IAOS

International Association for Obsidian Studies

Bulletin

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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 AUSTIN

The annual IAOS business meeting will be held during the SAA conference in Austin, Texas, on Saturday, April 25, 2020 from 12-1pm. Please see your conference program for meeting location. All IAOS members are invited to attend.

This year's meeting will include a vote on changes to the IAOS By-Laws as outlined in the Notes from the President on the next page. Please attend and participate.

Please watch your email and the IAOS webpage for additional announcements about IAOS events, meetings, and trips in Austin. If you have items for the meeting agenda, please send them to Kyle Freund at kylepfreund@gmail.com.

NOTES FROM THE PRESIDENT

Another year has flown by, and this will be my last introduction in the *Bulletin* as IAOS President. There will be a couple of changes to the IAOS Executive Board next year as new officers are instated, and I look forward to seeing how they implement their new ideas and visions. Sean Dolan will take over from me at the upcoming SAA Annual Meeting in Austin, and IAOS will hold an election for a new Secretary/Treasurer in the upcoming months; the candidate statement from Lucas Martindale Johnson is included below. I would like to be the first to thank Matt Boulanger for his service as Secretary/Treasurer since 2015. His contribution to the organization has been considerable, and I hope that he continues to stay active in IAOS business.

This summer, the International Obsidian Conference (IOC) took place in Sárospatak, Hungary, and I was fortunate enough to attend this well-organized event. One of the highlights of the conference was the excursions to all three of the major obsidian sources in the region, one of which was (conveniently) located in a Tokaj wine cellar. I am including a photo from our trip to the Ukrainian source of Rokosovo, also known as Carpathian 3.

The next IOC meeting will be held at UC Berkeley in 2021, being organized by Lucas Martindale Johnson, Nico Tripcevich, and myself. IOC 2021 will take place immediately preceding the SAA Annual meeting that year in San Francisco, and IAOS members will receive a discount for registration. The IOC is an obvious fit with our members' interests and expertise, and I hope that we will be well represented at the next conference. I also hope that IAOS can continue to provide logistical and financial support for this venue moving forward. Note that the following IOC will be in Japan in 2023, being organized by long-time member Dr. Akira Ono.

One last issue that the IAOS board has been discussing relates to our policies on sexual harassment and misconduct. This is of critical importance, and we are working to update our by-laws. We plan to send the membership our proposed changes for review and potential ratification at least 30 days prior to our annual business meeting, in compliance with the procedures outlined in Article 13 of the IAOS Bylaws, which state:

"1. The By-laws may be amended by a two-thirds vote of the members present at a business meeting of the Annual Meeting or at a Special Meeting called in accordance with Article 10, paragraph 3. The By-laws may also be amended by mail or email ballot provided that a proposed amendment is approved by two-thirds vote of the votes cast.

2. Amendments may be proposed by the Executive Board or by any ten (10) members of the IAOS. The proposed amendments shall be mailed or emailed to the members of the IAOS by the Secretary at least thirty (30) days before an Annual Meeting or Special Meeting. In the case of a mail ballot upon an amendment, members shall address ballots to the Secretary and place them in the mail and postmarked not more than thirty (30) days from the date they were mailed out and postmarked by the Secretary. An amendment shall go into effect immediately upon approval unless otherwise specially provided."

Don't forget to renew your IAOS membership for 2020.

Happy Holidays!

Kyle Freund, IAOS President
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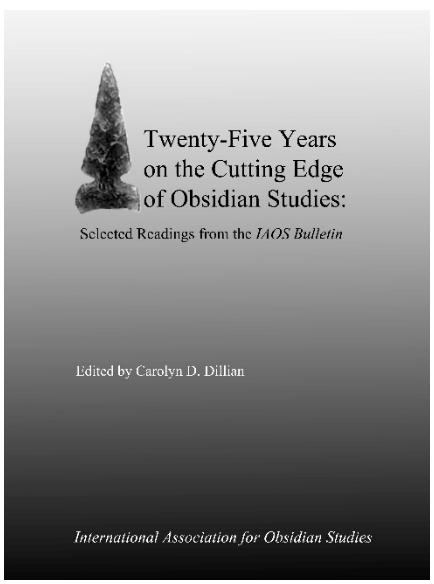
Indian River State College
kfreund@irsc.edu

IOC 2019 excursion to the Rokosovo obsidian source, Ukraine



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.

CANDIDATE STATEMENT: IAOS SECRETARY/TREASURER

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

Lucas R. M. Johnson, Ph.D., Far Western Anthropological Research Group, Inc.

Personal Background:

My current role at Far Western Anthropological Research Group, Inc. is as a senior archaeologist responsible for lithic technological and XRF 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 techniques and sourcing a unique artifact from Belize.

Statement of Interest:

Although my participation in the IAOS has been as a recent member and contributor, I understand the breadth of its impact and its part in archaeological research and professional networking. My perspective on the role of the Secretary/Treasurer is to document the IAOS meetings, track its financial transactions, and aid in recruitment. As a co-organizer of the forthcoming 2021 International Obsidian Conference (IOC) in Berkeley, CA, I aim continue documenting and managing transactions within the IAOS through this important meeting. The role of Secretary/Treasurer fulfils an essential function for any organization. The next two years will be an important time for the IAOS and its members because of its participation in the 2021 IOC. This meeting should allow expanded international participation and enable a climate for recruitment of new members. Thank you for considering electing me as your next Secretary/Treasurer.

International Obsidian Conference 2021
1st Circular – IOC 2021

Venue: University of California, Berkeley Campus
Hosted by *Far Western Anthropological Research Group, Inc*. (FWARG), *International Association of Obsidian Studies* (IAOS), and the *Archaeological Research Facility* (ARF)

April 10-13, 2021
(Preceding the Society for American Archaeology Annual Meeting)

IOC 2021
International Obsidian Conference
Berkeley, CA

IAOS
International Association for Obsidian Studies

ARCHAEOLOGICAL
RESEARCH
FACILITY

FAR WESTERN
ANTHROPOLOGICAL RESEARCH GROUP, INC.

Dear Friends and Colleagues,

We invite you to participate or attend the International Obsidian Conference to be held on the UC Berkeley Campus between April 10-13, 2021.

As before, our aim is to invite specialists in all aspects of obsidian studies extending from natural sciences to anthropology. Following prior meetings, we hope that the conference will be global in scope, 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.

Suggestions for conference sessions and themes:

- Formation and geology of obsidian and FGV
- Sources and their characterization
- Analytical and methodological aspects
- Archaeological obsidian and FGV by chronological periods
- Lithic technology and use wear
- Theoretical and cultural concerns

Local Organizing Committee

- Lucas R. M. Johnson – Far Western Anthropological Research Group, Inc.
- Lisa Maher - University of California, Berkeley
- Nicholas Tripcevich – University of California, Berkeley Archaeological Research Facility

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

Kyle Freund, kfreund@irsc.edu
Lucas R. M. Johnson, lucas@farwestern.com
Nicholas (Nico) Tripcevich, tripcevich@berkeley.edu

Technical Information

Duration and Dates: 3 days, April 10-12, 2021
Post Conference Excursion: 1 day, April 13, 2021
Location: UC Berkeley campus (building and room TBA)

Oral Contributions: Oral contributions will be 15 minutes, followed by 5-minute discussion. Please prepare them in common presentation format (e.g., PPT). Video conference will likely be a possibility for registered participants, but we would prefer you present in person.

Poster Presentations: The posters should be planned as standing (portrait) orientation and their size must not exceed A0 (841 x 1189 mm).

Abstracts: must not exceed 300 words (including author's details and institutional affiliation).

Language: The official language of the conference is English.
Deadline for submitting abstracts: December 1, 2020
Deadline for registration: December 1, 2020 for presenters (April 1, 2021 for attendees not presenting a poster or paper)

Registration Fee:

Full registration	$100 USD
Early-bird registration (before July 1, 2020)	$80 USD
Distance participants	$50 USD
Students and accompanying persons	$50 USD
Early-bird registration (before July 1, 2020)	$40 USD

*A discount will be offered to members of the International Association for Obsidian Studies (IAOS)

Other costs:

Conference dinner	$50 USD

Conference excursion:
Visit to Napa Valley winery and obsidian quarry location of Napa Valley obsidian. Price TBA

Accommodations:
UC Berkeley is located in the center of town with many hotel options. Accommodations can also be found in the Oakland, Emeryville, and San Francisco. Mass transit or ride-shares are easily accessible no matter where you stay. In you stay in downtown Berkeley, most everything is just a short walk away including restaurants and grocery.

Transportation:
UC Berkeley is located in the center of town near to Bay Area Rapid Transit (BART) stops. The campus can be reach in about 30 minutes from the Oakland International Airport and about 1.5 hours from the San Francisco airports if by BART. Taxi and rideshare services are faster but more expensive. Via BART the cost is about $10-12 USD.

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

On-line registration will be open from June 1, 2020 at the conference web page.

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

Lucas, Kyle, and Nico

ROLE OF MINIMUM ANALYTICAL NODULES IN OBSIDIAN HYDRATION MEASUREMENT: INSIGHT FROM KYU-SHIRATAKI 3 IN HOKKAIDO, JAPAN

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Abstract

To obtain reliable dates for multiple assemblages from a single site, measurements of obsidian hydration rim thicknesses from the flakes of Kyu-Shirataki 3 (northeastern Hokkaido, Japan), a large prehistoric open-air site, are evaluated using Minimum Analytical Nodules (MAN). Variations in measured rim thicknesses within the unit of MAN are minimal and less than those of samples from artifact assemblages without considering MAN. This suggests MAN is an effective method to increase the reliability of obsidian hydration dating, particularly for its application to prehistoric sites that are potentially palimpsests of long-term human exploitation of obsidian.

