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CONTENTS

NEWS AND INFORMATION

IAOS Annual Meeting

The International Association for Obsidian Studies will hold its annual meeting during the Society for American Archaeology conference in San Francisco, California, April 15-19, 2015. Please see your SAA program for time and location information.

CONSIDER PUBLISHING IN THE IAOS *BULLETIN*

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

CALL FOR NOMINATIONS

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

NOTES FROM THE PRESIDENT

I hope everyone is having a restful (or productive – depending on your personality type) holiday break. I am planning to catch up on a number of lingering tasks before the start of the spring semester. This past summer and fall was full of obsidian-related activities. In early August, I met Steve Shackley in Phoenix to continue my efforts to drag him back out to all of the known Southwestern obsidian sources. I think I have about half of Arizona and just a couple sources in New Mexico left to go. We focused this trip on the San Francisco and Partridge Creek source areas to the west of Flagstaff, and I managed to collect samples from a few additional sources on the scorching drive back into Phoenix. I am hoping that my Japanese colleague (and fellow IAOS member), Dr. Masami Izuho, will be able to join Steve and me to visit the remainder of the major sources in Arizona this coming September.

Photo 1. Steve Shackley (left) and Jeff Ferguson near the Government Mountain obsidian source in Arizona

Speaking of Dr. Izuho, in October, I spent about a week with him and his colleagues and students collecting geologic samples from obsidian sources in Hokkaido, Japan. We were able to visit about five primary sources and even more secondary gravel deposits. The sources are quite impressive, but I will never forget the hospitality. I hope to write up a full account of the trip, with Masami's help, for a future issue of the *IAOS Bulletin*.

Photo 2. The climb to the primary outcrops of the Rubeshibe source in Hokkaido, Japan.

Please make sure to make time for the annual IAOS meeting that will take place during the SAA meeting this April in San Francisco, California. As of the time I am writing this, the exact time and location of the meeting are not yet determined, but we will let you know as this information becomes available. IAOS is sponsoring a symposium titled "Exotic, Lustrous, and Colorful: Obsidian in Symbol, Society, and Ceremony" that is chaired by Robin Torrence and Carolyn Dillian. Despite the Sunday morning time slot, we are anticipating a great session.

Along the lines of symbolic approaches to examining obsidian, I would like to make a quick plug for an edited volume just off the press. *Obsidian Reflections: Symbolic Dimensions of Obsidian in Mesoamerica*

(2014, University Press of Colorado, edited by Marc Levine and David Carballo) includes some great chapters incorporating some purely archaeological as well as ethnographic studies of obsidian that go beyond the function-economic approaches that tend to dominate lithic studies.

Photo 3. Approach to Tokyo with Mt. Fuji in the background.

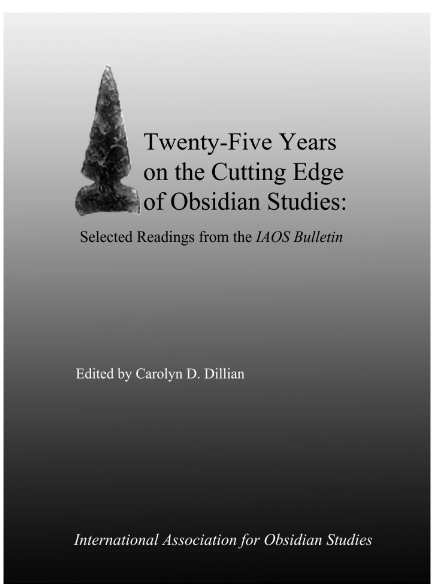
One final important topic to address is upcoming IAOS elections. While I am happy to retain the private jet privileges associated with the IAOS Presidency, it is time to take nominations for my successor. Please send any nominations to fergusonje@missouri.edu. We will conduct the election via email in the near future, and the President-Elect will begin a one-year term as Vice President at the SAA meeting in April and then take the role of President the following year for a 2-year term.

I would like to extend my gratitude to our former President and out-going Vice President Ellery Frahm. It has been a pleasure working with him on IAOS issues for the past year and I hope he will remain involved with future workings of the organization. As usual this organization would not function without the efforts of Carolyn Dillian, Kyle Freund, Craig Skinner, and Anna Steffen. Thanks.

I hope to see everyone in April,

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

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



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

Edited volume now available online!

