectrometer was a Bruker III-V operated at 40 kV and 25 microamps and used the green filter (6 mil Cu, 1 mil Ti, and 12 mil Al). The sourcing results are summarized in Table 1 along with a scatterplot of Rb/Zr versus Sr/Rb shown in Figure 2.

The results indicate that the artifacts from Tell Ziyadeh could be easily separated into five different groups associated with six compositional types from sources located in eastern Turkey. The largest group consisting of 45 artifacts matches the peralkaline obsidian from the sources located at Nemrut and Bingöl A which have nearly identical compositions. Although other works, especially those by Frahm (2012) and Glascock (2020), have reported other methods for distinguishing Nemrut Dağ from Bingöl A obsidian, the data from XRF alone in this study are incapable discerning the differences between the sources.

Source	Number	Percentage
Nemrut Dağ/Bingöl A	45	61.6%
Group 3d	20	27.4%
Bingöl B	6	8.2%
Meydan Dağ	1	1.4%
Suphan Dağ	1	1.4%

Table 1. Sources of obsidian found at Tell Ziyadeh as identified by pXRF.

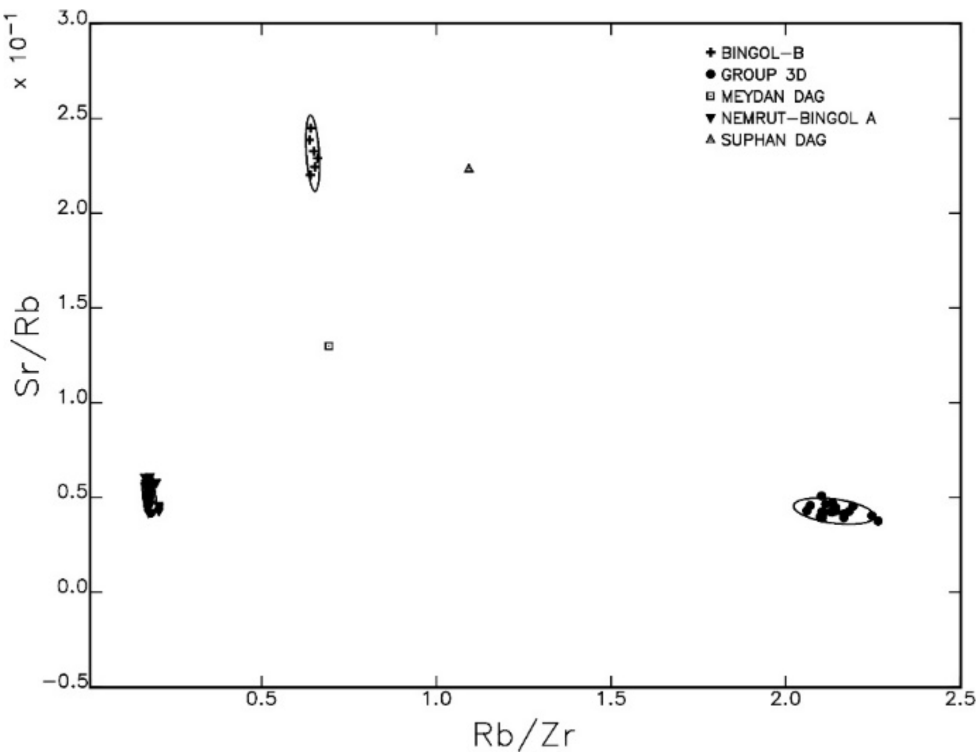


Figure 2. Scatterplot of Rb/Zr versus Sr/Rb for artifacts from Tell Ziyadeh analyzed by XRF at Yale.

In addition to the Nemrut/Bingöl A group, four other compositional profiles are present in the obsidian assemblage. Three of these belong to the known sources at Bingöl B (n=6), Meydan Dağ (n=1), and Suphan Dağ (n=1). The remaining 20 artifacts have the high Rb signature characteristic of the Group 3d type.

Group 3d type artifacts were initially observed by Renfrew et al. (1966) in analyses of Near Eastern obsidian artifacts by atomic emission spectroscopy. During the past 50+ years, several hundred artifacts made from Group 3d obsidian have been reported at numerous archaeological sites located in Turkey, Syria, and Iran. Despite these discoveries, the actual location of the source remains unknown. A recent review of Group 3d obsidian by Campbell et al. (2020) summarizes all that is currently known about the occurrence of 3d obsidian throughout the region.

