IAOS

International Association for Obsidian Studies

Bulletin

ISSN: 2310-5097

Number 60 **Winter 2018**

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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!

IAOS AT THE SAA IN ALBUQUERQUE

The annual IOAS business meeting will be held during the SAA conference in Albuquerque, NM, at noon on Friday, April 12, 2019. Please see your conference program for meeting location. All IAOS members are invited to attend.

Please also join us in honoring Prof. M. Steven Shackley, the 2019 Fryxell Award winner, with a session to celebrate his extensive influence on archaeological obsidian studies on Saturday, April 13, 2019. See your SAA program for location.

Please watch your email and the IAOS webpage for additional announcements about IAOS events, meetings, and trips in Albuquerque. If you are willing to assist with the IAOS table in the exhibit hall, please contact Kyle Freund at kfreund@irsc.edu

NOTES FROM THE PRESIDENT

For many of you, this time of the year offers a brief respite from everyday responsibilities and obligations. On my part, I recently completed my fall semester and have finally found a few moments to relax before preparing for the upcoming year. This has been a busy fall, but I did find time to attend the Annual Meeting of the European Association of Archaeologists (EAA) in Barcelona. In addition to enjoying lots a great food and sangria, I was able to participate in several obsidian themed sessions, and I was inspired by the amount of new research pushing the discipline forward, particularly relating to the use of obsidian sourcing data to address theoretically informed and meaningful archaeological questions.

IAOS has had a productive year, and we are planning more for the future. Three great candidates for IAOS President have put forward their names for consideration, and their statements are provided below. Be sure to cast your vote so we can announce the winner at the SAA conference in April. Indeed, the SAAs will be here soon, and IAOS is well represented. Former IAOS President Steve Shackley won the 2019 Fryxell Award for Interdisciplinary Research, and a special session has been organized in his name. This is a well-deserved honor, and in looking at the preliminary program a number of IAOS members will be speaking. This is something you won't want to miss. In addition, Yuichi Nakazawa and Phyllis Johnson have organized an IAOS-sponsored session entitled "Advances in Obsidian Studies of the Old and New Worlds," taking a global perspective on the diverse theoretical and methodological developments in obsidian studies over recent years.

There are several obsidian sources outside of Albuquerque, and IAOS is working with the Prehistoric Mines and Quarry Interest Group (PQEMIG) to plan a field trip to the Jemez Mountains Obsidian Quarry. These plans are still in the works and further details are provided below. Also on the horizon in May 2019 is the 2nd International Obsidian Conference in Budapest, Hungary, building upon the successful 2016 symposium on the island of Lipari, Italy.

Don't forget to renew your IAOS membership for 2019.

Happy Holidays!

Kyle Freund, IAOS President
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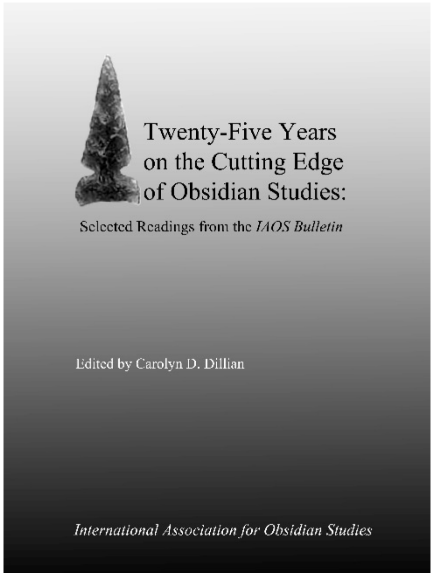

Twenty-Five Years on the Cutting Edge of Obsidian Studies: Selected Readings from the IAOS Bulletin

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://members.peak.org/~obsidian/iaos_publications.html

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

Proposed Jemez Mountains Obsidian Quarry Field Trip, SAA Meetings, April 2019

IAOS and PQEMIG (Prehistoric Mines and Quarry Interest Group) are tentatively planning to host a field trip to obsidian quarries in the Jemez Mountains in conjunction with the April 2019 Society for American Archaeology meetings in Albuquerque. This would be a full-day trip (e.g., 8 am to 5:30 pm) leaving from a convenient location in Albuquerque. We would visit two quarry areas, Cerro Toledo Rhyolite / Obsidian Ridge on the Santa Fe National Forest, and Valles Rhyolite / Cerro del Medio inside the Valles Caldera National Preserve). Due to the high elevation of the areas (7000'-9000') the trip will be subject to weather constraints, and will not occur if snow-cover persists late this spring. With transportation and lunch included, the anticipated cost is $35-$60. Due to scheduling concerns, it is uncertain whether the trip would be on Tuesday April 9, or Wednesday April 10. To assess potential participant numbers (and to see if there is any interest in the Tuesday option), please complete a Doodle poll entry if you think you might attend: https://doodle.com/poll/76vg35pg8uiu36qi

We currently have no guarantee that this field trip will happen (so please do not book flights or miss other opportunities assuming it will!). We plan to provide final details by January 10, 2019, though planning may be delayed due to the U.S. government shutdown. **Note: this field trip is not an official SAA Excursion.**

Ana Steffen, Valles Caldera National Preserve, ana_steffen@nps.gov

CANDIDATE STATEMENTS: IAOS PRESIDENT-ELECT

Please email your vote for the next IAOS President directly to Kyle Freund, kfreund@irsc.edu

Candidate Statement: Sean Dolan, Ph.D.

My name is Sean Dolan, and I would like to become the next President of the International Association for Obsidian Studies (IAOS). I manage cultural resources at N3B Los Alamos on Los Alamos National Laboratory property in northern New Mexico, which is directly east of the Jemez Mountains where obsidian is abundant. I have been interested in obsidian for the past 10 years after learning about what this extremely sharp, volcanic glass can tell us about past human culture. My research focuses on which obsidian sources people in the U.S. Southwest and Mexican Northwest used through time, and I publish my results in regional and international journals, including in the *IAOS Bulletin*. I am a member of the IAOS and regularly attend annual meetings at the Society for American Archaeology (SAA) conference.

One of my goals as IAOS President is to network with members of the cultural resource management (CRM) community in the United States and encourage them to publish results of their obsidian studies in the *IAOS Bulletin*. CRM reports and results are often inaccessible to most archaeologists and the public, and the *IAOS Bulletin* is an excellent venue for CRM practitioners who are interested in publishing their findings. Also, I propose to increase the society's online presence through social media posts about new obsidian research and upcoming conferences. If this is accomplished, I believe membership in the IAOS will increase both locally and abroad. Furthermore, much like past IAOS Presidents, I would like to organize poster and podium sessions on obsidian at the SAA meetings and other conferences possibly in the U.S. Southwest. Finally, with the support of colleagues, I hope to make the IAOS website the "one-stop shop" for all things obsidian by maintaining new published research in the online PDF Library and updated state and regional maps of obsidian sources.

Candidate Statement: Lucas R. M. Johnson, Ph.D.

My current role at Far Western Anthropological Research Group, Inc. is as a senior archaeologist responsible for lithic technological and geochemical analysis. Through this compliance and research role, I have learned much about indigenous trade economies and crafting strategies in California and the Great Basin. These two essential research topics are just as complex as those I studied at Caracol, Belize for my master's and doctoral research at the University of Central Florida and the University of Florida respectively. Before my research at Caracol, little was known about the chert and obsidian industries practiced there during the ancient Maya period (~ AD 100-950). My dissertation research emphasized the "itinerant" and socially embedded nature of obsidian through sourcing more than 2,000 artifacts using handheld XRF, analyzing the varied reduction sequences (i.e., crafting), recording macro-scale use-wear patterns, mapping the distributional nature of depositional context (both ritualized and quotidian), and understanding the market and non-market mechanisms for intra-city circulation. During this research I developed critical networks with scholars at MURR, University of Pennsylvania, University of Central Florida and others who helped facilitate important aspects for this research. This network included members of the IAOS. Since then I have submitted two publications to the IAOS on obsidian imaging and sourcing a unique artifact from Belize.

Although my participation in the IOAS has been as a recent member and contributor, I understand the breadth of its impact. My perspective on the role of the president is to continue those goals articulated by past presidents to expand enrollment and visibility at the student level (including and apart from the SAA). Other goals would include providing analysis and materials for those in need of obsidian analytical schemes and source reference material. These resources could ensure new students follow important conventions, which will enable the production of good science and hypothesis testing. The IAOS could expand these resources as they have done with access to publications archives. Additionally, the IAOS is uniquely positioned to provide technical training on handheld XRF analysis. Senior members of the IAOS have a solid history of geochemical analysis of obsidian and most other materials. Therefore, I suggest, the creation of a volunteer network that can advise newer students on the technical and *practical* details of obsidian XRF analysis and potentially of materials analysis more generally. I feel this need will manifest as newly enrolled graduate students use existing XRF instruments now at most universities, but where local training on actual use and data processing is absent. This volunteer training network can ensure the production of good – *accurate* – data and act as a recruitment tool that may generate increased money for special events.

Candidate Statement: Theodora Moutsiou, Ph.D.