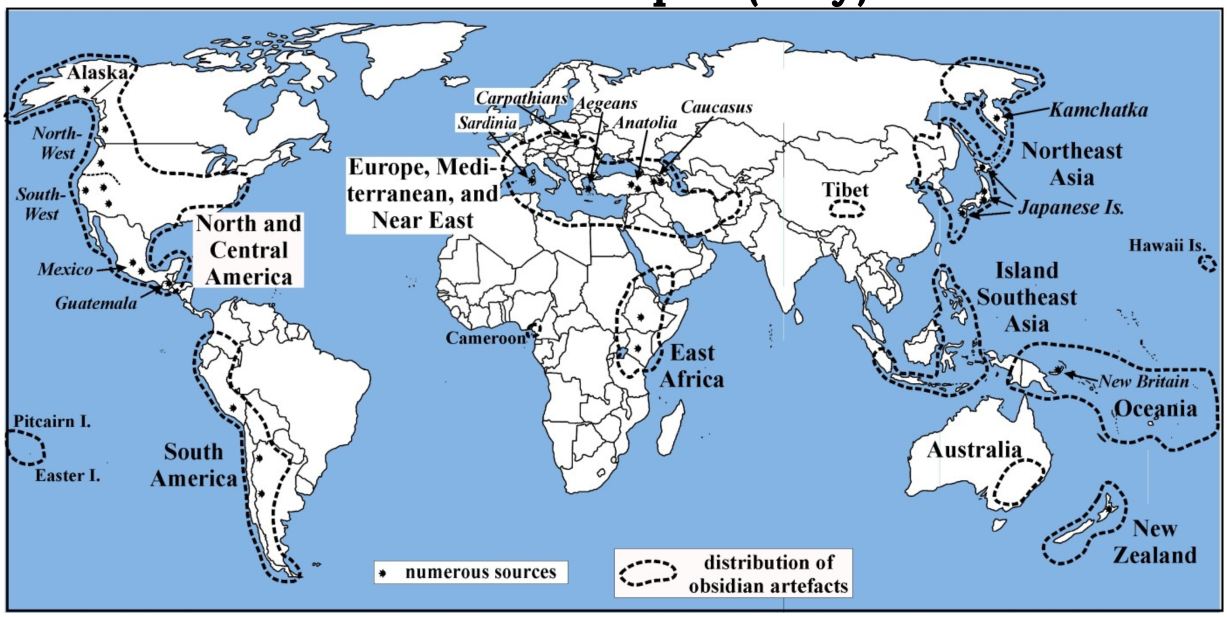
As part of our celebration of the 25th anniversary of the IAOS, we published an edited volume highlighting important contributions from the *IAOS Bulletin.* Articles were selected that trace the history of the IAOS, present new or innovative methods of analysis, and cover a range of geographic areas 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 or to reserve a copy at the SAA meetings in San Francisco.

International Obsidian Conference (1–3 June, 2016)

Dear colleagues, we invite you to participate in the International Obsidian Conference, 1–3 June, 2016 on the island of Lipari (Italy).



The meeting's program will include issues related to different fields of obsidian studies — archaeology, geology, anthropology, and archaeometry. The meeting's venue is the **Regional Aeolian Archaeological Museum "Luigi Bernabò Brea", on Lipari** which is reachable by hydrofoil or ferry from Milazzo, Messina, and Palermo in Sicily, as well as Reggio Calabria and Naples in Italy. Non-stop flights from Rome to Reggio are available for about $140 roundtrip. On Lipari, a range of hotels and residences within walking distance are available, many for $100 or less per night.

The suggested registration fee, depending on financial support, is about **100 € (125 US $) for professionals, and 50 € (65 US $) for students**.

We would appreciate a response about your intention to participate (send it to Y. Kuzmin and R. Tykot; see emails below). Please let us know at the earliest convenience, **preferably not later than 20 December 2014.** We plan to open the meeting's website in early 2015.

Yaroslav Kuzmin (kuzmin@fulbrightmail.org)
Robert Tykot (rtykot@usf.edu)
Akira Ono (onoak@meiji.ac.jp)
Michael Glascock (glascockm@missouri.edu)
Maria Clara Martinelli (mariaclara.martinelli@regione.sicilia.it)

International Association for Obsidian Studies events and obsidian-related sessions at the Society for American Archaeology Annual Meeting, San Francisco, California, USA.
April 15-19, 2015. www.saa.org

Thursday afternoon, April 16, 2015
Poster Session: "Global Studies of Obsidian: Analytical Techniques and Archaeological Interpretations"

Friday afternoon, April 17, 2015
IAOS Annual Meeting. See SAA conference program for exact time and location.

Sunday morning, April 19, 2015
IAOS Sponsored Symposium: "Exotic, Lustrous, and Colorful: Obsidian in Symbol, Society, and Ceremony"

Chairs: Robin Torrence and Carolyn Dillian

Participants and Paper Titles:
Ellery Frahm "Exploring Hominin Cognition via Palaeolithic Obsidian Provisioning, Transport, and Technology"
Theodora Moutsiou "From Raw Material to Symbol of Social Value: Obsidian Movement in the Palaeolithic"
Elizabeth Healey and Stuart Campbell "More than Just a Shiny Stone? The Sources and Significance of Obsidian found in Early State Contexts in the Near East"
Kyle Freund, Robert Tykot, and Andrea Vianello "A Longue Durée Approach to Obsidian Consumption and Social Value in Prehistoric Sicily (Italy)"
Mara Mulrooney, Andrew McAlister, Christopher M. Stevenson, and Alexander E. Morrison "Sourcing Rapa Nui Mata'a from the Collections of Bishop Museum using Non-destructive pXRF"
Rennie Horneman, Carl Lipo, Terry Hunt, and Vincent Bonhomme "Morphometric analysis of Stemmed Obsidian Tools from Rapa Nui (Easter Island, Chile)"
Robin Torrence "More than a Pretty Face? Exploring the Allure of obsidian Valuables from Papua New Guinea"
Pip Rath "Negotiating Social Identity through Practices with Stone"
Marisa Lazzari and Marina Sprovieri "Weaving People and Places: A Long-Term Perspective on Obsidian Circulation and Social Value in NW Argentina"
Karen Holmberg "The Vast and Secret Museum of Chiriqui: Stripping the Sharpness and Beauty from Obsidian"
Jeanne Lopiparo "Crafting Houses for the Living and the Dead: Obsidian Production, Multicrafting, and Household Identities at a Classic Maya Center, Chinikihá, Mexico"
Lucas Martindale Johnson "Preliminary Interpretations of the Reduction Technology and Distribution of Obsidian Cores at Caracol, Belize: Learning to Reconsider Maya 'Eccentrics' and Social Relations of Ritual Objects"
Carolyn Dillian "Evocative Stones: Variable Obsidian Source Use in Northern California"
Steven Brandt "Not Always Shiny and Pretty: The Darker Side of Obsidian in Symbolizing Power, Ethnicity and Inequality in Contemporary Ethiopia"