To collect additional information, three of the Group 3d artifacts were sent by Tonoike to Glascock at the University of Missouri Research Reactor (MURR) for analysis by neutron activation analysis (NAA). The samples were irradiated and analyzed along with the SRM-278 Obsidian Rock standard according to procedures described previously (Glascock et al. 1998). A total of 29 elements were measured as listed in Table 2. The NAA data for Group 3d obsidian were also compared to data for all known sources in the Near East, including sources in Turkey, Armenia, Azerbaijan, and Georgia. However, none of the sources are even close to matching the composition of Group 3d.

Table 2 shows a comparison of the NAA analyses to LA-ICP-MS data by Gratuze (n.d.) which indicate a good agreement for most of the elements measured in common. Finally, we note that not only is the concentration of Rubidium more than double that of other obsidians in the region, but Cesium is approximately three to four times that of most other Near Eastern sources.

Element	NAA (n=3) This Work	LA-ICP-MS (n=13) Gratuze (personal comm.)
Na (%)	3.39 ± 0.04	3.15 ± 0.18
Al (%)	7.48 ± 0.18	7.61 ± 0.44
Cl	521 ± 37	---
K (%)	4.01 ± 0.14	3.75 ± 0.14
Sc	1.14 ± 0.02	6.58 ± 2.37
Mn	386 ± 4	354 ± 20
Co	0.47 ± 0.02	---
Fe (%)	1.22 ± 0.01	1.21 ± .09
Zn	97 ± 3	104 ± 11
Br	3.10 ± 0.27	---
Rb	482 ± 3	454 ± 28
Sr	20 ± 10	10 ± 2
Zr	314 ± 6	178 ± 34
Sb	2.89 ± 0.03	---
Cs	42.2 ± 0.4	39 ± 3
Ba	93 ± 15	25 ± 3
La	48.1 ± 0.6	44 ± 8
Ce	95 ± 1	86 ± 12
Nd	32.0 ± 1.4	27 ± 3
Sm	7.27 ± 0.28	5.4 ± 0.5
Eu	0.187 ± 0.004	0.14 ± 0.04
Tb	0.84 ± 0.01	0.72 ± 0.09
Dy	4.21 ± 0.20	3.9 ± 0.4
Yb	2.85 ± 0.05	2.4 ± 0.3
Lu	0.82 ± 0.03	0.33 ± 0.04
Hf	5.39 ± 0.09	4.5 ± 0.7
Ta	3.25 ± 0.03	2.8 ± 0.3
Th	40.4 ± 0.5	38 ± 6
U	18.0 ± 0.4	18 ± 1

Table 2. Means and standard deviations in ppm obtained for three samples of Group 3d obsidian analyzed by NAA at MURR versus LA-ICP-MS from Gratuze.

Discussion and Conclusions

Our results for the obsidian artifacts from Tell Ziyadeh indicate the presence of five compositional groups. The largest group of artifacts (62.2%) has a composition corresponding to the sources at Nemrut Dağ and Bingöl A. Although our XRF data do not offer the ability to differentiate between the pair, most sites in the region with have between two and four times as many from Nemrut Dağ as from Bingöl A. We anticipate the peralkaline artifacts recovered at Tell Ziyadeh are present in similar proportions. The presence of artifacts from Bingöl B (n=6), Meydan Dağ (n=1), and Suphan Dağ (n=1) confirm that obsidian from both Bingöl and Lake Van areas was reaching Tell Zidayeh.

Finally, the most significant discovery in this study is the proportion of artifacts with the Group 3d compositional profile. The presence of twenty artifacts (27.4% of the total) makes Tell Ziyadeh one of the sites where Group 3d obsidian is in greater abundance than almost all other sites. The sole exception is the site of Kenan Tepe where 31.5% of the artifacts have the Group 3d signature (Campbell and Healey 2016). All evidence regarding Group 3d obsidian suggests the source is probably located in the area from the Tarsus Mountains to Lake Van.