My interest in obsidian began about twenty years ago when I first realised that there was surprisingly little known about the use of this unique material in the earliest human past. Investigating Palaeolithic obsidian became the focus of my Ph.D. thesis that brought together all the available information on use and movement of obsidian spanning three continents – Africa, Europe, Asia. I have excavated obsidian-bearing sites, analysed material and investigated obsidian sources in east Africa, central and southeastern Europe, and Japan.

I have studied obsidian as a proxy of past human behaviour and cognition and, recently, my research focus has expanded to geochemical characterisation studies using non-destructive techniques. In 2015, I joined the Archaeological Research Unit, University of Cyprus, as a Marie Sklodowska-Curie Fellow (EU Horizon 2020) and have been researching Epipalaeolithic/Neolithic obsidian and other rare raw materials in the eastern Mediterranean (provenance and distribution patterns). Currently, I investigate the Pleistocene occupation of Cyprus through geospatial modeling and geophysical survey. For more details you can visit: http://www.ucy.ac.cy/dir/en/cb-profile/tmouts01

As President of the IAOS, I will continue the efforts made by our previous presidents in managing the Association's business activities, including the newsletter, document library and website. An important issue I wish to address is the lack of a shared reference library of geochemical data on obsidian sources worldwide. It was one of the initial goals/founding principles of IAOS and I believe it is imperative that we work together towards establishing such a library for the promotion of obsidian research. I will also undertake outreach activities and intensify actions that promote the significance of our work to a wider academic/scientific audience as well as the public. As a European researcher I believe that I am ideally positioned to increase IAOS visibility outside North America (where the bulk of our members are based) and attract new members from regions not traditionally linked to the IAOS. To this effect, I will work towards increasing IAOS visibility in international conferences/workshops and elsewhere, for example the extremely popular European *Researchers' Night* events. Finally, I will initiate actions to raise public awareness and interest in archaeology and geology through obsidian, a material that has attracted people's imagination for over one million years. I look forward to serving the needs and interests of the IAOS community.

2nd Circular IOC 2019,

27-29 May 2019 Sárospatak

Event

The International Obsidian Conference 2019 is a direct continuation of the 2016 Lipari Meeting (http://rtykot.myweb.usf.edu/Obsidian%202016/index.html). It is planning to deal with all aspects of obsidian studies, from geology to anthropology and instrumental analyses.

The planned sessions of the Conference are:

- Formation and geology of obsidian
- Obsidian sources and their characterisation
- Analytical / methodological aspects of obsidian studies
- Archaeological obsidian by chronological periods
- Lithic technology and use wear
- Obsidian hydration dating
- Dating of geological obsidian
- Exploring the allure of obsidian: symbolic, social, and practical values for obsidian
- Super-long distance movement of obsidian in prehistory: why, how, and what for?

You will find all necessary information on our conference and registration webpage:
http://ioc-2019.ace.hu
We would ask you to check the webpage from time to time for any updated information.

Venue

The venue of the Conference will be

Rákóczi Museum of the Hungarian National Museum at Sárospatak, NE Hungary

We try to facilitate your participation by booking accommodation in Sárospatak.

Registration

Registration will be implemented via the Conference web page (http://ioc-2019.ace.hu/) starting from May 2018.

Registration & fees:

early bird registration (by 15 January 2019)

full fee	80 EUR
student fee	40 EUR

normal registration (by 1 April 2019)

full fee	100 EUR
student fee	50 EUR

late/on site registration (after 1 April 2019)

full fee	140 EUR
student fee	80 EUR

daily registration (on site only)

full & student	80 EUR

Payment

Payment will be realised via bank transfer.
Registration and other conference related costs should be transferred to the account of the Hungarian National Museum (1088 Budapest, Múzeum krt. 14-16.) curated at the Hungarian State Treasury (Magyar Államkincstár):

account number: 10004885-10002010-01016431
IBAN number: HU03 1000 4885 1000 2010 0101 6431„account with institution”: Hungarian State Treasury (Magyar Államkincstár)

SWIFT code: HUSTHUHB„correspondent”: Hungarian National Bank (Magyar Nemzeti Bank)

SWIFT code: MANEHUHB

preferentially at the same time as the registration but not later than 30 April 2019.

Cancellation policy

80% refund till 1 April 2019 (closing of normal registration)
20% refund till 1 May 2019 (completing the conference program)
No refund after 1 May 2019

Communications

The official language of the conference is English.
Only one lecture for each (registered) participant can be accepted. The same participant may submit several posters. Please indicate their number precisely on the Registration Form.

As the conference time is limited, organisers may have to limit the number of oral presentations.

Abstract submission:
For abstract submission please use our webpage (see Registration). Please prepare 3 – 5 keywords. The abstract should not be longer than 300 words. The abstract can only be accepted when at least one of the authors is registered. Please contact us if you encounter any problem. The deadline for abstract submission is **1 April 2019.**

Proceedings: We are planning to publish the Proceedings of the Conference hopefully in one volume. Decision on the means and place will be made later on. Please check our webpage for details

Program: We aim to create the program as fast as possible. The program will be published on the webpage and can be downloaded there.

The length of oral presentations is expected to be 20 minutes including discussion. Please prepare them in a common presentation format (ppt, pps).
Internet video conference possibility will be provided for registered participants but we definitely prefer your personal presence!

The poster sections will be held on the corridors of the Sárospatak Museum.
The posters should be planned as standing (portrait) orientation and their size must not exceed A0 (841 x 1189 mm).
You can send lectures / posters in advance if you like, for checking technically on our devices or printing: please specify your needs on the Registration form.

Excursions

On the second and third day excursions to Hungarian (Mád and Tolcsva) and Slovakian (Brehov and Viničky) obsidian sources will be organised as part of the Conference.
A post-conference tour to the so-called Carpathian 3 sources (around Rokosovo, Ukraine) is anticipated depending on possibilities at extra costs.

Please keep in your mind that for citizens of a number of countries visa is required to Ukraine.
Remember that you have to cross the EU (Schengen) border twice, that means multiple visa.
Please visit the Consular Service website of your respective countries for more information.

Satellite events

In the Rákóczi Museum of the HNM we are planning a chamber exhibition on obsidian from the material of local collections of geological and archaeological obsidians under the title „**Our glass, our past**".
We are also planning to install conference posters on an open exhibition space where they will be temporarily available for the general public.

Social events

26 May 2019
The Conference will start with an Ice-Breaking Party at the courtyard of the Rákóczi Museum, Sárospatak from 18:00 till 21:00

29 May 2019
Conference Dinner will be organised at Sárospatak, Vár Restaurant after the excursion to the Slovakian sources.

Accommodation

Sárospatak is a charming small town in the northeastern part of the country. The organisers will book hotel and hostel accommodation between 26 to 30 May to secure availability, therefore the booking of hotels and payment for Sárospatak will be arranged via the Hungarian National Museum (see Registration Form). We give the price for rooms, you may team for double rooms in Hotel Bodrog or houses in the Motel.

Transport

Sárospatak is about 250 kms from Budapest to the North-East, easily accessible by private car but not so easy by train or bus. Budapest is easily accessible by air, train, bus and car.

Nearest international airports to Sárospatak are found at Košice (Slovakia) and Debrecen at a distance of 70 and 120 km.

Conference buses will be available for the conference excursions.
The excursion to the Ukrainian source (30 May 2019) has a special fee.

Please calculate with transport timing when you are planning your travel and accommodation: when in doubt, please feel free to contact us.

Weather

The weather in the end of May is typically nice and warm, with an average daily temperature of 15-17 °C and 14 rainy days. Be prepared for rain and muddy soil, anyway.

Local Organising Committee

T. Biró, Katalin - HNM, Markó, András - HNM, Kasztovszky, Zsolt - MTA EK, Weiszburg, Tamás - ELU, Csengeri, Piroska - HOM, Kereskényi, Erika - HOM, Péterdi, Bálint - MFGI, Pap, Gábor - HNHM, Rajczy, Miklós - HNHM, Tamás, Edit - HNM-RM, Hegyi, Borbála - HNM-RM, Szepesi, János - VRG, Kaminská, Ľubomíra - IA-SAS, Bačová, Zuzana & Bačo, Pavel - SGI, Přichystal, Antonín - MU, Rácz, Béla - KMF, Ryzhov, Sergei - TSNU

International Scientific Committee

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

Please forward this circular to anybody who might be interested.
Looking forward to see you in 2019!

Registration is on-line

should you meet difficulties contact the organisers by email personally:
ioc-2019@hnm.hu

THE ZAYUKOVO (BAKSAN) ARCHAEOLOGICAL OBSIDIAN SOURCE, GREATER CAUCASUS, RUSSIA

M. Steven Shackley[a], Ekaterina V. Doronicheva[b], Vladimir B. Doronichev[b], Liubov V. Golovanova[b], Sergey A. Nesmeyanov[c], Olga A. Voeykova[c], Alexander A. Muriy[c]

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[b]ANO Laboratory of Prehistory, 14 linia 3-11, 199034 St. Petersburg, Russia
[c] Institute of Geoecology named after E.M. Sergeev RAS Ulanskiy pereulok, 13, str. 2, Moscow, 101000, Russia

ABSTRACT
The aphyric high quality, high silica Zayukovo (Baksan) obsidian source in the north central Caucasus range in Russia was a favored obsidian raw material from the Middle through Late Pleistocene in the region. Recent archaeological research has pointed to the value of the obsidian to both Neanderthal and modern human populations, indeed exclusively favored by Neanderthal tool makers in a number of archaeological contexts discussed below. Based on field examination of the pyroclastic and secondary deposits of the source, this discussion moves beyond previous mentions of the source in the regional literature providing some baseline geographical, geological, archaeological, and geochemical data through an x-ray fluorescence (XRF) analysis of collected source standards.

