IAOS

International Association for Obsidian Studies

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International Association for Obsidian Studies

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President-Elect	Rob Tykot
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NEWS AND INFORMATION

NEWS OR NOTES TO SHARE?

The IAOS *Bulletin* is happy to publish lab news, research notes, or brief announcements for members at no cost. Please send items to IAOS.Editor@gmail.com with the subject line "IAOS News."

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!

SAA Paper Abstracts due September 10, 2015

Abstracts for the 2016 annual meeting of the Society for American Archaeology will be due on September 10, 2015. The International Association for Obsidian Studies will sponsor sessions that focus on obsidian. Though sponsorship rarely involves financial support, IAOS sponsorship is indicated in the SAA meeting program. Sessions that the IAOS has sponsored in previous years have included themes such as social or cultural meaning of obsidian, analytical methods for characterization or dating, prehistoric and historic lithic technologies, quarries, trade, and regional syntheses. If you are proposing a session and would like to inquire about IAOS sponsorship, please contact IAOS President, Jeff Ferguson at fergusonje@missouri.edu.

NOTES FROM THE PRESIDENT

The IAOS has had an eventful past few months with a productive membership meeting and a great sponsored session at the Society for American Archaeology Meetings in San Francisco in April, and some newly elected officers. I hope summer fieldwork is safely underway and many of you are reading this while lounging about on a shaded veranda as your field crews sweat through the afternoon's labors.

The IAOS sponsored session at the SAA meetings in San Francisco was a particularly well attended session, especially for the dreaded Sunday morning slot. Under threats from the SAA to forcibly remove us from the room if we were even a minute over the allotted time, the session co-chairs Carolyn Dillian and Robin Torrence kept the entire 4-hour session on time. The papers covered a wide variety of different approaches to symbolic aspects of obsidian, including an interesting paper by Steve Brandt on the low social status ascribed to some of the last remaining stone tool-using hide scrapers in Ethiopia.

The IAOS meeting was attended by only about 10 members, but many may have given up trying to find the room as I almost did after 15 minutes of wandering narrow abandoned hallways. Hopefully we can draw a larger crowd next year despite the lures of Disney. We discussed the possibility of free student memberships (something I have supported for many years) and the possibility of hosting another booth in the exhibit hall. We might team up with another group (such as PQMIG) to lower the cost. If anyone has suggestions for future IAOS activities please let me know at fergusonje@missouri.edu.

The new officers were also announced at the meeting. There were four candidates for President and each one had at least 15 percent of the vote. Rob Tykot won the election for President and will serve this year as the Vice President/President Elect until taking over at the IAOS meeting next April in Orlando. Matt Boulanger was elected as the Treasurer/Secretary and has already taken over the reins from outgoing officer Kyle Freund. Kyle has completed many years of dedicated service to IAOS and I would like to thank him for his hard work.

Please remember to submit your research to our IAOS Bulletin editor Carolyn Dillian for publication in the Bulletin. This is a great place to submit your SAA papers. IAOS.Editor@gmail.com

I hope everyone has a safe and productive summer. I am off to Colorado for fieldwork in August and then again to visit obsidian sources in New Mexico and Arizona in September and October.

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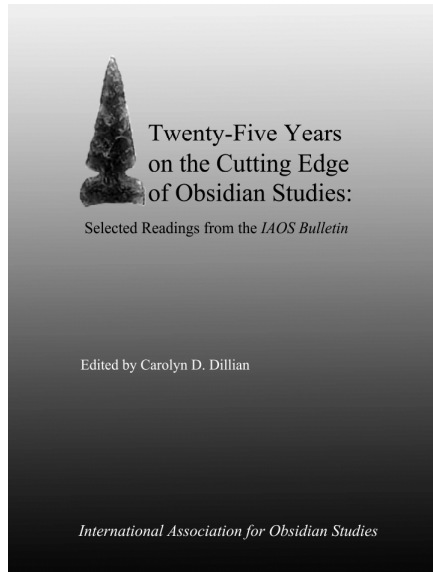
Twenty-Five Years on the Cutting Edge of Obsidian Studies: Selected Readings from the IAOS Bulletin

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.