Acknowledgements

We acknowledge Bernard Gratuze for sharing his data on Group 3d obsidian artifacts analyzed by LA-ICP-MS. The Archaeometry Lab at MURR is partially supported by a grant from the National Science Foundation's Archaeometry Program (NSF #1912276).

References

Buccellati, G., D. Buia, and S. Reimer (1991) Tell Ziyade: The First Three Seasons of Excavation (1988-1990). *Bulletin of the Canadian Society for Mesopotamian Studies* 21: 31-62.

Campbell, S. and E. Healey (2016). Multiple Sources: The pXRF Analysis of Obsidian from Kenan Tepe, S.E. Turkey. *Journal of Archaeological Sciences: Reports* 10: 377-389. https://doi.org/10.1016/j.jasrep.2016.10.014

Campbell, S., E. Healey, and O. Maeda (2020) Profiling an Unlocated Source: Group 3d Obsidian in Prehistoric and Early historic Near East. *Journal of Archaeological Science: Reports* 33: 102533. https://doi.org/10.1016/j/jasrep.2020.102533

Chataigner, C., J. L. Poidevin, and N. O. Arnaud (1998) Turkish Obsidian Occurrences of Obsidian and Use by Prehistoric Peoples in the Near East from 14,000 to 6000 BP. *Journal of Volcanology and Geothermal Research* 85: 518-537.

Frahm E. A. (2012) Distinguishing Nemrut Dağ and Bingöl A Obsidians: Geochemical and Landscape Differences and the Archaeological Implications. *Journal of Archaeological Sciences* 39(5): 1435-1444. https://doi.org/10.1016/j./jas.2011.12.038

Glascock, M. D. (2020) A Systematic Approach to Geochemical Sourcing of Obsidian Artifacts. *Scientific Culture* 6(2): 35-46. https://doi.org/10.5281/zenodo.3724847

Glascock, M. D., G. E. Braswell, and R. H. Cobean (1998) A Systematic Approach to Obsidian Source Characterization. In *Archaeological Obsidian Studies: Method and Theory*, edited by M.S. Shackley, pp. 15-65. Plenum Press, New York and London.

Gratuze, B. and M. Zambello (2014) Analyse physico-chimique de l'outlilage en obsidienne de Tell Beydar (Djézireh syrienne, Âge du Bronze). In *Tell Beydar Environmental and Technical Studies, Volume II,* edited by Milano, L. and M. Lebeau, pp. 115-120. Turnhout, Brepols.

Hole, F. and Y. Tonoike (Eds.) (2016) *Homesteads on the Khabur: Tell Ziyadeh and Other Settlements*, BAR International Series 2827. BAR Publishing, Oxford.

Khalidi, L., B. Gratuze, and S. Boucetta (2009) Provenance of Obsidian Excavated from Late Chalcoliothic Levels at the Sites of Tell Hamoukar and Tell Brak, Syria. *Archaeometry* 51(6): 879-893.

Khazaee, M., M. D. Glascock, P. Masjedi, F. Khademi Nadoshan, R. Soleimani Farsani, M. Delfan, A. Mansori, B. Sodaie, and A. Dolatyari (2014). Sourcing the Obsidian of Prehistoric Tools Found in Western Iran to Southeastern Turkey: A Case Study for the Sites of Eastern Chia Sabz and Choga Ahovan. *Anatolian Studies* 64: 23-31.

Monchambert, J. Y. (1983) Le Moyen Khabour: Prospections Preliminaire a la Construction d'Unbarrage. *Annales Archeologiques Arabes Syriennes* 33(1): 233-237.

Monchambert, J. Y. (1984) Prospection Archeologique sur l'Implacement du future Lac du Moyen Khabour. *Akkadica* 39: 1-7.

Renfrew, C., J. E. Dixon and J. R. Cann (1966) Obsidian and Early Cultural Contact in the Near East. *Proceedings of the Prehistoric Society* 32: 30-72.

Tonoike, Y. (2016) Appendix Three: Sourcing Obsidian at Tell Ziyadeh. In *Homesteads on the Khabur: Tell Ziyadeh and Other Settlements*, edited by F. Hole and Y. Tonoike, BAR International Series 2827, pp. 441-453. BAR Publishing: Oxford.