Keywords: Zayukovo (Baksan) obsidian source, Middle and Upper Paleolithic, x-ray fluorescence analysis (XRF)

Introduction

The Zayukovo (Baksan) obsidian source, located approximately 70-80 km to the north-east of Mount Elbruz, presented here is the most commonly recovered archaeological obsidian in the region (Blackman 1998; Doronicheva and Shackley 2014; Doronicheva et al. 2013, 2017; Keller et al. 1996; Lebedev et al. 2008; Le Bourdonnec et al. 2012). It is a high quality, high silica obsidian raw material favored during the late Middle through late Upper Paleolithic in the region. It could be distributed over a much larger region through secondary deposition in the Baksan River sediments than discussed, and is certainly present in Quaternary sediments throughout the Baksan valley. The source has been mentioned in a number of essays, but given its importance in the region of interest, a more thorough examination is offered here (see Doronicheva et al. 2019). A geological and megascopic characterization of the obsidian is followed by a discussion of the geochemistry and XRF results.

Geographic/Geologic Context

The Greater Caucasus Mountains (or Greater Caucasus), up to 1100 km in length and about 180 km in the maximum width in the central part, with elevations up to 4000 m above sea level (asl) and more, occupy the central position within the Caucasus and divide it into two parts—the Northern Caucasus and the Southern Caucasus (Gvozdetskiy, 1963; see Figures 1 and 2). The north-central Caucasus — the defined geographic region located between the highest Caucasian volcanic mountain peaks of Elbrus (5642m asl) and Kazbek (5034m asl) — is notable as the area producing the only

Figure 1. Regional map showing the location of the Zayukovo (Baksan) obsidian source (large dot).

obsidian source (called Baksan or Zayukovo) known from the Northern Caucasus.

The Zayukovo obsidian source area lies 70-80 km northeast of the Elbrus stratovolcano (Elbrus neovolcanic region; Laverov et al. 2005) and close to the town of Zayukovo in the Baksan river valley (Terek river basin), in the territory of the Kabardino-Balkaria Republic (Russia), about 20 km north-west of the city of Nalchik. This area is located on the border of the two main structural elements of the Greater Caucasus—the Laba-Malka monoclinal uplifting zone represented here by the Chegem tectonic step near its articulation with the Kabardian lowland, which represents the most western element of a huge Terek-Caspian tectonic depression (Milanowskiy and Koronovskiy 1969; Nesmeyanov 1999).

The characteristic feature of the area is the presence of Late Pliocene and Lower Pleistocene volcanogenic formations. Initially, Malinowskiy and Koronovskiy (1969; 1973) and then other researchers defined three volcanogenic complexes significantly different in their age and conditions of occurrence (see Figure 3):

1. Late Pliocene (Akchagylian age) complex of rhyolite tuffs, andesite-basalts, and ignimbrites of rhyolite composition, which forms the Lower Chegem volcanogenic formation lying with inclination of about 3-4^0 to the north-east on local river watersheds.
2. Lower Pleistocene (Akchagylian—Apsheronian age) complex of liparite and

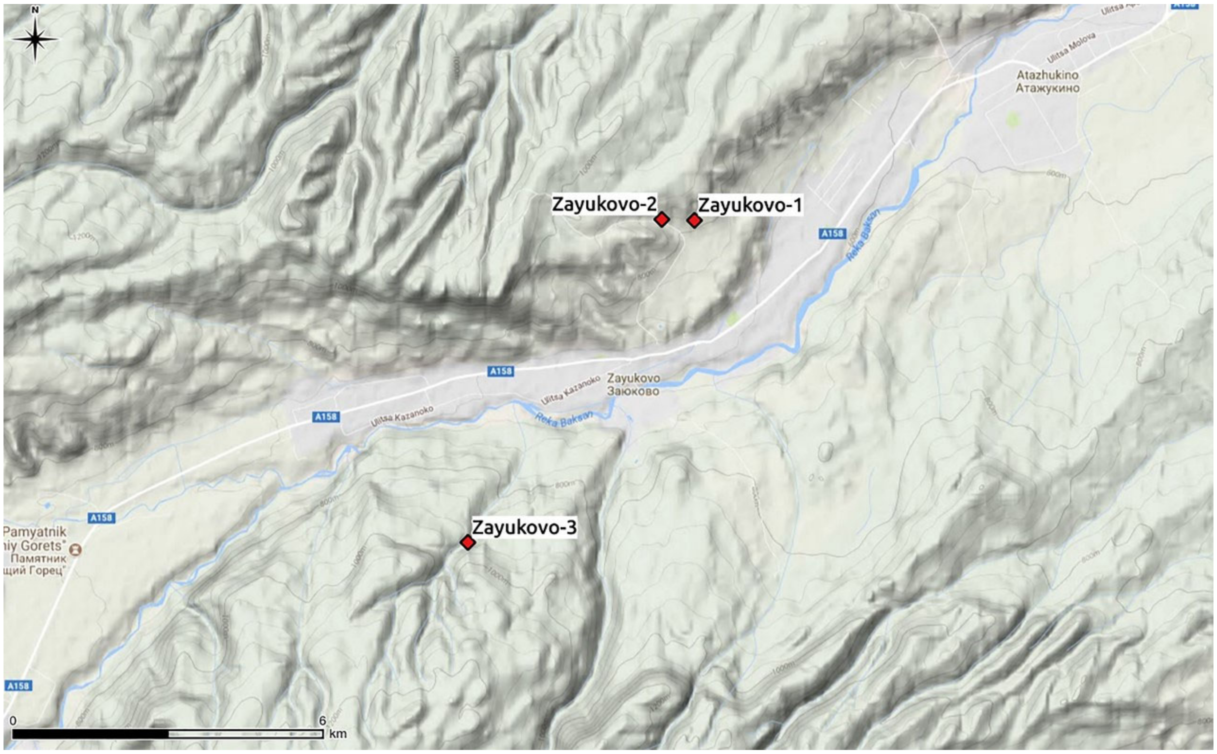

Figure 2. Detailed map showing the location of Zayukovo (Baksan) obsidian sources and the three collection localities within the source area in the Baksan river valley.

dacitic pyroclastic, and fluvial-proluvial and partially volcanic mudflow formations (called Kyzburun and Baksan-ges) that cover high river terraces between the towns of Zayukovo and Atazhukino in the Baksan valley.

3. Late Pleistocene complex of dacite and liparite-dacite tuffs, tuff breccias and ignimbrites that are represented on 20-40 m terraces in the Baksan river valley between the towns of Zayukovo and Gundelen. The total thickness of these volcanogenic deposits reaches 95-100 m, and the centre of explosive eruptions associated with this complex is located in the Baksan valley against the town of Zayukovo (see Fig. 4).

The Lower Chegem volcanogenic complex, with a range from a few dozen meters to 220-490 m, lies in an unconformity on the multi-temporal sediments dating from the Upper Jurassic to the Miocene. This formation originally covered an extensive area (Milanowskiy and Koronovskiy 1969), which was later deeply dissected by Pleistocene fluvial erosion. The Late Pliocene (Akchagylian) age of the Lower Chegem complex is defined by numerous dates in the range from 3.2+/- 0.6 and 3.7+/-0.6 Ma (on liparite) to 2.63+/-0.4 Ma (K/Ar) and 2.72+/-0.27 Ma ($^{40}Ar/^{39}Ar$; Bogatikov et al. 2006). The accumulation of the Lower Chegem complex most researchers relate to the explosive eruptions in the Upper Chegem caldera located about 60 km to the south (Chernyshov et al. 2008: 207, and references therein).