Discussants: Jeffrey Ferguson; Tristan Carter

A METHOD FOR CORRECTING OHD AGE FOR PALEO-TEMPERATURE VARIATION

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

Abstract

Obsidian hydration dating (OHD), as a method for estimating age of an obsidian artifact based on time-dependent absorption of water, requires making assumptions about the temperature regime to which an artifact has been exposed. The usual assumption is that the parameters which characterize the current temperature regime were valid over the entire time the hydration has been in process. Although the assumption is generally valid for ages in the Holocene, it is questionable for earlier ages. This paper describes a simple numerical method for correcting OHD ages for long-term changes in climatic temperature regimes, based on a spreadsheet on the IAOS website: http://members.peak.org/~obsidian/rogers_paleotemp200K.xls

Introduction

Obsidian hydration dating (OHD) is a method for estimating age of an obsidian artifact based on time-dependent absorption of water. The process is temperature-sensitive, and its application to archaeological dating currently requires making assumptions about the temperature regime to which an artifact has been exposed. The usual assumption is that the parameters which characterize the current temperature regime, whether determined by use of sensors or meteorological records, are a reasonable approximation to ancient temperatures. The assumption is generally valid for ages in the Holocene.

However, data have been published which show significant shifts in ancient temperatures relative to the present (e.g. West et al. 2007), especially for ages before approximately 12-13Kya. For these ages, the prevailing temperatures were significantly cooler than today, and ages computed assuming current conditions will be too young.

This paper describes a simple numerical method for correcting OHD ages for long-term changes in climatic temperature regimes. It represents a significant improvement over the method reported in Rogers (2010a), both in terms of accuracy and in the extent of age coverage. The method as presented here is in terms of reading hydration rims by optical microscopy, and the numerical examples are based on this technique. However, since the paleo-temperature correction method applies to the ages and not to the measurements themselves, it will also work for other measurement methods: measurement of water penetration depth by secondary ion mass spectrometry (SIMS) (Anovitz et al. 1999, 2004, 2008; Stevenson et al. 2004); measurement of diffused water mass by infrared spectrometry (Stevenson and Novak 2011) or by manometry (Ebert et al. 1991); or ages determined by the SIMS/SS technique. (Liritzis and Laskaris 2012, and references cited therein).

Analysis

Temperature Effects:

The key parameter in temperature studies of obsidian is effective hydration temperature (EHT), which is defined as a constant temperature which would yield the same hydration as the actual, time-varying temperature history (Rogers 2007, 2012). The EHT is not equal to the mean temperature, but is generally greater. In an archaeological case, where artifacts are exposed to natural temperatures, EHT depends on three climatic parameters: annual mean temperature, annual temperature variation, and mean diurnal variation. Rigorous computation of EHT requires all three of these parameters, which can be easily determined for current conditions, either from meteorological records or from temperature sensors.

The situation is different for ancient climates. The published temperature summaries such as West et al. (2007) are based on proxy data, and represent changes in mean annual temperatures. Ideally they should be accompanied by similar proxy data showing how annual variation and diurnal variation have also changed over time. Either such proxy data do not exist, or, if they do, they have not been published. However, experience has shown that within any given climatic regime, the *difference* in EHT between two sites is determined largely by the difference in annual mean temperature, with the annual and diurnal variations having almost no effect. Thus, for example, for two sites in the desert, the difference in EHT is largely accounted for by the difference in mean annual temperature. This is not true between climate regimes. In comparing a desert site with a coastal site or a site with significant temperature inversions, both annual and diurnal variations must be taken into account.

For this analysis the assumption is made that differences in EHT at different times at any given site are again largely determined by differences in mean annual temperature. Thus, temperature deltas from proxy data translate directly into differences in EHT, which in turn translate into differences in hydration rate.

The equation describing the temperature dependence of hydration rate is the familiar Arrhenius equation

$$R = A \times \exp(-E/T) \qquad (1)$$

where R is hydration rate, E is activation energy in °K, T is temperature in °K, and A is a pre-exponential called the diffusion constant (Doremus 2002). For this analysis we are interested in the ratio between the rate at some earlier time and the rate at present. If T is the EHT at an earlier time and T_r is EHT at the present, the ratio of rates is

$$k = \exp(-E/T) / \exp(-E/T_r) \qquad (2)$$

or

$$k = \exp(-E/T + E/T_r) \qquad (3)$$

Note that diffusion constant A cancels and has no effect on the ratio. The temperature at an earlier time t_n can be expressed as $T_r + \delta T_n$, where δT_n is the corresponding temperature change based on from proxy data, so the rate ratio k_n becomes

$$k_n = \exp[-E/(T_r+\delta T_n) + E/T_r] \qquad (4)$$

The value k_n applies at a particular time t_n; however, the water which obsidian acquires by hydration is determined by the average hydration rate since the hydration process began (Crank 1975; Rogers 2007, 2012). For an artifact whose age is t_N, the average rate K_N is simply given by the average of k_n for all t_n between zero and t_N:

$$K_N = (1/N)\sum k_n \qquad (5)$$

where the sum is taken between 0 and N. Given a series of δT_n vs. t_n from a proxy record, the corresponding values of k_n and K_N can be computed by an Excel spreadsheet using equations (4) and (5). Note the distinction: k_n is the hydration rate at time t_n, while K_N is the average rate since time t_N.