Introduction

It is a challenge for archaeologists to provide reliable dates for artifacts that encompass multiple assemblages that potentially experienced various formation histories. This situation is often brought to mind when needing to analyze large-scale sites such as quarries and workshops in and around obsidian outcrops. Here, we report the preliminary results of a study on obsidian hydration dating (OHD) from Kyu-Shirataki 3 (northeastern Hokkaido, Japan), an extensive and deeply-buried open-air site characterized by dense obsidian scatters. The study site of Kyu-Shirataki 3, excavated in 2009, is characterized by various lithic assemblages that were techno-typologically distinguished through three years of intensive laboratory work in 2010–2012 (Hokkaido Archaeological Operation Center 2015). Based on the lithic typology of the study region, it is estimated that the assemblages are mostly attributed to the late Upper Paleolithic age (ca. 25,000-11,000 BP). Furthermore, they are hypothetically ordered in the timeframe between ca. 30,000 and 10,000 BP (Hokkaido Archaeological Operation Center 2015, Izuho et al. 2012, Naoe 2015). However, the extent to which temporal differences are present between typologically distinctive assemblages that are hypothetical in local cultural chronologies remains unclear. Given this situation, we employed OHD to the study assemblages to evaluate the temporal relationships of late Upper Paleolithic assemblages.

Materials and Methods

Although establishing dates for multiple assemblages is a challenge, the Kyu-Shirataki 3 site provides an ideal setting for using OHD. Kyu-Shirataki 3 is located on the western river terrace along the Yubetsu River, which flows from the high mountain range (1,500–1,800 m asl.) known as the Daisetsu Mountains (*Daisetsuzan-kei*) to the Sea of Okhotsk in northeastern Hokkaido (Figure 1). In 2009,

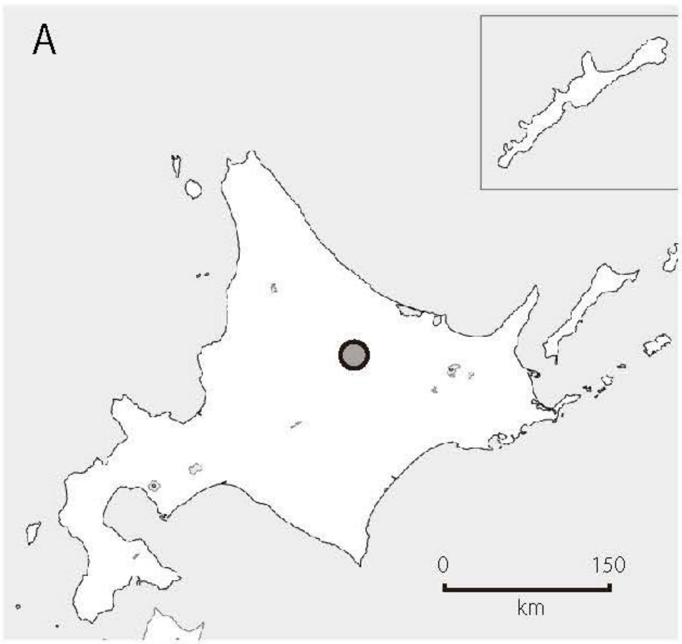
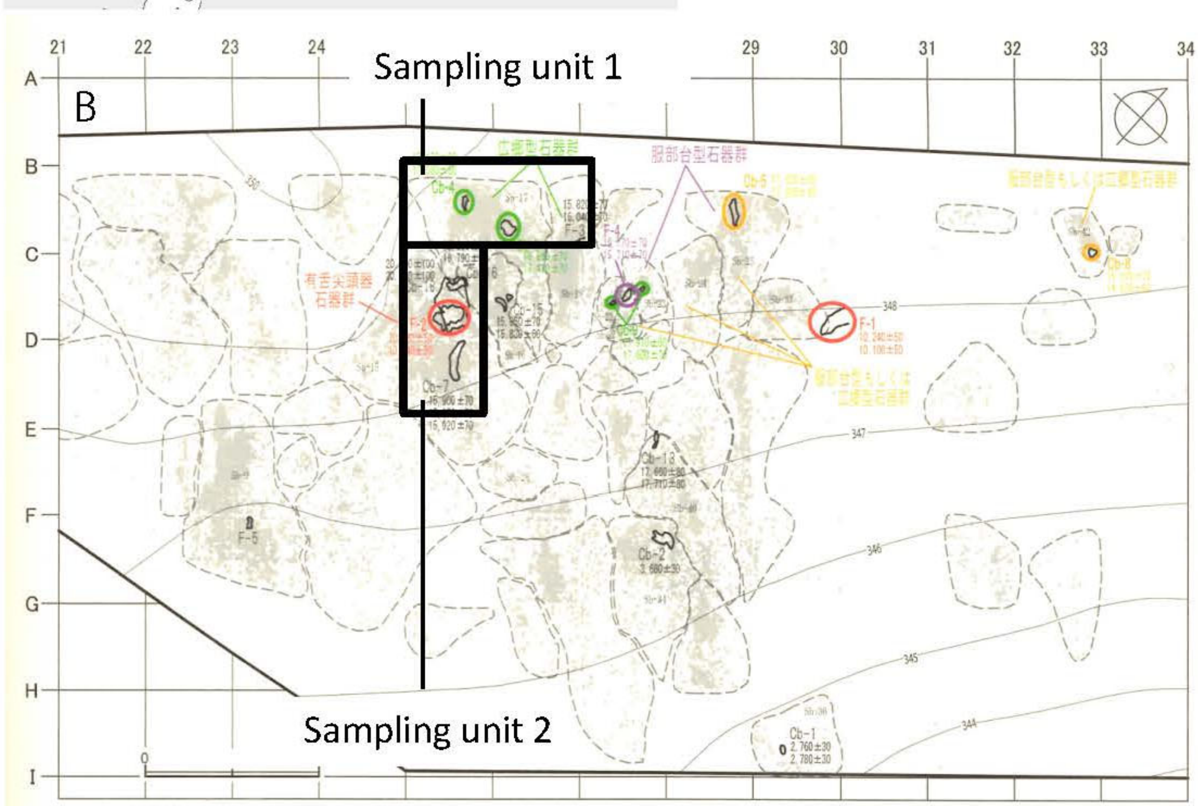


Figure 1. Location of the Kyu-Shirataki 3 site in northeastern Hokkaido (A), and locations of sampling units 1 and 2 within the distribution of lithic scatters and features of the Kyu-Shirataki 3 site (B). The map of B is from Hokkaido Archaeological Operation Center (2015).



Sampling Grids	MAN#	Obsidian sources	Lithic assemblages	N	Mean	Standard Deviations	Coefficient of Variation
B-25	23	Shirataki-Tokachiishizawa	Hirosato-type microblade cores	15	4.8	0.268	0.056
C-25	33	Shirataki-Akaishiyama	Stemmed-points	10	3.57	0.15	0.042
C-25	35	Shirataki-Akaishiyama	Stemmed-points	10	4.42	0.193	0.044
B-25	46	Shirataki-Akaishiyama	small boat-shaped tools	10	5.5	0.229	0.042
D-25	52	Shirataki-Akaishiyama	small boat-shaped tools	10	5.41	0.231	0.043
B-26	82	Shirataki-Akaishiyama	bifacial points associated to Hirosato-type microblade cores	5	4.89	0.1	0.02
B-25	-	Shirataki-Akaishiyama	Shirataki Group I	5	5.52	0.997	0.181

Table 1. Summary of the measurements of hydration rim thicknesses (μm) (means, standard deviations, and coefficient variations) shown by Minimum Analytical Nodules (MAN) from Kyu-Shirataki 3.

archaeologists of the Hokkaido Archaeological Operation Center conducted a salvage excavation for compliance with cultural resource laws in Japan, yielding 147,000 obsidian artifacts (Hokkaido Archaeological Operation Center 2015). Recovering this large number of obsidian artifacts is not unusual in the upper stream of the Yubetsu River, because large obsidian outcrops are located in the Akaishi Mountain just 5 km north of the river. Approximately 100 open-air sites are clustered in the upper stream of the Yubetsu River (named the Shirataki district after the local village of Shirataki). All of these sites have a large number of obsidian artifacts left by the intensive prehistoric human exploitation of obsidian. Based on the lack of Jomon pottery from most of these clustered sites, 90% were dominated by human activities during the Late Glacial to early Holocene periods (ca. 25,000 – 10,000 BP), culturally comparable to the Upper Paleolithic and Incipient Jomon eras.

Taking advantage of the regional abundance of prehistoric obsidian, we obtained samples for OHD from study units B25/26 (Sampling unit 1 measuring 4 by 8 m) and CD25 (Sampling unit 2 measuring 4 by 8 m) at the study site, namely Kyu-Shirataki 3 (Figure 1, Table 1), because these units have groups of artifacts with different temporal periods based on technological and typological criteria (Hokkaido Archaeological Operation Center 2015, Naoe 2014).

OHD is a dating method using the hydration rim developed over time since the obsidian surface was exposed at the time of knapping. Because obsidian was used to make an artifact, OHD has the advantage over other methods (e.g., radiocarbon dating, optically stimulated luminescent dating) of a time lag between non-artifact formation (e.g., generation of charcoal, accumulation of sediment) and obsidian artifact deposition.

In addition, obsidian artifacts can be sorted into analytical units known as the "minimum

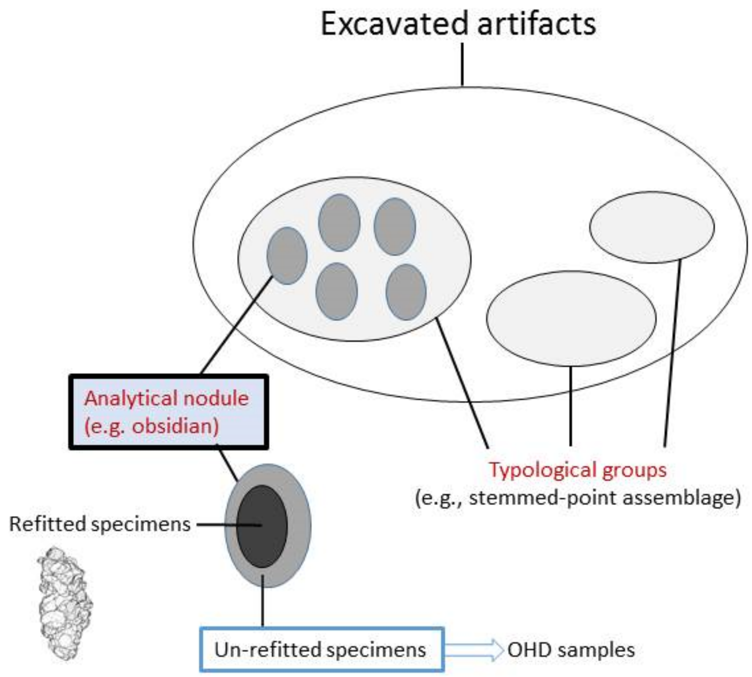


Figure 2. The schematic relationships of excavated artifacts, typological groups (assemblages), analytical nodules, refitted specimens, and un-refitted specimens from which OHD samples were taken.

analytical nodule" (MAN) based on visual characteristics (e.g., color, texture) (Larson and Kornfeld 1997: 4). Because Japanese Paleolithic archaeologists have routinely employed artifact sorting using analytical units comparable to MAN, along with lithic-refitting, analysis since the 1970's (e.g., Anbiru 1992, see Bleed 2002, Takakura 2011), obsidian artifacts from the Kyu-Shirataki 3 site were also sorted into numerous MANs, the majority of which have artifacts that refit.