The Kyzburun and Baksan-ges formations, 50-60 m in thickness each, overlies the watershed Lower Chegem formation exhibiting deep erosion, and have the same ($3\text{-}4^0$) inclination to the north-east. The older Kyzburun formation starts with rough tuffaceous conglomerates and breccias representing the product of collapse and

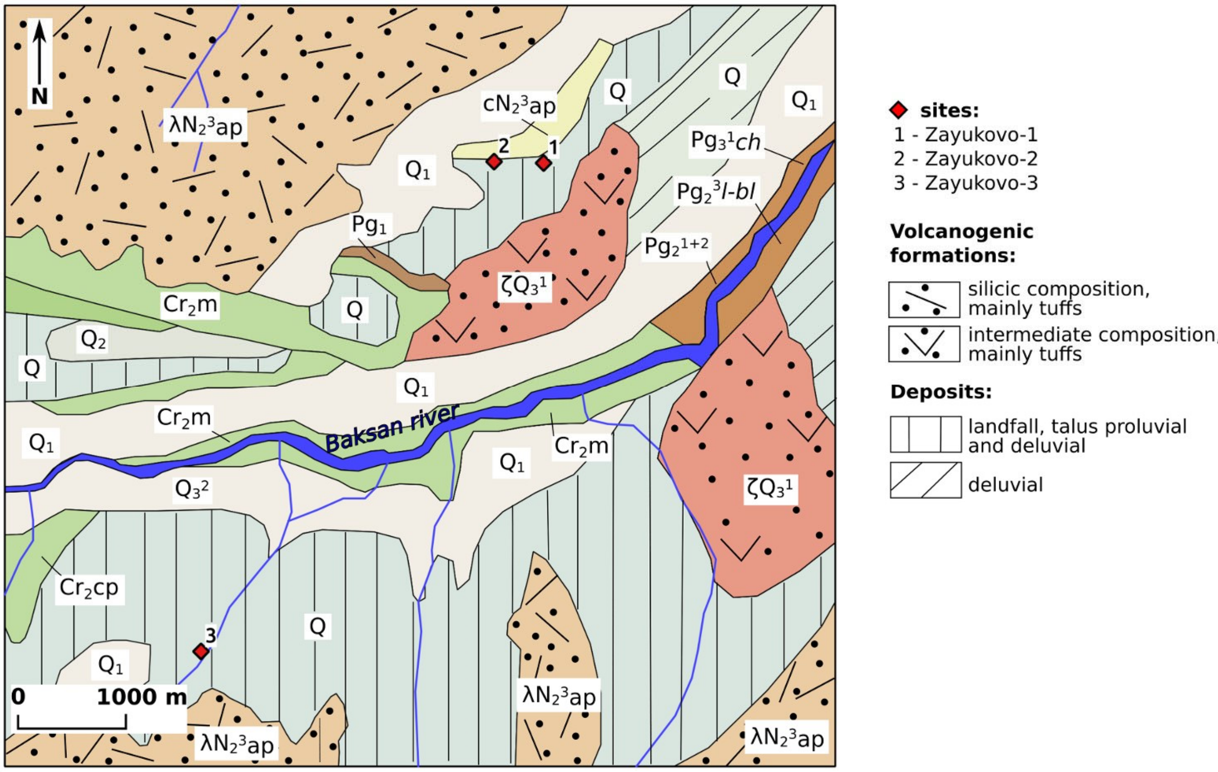

Figure 3. Simplified geologic map of the Zayukovo (Baksan) source area. Q – not dissected Quaternary sediments (clay loams, clay loams with scree, landslides); Q_3^2 – gravels and sands; Q_2 – shingle beds and clay loams, moraine, clay loams with scree, landslides; Q_1 – shingle beds, clay loams with scree, travertines; $ζQ_3^1$ – dacite lava and tuffs; $λN_2^3$ap – Neogene; Apsheron horizon; liparitic lava and tuffs; cN_2^3ap – Neogene; Apsheron horizon; alluvial shingle beds; Pg_3^1*ch* – Paleogene; Khadum horizon; clays, marls; Pg_2^3*l-bl* – Paleogene; Kuma and Belaya Glina series; marls; Pg_2^{1+2} – Paleogene; Cherkessk series; marls; Cr_2m – Maastricht stage; limestones, marls; Cr_2cp – Campanian stage; limestones, marls (Adapted from the Geological map of the USSR, 1959. Scale 1:200 000. Sheet K-38-II. All-Russian Scientific Research Geological Institute named after A.P. Karpinskiy. Author: Kizevalter D.S.)

redeposition of Late Pliocene liparite tuffs and clays from slopes of the ancient Baksan valley. Above, there is an alternation of liparite, pumice and ash tuffs, pebbles, sands, and clays and marls with remnants of terrestrial gastropods, suggesting accumulation of these deposits in the lake basin.

The Baksan-ges formation overlies the Kyzburun formation with erosion and is composed mainly of rough tuffaceous and clastic material having fluvial-proluvial and partly volcanic mudflow (lahar) origin — tuff-conglomerates, tuff-gravelites, and tuffaceous sands with interlayers of volcanic ashes. Paleomagnetic research indicated that the main part of the later Baksan-ges formation has reverse polarity (Reisner and Bogachkin 1989) and is dated to 2.2+/-0.05 Ma according to a uranium fission track analysis (Komarov et al. 1972). Consequently, both Kyzburun and Baksan-ges formations have the late Akchagylian age (2.6-1.6 Ma), corresponding to the early Lower Pleistocene of the European stratigraphic scale.

The top of the Baksan-ges formation is eroded and unconformably overlain by river gravels of the late Apsheronian (=late Lower Pleistocene) terrace (called 'Sarmakov

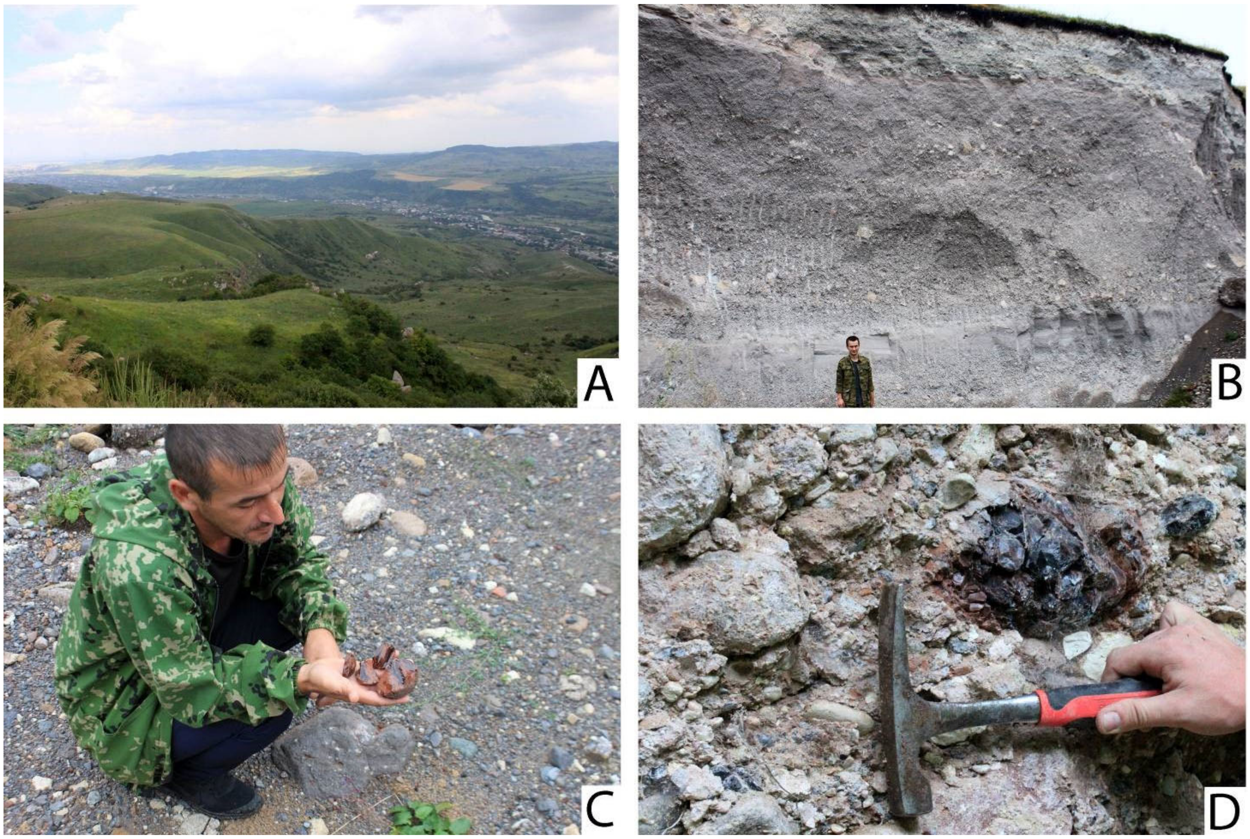

Figure 4. Photos of Zayukovo (Baksan) obsidian source and localities of occurrence of obsidian nodules.
A – view toward the Baksan river valley and the village of Zayukovo from the area of the obsidian collection localities;
B – pyroclastic deposits with obsidian nodules ("volcanic bombs") at Zayukovo-1;
C – collection of obsidian samples at Zayukovo-1 source in 2017;
D - obsidian nodules in pyroclastic breccia at Zayukovo-3.

terrace') of the Baksan river (Reisner and Bogachkin 1989). The gravels of this terrace have a much lower (1-2^0) inclination than the Baksan-ges formation (Milanowskiy and Koronovskiy 1969) and are correlated to accumulation of the large gravel deposits dated to the late Lower Pleistocene in the interfluve of the Malka — Baksan — Chegem rivers (Reisner and Bogachkin 1989).

In the Zayukovo (Baksan) obsidian source area, obsidian is found as cobbles ('volcanic bombs') in pyroclastic and secondary contexts on high river terraces along the north and south bank of the Baksan river (Chirvinskiy 1934). The known obsidian outcrops are located within a radius of 10 km between the modern towns of Zayukovo and Atazhukino in the Baksan valley, but the largest quantity of obsidian cobbles and especially larger-sized cobbles is confined to the outcrops near Zayukovo (Figures 4, 5). One fission track analysis defined the age of a single piece of the Zayukovo obsidian at 2.2+/-0.2 Ma (Komarov et al. 1972). This is the only age estimate available today suggesting that the origin of the Zayukovo obsidians might be related to the explosive volcanic eruption which formed the pyroclastic deposits of the Baksan-ges formation.