The author has developed a data table in MS Excel giving temperature deviation δT_n as a function of age t_n, by reading data from West et al. (2007: 17, Fig 2.2) back to an age of 200Kya. Values of δT_n vs. t_n were measured at peaks and valleys and a Stineman

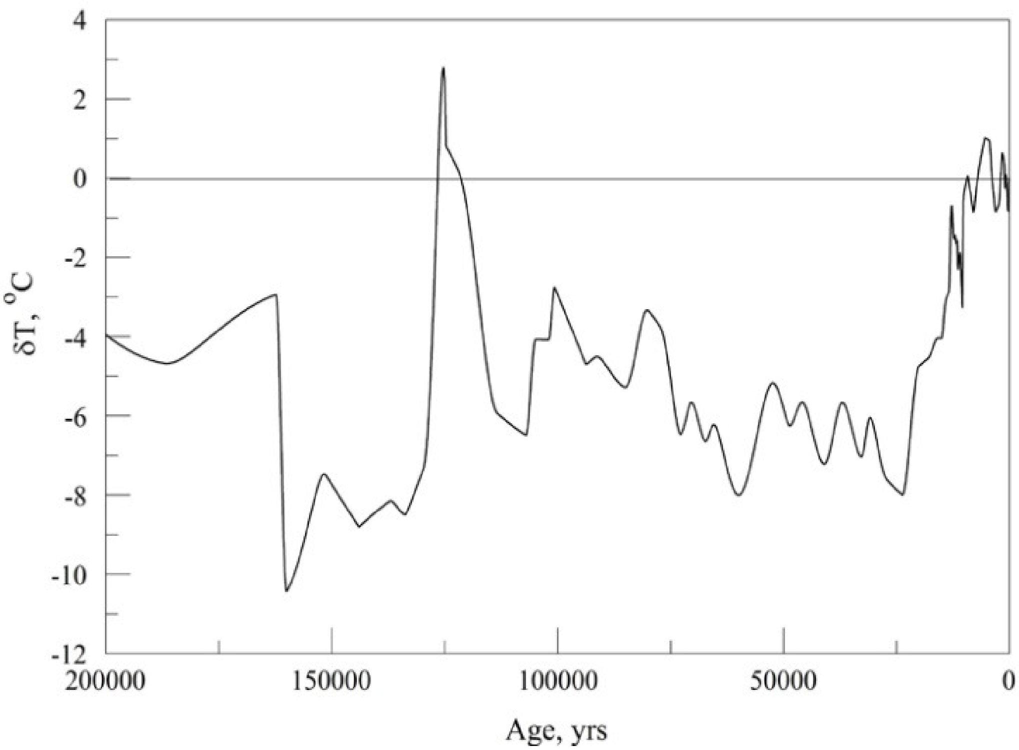


Figure 1. Proxy data for western hemisphere mean temperature relative to present (reconstructed from West et al. 2007). The data set forms the basis of the spreadsheet, and is in increments of 100 years.

fit was used to yield a smooth interpolation (Stineman 1980). Values of δT_n were computed from the interpolation fit at intervals of 100 years. Figure 1 shows the result graphically. There are 2,000 data points in the series, which makes publication unreasonable; an electronic copy can be obtained from the IAOS website, along with instructions for use. Please go to: http://members.peak.org/~obsidian/rogers_paleotemp200K.xls

Corresponding values of k_n and K_N were computed by equations (4) and (5), and are shown in Figure 2. A table of computed values is included in the online spreadsheet.

Examination of Figure 2 shows that the paleo-temperature correction effect is only significant for ages prior to about 12 - 13Kya. Thus, including it in age computations in the Holocene is probably not necessary. However, for ages prior to the last glacial maximum, around 25Kya, the correction is highly significant and can add nearly 40% to the age computed based on current conditions.

Age Computation:

The general equation for age based on obsidian hydration is

$$t = r^2/K \tag{6}$$

where t is age, r is either hydration rim or diffused water content, and K is hydration rate (Doremus 2002). Both r and K must be for the same EHT. The rate K is a function of temperature, per equation (1), and is the average rate over the age of the artifact (Crank 1975; Rogers 2007, 2012). As shown by Figure 2, K is essentially constant for $t < \sim 12$Kya. However, for $t > \sim 12$Kya, K varies because ancient climatic temperature regimes were different from today.