To make thin sections to observe hydration rims, we took samples of obsidian flakes that do not refit, but are sorted into an identical MAN (Figure 2). To evaluate the hydration rim thicknesses, we chose six MANs from which appropriate samples were collected (Table 1). Based on the tool typology, the six MANs from which samples for the OHD were taken are attributable to four techno-typological groups of assemblages consisting of groups of small boat-shaped tools, Hirosato-type microblade cores, bifacial points associated with Hirosato-type microblade cores, and stemmed points. For the purpose of comparison, samples from Shirataki Group I, characterized by small amorphous flakes, were collected without controlling MAN.

All thin sections were made by the last author using the facility at the Thin Section Laboratory of the Graduate School of Science at Hokkaido University. The obsidian hydration rim was observed under a polarized light microscope (MT9300, Meiji Techno Co., LTD.) at a magnification of 400–500×. Following the standard recording system (Nakazawa 2015, Origer 1989), the thicknesses of the hydration rims were taken by three measurements on the exterior and interior surfaces of a single obsidian sample in μm using a computer-assisted measuring device (Art Measure, Artray Inc.). To nullify inter-observer error, only the first author took the measurements. The fifth author measured the geochemistry of the sampled obsidian using a portable ED-XRF, following the method of Izuho et al. (2017).

Results

Table 1 summarizes all measured thicknesses. The measured rim thicknesses among the MAN have small deviations and coefficient of variations (CV), mostly within

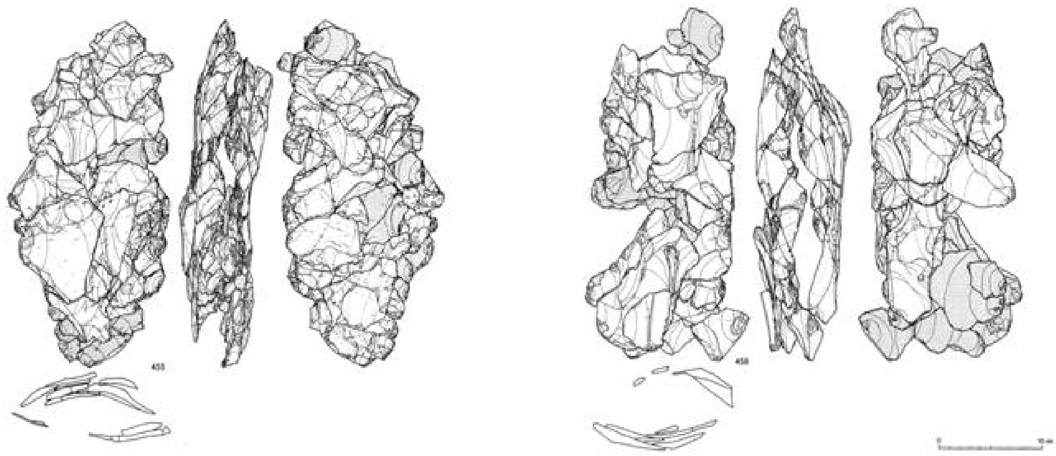


Figure 3. Illustrations of refitted bifacial-thinning flakes of Minimum Analytical Nodules (MAN) No. 33 and No. 35.

the range of 0.1–0.3 and less than 0.06, respectively. The largest set of deviations and CV was observed for Shirataki Group I, which consists of samples without regard to MAN. While measurement errors are minimized within the unit of MAN, differences in hydration rim thicknesses in the same assemblage were observed. In the group of stemmed-point assemblages, MAN #33 and #35 have significant differences in the means of the hydration thicknesses: the mean thickness for MAN #33 is 3.57 µm, and that of MAN #35 is 4.42 µm, a difference of 0.9 µm. This is 10 times larger than the difference between MAN #46 and #52 (i.e., 0.09 µm).

Discussion

The small deviations in the observed measurements of hydration rim thicknesses suggest that choosing samples from MAN gives reliable measurements for OHD. However, the difference in mean rim thicknesses between two MANs (#33 and #35) in the stemmed point assemblage needs explanation. Because these two MANs are derived from the same geochemical group of obsidian sources (Akaishiyama), the hydration rates likely differed even in nodules from the same source.

Differences in hydration rates necessarily relate to differential rates of water diffusion, because hydration is the process of water diffusion into the glass. Besides ambient temperature (Ambrose 1976, Friedman and Smith 1960), rate of water diffusion into obsidian glass is affected by endogenous factors, notably obsidian geochemistry (Friedman and Long 1976, Kimberlin 1976, Suzuki 1973) and intrinsic water content of obsidian (Rogers 2008, Steffen 2005, Stevenson et al. 1993, Stevenson et al. 2019). In particular, systematic studies of water diffusion in silicate melts and glasses have suggested that water diffusion increases with increasing water content, and molecular water (H_2O_m) reacts with the silicate structure of glass (e.g., Behrens and Zang 2009, Schmidt et al. 2013, Zhang et al. 1991). According to Ni and Zhang (2018), the molecular water (H_2O_m) increases exponentially with water content, but diffusivity of hydroxyl groups (OH) is independent of water content at high temperatures (403－1629℃). Mechanistic relationships between water diffusion and water content have been modeled based on experimental studies in high pressure and high temperature conditions (>400℃), whereas the mechanism of water diffusion in low temperature conditions (<100℃), in which obsidian hydration normally occurs, is still unclear (but see Yokoyama et al. 2008).

Given the complex processes of water diffusion in obsidian, we present three potential factors to explain the difference in rim thicknesses between analytical nodules typologically classified into the same group. First, the difference simply shows the time the artifacts were manufactured. MAN #33 and #35 are both bifacial-thinning flakes (Figure 3). Most of these flakes are refitted to shape phantom bifaces, implying that manufactured bifaces were transported from the site. Because the precise shapes of the bifaces, whether they have stems or not, are undetermined based on the refitted bifacial-thinning flakes of MAN #33 and #35, either of these bifaces is indeed from an older assemblage than the terminal Pleistocene stemmed-point assemblage (e.g., Naoe 2014). Second, the rim thicknesses between the two nodules validly reflect the duration of site occupation. Since the site was occupied multiple times over an extensive duration, likely for thousands of years without changing tool morphologies, the remaining artifacts differ greatly in age. This is the effect of the palimpsest of human activities (e.g., Nakazawa et al. 2009, Stern 1993, Straus 1979), and large quarries are generally expected to demonstrate this situation. Third, the difference in rim thicknesses is the effect of the intrinsic water content of obsidian. Since the geochemically identified obsidian source for MAN #33 and #35 is identical (Akaishi Mountain) and the measured samples were buried under the same conditions and same chronological period, the difference in rim thicknesses may be explained by intrinsic water content. The slight difference in water content between the nodules may have affected the hydration rates, resulting in the difference in rim thicknesses.

Conclusion

An implication of the results of this study is that sampling obsidian while taking into account MAN will lead reliable measurements of obsidian hydration rim thicknesses, which will enable a good estimation of hydration dates. Specifically, employing MAN is also effective in studying palimpsest sites potentially created by long-term human occupation. Archaeologists are struggling to understand site formation processes and establish a temporal order of techno-typologically distinguished stone tool assemblages. Since this is the preliminary report, we will continue to build a data set to evaluate the role of OHD in identifying patterns of prehistoric exploitation of obsidian.

Acknowledgements

This paper is based on a presentation in the symposium "An advancement of obsidian studies in the Old and New Worlds" held at the 84th annual meeting of the Society for American Archaeology in Albuquerque, New Mexico in 2019. We thank IAOS for supporting the symposium, Phyllis Johnson for her enthusiasm and consistency in organizing the session, and Robert Tykot for serving as the discussant. Ana Steffen and Kyle Freund also provided support to enable the session. In the sampling of obsidian artifacts at the Shirataki GeoPark in Engaru Town, we thank Yoshifumi Matsumura and Naoto Seshimo for their generous help.

References Cited

Ambrose, W.R. (1976) Intrinsic Hydration Rate Dating of Obsidian. In *Advances in Obsidian Glass Studies,* edited by R. E. Taylor, pp. 81–105, Noyes Press, Park Ridge, New Jersey.

Anbiru, M. (1992) Stone tool production and site formation at Sunagawa. *Sundai Historical Review* 86:101-128. (in Japanese with English abstract)

Behrens, H., and Y. Zhang (2009) H_2O Diffusion in Peralkaline to Peraluminous Rhyolitic Melts. *Contributions to Mineralogy and Petrology* 157: 765-780.

Bleed, P. (2002) Obviously Sequential, but Continuous or Staged? Refits and Cognition in Three Late Paleolithic Assemblages from Japan. *Journal of Anthropological Archaeology* 21: 329-343.

Friedman, I., and W. Long (1976) Hydration Rate of Obsidian. *Science* 191: 347–352.

Friedman, I., and R.L. Smith (1960) A New Dating Method using Obsidian: Part I, the Development of the Method. *American Antiquity* 25: 476–493.

Hokkaido Archaeological Operation Center (2015) *Shirataki Isekigun XIV [Shirataki Sites XIV]*. Hokkaido Archaeological Operation Center, Ebetsu. (in Japanese)

Izuho, M., J.R. Ferguson, A. Vasilevski, V. Grishchenko, S. Yamada, N. Oda, and H. Sato (2017) Obsidian Sourcing Analysis by X-ray Fluorescence (XRF) for the Neolithic Sites of Slavnaya 4 and 5, Sakhalin Islands (Russia). *Archaeological Research in Asia* 12: 54-60.

Izuho, M., F. Akai, Y. Nakazawa, and A. Iwase (2012) The Upper Paleolithic of Hokkaido: Current Evidence and Its Geochronological Framework. In *Environmental Changes and Human Occupation in East Asia during the OIS3 and OIS2*, edited by Akira Ono and Masami Izuho, pp.109-128. Archaeopress, Oxford.