Figure 5. Obsidian nodules from the Zayukovo (Baksan) source.

Although the eruptive centre for the Zayukovo obsidians is not yet defined, available radiometric results suggest that their primary source might be associated with the eruption of one of the volcanic centres located close to the city of Tyrnyauz, as much as 30 km to the south of the Zayukovo obsidian collection localities. Within the Elbrus region in the north-central Caucasus, the early Lower Pleistocene magmatism is recorded at present only in the the Tyrnyauz volcanic area (Chernyshov et al. 2008: 207, and references therein), where it is associated with the formation of the El'djurtin granite massif at 2.5–2.1 Ma (Hess et al. 1993) and the Kyrtyk granite-porphyritic massif at 2.0+/-0.15 Ma (Borsuk 1979).

Obsidian Megascopic Description

The Zayukovo obsidian is mainly uniform aphyric black or brownish-red (mahogany), sometimes black with rare very small (<0.01 mm) sanidine phenocrysts, banded black and brownish-red. In thin section, the obsidian shows alternation of brown, reddish-brown, and colorless bands each divided into smaller thin bands (Figures 4 and 5). These bands are straight, curved, and sometimes folded. Under light microscopy, one can see isotropic colorless or pinkish glass, in which there are small inclusions of mafic ore particles (magnetite, iron, mica). This obsidian is an excellent media for chipped stone tool production, however, most of the obsidian nodules (marekanites) are small in size (less 10 cm in diameter and rarely more). The obsidian marekanites have cortical surfaces that are deeply etched and roughened by pits often having circular lunar crater forms, and grooves, and many cobbles are covered by a thin chalcedonic and sometimes travertine/ash crust (Chirvinskiy 1934). Although Zayukovo obsidian is highly variable in colour, trace element analyses discussed below suggest a single, homogeneous composition of all obsidian samples from the area and their distinction from other obsidian sources known in the Southern and Lesser Caucasus on the basis of trace element composition (see also Keller et al. 1996; Le Bourdonnec et al. 2012).

X-Ray Fluorescence (XRF) Analysis

A collection of 34 source samples from three collection localities along the Baksan River were analyzed by XRF to provide an initial baseline for the understanding of raw material procurement in regional sites (Doronicheva and Shackley 2013; Doronicheva et al. 2013, 2017). The samples were analyzed initially at the Archaeological XRF Laboratory, University of California, Berkeley. The bulk of the samples were analyzed at the Geoarchaeological XRF Laboratory in Albuquerque, New Mexico, USA, by MSS, both analyses using the ThermoScientific *Quant'X* EDXRF instruments. The instrument methodology is

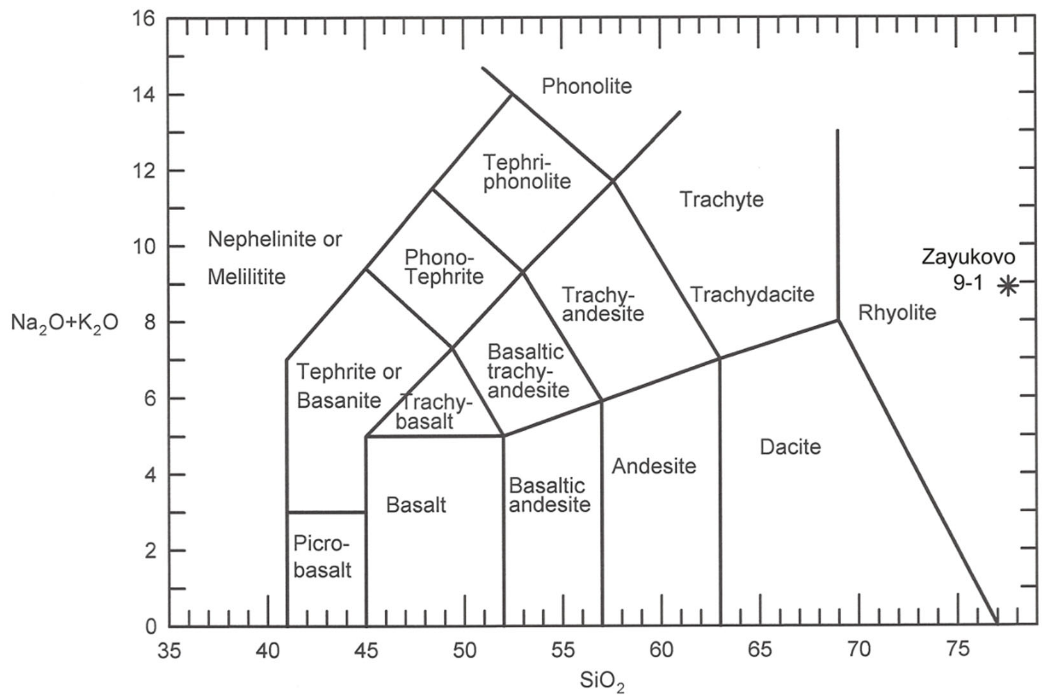

Figure 6. TAS plot of Zayukovo sample 9-1 from Locality 1 (Le Maitre et al. 1989).

available in Shackley (2005, 2011), Shackley et al. (2016, 2017), and online at http://swxrflab.net/anlysis.htm. Both trace elements and oxides were acquired (Tables 1 and 2). The obsidian is a high silica rhyolite glass with relatively unique trace element composition in the region (see also Le Bourdonnec et al. 2012).

Major, Minor, and Trace Element Results

Table 1 exhibits the major and minor oxide analysis of one source sample from Locality 1, results from the Keller et al. (1996) study, and the results of the analysis of USGS RGM-1 rhyolite standard for this study and USGS recommended values. The Keller et al. (1996) study and this study are in good agreement. The Zayukovo obsidian is a high silica rhyolite glass, reflected in its excellent value as a media for tool production (Figure 6).

Table 2 exhibits the raw trace element data from the analysis of the 34 source samples by sample number and locality. Locality is denoted by the suffix. The NAA results from Blackman's 1998 study, and the XRF results from the Keller et al. (1996) study are also included for reference. As with the major and minor oxide results, there is good agreement between this study and Keller's (Table 2). The NAA results from Blackman's (1998) study are somewhat deviant, in part due to the differences in instrumental precision between NAA and XRF and that some elements such as Zr and Ba are actually measured more accurately with XRF versus NAA (Glascock 2011). In general, however, NAA measures many more elements with greater precision than XRF, particularly the rare earth elements (REEs; see Glascock 2011). However, given that most analyses of obsidian in the region use XRF, PIXE, or LA-ICP-MS, which have been shown to yield statistically similar results, the XRF data offered here should be comparable to most regional studies (see Poupeau et al. 2010).

Table 3 exhibits the mean and central tendency for the 34 Zayukovo source samples in table 2. It has generally been noted that the

SAMPLE	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	MnO	$Fe_2O_3^T$	Σ
Zayukovo 9-1	4	0	12.39 5	76.74	4.796	0.831 3	0.046	0.0884	0.9892	99.89
Keller et al. (1996)	4.21	0.11	13.71	75.75	4.42	0.73	0.05	0.07	0.92	99.97
RGM-1 (this study)	3.66	0	12.20 2	74.66	5.19	1.492 3	0.266	0.0449	2.281	99.796
RGM-1 (USGS recommended)	4.07± 0.15	0.28± 0.28	13.7± 0.19	73.4± 0.53	4.30± 0.10	1.15± 0.07	0.27± 0.02	0.036± 0.0004	1.86±0.03	99.06

Table 1. Major and minor oxides for one source sample from Zayukovo Locality 1, results from the Keller et al. (1996) study, analysis of USGS RGM-1 rhyolite standard, and USGS RGM-1 recommended values. All measurements in weight percent.

Zayukovo (Baksan) obsidian "suggest a single homogeneous composition" (Le Bourdonnec et al. 2012: 1320), which is true generally, but there is elemental variability evident in this larger study, typical as source sample size increases (Shackley 2008). Evident in the mean and central tendency data are some trace elements, many of the mid-Z light-ion lithophile (LILE) and high-field strength (HFSE) elements that are measured well by XRF, that here have significant variability, including Rb and Ba and the minor element Mn (Table 3). This variability is rather typical of many rhyolite compositions, but should be heeded in source assignment (Glascock 2011; Shackley 2005, 2011; Shackley et al. 2017). Still, as Le Bourdonnec and others noted it is still compositionally distinct from other regional obsidian sources (2012).

The variability within the Zayukovo source is also evident graphically. Figure 7 plots four elements Mn, Rb, Zr, and Ba overlain by 95% confidence ellipses for each collection locality. Depending on the elements of interest and the bivariate plots here, various localities exhibit more or less variability. However, in each case the vast majority of the Zayukovo source data are contained in the smallest confidence ellipsis and all three collection localities overlap compositionally (Figure 7). Again, however, as noted by Le Bourdonnec et al., even with the intra-source variability, the Zayukovo obsidian is elementally distinct from all the other known regional sources (2012: 1320; see also Blackman 1998; Poidevin 1998).