THE IAOS .PDF LIBRARY

IAOS Webmaster, Craig Skinner, has begun to assemble an ever-expanding collection of obsidian-related full-text articles, reports, monographs, papers, theses, and dissertations, all in Adobe Acrobat (.pdf) format. If you have PDFs that you'd like to contribute to the new PDF library, he would very much like to hear from you! To add a reference to the library, simply send an email to cskinner@obsidianlab.com, write "IAOS LIBRARY" in the subject line of the email, and attach the PDFs that you'd like to contribute. Check back often for new additions. The latest papers were added in May 2015! The library can be accessed by going to http://members.peak.org/~obsidian/library_index.html

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).
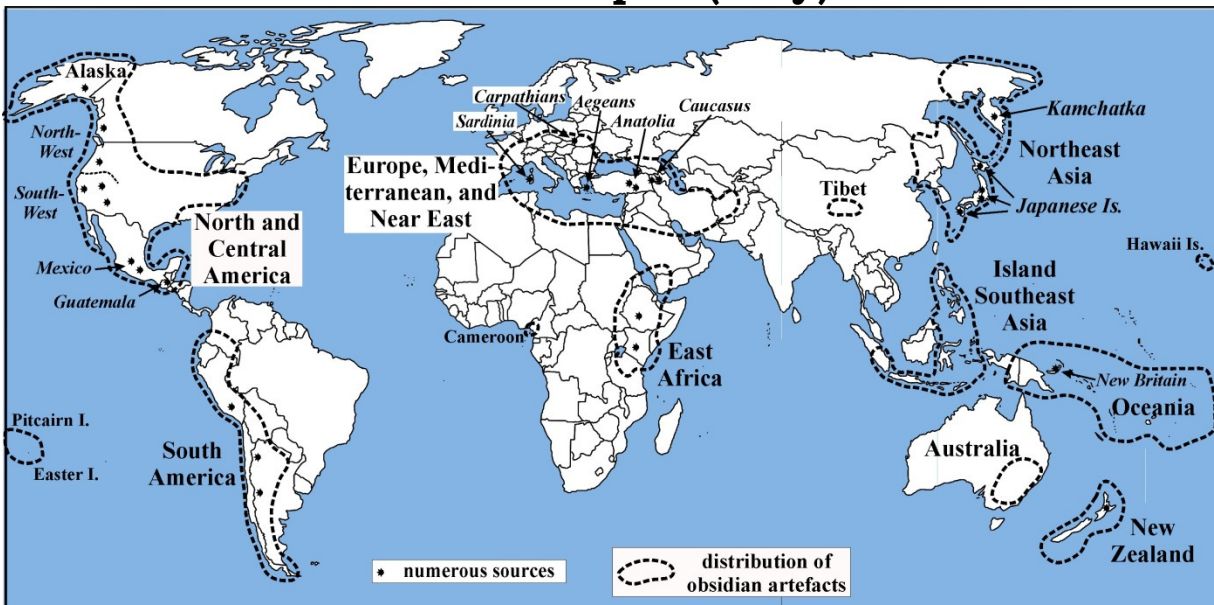
The meeting's program will include issues related to different fields of obsidian studies — archaeology, geology, anthropology, and archaeometry. The meeting's venue is the **Regional Aeolian Archaeological Museum "Luigi Bernabò Brea", on Lipari** which is reachable by hydrofoil or ferry from Milazzo, 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**.

The website for the conference is now available. Please go to:
http://rtykot.myweb.usf.edu/Obsidian%202016/

We are now ready to accept your suggestions about the sessions and topics; please contact the Organizing Committee.