MEASUREMENT OF INTRINSIC WATER CONTENT IN OBSIDIAN BY TRANSMISSION INFRARED SPECTROSCOPY AT THE 3570cm^{-1} ABSORPTION BAND

Alexander K. Rogers[a] and Christopher M. Stevenson[b]

[a] Maturango Museum, Ridgecrest, CA 93555 USA
[b] School of World Studies, Virginia Commonwealth University, Richmond, VA 23284 USA

Abstract

This paper gives the physical basis and mathematics required for applying transmission infrared (IR) spectroscopy to measure intrinsic (structural) water in obsidian, based on absorption measurements at 3570cm^{-1}. Water in glass occurs as two species, molecular water (H_2O_m) and hydroxyl (OH), both of which absorb infrared radiation. Thus, knowing the specimen density, optical path length, and IR absorbance, the water content can be computed by the Beer-Lambert law (Newman et al. 1986). The 3570cm^{-1} absorption band is a convenient point in the IR spectrum to make the measurement. However, this band is a vibrational response to both H_2O_m and OH, which introduces an additional unknown in the computation. In this paper we discuss an alternative method to resolve the ambiguity, and we provide code in MatLab and in MS Excel to facilitate the computation. The outputs are the values for H_2O_m, OH and total water (H_2O_t). The resulting value of total intrinsic water content can then be used in the computation of obsidian hydration rates.

Introduction

Obsidian is a rhyolitic (alumino-silicate) glass formed from the cooling of magma, and all obsidians contain small amounts of water which is "frozen in" during the cooling process (Doremus2002; Shelby 2005). The water occurs as two species, molecular water (H_2O_m) and hydroxyl (OH), the latter which is formed by a chemical reaction between molecular water and the glass matrix (notably Si and Al) when the glass is in its molten form. The molecular water is free to diffuse, while the hydroxyl becomes bound to the glass matrix. Total water content in natural obsidians is very small, typically < 2 wt%, but it has a profound effect on hydration rate, and it is in fact, the primary determinant (Rogers and Stevenson 2017). Both species absorb infrared (IR) radiation (Newman et al. 1986).

Transmission IR spectroscopy is a method for measuring intrinsic water establishes the basis for inferring hydration rate. Newman et al. (1986) showed the method could be applied via the Beer-Lambert law, in which the water content can be computed based on measurements of specimen density, optical path length (thickness) of the specimen, and IR absorbance. The 3570cm^{-1} IR absorption band is a convenient point in the IR spectrum to make the measurement. However, this band responds to both H_2O_m and OH, which introduces circularity into the computation, since an a priori knowledge of the speciation is required for an accurate computation of water content.

In this paper we explore the effects of this ambiguity on the water computation. An approximate computation can be made by simply assuming the species proportions but for a more accurate computation, we develop a speciation model which resolves the ambiguity. We provide code in MatLab and in MS Excel to facilitate the computation, whose output is the value for H_2O_m, OH and total water (H_2O_t). The resulting value of total intrinsic water content can then be used in the computation of an obsidian hydration rate.

Infrared Absorption and the Beer-Lambert Law

The Beer-Lambert law is derived from the mathematical theory of IR absorption by a transparent, absorbing, medium (Levine 2002:741-745). The weight fraction w of absorbing molecules is given by

$$w = M*A/(\rho*\varepsilon*X) \qquad (1)$$

where M is the molecular weight of the absorbing molecules, ρ is density in g/L, A is the measured absorbance (unitless), X is the optical path length in cm, and ε is the extinction coefficient (or molar attenuation coefficient) in L/(mol*cm). The value of ε is a constant that reflects how much the material reduces the penetration of light and it is specific to the absorbing molecules, in this case the various species of water.

The absorption band at $3570cm^{-1}$ is especially convenient for measurement, since it is prominent and typically has a flat baseline. The flat baseline facilitates determining the peak height of the absorption band, or, alternatively, its integrated area. However, since this absorption band is due to stretching of the O-H chemical bond, both OH and H_2O_m contribute to the peak. The two species have significantly different extinction coefficients, so using absorbance measurements at $3570cm^{-1}$ to compute intrinsic water content requires *a priori* knowledge of the degree of speciation (MacIntosh et al. 2017; Newman et al. 1986). Table 1 presents the extinction coefficients for OH and H_2O_m at $3570cm^{-1}$.