Kimberlin, J. (1976) Obsidian Hydration Rate Determinations on Chemically Characterize Samples. In *Advances in Obsidian Glass Studies,* edited by R. E. Taylor, pp. 63–80, Noyes Press, Park Ridge, New Jersey.

Larson, M.L., and M. Kornfeld (1997) Chipped Stone Nodules: Theory, Method, and Examples. *Lithic Technology* 22: 4-18.

Nakazawa, Y. (2015) The Significance of Obsidian Hydration Dating in Assessing the Integrity of Holocene Midden, Hokkaido, Northern Japan. *Quaternary International* 397: 474–483.

Nakazawa, Y., M. Izuho, and F. Akai (2009) Between the Two Hearths: Site Formation Processes and Spatial Organization at the Upper Paleolithic Open-Air Site of Kamihoronai-Moi, Hokkaido (Japan). *The Quaternary Research (Daiyonki-Kenkyu)* 48(2): 85-96.

Naoe, Y. (2014) Chronology and Radiocarbon Dates from the Early Upper Paleolithic to the Incipient Jomon in Hokkaido. *Palaeolithic Research* 10: 23-39. (in Japanese with English abstract)

Ni, H., and L. Zhang (2018) A General Model of Water Diffusivity in Calc-alkaline Silicate Melts and Glasses. *Chemical Geology* 478: 60-68.

Origer, T.M. (1989) Hydration Analysis of Obsidian Flakes Produced by Ishi During the Historic Period. In *Contributions of the University of California Archaeological Research Facility* 48, edited by Richard E. Hughes and Mark Basgall, pp. 69-77. Archaeological Research Facility, Department of

Anthropology, University of California, Berkeley.

Rogers, A.K. (2008) Obsidian Hydration Dating: Accuracy and Resolution Limitations Imposed by Intrinsic Water Variability. *Journal of Archaeological Science* 35: 2009-2016.

Schmidt, B.C., N. Blum-Oeste, and J. Flagmeier (2013) Water Diffusion in Phonolite Melts. *Geochimica et Cosmochimica Acta* 107: 220-230.

Steffen, A. (2005) *The Dome Fire Study: Investigating the Interaction of Heat, Hydration, and Glass Geochemistry*. PhD dissertation, Department of Anthropology, The University of New Mexico, Albuquerque.

Stern, N. (1993) The Structure of the Lower Pleistocene Archaeological Record. *Current Anthropology* 34: 201-225.

Stevenson, C.M., E. Knauss, J.J. Mazer, and J.K. Bates (1993) Homogeneity of Water Content in Obsidian from the Coso Volcanic Field: Implications for Obsidian Hydration Dating. *Geoarchaeology* 8: 371-384.

Stevenson, Christopher M., Alexander K. Rogers, and Michael D. Glascock (2019) Variability in obsidian Structural Water Content and its importance in the hydration dating of cultural artifacts. *Journal of Archaeological Science: Reports* 23:231-242.

Straus, Lawrence Guy (1979) Caves: A Paleoanthropological Resource. *World Archaeology* 10(3): 331-339.

Suzuki, M. (1973) Chronology of Prehistoric Human Activity in Kanto, Japan, Part I: Framework for Reconstructing Prehistoric Human Activity in Obsidian. *Journal of the Faculty of Science, Univ. Tokyo Section V Anthropology* IV-1: 241–317.

Takakura, J. (2011) Refitted Material and Consideration of Lithic Reduction Sequence Among the Microblade Assemblages: A View from the Okushirataki-1 Site, Hokkaido, Northern Japan. *Asian Perspectives* 49(2): 332-347.

Yokoyama, T., S. Okumura, and S. Nakashima (2008) Hydration of Rhyolitic Glass During Weathering as Characterized by IR Microspectroscopy. *Geochimica et Cosmochimica Acta* 72: 117-125.

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

APPLICATION OF MODERN OBSIDIAN HYDRATION DATING (OHD) METHODS TO OLD DATA SETS: A CASE STUDY BASED ON DATA FROM THE INDIAN HILLS ROCKSHELTER (CCA-SDI-2537), ANZA-BORREGO STATE PARK, CALIFORNIA

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Abstract

This paper describes an obsidian hydration analysis for Indian Hills Rockshelter (CA-SDI-2537) in Anza-Borrego State Park, which was excavated in 1984 - 1987. The data set is from a PhD dissertation from 1992. The assemblage included significant quantities of obsidian, but unfortunately, the state of the OHD art at the time did not permit a cogent OHD analysis. Advances in the last decade now make this possible, but the question remains as to whether application of newer mathematical methods to an old (and previously intractable) data set can provide useful results. In this case study we apply modern methods to the obsidian specimens from Indian Hills Rockshelter, focusing on those which were sourced to Obsidian Butte. The age computations are based on modeling the hydration process by temperature-dependent diffusion theory, using a flow-specific hydration rate and with corrections for local temperature, artifact burial depth, and site formation processes. Ages are computed for each class of artifact: preforms, projectile points, bifaces, and flakes; ages thus determined are compared with radiocarbon data. The ages determined for temporally-sensitive projectile points are as expected for those morphological types, which suggests the temperature parameters for the site are valid, as is the hydration rate for Obsidian Butte. We find the site experienced a sequence of three occupation or use episodes: 6000 – 5000 BP, 3800 – 3800 BP, and less than 1000 BP, all of which agree reasonably well with radiocarbon ages. This analysis shows the potential of applying modern methods to previously-intractable data sets.

Introduction

This study describes an obsidian hydration dating (OHD) analysis for Indian Hills Rockshelter (CA-SDI-2537) in Anza-Borrego State Park. The data set is from the Ph.D. dissertation of Alison M. MacDonald, who excavated the site in 1984-1987 for the University of California, Riverside (MacDonald 1992). A considerable quantity of obsidian was recovered, the majority from Obsidian Butte near ancient Lake Cahuilla. However, the state of the art in OHD was not sufficiently advanced at the time to do a cogent OHD analysis. Advances in the physics, chemistry, and mathematics of OHD since 2007 now permit such an analysis. The current age computations are based on modeling the hydration process by temperature-dependent diffusion theory, using flow-specific hydration rates and with corrections for local temperature, artifact burial depth, and site formation processes.

This analysis focuses only on the specimens which were sourced to Obsidian Butte. A set of temperature parameters for the site is established based on meteorological data and on known properties of rockshelters; since specimens were collected both inside and outside the shelter, the temperature parameters take this into account. A hydration rate for Obsidian Butte was derived from obsidian-radiocarbon data at the shelter. Ages were computed for each class of artifact: preforms, projectile points, bifaces, and flakes. Ages derived from OHD were compared with radiocarbon, and with the expected ages for diagnostic artifacts.

Obsidian Butte is an outcrop of rhyolitic lava, which is part of the Salton Buttes formation. Geochronologic studies have shown that the buttes erupted in late Holocene times (Schmitt et al. 2013, Wright et al. 2015). Recently published research, based on infrared stimulated luminescence dating of feldspar from a geothermal exploration well have determined an age of 490 ± 230 BC, 1-sigma, or approximately 2500 cal BP (Schmitt et al. 2019). Prior to that time the obsidian source did not exist.

A major caveat is that the site has been heavily disturbed over the years, both by natural processes and by looters, which places a limit on what can be determined.

Obsidian Hydration

Hydration of obsidian is known as a diffusion-reaction process (Doremus 1994, 2000, 2002). The basis of chronometric analysis using obsidian hydration is the equation

$$t = r^2/k \qquad (1)$$

where t is age in calendar years, r is rim thickness in microns, and k is the hydration rate. Although other equations have been proposed (e.g., Basgall 1991, Pearson 1994), equation 1 is the only form with both theoretical (Ebert et al. 1991, Doremus 2002) and laboratory (Doremus 1994; Stevenson et al. 1998, 2000) support.

The hydration rate is affected by five parameters: ground-water chemistry (Morgenstein et al. 1999), obsidian anhydrous chemistry (Friedman et al. 1966), obsidian intrinsic water content (Zhang 2008, Zhang et al. 1991, Zhang and Behrens 2000), humidity (Mazer et al. 1991); and temperature (Rogers 2007). Ground-water chemistry is only a problem in cases where potassium content is very high, as in some desert playas, otherwise it can be ignored. Obsidian anhydrous chemistry is controlled by sourcing the obsidian. Intrinsic water concentration can vary within an obsidian source (Stevenson et al. 1993), and can affect hydration rate significantly (Zhang 2008, Zhang et al. 1991, Zhang and Behrens 2000). There are no archaeologically appropriate techniques for measuring intrinsic water at present, so its effects must be controlled statistically by sample size. Humidity is a small effect which can generally be ignored.

It is now known that temperature is the major environmental effect which needs to be controlled for in performing an OHD analysis, and techniques for doing so have been developed and published (Rogers 2007, 2012). Effective hydration temperature (EHT) is defined as a constant temperature which yields the same hydration results as the actual time-varying temperature over the same period of time. The exact solution for EHT requires integration of the temperature-dependent

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max F	69.3	72.3	77.9	84.5	93.2	102.7	107.4	106.1	101	89.7	77.9	68.9
Min F	44.0	46.5	50.0	53.8	60.7	68.4	75.8	75.5	70.3	60.6	50.4	43.4
Max C	20.72	22.39	25.50	29.17	34.00	39.28	41.89	41.17	38.33	32.06	25.50	20.50
Min C	6.67	8.06	10.00	12.11	15.94	20.22	24.33	24.17	21.28	15.89	10.22	6.33
Mean	13.69	15.22	17.75	20.64	24.97	29.75	33.11	32.67	29.81	23.97	17.86	13.42
Range	14.06	14.33	15.50	17.06	18.06	19.06	17.56	17.00	17.06	16.17	15.28	14.17

Table 1. Temperature data.

hydration rate over a time span in which the temperature varies diurnally and annually about an annual mean temperature (Rogers 2007, 2018). The temperature is modeled as the sum of a mean temperature and two sinusoids, one with 24-hour period and the other with a 12-month period. The amplitudes of the mean and the two sinusoids were estimated from meteorological records downloaded from the Western Regional Climate Center website. Table 1 summarizes the temperature data for Borrego Desert Park, Station 040983, for the period July 1, 1942 – June 10, 2016.