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AN EQUATION FOR ESTIMATING HYDRATION RATE OF OBSIDIAN FROM INTRINSIC WATER CONCENTRATION

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Maturango Museum

Abstract
Use of obsidian hydration for archaeological chronologies requires, among other data, the determination of a hydration rate. This paper suggests a preliminary equation relating intrinsic water content and temperature to hydration rate for obsidian, in a form suitable for use with either water mass increase or optical measurement of hydration depth. If intrinsic water content is measured, either by IR spectrometry or by gravimetry, the hydration rate can be computed for any desired EHT (which must still be computed separately). The resulting equations are consistent in form with previously-published rate equations (Zhang et al. 1991; Zhang and Behrens 2000), although the numerical coefficients are different. The equations give reasonable results for archaeological temperatures, but are based on a very small data set and should therefore be used with caution.

Introduction

Use of obsidian hydration for archaeological chronologies requires, among other data, the determination of a hydration rate. The hydration rate, in turn, is known to be determined principally by the intrinsic water content of the obsidian (many references, e.g. Karsten and Delaney 1981; Karsten et al. 1982; Stevenson et al. 2000; Zhang et al. 1991; Zhang and Behrens 2000). Geochemical studies have led to equations for the hydration rate of obsidian in terms of temperature, pressure, and intrinsic water content (Zhang et al. 1991; Zhang and Behrens 2000) for temperatures near the glass transition temperature. However, they do not extrapolate correctly to archaeological temperatures.

This paper suggests a preliminary equation relating intrinsic water content and temperature to hydration rate for obsidian, in a form suitable for use with either measurement of water mass increase or optical hydration depth. If intrinsic water content is measured, either by IR spectrometry or by gravimetry, the hydration rate can be estimated for any desired effective hydration temperature (EHT).

The analytic approach was, first, to develop the functional form of the equation from measurements of water mass increase in obsidian, based on data published by Stevenson and Novak (2011); since the mass increase and the depth of penetration are two aspects of the same phenomenon, the general form of the model should be similar. The second step was to adapt the model to optical measurement by adjusting the numerical value of the parameters, based on data from the obsidian flows in the Coso volcanic field in Inyo County, California.

Physics of Hydration Process

The term "obsidian hydration" describes the process by which water is absorbed by obsidian, a rhyolitic glass (Doremus 2002; Anovitz et al. 2008). As hydration proceeds, atmospheric water penetrates the glass matrix, causing a mass increase and also causing formation of a stress zone between the hydrated and unhydrated volumes. A fraction of the water molecules reacts with atoms of the glass matrix and form hydroxyl ions (OH^-) bound to the matrix (Silver et al. 1990); "total water", as used below, is the sum of molecular

water and hydroxyl ions, all expressed as weight percent (wt%).

Three general classes of methods have been proposed for measuring obsidian hydration, the first and most direct being measurement of water mass increase or loss vs. time (Ebert et al. 1991; Stevenson and Novak 2011). This is the most physically fundamental method of measuring hydration, and has a long history. Methods employed for such measurements have been mass loss on heating (e.g. Ebert et al. 1991), IR transmission spectrometry (e.g. Newman et al. 1986), and IR photo-acoustic spectrometry (e.g. Stevenson and Novak 2011). It has been shown that the process of water mass increase is a function of temperature, pressure, and openness of the glass matrix as measured by intrinsic water concentration. Mass gain or loss proceeds proportional to t^n where t is time and n is an exponent lying between approximately 0.5 and 0.6 (Stevenson and Novak 2011).