Measurement Method	OH	H_2O_m	Units
Peak height	100 ± 2	56 ± 4	L/(mol*cm)
Area (integrated)	44,000 ± 1,000	26,300 ± 2,200	L/(mol*cm^2)

Table 1. Extinction coefficients at $3570cm^{-1}$ (Newman et al. 1986: 1537, Table 7)

Newman (1986:1538) also showed that, for an IR absorption band which expresses both species, the effective extinction coefficient is

$$\varepsilon = (\varepsilon_o X_o + \varepsilon_m X_m)/(X_o + X_m) \qquad (2)$$

where ε_o is the extinction coefficient for OH, ε_m is the extinction coefficient for H_2O_m, X_o is the mole fraction of OH, and X_m is the mole fraction of H_2O_m. In turn, X_o = weight fraction OH/17.00 and X_m = weight fraction H_2O_m/18.02. Thus, to apply equation (1) to determine the water content, the fraction of each species must be known in advance, and the resulting values used to compute the effective extinction coefficient per equation (2). This can be accomplished either by measuring absorbance at another band, such as 1630 cm^{-1}, which measures only molecular water (MacIntosh et al. 2017); by simply assuming a degree of speciation; or by a speciation model. Here we present the speciation model as background for discussing computation.

Speciation Model

Molecular water in glass tends to react with the glass matrix (Doremus 2002; Shelby 2005; Zhang 2008), particularly when the temperature is near or above the glass transition temperature. The resulting hydroxyl (OH) is bound to the Si or Al atoms of the glass. The reaction is temperature-dependent, and also depends on the concentration of molecular water available for reaction (Doremus 2002:129ff.); the reaction saturates when all the available Si or Al sites are taken. Speciation data have been measured and published for obsidian sources of archaeological interest (Stevenson et al. 2019:232, Table 1), and a mathematical relationship between OH and H_2O_m can be developed from such data. The data of Stevenson et al. (2019) represent 35 obsidian geochemical sources, world-wide, and yield a consistent relationship between OH and H_2O_m

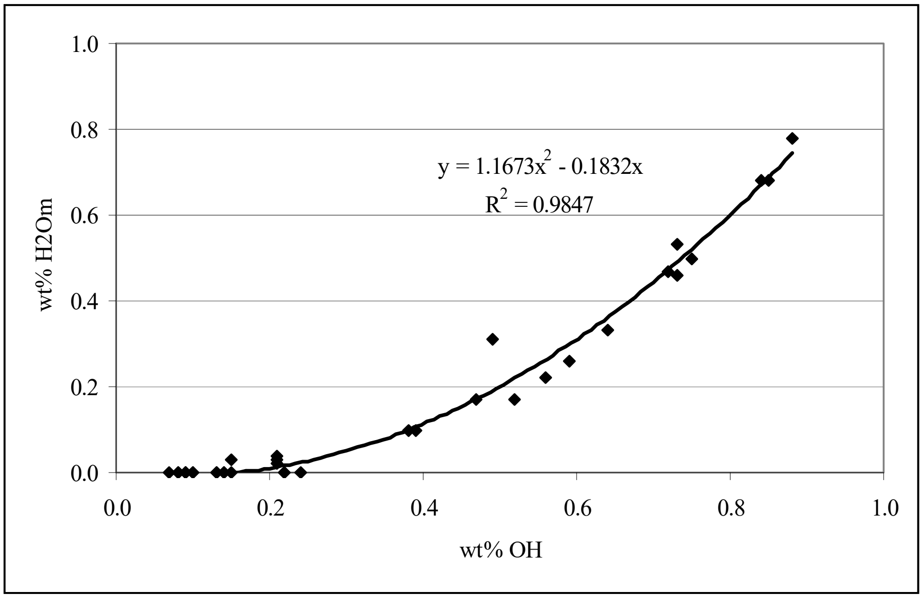


Figure 1. Complete data set from Stevenson et al. (2019:232, Table 1). N = 35. The best fit is not a useful model because it yields negative values of H_2O_m for OH < 0.16 wt%.

content (Figure 1). Since we know that wt%H_2O_m = 0 corresponds physically with wt%OH = 0, the best-fit curve shown is computed such that it passes through the origin. However, this fit is not a satisfactory model, since it yields negative values of wt%H_2O_m for wt%OH < 0.16, and negative concentrations are not physically possible. Thus, to develop a useful speciation model, all data points with H_2O_m = 0 were excluded as this is not physically possible (the speciation reaction has a back-reaction, so molecular water is always present, although it may be below the detection limit for the spectrometer). Second, the model is computed based on H_2O_m vs. $(OH)^2$.