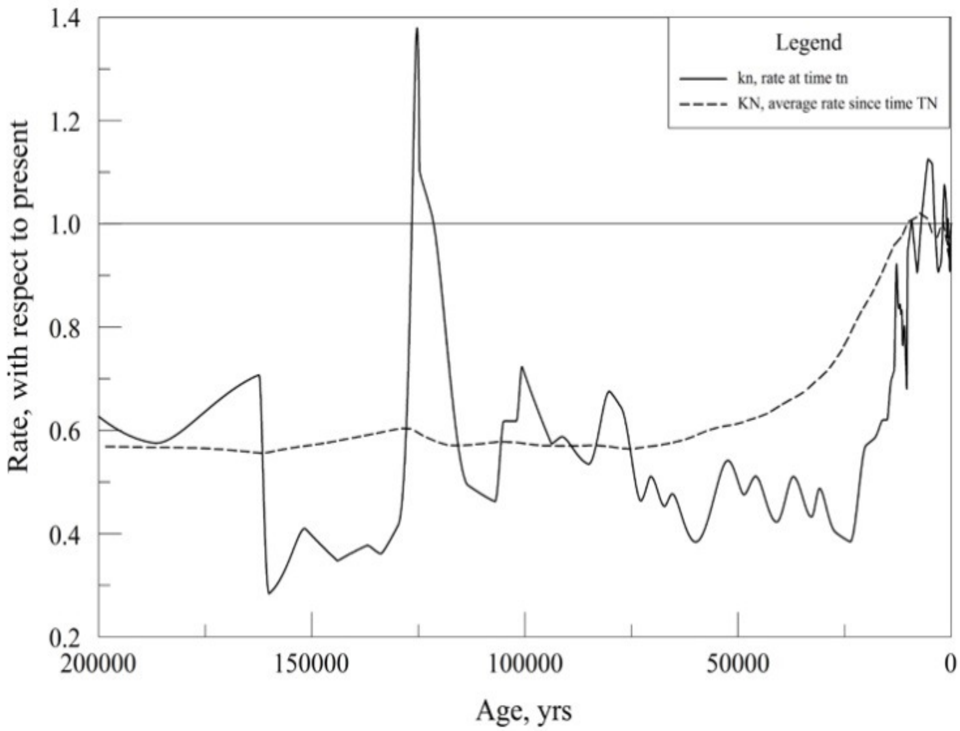


Figure 2. Hydration rates relative to present conditions. The curve for k_n (solid line) shows the hydration rate that would apply within any century in the past 200,000 years. The curve for K_N (dashed line) shows the average hydration rate from time t_N to the present. In both cases the hydration rates are relative to that at present conditions.

The question is how to compute t when K is itself a function of time. The hydration rate K(t) can be expressed as a product of two quantities, the present $K = K_r$ (a constant), and a time-varying function f(t),

$$K(t) = K_r \times f(t), \quad (7)$$

so that

$$t = r^2/[K_r \times f(t)] \quad (8)$$

If we define the age correction factor F(t)=1/f(t), then

$$t = (r^2/K_r) \times F(t) \quad (9)$$

which is the same as saying

$$t = t_r \times F(t) \quad (10)$$

where t_r is the age computed from current conditions.

Since F(t) is a table look-up, there is no way to compute t as a closed-form solution from equation (9) or (10). However, there is a straight-forward method for obtaining a solution. Equation (9) can be rearranged as

$$(r^2/K_r) = t/F(t) \quad (11)$$

The left-hand side of the equation is a constant, equal to the age computed for current conditions. The right-hand side is not constant but is a series of increasing values; the value of t where the two are equal is the corrected age. If the value falls between two age increments, the final age can be obtained by interpolation. Figure 3 shows the process graphically for a notional case where rim=15.6μ, rate=0.005μ^2/yr, activation energy =10,000°K (a nominal value, per Friedman

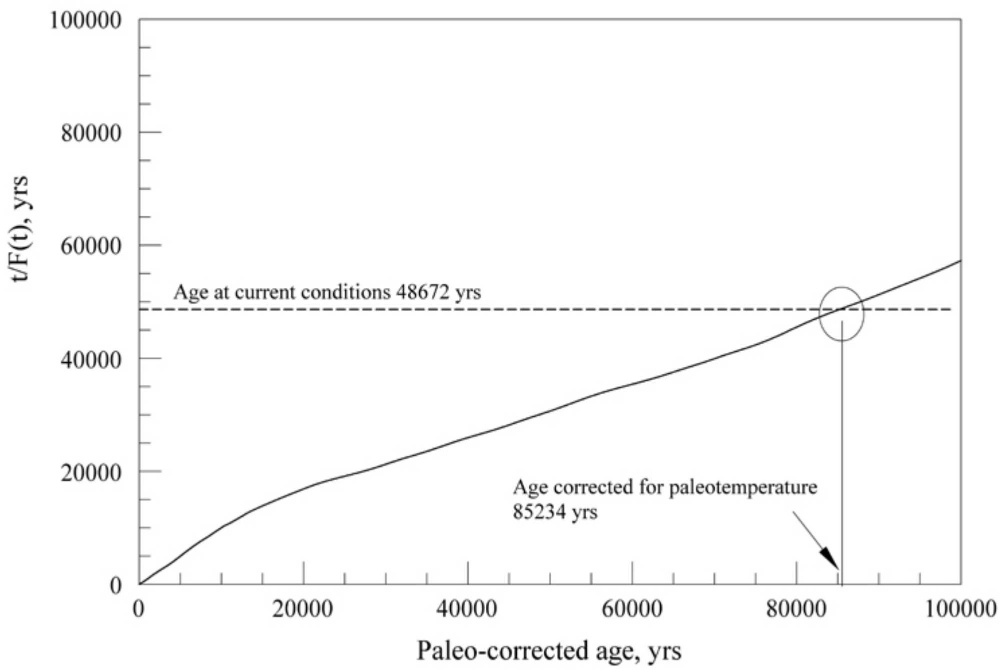


Figure 3. Graphical view of paleo-age computation, showing an example for a hydration rim of 15.6μ, and a hydration rate of $0.005\mu^2$/yr at 20°C. The age assuming current conditions is computed to be 48672 years (dashed line). The solid line is the function t/F(t), from column G of the spreadsheet. The intersection of the two lines gives the age with paleo-temperature correction.

and Long 1976), and the reference temperature is 20°C.

The computation can be easily performed using MS Excel, by creating a column which computes the value of t/F(t) for each age increment (column G on the spreadsheet on the IAOS website). The column can be inspected visually for the age where equation (11) is satisfied. Alternatively, a column can be added which makes the test

$$\text{abs}(t/F(t) - r^2/K_r) < 50 \qquad (12)$$

and enters 0 if it is false, 1 if true. This makes it easy to spot where the condition is satisfied. This test is included in column H of the spreadsheet on the website.