The presence of a rockshelter also affects the magnitude of the temperature variation terms (although it has no effect on annual mean temperature). Measurements at Ray Cave (CA-INY-444) in the Coso Range of eastern California showed that the annual variation inside the cave is approximately 75% of the variation outside the cave; further, published data show that the mean diurnal variation seldom exceeds 5°C (Curran-Everett et al. 1991: 113). The surface EHT is computed from the equation

$$EHT = T_a + 0.0062*(V_a^2 + V_d^2) \qquad (2)$$

From these data the temperature parameters for the site were computed (Table 2).

For buried artifacts, V_a and V_d represent the temperature variations at the artifact burial depth, which are related to surface conditions by

$$V_a = V_{a0}\exp(-0.44z) \qquad (3a)$$

and

$$V_d = V_{d0}\exp(-8.5z) \qquad (3b)$$

where V_{a0} and V_{d0} represent nominal surface conditions and z is burial depth in meters (Carslaw and Jaeger 1959:81). Depth correction for EHT is desirable, even in the presence of site turbation, because the depth correction, on the average, gives a better age estimate.

Burial depth is often a function of site formation processes, such that an artifact is discarded on the surface and is gradually covered with soil over time. Equally, a buried artifact may be exposed by erosion or deliberately recovered and reused or repurposed. Thus, the depth at which the artifact was recovered archaeologically is may not be characteristic of its entire life. To account for this uncertainty, the computer code assumes the artifact was buried at the recovery depth for half its life, and on the surface the other half, which affects the uncertainty in age.

Finally, EHT should in principle also be affected by paleotemperature shifts (West et al. 2007), however analysis shows the effect in the north temperate zone is negligible for ages less than about 13000 cal BP, so they are not included here (Rogers 2015a).

Once EHT has been computed, the measured rim thickness is multiplied by a rim correction factor (RCF) to adjust the rims to be comparable to conditions at a reference site:

$$RCF = \exp\{[(E/EHT) - (E/EHT_r)]/2\} \qquad (4)$$

where EHT_r is effective hydration temperature for the hydration rate (20°C here) and E is the activation energy of the obsidian. The EHT-corrected rim value r_c is then

$$r_c = RCF \times r \qquad (5)$$

There are always errors, or uncertainties, in the parameters used for age computation, which in turn lead to errors in the computed age. The primary error sources are: obsidian rim measurement, errors in the hydration rate ascribed to a geochemical source (Rogers 2010), intra-source rate variability due to uncontrolled intrinsic water in the obsidian (Ambrose and Stevenson 2004; Rogers 2008; Stevenson et al. 1993, 2000; Zhang 2008; Zhang et al. 1991; Zhang and Behrens 2000),

Parameter	Remarks	Outside rockshelter	Inside rockshelter
Annual mean temperature, T_a	Average of Max C and Min C for 12 months	22.74°C	22.74°C
Annual variation, V_a	Hottest-month mean minus coldest-month mean	19.69°C	14.77°C
Mean diurnal variation, V_d	Mean of the monthly diurnal range	16.27°C	5.00°C
Effective hydration temperature, EHT	Surface conditions	26.79°C	24.25°C

Table 2. SDI-2537 Temperature parameters.

errors in reconstructing the temperature history (Rogers 2007, 2012), and association errors caused by site formation processes (Schiffer 1987). The effects of these errors have been examined in detail, with the analysis is documented in Rogers 2010.

Sample standard deviation is generally not a good estimate of age accuracy because obsidian sample sizes are generally relatively small due to cost constraints, while the uncertainty sources introduce at least five degrees of freedom in the errors. The optimal strategy for estimating age accuracy is to use *a priori* information about the individual error sources, and infer the accuracy of the age estimate. With this method, the coefficient of variation of the age estimate, CV_t, can be shown to be

$$CV_t^2=4[(\sigma_r/r)^2+(0.06\sigma_{EHT})^2+(CV_{ks}/2)^2+CV_{ke}^2] \quad (6)$$

where the variables are defined as follows: σ_r is the standard deviation of the hydration rim measurement, and is ~0.1μ; r is the mean hydration rim; σ_{EHT} is the uncertainty in EHT post-correction, and is ~1.0°C; CV_{ke} is the coefficient of variation of the hydration rate ascribed to the obsidian source, and is typically ~0.05; and CV_{ks} is the coefficient of variation of the intra-source rate variations, which are source-specific.

Once age t is computed from equation (1) and CV_t is computed from equation (6), the standard deviation of the uncertainty in the age estimate is

$$\sigma_t = CV_t \times t \quad (7)$$

This is the accuracy figure quoted in the computer program output in Tables 3 - 5.

A hydration rate for Obsidian Butte was developed from the data at SDI-2537, based on obsidian-radiocarbon association. The radiocarbon data point is UCR-1927D, on bone collagen at a level of 48-57 inches, with an age of 4070 ± 100 rcybp; the median calibrated age is 4676 cyb2k (= cal BP + 50). The obsidian specimen chosen for association was Cat. No. C4-259, from the 45-48 inch level; the hydration rim is 8.4μ. The resulting rate is $8.4^2/4.676 = 15.09\ \mu^2/1000$ years at an EHT of 24.45°C inside the rockshelter.

Age computation is based on a standard EHT of 20°C, so it is necessary to modify the rate to this temperature by multiplying it by a correction factor:

$$\text{Correction factor}=\exp[(E/EHT)-(E/EHT_r)] \quad (8)$$

Most computations of EHT corrections employ an approximate value for the activation energy E of 10000°K (e.g. Rogers 2007, 2012), a value derived from Friedman and Long (1976). The accuracy is improved, however, if a value specific to the obsidian source is used. This value is a function of the intrinsic water content of the obsidian, but not of temperature. The hydration rate at archaeological temperatures has been shown to be related to temperature and water content by the equation

$$k=\exp(37.76–2.289*w–10433/T+1023*w/T) \quad (9)$$

where k is rate in μ^2/1000 yrs, w is total water content in wt%, and T is temperature in °K

Cat. No.	Level, in	R_m, µ	R_{20}, µ	Age, cyb2k	Age SD, yrs
D7-25	3-6	1.3	1.01	112	30
D6-76	12-15	1.6	1.26	173	44
B4-97	15-18	2.2	1.73	329	78
S84-7	Surface	2.7	1.77	346	79
C4-148	21-24	2.7	2.13	500	115
D7-163	24-27	2.7	2.14	502	116
C4-206	33-36	2.8	2.23	545	126
C5-127	18-21	3.2	2.52	700	159

Table 3. Obsidian Butte Cottonwood Triangular Points, inside Rockshelter.

(Rogers 2015b). Knowing k and T, w can be computed, and activation energy is then

$$E = 10433 - 1023*w \qquad (10)$$

For Obsidian Butte obsidian, w = 0.30 wt%, and E = 10402°K. Using this value in equation (8) yields a hydration rate of 9.09 μ^2/1000 years at an EHT of 20°C. This value was used in the age computations.

Analysis of Obsidian Hydration Ages

Projectile points:

A total of 8 Cottonwood Triangular points was recovered from inside the rockshelter (Table 3). Remarkably, all fall within the expected range of ages for this point type, with no outliers (Justice 2002). The mean age is 401 cyb2k, standard deviation 211 years, CV = 0.53, and N = 8. Probable error of the mean is 75 years.

A single Cottonwood Triangular point was found on the surface outside the rockshelter (Cat. No. S84-7). Its age is 346 cyb2k, with a standard deviation of 79 years.

Three Desert Side-Notched points were recovered from inside the shelter. All fall within the expected age range, with a mean age of 145 cyb2k, a standard deviation of 97 years, and a CV of 0.67.

Four Dos Cabezas Serrated points were found inside the shelter. The mean age is 446

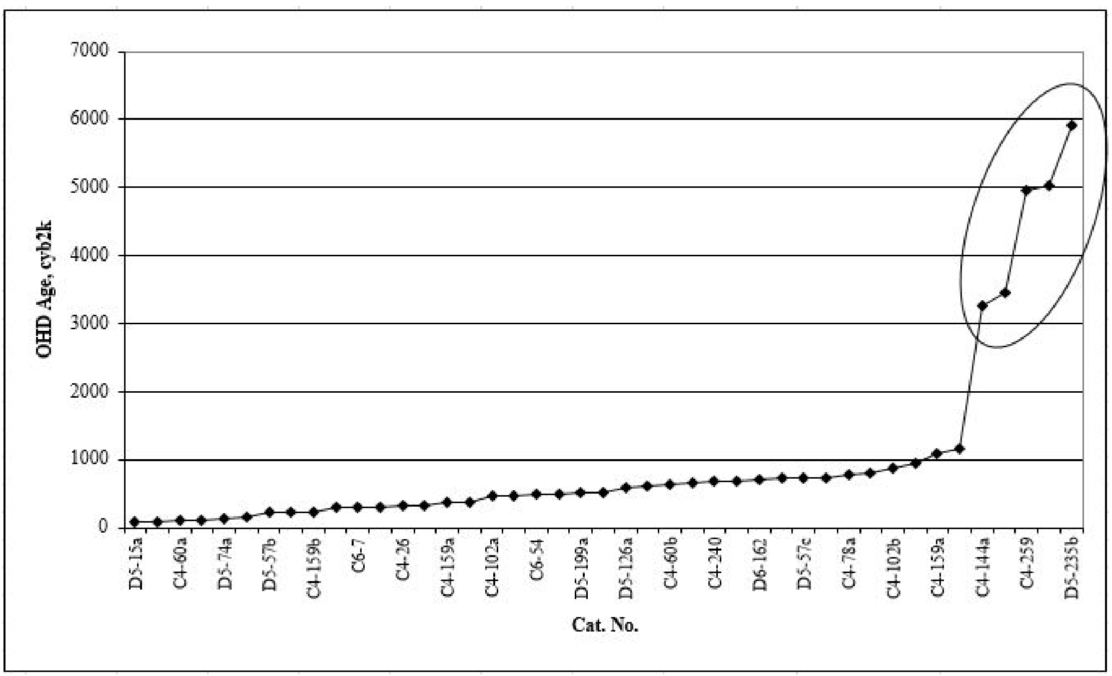

Figure 1. OHD ages on Obsidian Butte glass from CA-SDI-2537, showing points excluded from summary statistics.