The XRF analysis presented here can serve as a baseline for geoarchaeological studies of obsidian procurement in the region, particularly for analyses using XRF, LA-ICP-MS, and PIXE. The elemental variability evident is greater than indicated in earlier analyses with smaller sample sizes, but this is expected. The Zayukovo (Baksan) obsidian source is an important raw material source in the Cacausus region throughout prehistory, and these data should aid in the understanding of that prehistory.

Acknowledgements

The fieldwork and sampling at Zayukovo (Baksan) obsidian source and analyses of the obsidian were supported by the Russian Scientific Foundation grant No. 17-78-20082, "Human-nature interaction in the Central Caucasus: dynamics of environmental change and technological innovations, and subsistence strategies". Initial XRF analysis at the University of California, Berkeley, of the archaeological obsidian and Zayukovo source samples was, in part, funded by U.S. National Science Foundation grants BCS-0716333, BCS-0810448, BCS-0905411 to MSS. MSS thanks François-Xavier Le Bourdonnec and Bernard Gratuze for continued discussions and their friendship.

Locality/Sample	Mn	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th
1-1	458	78	303	60	31	72	14	211	50	30
2-1	509	93	276	54	23	72	15	273	51	33
3-1	475	82	288	60	33	73	13	234	62	20
4-1	415	66	276	53	30	73	18	225	62	27
5-1	466	153	268	51	25	76	17	213	52	25
6-1	436	54	284	51	26	76	16	229	43	22
7-1	508	61	300	56	25	73	15	295	52	27
8-1	430	48	273	53	29	70	11	292	49	24
9-1	456	59	293	54	27	71	20	193	47	32
10-1	499	64	308	57	31	79	23	244	53	31
11-1	446	59	277	55	31	76	18	199	49	26
12-1	469	61	288	51	23	76	21	204	50	33
13-1	455	83	288	56	29	76	13	204	51	28
1-2	530	96	324	61	29	79	22	239	61	26
2-2	441	86	281	52	29	81	20	224	52	31
3-2	477	104	291	54	26	76	11	224	52	33
4-2	448	88	289	53	26	77	22	226	53	27
5-2	412	94	281	54	26	78	16	207	46	24
6-2	541	69	311	63	26	85	26	229	55	32
7-2	455	73	280	52	31	75	19	242	47	19
8-2	441	73	294	54	30	75	20	234	55	34
9-2	445	72	279	52	27	73	16	205	47	25
10-2	444	130	278	56	25	70	16	191	51	26
11-2	450	75	281	52	26	75	15	227	47	33
1-3	435	69	275	53	27	72	16	233	50	31
2-3	441	78	293	56	29	75	14	153	51	28
3-3	459	70	293	52	33	73	18	233	47	27
4-3	431	82	273	53	24	74	14	190	43	29
5-3	445	65	291	56	31	71	19	245	48	34
6-3	471	72	293	50	25	77	13	209	50	25
7-3	445	86	288	57	27	74	20	179	57	32
8-3	467	100	294	55	26	69	21	238	55	29
9-3	469	62	288	53	25	75	13	215	47	21
10-3	470	73	278	52	30	74	18	212	46	24
Blackman 1998 (n=10)		43	301			127		536	21	
Keller et al. 1996 (n=1)	542	43	280	53	22	65	12	173		22
RGM-1 this study	293	42	147	109	26	220	11	843	22	16
RGM-1 USGS recommended	279± 31	32± nr	150±8	110± 10	25± nr	220± 20	9±0.6	810± 46	24±3	15±1.3

Table 2. Trace element concentrations for the Zayukovo (Baksan) source, results from Blackman (1998) and Keller et al. (1996), USGS RGM-1 rhyolite standard this study, USGS RGM-1 recommended values. All measurements in parts per million (ppm). Localities denoted by suffix (1-3).

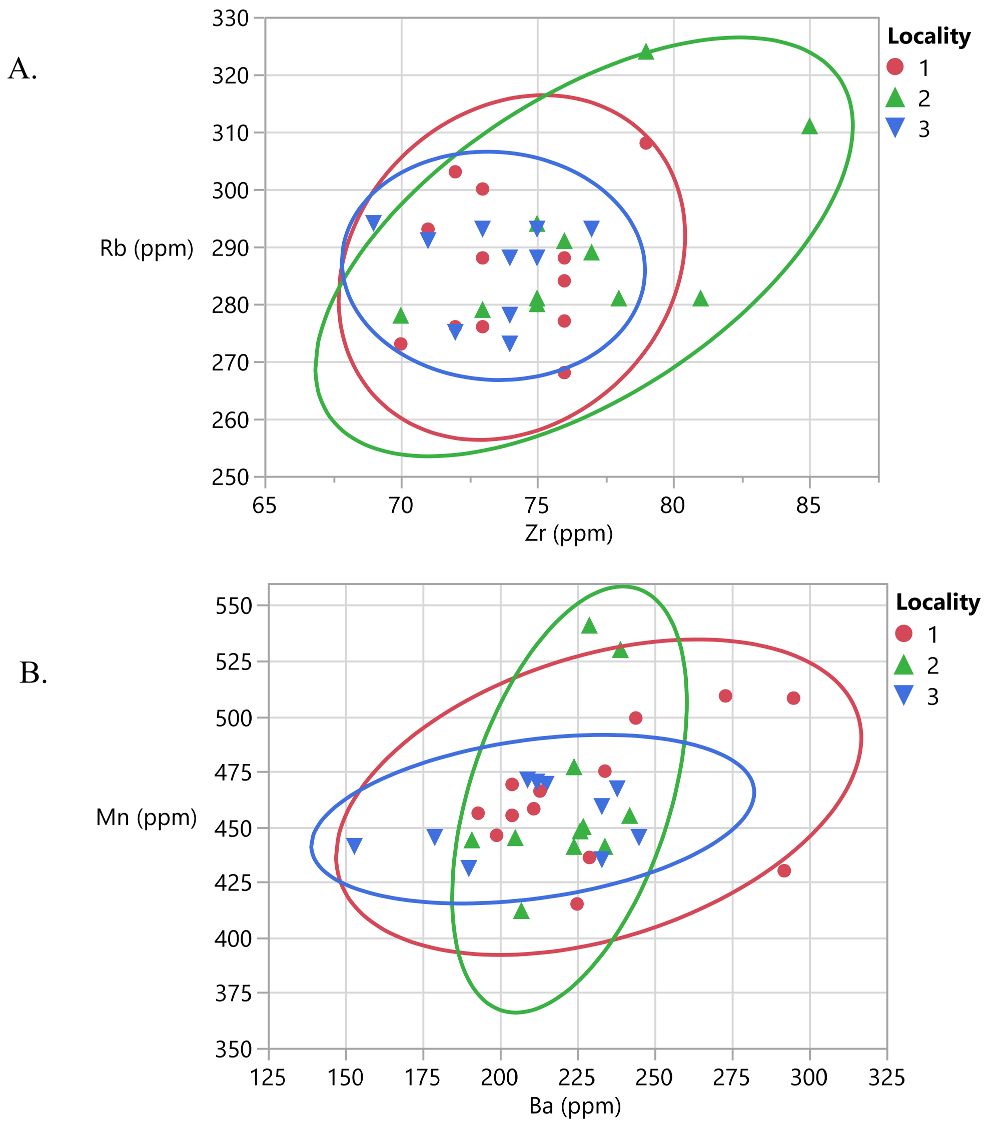

Figure 7. A- Zr versus Rb bivariate plot of the Zayukovo source samples by collection locality, and B- Ba versus Mn bivariate plot of the Zayukovo source samples by collection locality. Confidence ellipses at 95%.

	N	Minimum	Maximum	Mean	Std. Deviation
Mn	34	412	541	460.0	29.4
Zn	34	48	153	78.8	20.9
Rb	34	268	324	287.5	12.0
Sr	34	50	63	54.4	3.0
Y	34	23	33	27.6	2.6
Zr	34	69	85	74.7	3.3
Nb	34	11	26	17.1	3.6
Ba	34	153	295	222.7	28.6
Pb	34	43	62	50.9	4.7
Th	34	19	34	27.9	4.1

Table 3. Mean and central tendency data for the Zayukovo elements in Table 2. All measurements in parts per million (ppm).

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AN INNOVATIVE METHOD FORCOMPUTING THE HYDRATION RATE FOR THE BROWNS BENCH OBSIDIAN SOURCE

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Daron Duke, PhD, RPA

Introduction

As referred to here, Browns Bench represents three chemically clustered but overlapping groups that all occur across a roughly 4,400 km^2 region at the Nevada-Idaho-Utah border (Hughes and Smith 1993; Page and Bacon 2016). The most familiar source names for these are Browns Bench, Browns Bench Area, and Butte Valley Group A. Prior work with large samples of each suggests there is no meaningful distinction in hydration rate among them (Duke 2008, 2011).