If the age falls between two increments, as it usually does, the age estimate can be refined by a simple linear interpolation. Suppose the age based on current conditions is T_c; the paleo-corrected ages in column A which bracket the solution to equation (11) are t_n and t_{n+1}; the corresponding values of t/F(t) in column G are T_n and T_{n+1}. The interpolated value of paleo-corrected age is then

$$\text{age} = t_n + (t_{n+1} - t_n)\times(T_C - T_n)/(T_{n+1} - T_n) \qquad (13)$$

or, since the spreadsheet uses 100 year increments,

$$\text{age} = t_n + 100 \times (T_C - T_n)/(T_{n+1} - T_n) \qquad (14)$$

A simple linear interpolation is appropriate since equation (11) is very close to being linear, as can be seen in Figure 3.

Example

Suppose an artifact has been recovered which exhibits a hydration rim of 14.0μ when corrected to an EHT of 20°C. The activation energy is assumed to be 10,000°K. Suppose further that the obsidian source is a slow obsidian with a hydration rate of $0.006\mu^2$/yr.

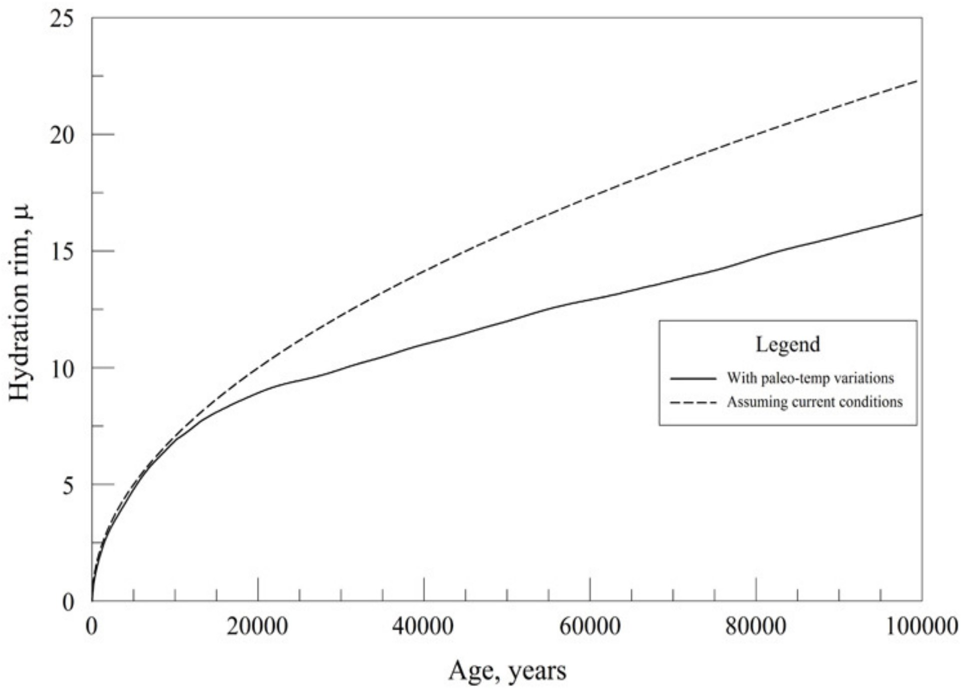


Figure 4. Comparison of hydration rim growth with paleo-temperature changes (solid line) and growth that would have been observed had current temperature conditions prevailed for the last 100,000 years (dashed line).

Equation (6) then yields an age at current conditions of 32667 yrs. This is greater than 13,000 yrs, so a paleo-correction is needed. Accessing the spreadsheet on the IAOS website, entering the hydration rim and rate, and comparing column H with column A shows that equation (11) is satisfied between the ages of 53,700 and 53,800 yrs (column A). The corresponding values of T_{n+1} and T_n (from column G) are 32677 and 32624 yrs, respectively. Performing the interpolation per equation (12) yields a paleo-corrected age of 53705 yrs. Notice the extent of the paleo-correction, which amounts to about 21,028 years; if the paleo-correction had not been made, the computed age would have been nearly 40% too young.

Sources of Uncertainty

Errors affecting the computation of OHD dates have been extensively analyzed and methods to control them and quantify residual effects discussed (Rogers 2008, 2010b). The age correction method described here is subject to five additional sources of uncertainty. First, the validity of the paleo-temperature curve for the locale of interest must be established in each case. The data on which this analysis is based are applicable for the general western hemisphere, but should be verified before being applied in other areas such as East Africa.

Second, some aspects of the morphology of the temperature curve are uncertain, especially high-frequency (i.e. rapid) variations deep in the past. For recent dates, back to a few thousand years, high-frequency data are available from tree-ring studies; for much earlier times they are not, yet it is likely that rapid changes occurred then too. Rapid change could significantly influence OHD, especially if there were large, short-term increases in temperature (“spikes”) which are not visible in proxy data. Since temperature increases affect OHD more than temperature decreases, such spikes would lead to a higher EHT than expected. The more rapid hydration would lead to a thicker rim and hence the computed age would be somewhat too old. For the purposes of analysis, the overall effect of short duration spikes is assumed to be negligible.

The third issue is the behavior of the annual and diurnal variation through time. The present analysis assumes they have been invariant, which is only approximately true. In particular, higher mean temperatures may cause higher annual or diurnal variation, but the effect has not been quantified. In the absence of other data, uniformity is all that can be assumed.