Cat. No.	Type	Level, in	R_m, µ	R_{20}, µ	Age, cyb2k	Age SD, yrs	Remarks
C6-7	MODFL	0-3	2.2	1.67	305	72	
E5-144	MODFL	21-24	7.1	5.61	3460	762	Exclude
D6-162	MODFL	27-30	3.2	2.54	707	161	
D5-15a	FLK	0-3	1.1	0.83	76	22	
C4-13b	FLK	0-3	2.8	2.12	495	113	
C4-13a	FLK	0-3	2.2	1.67	305	72	
C4-40b	FLK	3-6	1.1	0.85	80	23	
C4-40a	FLK	3-6	1.5	1.16	149	38	
C4-26	FLK	3-6	2.2	1.71	320	75	
C4-60a	FLK	6-9	1.3	1.01	113	30	
D5-57b	FLK	6-9	1.8	1.40	217	53	
D5-57a	FLK	6-9	1.8	1.40	217	53	
C6-54	FLK	6-9	2.7	2.11	488	112	
C4-60b	FLK	6-9	3.1	2.42	644	146	
D5-57c	FLK	6-9	3.3	2.57	729	164	
D5-57c	FLK	6-9	3.3	2.57	729	164	
D5-74a	FLK	6-9	1.4	1.09	131	34	
C5-310	FLK	6-9	2.1	1.64	295	70	
D5-74b	FLK	6-9	2.8	2.18	525	120	
C4-78b	FLK	6-9	3.3	2.57	729	164	
C4-78a	FLK	6-9	3.4	2.65	774	174	
C4-102a	FLK	12-15	2.6	2.04	458	106	
C4-102b	FLK	12-15	3.6	2.83	878	197	
Ca-123a	FLK	15-18	1.3	1.02	115	31	
C4-123b	FLK	15-18	8.6	6.76	5034	1103	Exclude
D5-126b	FLK	18-21	2.6	2.05	462	107	
D5-126a	FLK	18-21	2.9	2.29	575	132	
C4-144b	FLK	18-21	3.4	2.68	790	179	
D5-126c	FLK	18-21	4.1	3.23	1149	257	
C4-144a	FLK	18-21	6.9	5.44	3255	716	Exclude
C4-159b	FLK	21-24	1.8	1.42	222	55	
C4-159a	FLK	21-24	2.3	1.82	363	85	
C4-159a	FLK	21-24	4.0	3.16	1098	246	
C4-175a	FLK	24-27	2.2	1.74	333	79	
C4-175b	FLK	24-27	3.0	2.37	620	142	
C4-189	FLK	27-30	3.7	2.93	946	213	
D5-187a	FLK	30-33	2.3	1.83	367	86	
D5-187b	FLK	30-33	3.1	2.46	666	152	
D5-199a	FLK	33-36	2.7	2.15	507	117	
C4-240	FLK	39-42	3.1	2.47	671	154	
D5-235a	FLK	42-45	3.1	2.47	672	154	
D5-235b	FLK	42-45	9.2	7.34	5922	1312	Exclude
C4-259	FLK	45-48	8.4	6.71	4947	1098	Exclude

Table 4. Obsidian Butte flakes from inside the shelter.

cyb2k with a standard deviation of 174 years, CV = 0.39. The probable error of the mean is 87 years. These ages do not conform to expectations, and are discussed further below.

Projectile Point Preforms:

Five projectile point preforms were recovered from inside the shelter. The mean age is 422 cyb2k, with a standard deviation of 197 years and a probable error of the mean of 88 years; CV = 0.47. Assuming these are preforms for Desert Series points, the ages again fall in the correct region.

Bifaces:

A single biface was recovered (Cat. No. B4-99), with an age of 221 ± 54 cyb2k.

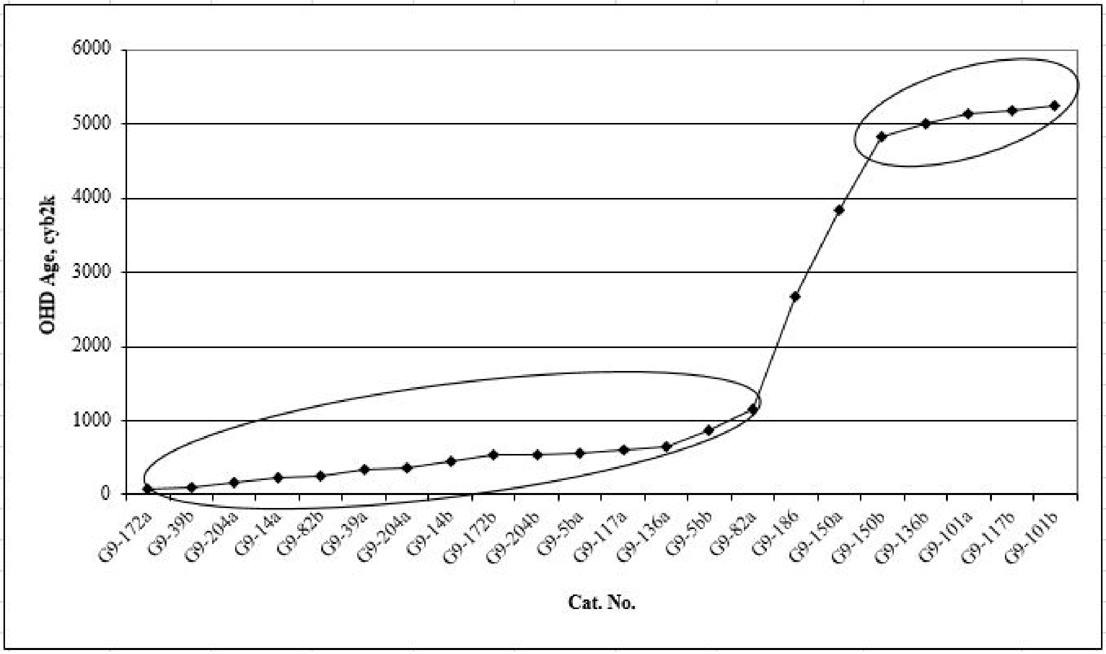

Figure 2. OHD ages on Obsidian Butte material from CA-SDI-2537, showing two plateaus indicating sustained site use.

Projectile Point Blank:

A single blank was recovered from inside the shelter, with an age of 572 ± 131 cyb2k.

Flakes:

Obsidian Butte flakes recovered from inside the shelter are listed in Table 4. Figure 1 shows a plot of the ages vs. catalog numbers (Cat. Nos.), and clearly shows that the five data points marked "Exclude" in Table 4 are anomalous. They may reflect reuse of very old toolstone, or they may have been read on a geologic surface. They are not included in the statistics. The age statistics for flakes from

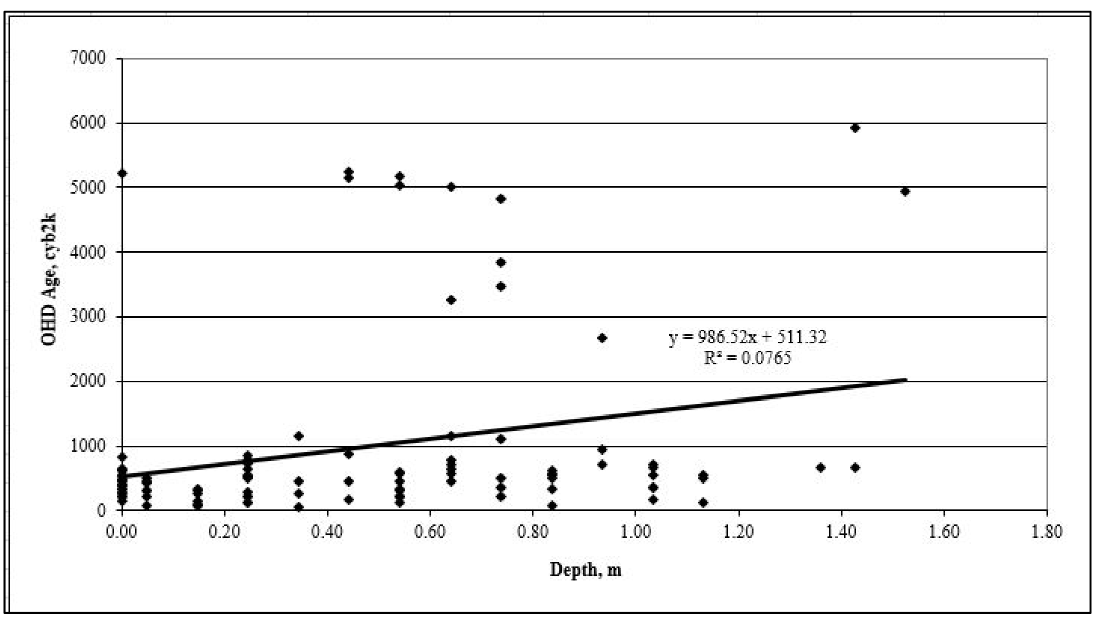

Figure 3. Obsidian Butte OHD ages for CA-SDI-2537 vs. depth, showing effects of extreme turbation. The best fit line has no statistical significance.

Cat. No.	Type	Level, in	R_m, µ	R_{20}, µ	Age, cyb2k	Age SD, yrs	Remarks
G9-14a	FLK	0-3	2.1	1.42	223	53	Late period
G9-14b	FLK	0-3	3.0	2.03	455	105	Late period
G9-39b	FLK	3-6	1.3	0.90	89	25	Late period
G9-39a	FLK	3-6	2.5	1.73	331	80	Late period
G9-5ba	FLK	6-9	3.2	2.24	551	131	Late period
G9-5bb	FLK	6-9	4.0	2.80	860	203	Late period
G9-82b	FLK	9-12	2.2	1.54	262	66	Late period
G9-82a	FLK	9-12	4.6	3.23	1148	271	Late period
G9-101a	FLK	12-15	9.7	6.84	5142	1211	Early period
G9-101b	FLK	12-15	9.8	6.91	5249	1236	Early period
G9-117a	FLK	15-18	3.3	2.33	599	146	Late period
G9-117b	FLK	15-18	9.7	6.86	5178	1229	Early period
G9-136a	FLK	18-21	3.4	2.41	640	157	Late period
G9-136b	FLK	18-21	9.5	6.74	4998	1196	Early period
G9-150a	FLK	21-24	8.3	5.91	3838	926	Exclude
G9-150b	FLK	21-24	9.3	6.62	4818	1162	Early period
G9-172a	FLK	24-27	1.2	0.86	81	24	Late period
G9-172b	FLK	24-27	3.1	2.21	538	135	Late period
G9-186	FLK	27-30	6.9	4.93	2678	657	Exclude
G9-204a	FLK	30-33	1.7	1.22	163	44	Late period
G9-204a	FLK	30-33	2.5	1.79	353	91	Late period
G9-204b	FLK	30-33	3.1	2.22	543	138	Late period

Table 5. Obsidian Butte flakes from outside the shelter, column sample.

inside the shelter are: mean age = 498 cyb2k, standard deviation = 309 years, probable error of the mean = 50 years, and CV = 0.62 (N = 38).