Figure 2 shows the remaining 19 data points plotted as H_2O_m vs. $(OH)^2$. A model which assures that a positive value of OH yields a positive value of H_2O_m is obtained by computing the fit between these two parameters, with the constraint that the best-fit curve must pass through the origin:

$$y = 0.3917*x^2 + 0.687*x$$

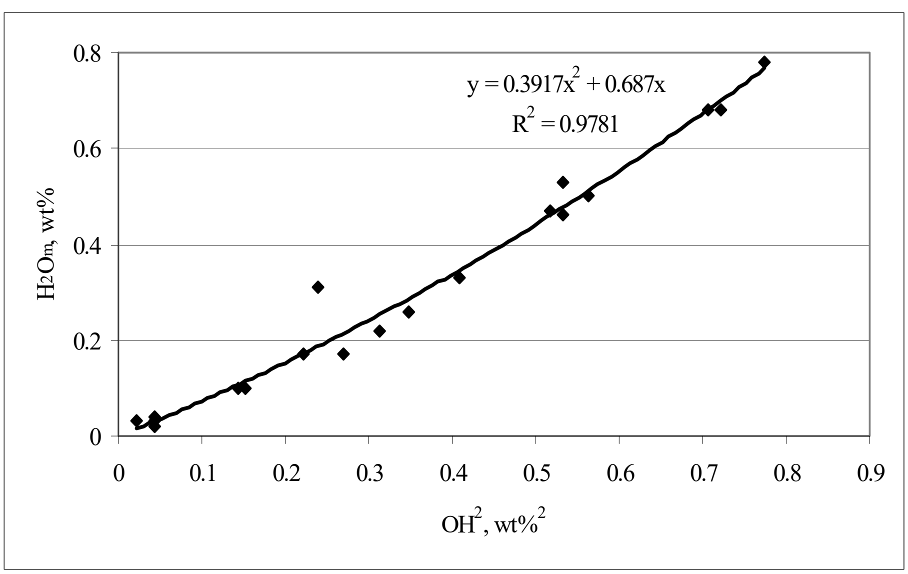


Figure 2. Speciation model and data set. N=19.

Since $y = wt\%H_2O_m$ and $x = (wt\%OH)^2$, this equation becomes

$$wt\%H_2O_m=0.3917*(wt\% OH)^4+0.687*(wt\%OH)^2 \quad (3)$$

with an $R^2 = 0.9781$. Further, since both coefficients are positive, and $(OH)^2$ is positive, the value of H_2O_m is always positive. Equation (3), referred to as a speciation model, allows inferring the molecular water content from the OH content.

At small values of total water the content is almost entirely OH, with essentially no molecular water. As the total water content increases, the fraction of OH decreases, from 94% at $H_2O_t = 0.1$ to 74% at $H_2O_t = 0.6$ to 43% at $H_2O_t = 2.64$. Doremus (2002:130ff.) showed that this can be explained by the Langmuir model of adsorption, applied to the case of reactions between H2Om and vacant Si and Al sites in the glass matrix; the finite number of Si and Al sites in the glass leads to saturation of the speciation reaction and a flattening of the OH vs. H_2O_t curve. Figure 3 is essentially identical to his results (Doremus 2002:134, Fig. 10.1).

Computation Methods

The most direct method of dealing with speciation is by making a separate IR absorbance measurement at 1630cm^{-1}, which responds only to molecular water. However, the baseline of the absorption peak is sloping and underlying absorption from the glass structure contributes to the peak height/area thus making the application difficult. This method is discussed in detail by MacIntosh et al. (2017) and is not addressed further here.