Hydration rates for obsidian can be computed in a straightforward manner by association with radiocarbon dates, using a linear least-squares best fit between the hydration rim and the square root of the age. To be useful beyond a particular site, however, an effective hydration temperature (EHT) must be associated with the rate, and the EHT is influenced strongly by local temperature conditions. Generally the temperature parameters need to compute EHT are developed from meteorological data, which is a valid method unless site formation processes are causing ambiguities in the temperature history. In this paper, we describe an innovative technique for determining the EHT of a site, and using it to adjust the hydration rate.

Method

Three sites were used as data sources (42To137 – "Mosquito Willies"; 42To2622 – the Cache Site; and 42To3817 – the Cone Site), and two of the three data sources involved obsidian specimens that were eroding out of sand dunes, so the burial depth and hence EHT were ambiguous (Duke 2011; Duke et al. 2019; Young et al. 2008). Because of this phenomenon, we anticipated that use of meteorological parameters would not be successful. Fortunately, the data sets included both Browns Bench and Topaz Mountain specimens, and the rate parameters for the latter have already been established by laboratory methods (Rogers and Duke 2011). The method employed here was to use the Topaz Mountain data to calibrate the EHT of the sites, and then apply that EHT in determining a hydration rate for Browns Bench.

In computing a hydration rate, it is necessary to adjust the hydration rim values to a single, known, EHT, including the effects of burial depth. At 42To137, the obsidian specimens were obtained from various burial depths, which were used in the computation. However, for 42To2822 and 42To3817, the obsidian was on the surface but had eroded out of dunes which were up to a meter in depth. For computation purposes, these specimens were assigned a burial depth of 1 meter, and the assumption was made that they had been exposed by erosion only recently.

In each case, the radiocarbon dates were calibrated with Calib 6.0, yielding the median calibrated age in calendar years before 1950. These were the then converted to the physical age, in calendar years before 2000 (cyb2k) by adding 50 years. Radiocarbon dates associated with the sites are presented in Table 1.

The mean age for 42To137 is 1291 cal BP, or 1341 cyb2k; the mean for 42T02822 is 10255 cal BP, or 10255 cyb2k; the mean for 42T03817 is 11106 cal BP, or 11156 cyb2k. These values were used in the rate computation.

42To137			42To2622			42To3817		
RC mean, rcybp	**RC std. dev, yrs.**	**Calib Median, cal BP**	**RC mean, rcybp**	**RC std. dev, yrs.**	**Calib Median, cal BP**	**RC mean, rcybp**	**RC std. dev, yrs.**	**Calib Median, cal BP**
1230	60	1159	9090	60	10249	9510	50	10823
1190	60	1117	8910	50	10035	9810	50	11226
1470	60	1367	8980	50	10159	9870	50	11270
1350	50	1277	9210	60	10376			
1330	40	1265						
1370	40	1295						
1410	50	1323						
1270	50	1207						
1450	60	1351						
1510	40	1394						
1550	70	1448						

Table 1. Radiocarbon ages for Utah Sites

Computing a temperature adjustment requires estimating the site temperature parameters. In this case, Wendover, Utah, which is at essentially the same elevation and in the same weather patterns, was used as a proxy. Temperature data were downloaded from the Western Regional Climate Center website and the temperature parameters were computed as described in Rogers (2016). The average annual temperature (T_a) was 11.35°C, the annual variation (V_{a0}, hot-month mean minus cold-month mean) was 29.17°C, and the mean diurnal variation (V_{d0}) was 12.07°C. These parameters are for conditions at the surface, so the EHT for surface conditions is given by

$$EHT_s = T_a + 0.0062*(V_{a0}^2 + V_{d0}^2) \quad (1)$$

For this case EHT_s = 17.53°C.

Topaz Mountain Obsidian

A hydration rate is computed by a linear least-squares best fit between the EHT-adjusted hydration rim and the square root of the age. For this case, the EHT for each artifact was adjusted to local conditions at the surface, a rate was computed and compared with the known laboratory rate, and the site EHT implied by this rate was computed. Mathematically, EHT at artifact depth is

$$EHT_d = T_a + 0.0062*(V_a^2 + V_d^2) \quad (2)$$

where V_d and V_a are given by

$$V_a = V_{a0}*\exp(-0.44*z) \quad (3)$$

$$V_d = V_{d0}*\exp(-8.5*z) \quad (4)$$

and z is burial depth in meters. The rim correction factor, RCF, which adjusts the rim value at depth to the value it would have had at surface EHT, is

$$RCF=\exp(E/(273.15+EHT_d) - E/(273.15+EHT_s))/2) \quad (5)$$

where E is the activation energy for the obsidian source (10370°C, in this case [Rogers and Duke 2011]).

Table 2 presets the data for the computation of a rate and associated EHT for Topaz Mountain obsidian; R_m is the measured hydration rim value, and R_s is the value adjusted to surface EHT, both in microns.

R_m	z, m	T_a	V_{a0}	V_{d0}	EHT_d	EHT_s	RCF	R_s	Mean CYB2K	Site
2.50	0.15	11.35	29.17	12.07	16.04	17.53	1.10	2.74	1341	42To137
3.60	0.15	11.35	29.17	12.07	16.04	17.53	1.10	3.95	1341	42To137
2.77	0.15	11.35	29.17	12.07	16.04	17.53	1.10	3.03	1341	42To137
3.72	0.25	11.35	29.17	12.07	15.60	17.53	1.13	4.19	1341	42To137
4.04	0.45	11.35	29.17	12.07	14.90	17.53	1.18	4.75	1341	42To137
1.80	0.45	11.35	29.17	12.07	14.90	17.53	1.18	2.11	1341	42To137
1.89	0.45	11.35	29.17	12.07	14.90	17.53	1.18	2.22	1341	42To137
2.03	0.55	11.35	29.17	12.07	14.60	17.53	1.20	2.43	1341	42To137
3.30	0.55	11.35	29.17	12.07	14.60	17.53	1.20	3.96	1341	42To137
4.10	0.35	11.35	29.17	12.07	15.23	17.53	1.15	4.73	1341	42To137
1.60	0.05	11.35	29.17	12.07	16.78	17.53	1.05	1.67	1341	42To137
4.30	0.25	11.35	29.17	12.07	15.60	17.53	1.13	4.85	1341	42To137
3.00	0.15	11.35	29.17	12.07	16.04	17.53	1.10	3.29	1341	42To137
3.00	0	11.35	29.17	12.07	17.53	17.53	1.00	3.00	1341	42To137
9.80	1	11.35	29.17	12.07	13.54	17.53	1.28	12.56	10255	42To2622
10.00	1	11.35	29.17	12.07	13.54	17.53	1.28	12.82	10255	42To2622
7.40	1	11.35	29.17	12.07	13.54	17.53	1.28	9.49	10255	42To2622
9.10	1	11.35	29.17	12.07	13.54	17.53	1.28	11.66	10255	42To2622
10.00	1	11.35	29.17	12.07	13.54	17.53	1.28	12.82	10255	42To2622
7.20	1	11.35	29.17	12.07	13.54	17.53	1.28	9.23	10255	42To2622
9.00	1	11.35	29.17	12.07	13.54	17.53	1.28	11.54	10255	42To2622
7.44	1	11.35	29.17	12.07	13.54	17.53	1.28	9.54	10255	42To2622
8.34	1	11.35	29.17	12.07	13.54	17.53	1.28	10.69	10255	42To2622
8.07	1	11.35	29.17	12.07	13.54	17.53	1.28	10.34	10255	42To2622
7.54	1	11.35	29.17	12.07	13.54	17.53	1.28	9.67	10255	42To2622
8.54	1	11.35	29.17	12.07	13.54	17.53	1.28	10.95	10255	42To2622
8.59	1	11.35	29.17	12.07	13.54	17.53	1.28	11.01	10255	42To2622
8.40	1	11.35	29.17	12.07	13.54	17.53	1.28	10.77	10255	42To2622
8.47	1	11.35	29.17	12.07	13.54	17.53	1.28	10.86	10255	42To2622
8.50	1	11.35	29.17	12.07	13.54	17.53	1.28	10.90	10255	42To2622
9.00	1	11.35	29.17	12.07	13.54	17.53	1.28	11.54	11156	42To3817
8.09	1	11.35	29.17	12.07	13.54	17.53	1.28	10.37	11156	42To3817
8.05	1	11.35	29.17	12.07	13.54	17.53	1.28	10.32	11156	42To3817
7.37	1	11.35	29.17	12.07	13.54	17.53	1.28	9.45	11156	42To3817
7.63	1	11.35	29.17	12.07	13.54	17.53	1.28	9.78	11156	42To3817
7.72	1	11.35	29.17	12.07	13.54	17.53	1.28	9.90	11156	42To3817
9.05	1	11.35	29.17	12.07	13.54	17.53	1.28	11.60	11156	42To3817
9.05	1	11.35	29.17	12.07	13.54	17.53	1.28	11.60	11156	42To3817
8.00	1	11.35	29.17	12.07	13.54	17.53	1.28	10.25	11156	42To3817
8.03	1	11.35	29.17	12.07	13.54	17.53	1.28	10.29	11156	42To3817
7.64	1	11.35	29.17	12.07	13.54	17.53	1.28	9.79	11156	42To3817
7.04	1	11.35	29.17	12.07	13.54	17.53	1.28	9.02	11156	42To3817
7.22	1	11.35	29.17	12.07	13.54	17.53	1.28	9.25	11156	42To3817
7.24	1	11.35	29.17	12.07	13.54	17.53	1.28	9.28	11156	42To3817
7.30	1	11.35	29.17	12.07	13.54	17.53	1.28	9.36	11156	42To3817
7.31	1	11.35	29.17	12.07	13.54	17.53	1.28	9.37	11156	42To3817
7.76	1	11.35	29.17	12.07	13.54	17.53	1.28	9.95	11156	42To3817
7.99	1	11.35	29.17	12.07	13.54	17.53	1.28	10.24	11156	42To3817
8.03	1	11.35	29.17	12.07	13.54	17.53	1.28	10.29	11156	42To3817
8.05	1	11.35	29.17	12.07	13.54	17.53	1.28	10.32	11156	42To3817
8.05	1	11.35	29.17	12.07	13.54	17.53	1.28	10.32	11156	42To3817
8.17	1	11.35	29.17	12.07	13.54	17.53	1.28	10.47	11156	42To3817