Obsidian Butte flakes recovered from outside the shelter are listed in Table 5. Figure 2 shows a plot of ages, from which it appears there were two occupation stages: an early one (five data points) around 5000 cyb2k, and a later one around 450 cyb2k (15 data points). Two data points are transitional and are excluded from the statistics. For the early use period the statistics are: mean age 5077 cyb2k, standard deviation 1217 years, probable error of the mean 54 years, and CV =0.24 (N = 5). For the later use period the mean is 456 cyb2k, standard deviation 311 years, probable error of the mean is 80 years, and CV = 0.68 (N = 15).

Table 6 shows the flakes collected on the surface outside the shelter. One data point, Cat. No. S84-16, is anomalous and is excluded from the statistics. Mean age is 439 cyb2k, standard deviation is 204 years, probable error of the mean is 46 years, and CV is 0.47 (N = 20).

Chronological Narrative

Figure 3 shows there is no consistent variation of OHD age with depth, confirming the impression of extreme turbation at the site.

Figure 4 shows the plot for the radiocarbon dates at SDI-2537 (MacDonald 1992: 102, Table 5, calibrated and converted to cyb2k). Dates are plotted in ascending order from left to right, and if site use had been uniform, the plot would be a straight line. Periods of intense use, evidenced by many dates, tend to appear as plateaus, while intervals of sparse use are represented by fewer dates and a steeper slope. Examination of Figure 4 shows relatively intense use between 5000 - 4000 cyb2k, between 3000 - 2500 cyb2k, and less than 1000 cyb2k.

For comparison, Figure 5 plots the corresponding OHD ages from Tables 3, 4, and 5 above. The earliest use period is slightly older, between 6000 - 5000 cyb2k and the middle use period is 4800 - 3800 cyb2k. The youngest use period is again less than 1000 cyb2k.

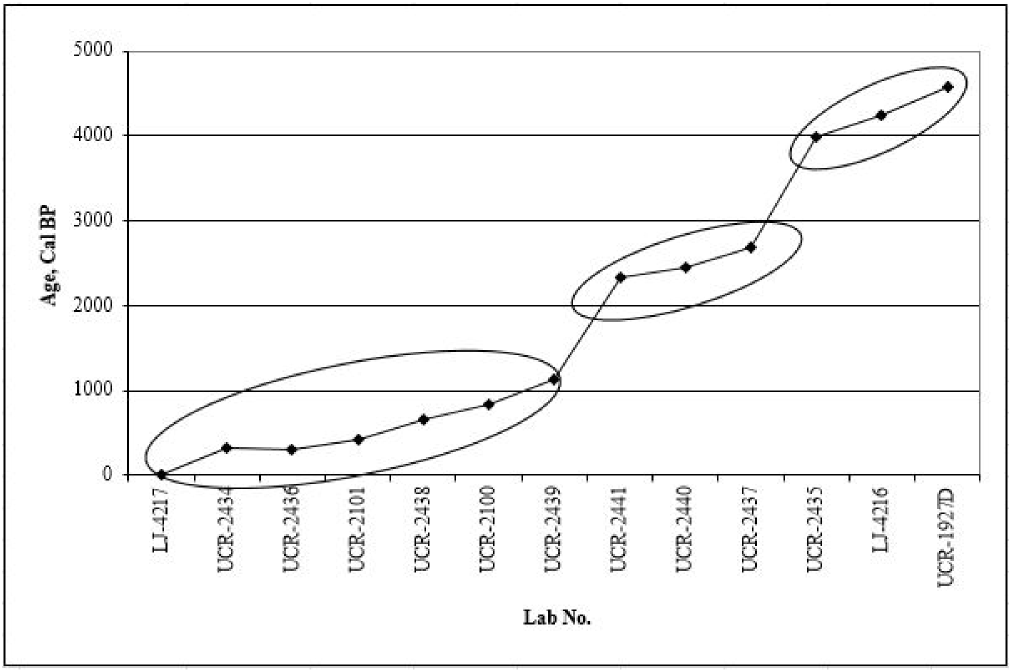

Figure 4. Use-density plot for dates derived from radiocarbon at CA=SDI-2537, showing plateaus indicating periods of sustained use.

Table 7 presents a statistical summary of the radiocarbon and OHD ages for these three use periods. It can be seen that, although there is an offset in ages, it is not statistically significant by t-test.

The slight discrepancy between OHD and radiocarbon dates can be explained by considering what is being measured. Radiocarbon dates represent physical occupation evidence, such as hearths, while OHD dates represent use of toolstone. If the toolstone is being recycled, as would be the case for an exotic obsidian, some of the

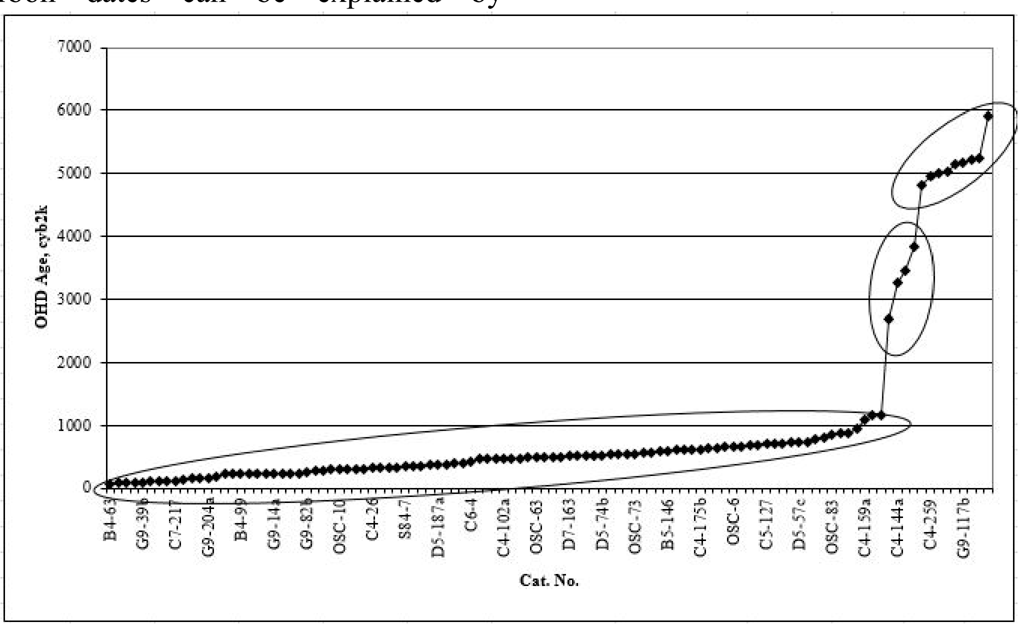

Figure 5. Use-density plot for dates derived from OHD of Obsidian Butte obsidian at CA-SDI-2537, showing plateaus indicating periods of sustained use.

Cat. No.	Type	Level, in	R_m, μ	R_{20}, μ	Age, cyb2k	Age SD, yrs	Remarks
OSC-16	FLK	Surface	1.8	1.18	154	37	
OSC-14	FLK	Surface	2.2	1.44	230	54	
OSC-62	FLK	Surface	2.2	1.44	230	54	
OSC-4	FLK	Surface	2.2	1.44	230	54	
OSC-79	FLK	Surface	2.4	1.58	273	63	
OSC-10	FLK	Surface	2.5	1.64	296	68	
OSC-116	FLK	Surface	2.7	1.77	346	79	
OSC-99	FLK	Surface	2.8	1.84	372	85	
OSC-81	FLK	Surface	2.9	1.90	399	91	
OSC-80	FLK	Surface	2.9	1.90	399	91	
OSC-64	FLK	Surface	3.1	2.04	456	103	
OSC-107	FLK	Surface	3.2	2.10	486	109	
OSC-63	FLK	Surface	3.2	2.10	486	109	
OSC-70	FLK	Surface	3.3	2.17	517	116	
OSC-73	FLK	Surface	3.4	2.23	548	123	
OSC-15	FLK	Surface	3.6	2.36	615	137	
OSC-84	FLK	Surface	3.6	2.36	615	137	
OSC-75	FLK	Surface	3.7	2.43	649	145	
OSC-6	FLK	Surface	3.7	2.43	649	145	
OSC-83	FLK	Surface	4.2	2.76	837	186	
S84-16	FLK	Surface	10.5	6.89	5229	1137	Exclude

Table 6. Obsidian Butte flakes from outside the shelter, surface collected.

hydration ages may represent earlier collection events.

In addition, the hydration rate is based on a single data point and clearly needs refinement with further data. It is probably close to the right value, because the ages for the Cottonwood Triangular and Desert Side-Notched points are in the expected range, but if it is slightly too large it would cause the offset in ages.

The ages of the Dos Cabezas Serrated (DCS) points are an issue as well. This point type is not mentioned in Justice (2002), but is listed on www.projectilepoints.net, which states the type was defined by Wilkie and MacDonald, who assigned the age to 1600 - 800 cal BP. No references are given, so we assume the ages are based on MacDonald's dissertation on CA-SDI-2537 (MacDonald 1992). MacDonald (1992:181ff) describes the points and their provenience, but does not discuss the age attribution. The points were recovered from moderate depths, up to approximately 50 cm below the surface, and Figure 6 shows that the radiocarbon age for that depth is indeed in the 1600 – 800 BP range. However, Figure 3 shows the severe degree of turbation that has affected the obsidian specimens, so that depth is not a good indicator of age for them. (Of course, it was not possible to compute the data plotted in Figure 3 in the 1980s.) Further, the ages determined by OHD ages are younger, 446 ± 174 cyb2k. Given the severe turbation that obviously occurred, it is likely the appropriate age for the DCS type is that computed by OHD.