Fourth, the method of creating a smooth curve (called interpolation) can affect accuracy. Interpolation methods considered here were step-wise, linear, cubic spline, and Stineman. The stepwise interpolation tends to give large errors at places, while the cubic spline tends to overshoot or create spurious oscillations. The linear interpolation creates large errors at the midpoints between data points. The Stineman interpolation is advantageous because it passes through the known data points and matches the slope at those points; further, the method never causes overshoot or introduces spurious oscillations (Stineman 1980). For these reasons the Stineman interpolation was used here, implemented in a software package on the PC known as PSI-Plot ® produced by PolySoftware International, Inc.

Finally, the accuracy of the linear interpolation used to compute the final age estimate (equation 14) depends on the linearity of the data set being interpolated. The general approach would be to use a cubic spline fit, which is implemented in many numerical analysis codes; however, inspection of Figure 3 shows the curve is highly linear and a much simpler linear interpolation should suffice. A numerical analysis of errors for ages around 50,000 years gives the error in the interpolation process as $> \pm 25$ years, which is adequately accurate in light of the other uncertainties inherent in OHD.

Overall, the previous estimate that EHT can be inferred to an accuracy not much better than ±1°C, 1-σ, still seems reasonable (Rogers 2007, 2012). In actual application of this method, it is recommended that the paleo-temperature curve be carefully reviewed, and modified if necessary to accommodate local proxy data.

Conclusions

As Figure 1 shows, temperature regimes have changed through time, with a notable negative excursion around the last glacial maximum, approximately 25Kya. Since obsidian hydration is a temperature-sensitive process, one would expect major sustained temperature excursions to affect any ages computed by OHD methods; examination of Figure 2 shows that, for ages greater than 13Kya, a correction is indeed needed.

This conclusion is reinforced by Figure 4, which compares the growth of the hydration rim for two cases. The dashed line shows growth as it would be observed if the current temperature conditions had prevailed for the past 100,000 years, and the solid line shows rim growth as affected by the temperature profile of Figure 1.

As new temperature proxy data become available they can be incorporated in the spreadsheet, replacing the current data. Further, if the archaeologist has reason to believe the obsidian being studied has an activation energy other than 10,000°K, inserting the preferred activation energy into the spreadsheet (cell B4) will modify the age correction accordingly.

The method described here provides a relatively straight-forward way to compute the paleo-corrected age, using an MS Excel spreadsheet. For those who have access to and knowledge of MatLab, a set of code has been developed which performs the entire process; the code can be obtained by contacting the author.

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PITCHSTONE: THE POOR COUSIN OF OBSIDIAN?

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Introduction

Having just received the IAOS Bulletin No. 51 – which turned out to be as interesting as ever – I noticed a small note on an upcoming obsidian conference on the island of Lipari, Italy. According to the conference note, this event is going to encompass "archaeology, anthropology, geology, geochemistry, archaeometry, etc.," and it was accompanied by an interesting map, showing the world's obsidian outcrops or zones.

Having worked extensively on the geological and archaeological aspects of Scottish pitchstone with geologist John Faithfull, the Hunterian Museum, University of Glasgow, I immediately noticed that the map did not include the Scottish pitchstone outcrops (Ballin 2006, 2008, 2009a, 2009b, 2011b, 2013; Ballin and Faithfull 2009; Ballin and Ward 2008; Ballin et al. 2008). I therefore wrote to Dr. Kuzmin from the Sobolev Institute of Geology and Mineralogy, Russia, who compiled the map, suggesting that it might be relevant to include these Scottish sources on the map. The response was that "... we only study pure obsidian."

This is in no way meant as criticism of Dr Kuzmin, for whom I have the greatest respect, but I thought that his response may represent a generally held view amongst obsidian researchers, and that it could therefore be used as the starting point of a brief discussion of an urgent question: Is there any sensible reason for the exclusion of pitchstone from the general discussion of obsidian, or from aspects of obsidian research?

Geological Aspects

Obsidian and pitchstone are both defined as being forms of acid volcanic glass, but first and foremost by containing more or less water. In Ballin and Faithfull (2009: 5), the authors wrote:

> Pitchstone is glassy, usually silica-rich, igneous rock with a characteristic lustre resembling that of broken pitch. Pitchstones are generally held to be hydrated equivalents of obsidians, although the usage of both terms [...] has often been imprecise (cf Pellant 1992).
>
> The International Union of Geological Sciences has recently published a comprehensive nomenclature scheme for these and other igneous rocks (Le Maitre 2002). Here, the term pitchstone is restricted to hydrated glassy rocks (typically 3–10% H2O), while obsidians are nearly anhydrous (<1% H2O). Most pitchstones have >5% H2O, and most obsidians <0.5%.

Some definitions suggest that obsidian is pure, whereas pitchstone contains crystalline inclusions, but this statement is so overly general that it must be characterized as less than helpful. Some rare obsidians (low water content) contain phenocrysts, spherulites or crystalites, whereas some pitchstones (high water content) are entirely aphyric. Although the higher water content frequently gives pitchstone a tar-like lustre (thus its name), whereas obsidian generally has a highly vitreous lustre, it may be almost impossible to distinguish, on the basis of hand-samples, between the purest aphyric pitchstones such as some of the material from the 'greater' Corriegills district on the Isle of Arran, Scotland (Ballin and Faithfull 2009) and common obsidian (see Figures 1-2).

Figures 1 and 2. Pitchstone artefacts from Early Neolithic Auchategan in Argyll (Ballin 2006) and Late Neolithic Barnhouse on Orkney (Ballin 2013).