R_m	z, m	T_a	V_{a0}	V_{d0}	EHT_d	EHT_s	RCF	R_s	Mean CYB2K	Site
8.26	1	11.35	29.17	12.07	13.54	17.53	1.28	10.59	11156	42To3817
8.27	1	11.35	29.17	12.07	13.54	17.53	1.28	10.60	11156	42To3817
8.34	1	11.35	29.17	12.07	13.54	17.53	1.28	10.69	11156	42To3817
8.87	1	11.35	29.17	12.07	13.54	17.53	1.28	11.37	11156	42To3817
9.01	1	11.35	29.17	12.07	13.54	17.53	1.28	11.55	11156	42To3817
9.03	1	11.35	29.17	12.07	13.54	17.53	1.28	11.57	11156	42To3817
9.65	1	11.35	29.17	12.07	13.54	17.53	1.28	12.37	11156	42To3817
9.74	1	11.35	29.17	12.07	13.54	17.53	1.28	12.49	11156	42To3817
9.78	1	11.35	29.17	12.07	13.54	17.53	1.28	12.54	11156	42To3817
10.98	1	11.35	29.17	12.07	13.54	17.53	1.28	14.07	11156	42To3817

Table 2. Topaz Mountain obsidian and radiocarbon data.

The rate as computed from the data of Table 2 is 10.84 μ^2/1000 years. The temperature dependence of hydration rate is given by the Arrhenius equation

$$k = k_0 * \exp(-E/T) \qquad (6)$$

where k is the rate in μ^2/unit time, k_0 is the pre-exponential in the same units, E is the activation energy expressed in °K, and T is effective hydration temperature (EHT) in °K. For Topaz Mountain obsidian, $k_0 = 1.87 \times 10^{13}$ μ^2/yr and E = 10370 °K (Rogers and Duke 2011), so knowing the rate allows computation of EHT. A rate of 10.84 μ^2/1000 years corresponds to a local EHT of 22.46°C, or 4.93°C above what was expected from meteorological data. This demonstrates, *inter alia*, the disproportionate effect of even a short surface hot-soak on the effective hydration temperature.

Browns Bench Obsidian

A similar process was used for Browns Bench obsidian, from the same three sites. Table 3 presents the data for the rate computation.

R_m	z, m	T_a	V_{a0}	V_{d0}	EHT_d	EHT_s	RCF	R_s	Mean CYB2K	Site
5.80	0.45	11.35	29.17	12.07	14.90	17.53	1.16	6.74	1341	42To137
4.20	0.35	11.35	29.17	12.07	15.23	17.53	1.14	4.79	1341	42To137
5.30	0.25	11.35	29.17	12.07	15.60	17.53	1.12	5.92	1341	42To137
3.70	0.35	11.35	29.17	12.07	15.23	17.53	1.14	4.22	1341	42To137
3.00	0.00	11.35	29.17	12.07	17.53	17.53	1.00	3.00	1341	42To137
11.29	1.00	11.35	29.17	12.07	13.54	17.53	1.26	14.19	10255	42To2622
13.22	1.00	11.35	29.17	12.07	13.54	17.53	1.26	16.61	10255	42To2622
11.32	1.00	11.35	29.17	12.07	13.54	17.53	1.26	14.23	10255	42To2622
12.20	1.00	11.35	29.17	12.07	13.54	17.53	1.26	15.33	10255	42To2622
11.06	1.00	11.35	29.17	12.07	13.54	17.53	1.26	13.90	10255	42To2622
11.00	1.00	11.35	29.17	12.07	13.54	17.53	1.26	13.82	11156	42To3817
12.04	1.00	11.35	29.17	12.07	13.54	17.53	1.26	15.13	11156	42To3817
8.85	1.00	11.35	29.17	12.07	13.54	17.53	1.26	11.12	11156	42To3817

Table 3. Obsidian and radiocarbon data for Browns Bench

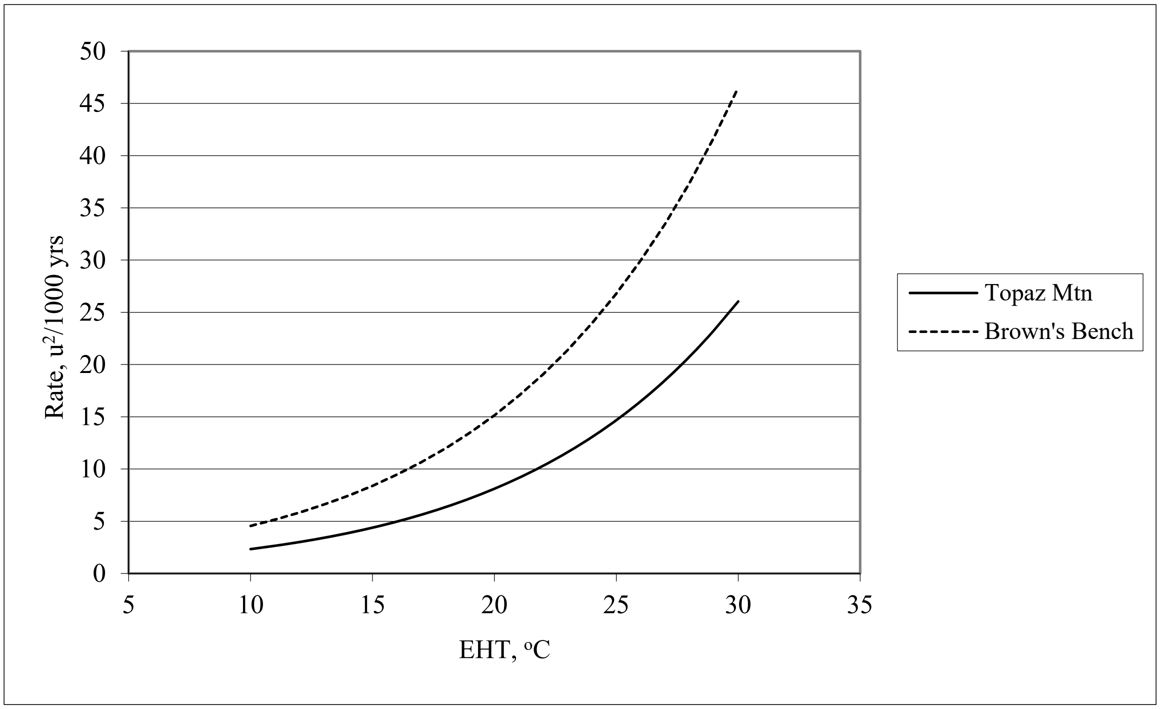

Figure 1. Hydration rate comparison for obsidians from the Topaz Mountain and Brown's Bench sources.

Computation of a rate, again by a linear least-squares best fit between the EHT-corrected rim and the square root of time, yields 20.11 μ^2/1000 years for local EHT conditions. The local EHT was computed above to be 22.46°C. Knowing a rate and a temperature, the intrinsic water content w can be computed from the equation

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

where k is rate in μ^2/1000 yrs, w is total water content in wt%, and T is temperature in °K (Rogers 2015). Knowing a rate and a temperature, w can be computed from equation (7) as w = 0.46wt%

The pre-exponential constant is

$$k_0 = \exp(37.76 - 2.2289*w) \quad (8)$$

or 8.74×10^{15} μ^2/1000 yrs. The activation energy is then

$$E = 10433 - 1023*w \quad (9)$$

or 9966°K.

Finally, a correction factor to adjust the rate to 20°C is

$$F_{rate}=\exp(E/(273.15+22.46)-E/(273.15+20.00)) \quad (10)$$

or 0.748 (note that this differs from equation (5) by the absence of a 2 in the denominator of the exponential). This leads to a Browns Bench hydration rate of 15.16 in μ^2/1000 yrs at 20°C.

This rate, and the rates computed for Topaz Mountain, give archaeologically reasonable ages for obsidian at the Bonneville Estates Rockshelter in eastern Nevada (Rogers and Duke 2019; publication forthcoming).

Finally, for convenience of archaeological use, Figure 1 presents a graph of hydration rate of these two sources for temperatures between 10° and 35°C.

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