Radiocarbon			OHD			t-value
Mean age	Std. dev. age	N	Mean age	Std. dev age	N	
617	551	7	451	513	95	0.77
2588	199	3	3308	878	4	1.59
4369	261	3	5169	1226	9	1.84

Table 7. Radiocarbon and OHD age statistics; all ages are in cyb2k

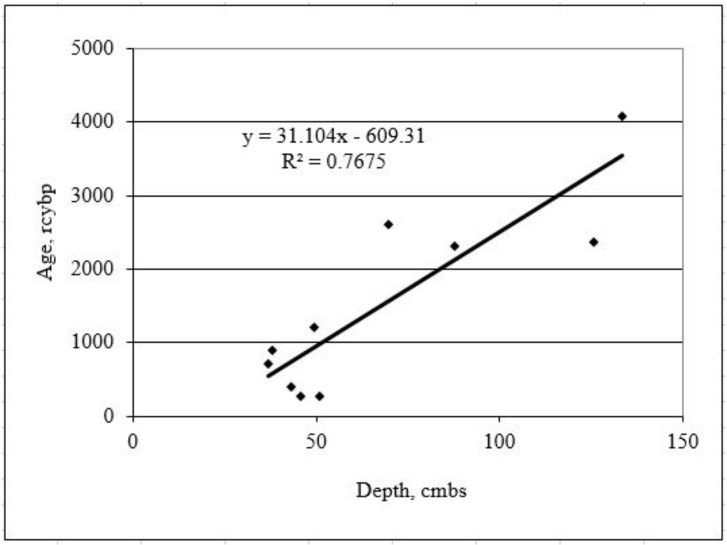

Figure 6. Ages derived from radiocarbon at CA-SDI-2537 vs. depth. Data points are from hearth features only. Despite turbation the ages show reasonable consistency.

Conclusions

In summary, this analysis shows the Indian Hills Rockshelter site experienced a sequence of three occupation or use episodes, for which there is good agreement between radiocarbon-based ages and OHD ages. The ages determined for temporally-sensitive projectile points are as expected, which suggests the temperature parameters for the site are valid, as is the hydration rate computed for the Obsidian Butte source.

The case of the Dos Cabezas Serrated points is of great interest methodologically. The DCS type was originally dated based on radiocarbon association, which was a reasonable assumption at the time. However, now that the obsidian ages can be computed, it is clear that severe turbation of the obsidian specimens had occurred and the DCS points were out of place stratigraphically. Obsidian hydration dating permits directly dating them to the Late Prehistoric period, less than 1000 BP. This was not possible in the 1980s.

As a case study, this analysis also shows the potential of applying the OHD technique, even with an old and previously-intractable data set. The principal difference between the OHD state of the art in the 1980s and at present is that now the physics and chemistry of obsidian hydration are much better understood. In addition, the necessary mathematical models for conducting the OHD analysis are now in place and published, so that OHD analyses become another element of the archaeological chronometric tool box.

Acknowedgements

We thank Meg MacDonald and her team for the hard work of excavating the rockshelter, and for incorporating the obsidian data in a document where it could be accessed for re-analysis some 30 years later. The fact that we can now make sense of the obsidian data is due to progress in the corporate knowledge of obsidian and the hydration process, and is not a criticism of the work done back then.

References Cited

Ambrose, W.R., and C.M. Stevenson (2004) Obsidian Density, Connate Water, and Hydration Dating. *Mediterranean Archaeology and Archaeometry* 4(2):5-16.

Basgall, M.E. (1990) *Hydration Dating of Coso Obsidian: Problems and Prospects*. Paper presented at the 24th Annual Meeting of the Society for California Archaeology, Foster City.

Carslaw, H.S., and J.C. Jaeger (1959) *Conduction of Heat in Solids*, 2nd ed. Clarendon Press, Oxford.

Curran-Everett, L., R.G. Milo, and D. Qiuatt (1991) Micrographic Comparisons of Climate Today Afford Inferences Concerning Past Behavior: An Overview of Data and its Applications from a Study of Chapin Mesa (Mesa Verde National Park) Climate. In *Proceedings of the Anasazi Symposium 1991,* compiled by A. Hutchinson and J.E. Smith, pp. 109-116. Mesa Verde Museum Association, Colorado.

Doremus, R.H. (1994) *Glass Science*, 2nd ed. Wiley Interscience, New York.

Doremus, R.H. (2000) Diffusion of Water in Rhyolite Glass: Diffusion-reaction Model. *Journal of Non-Crystalline Solids* 261 (1): 101-107.

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

Ebert, W.L., R.F. Hoburg, and J.K. Bates (1991) The Sorption of Water on Obsidian and a Nuclear Waste Glass. *Physics and Chemistry of Glasses* 34(4): 133-137.

Friedman, I., and W.D. Long (1976) Hydration Rate of Obsidian. *Science* 191(1): 347-352.

Friedman, I., R.I. Smith, and W.D. Long (1966) Hydration of Natural Glass and Formation of Perlite. *Geological Society of America Bulletin* 77: 323-328.

Hughes, R.E. (1988) The Coso Volcanic Field Reexamined: Implications for Obsidian Sourcing and Hydration Dating Research. *Geoarchaeology* 3(4): 253-265.

Justice, N.D. (2002) *Stone Age Spear and Arrow Points of California and the Great Basin*. Indiana University Press, Bloomington.

MacDonald, A.M. (1992) *Indian Hill Rockshelter and Aboriginal Cultural Adaptation in Anza-Borrego Desert State Park Southeastern California*. Unpublished PhD dissertation Department of Anthropology, University of California, Riverside.

Mazer, J.J., C.M. Stevenson, W.L. Ebert, and J.K. Bates (1991) The Experimental Hydration of Obsidian as a Function of Relative Humidity and Temperature. *American Antiquity* 56(3): 504-513.

Morgenstein, M.E, C.L. Wickett, and A. Barkett (1999) Considerations of Hydration-Rind Dating of Glass Artefacts: Alteration Morphologies and Experimental Evidence of Hydrogeochemical Soil-zone Pore Water Control. *Journal of Archaeological Science* 26(1999): 1193-1210.

Pearson, J. L. (1995) *Prehistoric Occupation at Little Lake, Inyo County, California: A definitive Chronology.* Unpublished MA thesis, Department of Anthropology, California State University, Los Angeles.

Rogers, A.K. (2007) Effective Hydration Temperature of Obsidian: A Diffusion-Theory Analysis of Time-Dependent Hydration Rates. *Journal of Archaeological Science* 34: 656-665.

Rogers, A.K. (2008) Obsidian Hydration Dating: Accuracy and Resolution Limitations Imposed by Intrinsic Water Variability. *Journal of Archaeological Science* 35: 2009-2016.

Rogers, A.K. (2010) Accuracy of Obsidian Hydration Dating based on Radiocarbon Association and Optical Microscopy. *Journal of Archaeological Science* 37: 3239-3246.

Rogers, A.K. (2012) Temperature Correction for Obsidian Hydration Dating, In *Obsidian and Ancient Manufactured Glasses*, edited by I. Liritzis and C.M. Stevenson, eds., pp. 46-55. University of New Mexico Press, Albuquerque.

Rogers, A.K. (2015a) A Method for Correcting OHD Age for Paleo-temperature Variation. *Bulletin of the International Association for Obsidian Studies* 52: 13-20.

Rogers, A.K. (2015b) An Equation for Estimating Effective Hydration Rate of Obsidian from Intrinsic Water Content. *Bulletin of the International Association for Obsidian Studies* 53: 5-13.

Rogers, A.K. (2018) A Computer Program in MatLab for Obsidian Hydration Age Computations. *Bulletin of the International Association for Obsidian Studies* 59: 10-18.

Rogers, A.K. and D. Duke (2011) An Archaeologically Validated Protocol for Computing Obsidian Hydration Rates from Laboratory Data. *Journal of Archaeological Science* 38: 1340-1345.

Schiffer, M.E. (1987) *Site Formation Processes of the Archaeological Record*. University of Utah Press, Salt Lake City.

Schmitt, A.K., A. Martin, D.F. Stockli, K.A. Farley, and O.M. Lovera. (2013) (U-Th)/He Zircon and Archaeological Ages for a Late Prehistoric Eruption in the Salton Trough, California, *Earth and Planetary Science Letters* 252: 260-274.

Schmitt, A.K., A.R. Perrine, E.J. Rhodes, and C. Fischer (2019) Age of Obsidian Butte in Imperial Valley, California, Through Infrared Stimulated Luminescence Dating of Potassium Feldspar from Tuffaceous Sediment. *California Archaeology* 11: 5-20.

Stevenson, C.M., E. Knauss, J.J. Mazer, and J.K. Bates (1993) The Homogeneity of Water Content in Obsidian from the Coso Volcanic Field: Implications for Obsidian Hydration Dating. *Geoarchaeology* 8(5): 371-384.

Stevenson, C.M., J.J. Mazer, and B.E. Scheetz (1998) Laboratory Obsidian Hydration Rates: Theory, Method, and Application. In *Archaeological Obsidian Studies: Method and Theory,* edited by M.S. Shackley, pp.181-204. Plenum Press, New York.

Stevenson, C.M., M. Gottesman, and M. Macko (2000) Redefining the Working Assumptions for Obsidian Hydration Dating. *Journal of California and Great Basin Anthropology* 22(2): 223-236.

West, G.J., W. Woolfenden, J.A. Wanket, and R.S. Anderson (2007) Late Pleistocene and Holocene Environments. In *California Prehistory: Colonization, Culture, and Complexity*, edited by T.L. Jones and K.A. Klar, pp. 11-34. Altamira Press, Walnut Creek, California.

Wright, H.M., J.A. Vasquez, D.E. Champion, A.T. Calvert, M.T. Hangan, M.E. Stelton, K.M. Cooper, C.Herzig, and A. Schriener (2015) Episodic Holocene Eruption of the Salton Sea Rhyolites, California, from Paleomagnetic, U-Th, and Ar/Ar Dating. *Geochemistry, Geophysics, Geosystems* 16: 1198-1210.

Zhang, Y. (2008) *Geochemical Kinetics*. Princeton University Press, New Jersey.

Zhang, Y., E.M. Stolper, and G.J. Wasserburg (1991) Diffusion of Water in Rhyolytic 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.

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