In terms of the scientific distinction between the two forms of volcanic glass, the main difference is clearly the content of more or less water. Due to the low water content of obsidian, it is possible to date archaeological obsidian directly by the application of obsidian hydration, which is based on the fact that obsidian, when fractured, starts absorbing water at a rate characteristic of specific obsidian sources (for details, see Renfrew and Bahn 1996: 150). It is still uncertain whether archaeological pitchstone can be dated in the same manner, but the considerably higher water content of pitchstone, generally up to 10 times as much as that found in common obsidians, may rule out hydration dating of pitchstones (geologist Jeremy Preston, University of Aberdeen, pers. comm.).

In terms of geological sourcing, it is possible to define the geological provenance of archaeological pitchstone by the application of the same methods as those used to source archaeological obsidian.

As readers of the *IAOS Bulletin* will know, much obsidian research has focused on hydration dating and the application of this approach, and it appears that the main reason for excluding pitchstone from the wider obsidian family may be the fact that it might not be possible to date it archaeologically in this manner.

Archaeological Aspects

In archaeological terms, obsidian and aphyric or lightly prophyritic pitchstone share many attributes:

- The general appearance is more or less the same: black and glassy, with obsidian being slightly more vitreous than pitchstone.
- Excellent flaking properties, allowing the production of long, slender, thin blades and microblades.
- Excellent (super-sharp) cutting-edges.
- In prehistoric time, both were highly valued for functional as well as symbolic reasons, and both were therefore traded across extensive geographical areas, through complex exchange networks (Figure 3).

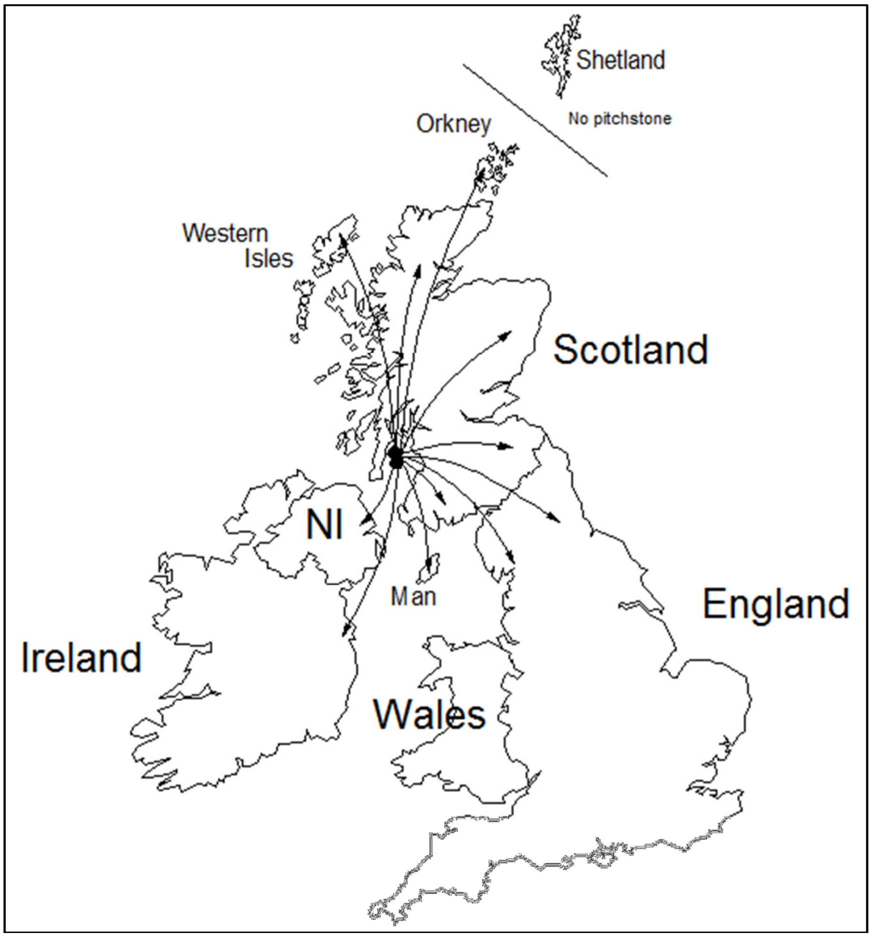

Figure 3. The distribution of archaeological pitchstone across northern Britain from the Isle of Arran in the Firth of Clyde, central Scotland. The only part of northern Britain where pitchstone artefacts have not been recovered is Shetland, where the import/export policy in Neolithic times appears to have been 'nothing in/nothing out' (Ballin 2011). The distance from Arran to Orkney is c. 400km.

In archaeological contexts, obsidian and pitchstone consequently behave very much in the same manner, and they frequently provide the same information, such as prehistoric territorial structures and exchange networks.

Conclusion

To summarize the case: In my view the only significant geological difference between obsidian and pitchstone (formed in the same geological environment by the same geological processes) is that pitchstone contains more water than obsidian, and that it therefore probably will not allow pitchstone artefacts to be dated by hydration dating. Archaeologically, the two raw materials behave very much in the same manner, and I suggest that we deal with the question as to whether pitchstone should be accepted into the wider obsidian family by exposing pitchstone to the Duck Test: as the American poet James Whitcomb Riley (1849-1916) said "...if it looks like a duck, swims [or walks] like a duck, and quacks like a duck, then it probably is a duck." Basically, apart from pitchstone's higher water content, it is an obsidian (or at least a first cousin; see definitions above), and when discussing the extensive prehistoric obsidian exchange networks in the Old World as well as in the Americas, Scottish pitchstone may have a contribution to make.

Author's Note

Apart from the works of Pellant and Le Maitre, all the papers cited here are freely available on my Academia page: http://independent.academia.edu/TorbenBjarkeBallin

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

1. Develop standards for analytic procedures and ensure inter-laboratory comparability.
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