A method of computation which does not require the additional measurement is to add the speciation model to equations (1) and (2). If we define oh = weight fraction of OH, and ml = weight fraction of H_2O_m, equations (1) and (2) can be combined to give

$$18.02*A/(\rho*d) = (oh + ml)* [\varepsilon_o(oh/17) + \varepsilon_m(ml/18.02)]/ [(oh/17) + (ml/18.02)] \quad (4)$$

The left-hand side of equation (4) is a constant, computed from laboratory measurements. The right-hand side is a function of wt fraction OH, and, by the speciation model, of wt fraction H_2O_m. The weight fraction total of water tt is simply

$$t = ml + oh \quad (5)$$

When the speciation model (equation (3)) is substituted into equation (4), the result is an eighth-order algebraic equation. This equation has no analytic solution, so a numerical method was developed solve it. The principle

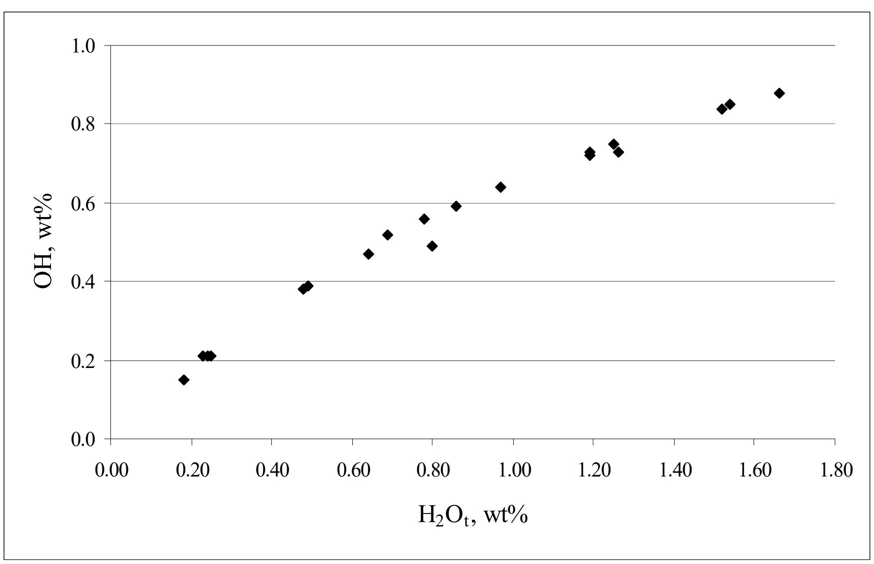


Figure 3. Speciation saturation, shown by wt% OH vs. H_2O_t. The shape of the curve is identical to the results of Doremus (2002:134, Fig. 10.1).

is to incorporate the speciation model into equation (4) and compute the left-hand side based on experimental data; the right-hand side is then computed for a sequence of values of oh. The value of oh is incremented until two successive solutions bracket the left-hand side; the desired value of oh, ml, and t are then computed by interpolation. The model was implemented in both MatLab and MS Excel. The MatLab program is actually two, one based on peak absorbance, the other on integrated absorbance, but the operation is the same.

The model in MS Excel operates the same but requires more intervention by the user. The user selects an increment size for oh (typically 0.005 wt%). The spreadsheet then performs the computation and flags the value of oh which causes the right-hand side to bracket the left-hand side. The desired value of oh, ml, and t are then computed by interpolation, which is built into another worksheet. Instructions in the workbook aid in using the model and performing the interpolation. With either method, the output is in wt% (not weight fraction) for OH, H_2O_m, and H_2O_t.

The computer code for these models is posted on the website of the International Association for Obsidian Studies.

Computation of Hydration Rate

Zhang et al. (1991) developed an equation relating hydration rate to water content for obsidians under geological conditions, with further refinements occurring in Zhang and Behrens (2000). The experimental data on which their equation was based were taken at temperatures of 400 - 1200°C, and pressures of 0.1 - 810 mPa. However, hydration rates computed by their method and extrapolated to archaeological conditions are not consistent with rates developed on archaeological data. The form of their equation is

$$k = \exp(A - B*t - C/T + D*t/T) \quad (6)$$

where k is hydration rate, t is total water, and T is absolute temperature, while A, B, C, and D are positive numerical coefficients. For archaeological purposes, Rogers and Stevenson (2017) derived an equation of the same form, but based on data taken under archaeological conditions (temperatures of 90-150°C and 0.1 mPa, or atmospheric pressure). This equation is

$$k=\exp(37.76-2.289*t-10433/T + 1023*t/T) \quad (7)$$

Here k is hydration rate in μ^2/1000 years, t is total intrinsic water in wt% (equation [4] above), and T is temperature in °K. Thus, knowing t from the Beer-Lambert analysis described above, the hydration rate can be computed for any desired temperature.

Conclusion

We have described a method of computing an obsidian hydration rate based on a single set of measurements on a specimen: density, thickness, and IR absorbance at 3570cm^{-1}.The method employs the Beer-Lambert law to compute intrinsic water content, and specifically includes the phenomenon of water speciation. The resulting value of total water can be used to compute hydration rate at any desired temperature.

References

Doremus, R. H. (2002) *Diffusion of Reactive Molecules in Solids and Melts*. Wiley Interscience, New York.

Levine, I. P. (2002) *Physical Chemistry*. McGraw-Hill, New York.

MacIntosh, I. M., A. R. L. Nichols, K. Tani, and E. W. Llewellin (2017) Accounting for the Species-Dependence of the 3500cm^{-1} H_2O_t Infrared molar Absorptivity Coefficient: Implications for Hydrated Volcanic Glasses. *American Mineralogist* 102: 1677-1689.

Newman, S., E. M. Stolper, and S. Epstein (1986) Measurement of Water in Rhyolitic Glasses: Calibration of an Infrared Spectroscopic Technique. *American Mineralogist* 71: 2527 – 1541.

Rogers, A. K., and C. M. Stevenson (2017) A New and Simple Laboratory Method for Estimating Hydration Rate of Obsidian. *Proceedings of the Society for California Archaeology* 31: 165-171.

Shelby, J. E. (2005) *Introduction to Glass Science and Technology*, 2nd. ed. Royal Society of Chemistry, Cambridge.

Stevenson, C. M., A. K. Rogers, and M. D. Glascock (2019) Variability in Obsidian Structural Water Content and its Importance in the Hydration Dating of Obsidian Artifacts. *Journal of Archaeological Science: Reports* 23: 231-242.

Zhang, Y., E. M. Stolper, and G. J. Wasserburg (1991) Diffusion of Water in Rhyolitic Glasses. *Geochimica et Cosmochimica Acta* 55: 441-456.

Zhang, Y, and H. Behrens (2000) H_2O Diffusion in Rhyolitic Melts and Glasses. *Chemical Geology* 169:243-262.

ABOUT OUR WEB SITE

The IAOS maintains a website at http://www.deschutesmeridian.com/IAOS/ 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!

CALL FOR ARTICLES

Submissions of articles, short reports, abstracts, or announcements for inclusion in the *Bulletin* are always welcome. We accept submissions 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.
http://www.saa.org/Portals/0/SAA%20Style%20Guide_Updated%20July%202018.pdf

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 #66 is May 1, 2021.

Email or mail submissions to:

Dr. Carolyn Dillian
IAOS Bulletin, Editor
Department of Anthropology & Geography
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/email information to Lucas Martindale Johnson at lucas@farwestern.com

MEMBERSHIP

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:

Regular Member: $20/year*
Student Member: $10/year or FREE with submission of a paper to the *Bulletin* for publication. Please provide copy of current student identification.
Lifetime Member: $200

Regular Members are individuals or institutions who are interested in obsidian studies, and who wish to support the goals of the IAOS. Regular members will receive any general mailings; announcements of meetings, conferences, and symposia; the *Bulletin*; and papers distributed by the IAOS during the year. Regular members are entitled to vote for officers.

*Membership fees may be reduced and/or waived in cases of financial hardship or difficulty in paying in foreign currency. Please contact the Secretary-Treasurer with a short explanation regarding lack of payment.

NOTE: The IAOS asks that all payments be made using the PayPal link on our website: http://www.deschutesmeridian.com/IAOS/membership.html

For more information about membership in the IAOS, contact our Secretary-Treasurer:

Lucas Martindale Johnson
lucas@farwestern.com

Membership inquiries, address changes, or payment questions can also be emailed to lucas@farwestern.com

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