A second method is direct determination of water penetration depth by measuring the H^+ profile (Anovitz et al. 1999, 2004, 2008; Riciputi et al. 2002; Stevenson et al. 2004), via Secondary Ion Mass Spectrometry (SIMS) or electron microprobe. Depth of penetration is typically measured by the point where the H^+ concentration has fallen to half its value at the surface, corrected for near-surface phenomena. The depth of this half-amplitude point is found to be proportional to t^n, where t is time and n is an exponent lying between approximately 0.6 and 0.7 (Anovitz et al. 1999, 2004; Stevenson and Novak 2011; however, re-analysis by the present author suggests the exponent is lower, and lies between 0.5 and 0.6). The half-amplitude measurement is again a function of temperature and openness of the matrix; however, since the measurement is a relative measurement, made to a half-amplitude point, the technique is not sensitive to the total amount of water present and should not be affected by water vapor pressure.

A third method is to determine water penetration depth by observation of the leading edge of the hydration stress zone by optical microscopy; this is the classic approach, described in many papers (e.g. Friedman and Smith 1960; Friedman and Long 1976; Stevenson et al. 1989). Measurement is by optical microscopy, using a polarized microscope at a magnification of at least 500X. All experimental evidence, and correlation with archaeological data, indicate that the position of this stress zone, or hydration front, progresses into the obsidian
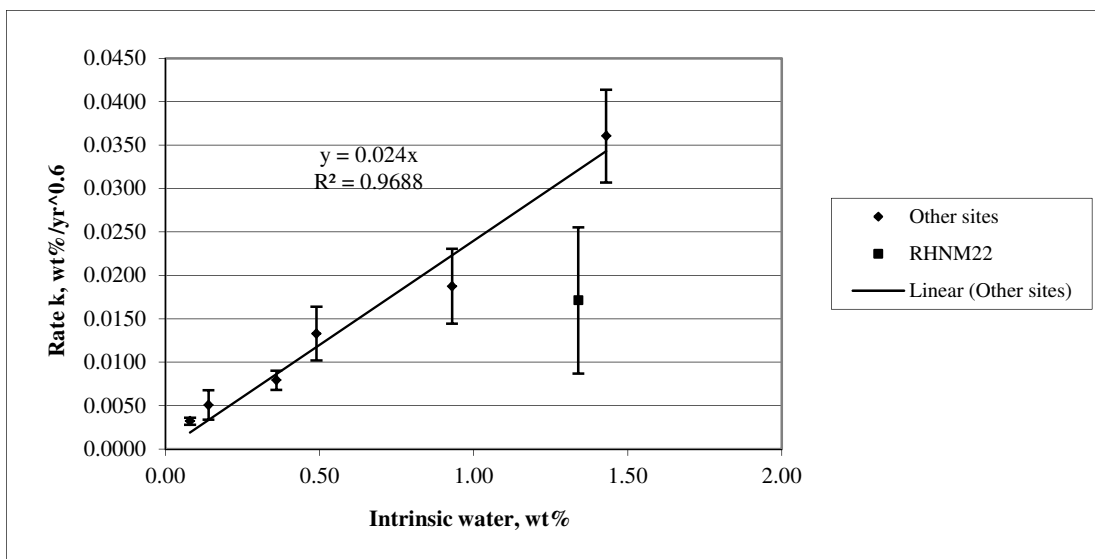

Figure 1. Hydration rate at 90°C as a function of intrinsic water content. Data from Stevenson and Novak 2011:1721, Table 1. The data point for RHNM22 is anomalous and was excluded from the best fit analysis.

proportional to t^n, where n is approximately 0.5 within limits of experimental error (Stevenson and Scheetz 1989; Stevenson et al. 1998; Rogers and Duke 2011). The agreement with classical diffusion theory, in particular Fick's formulations and the Boltzmann transformation (Crank 1975:105ff.; Rogers 2007, 2012), may be a coincidence or may be due to an as-yet-undiscovered property of the diffusion process itself.

Numerical Model Development

The first case to consider is modeling the water mass increase in hydration. Stevenson and Novak (2011) present data on water mass increase in seven obsidians, based on measurements made by Infrared Photo-Acoustic Spectrometry (IRPAS) and by IR transmission spectrometry (FTIR – Fourier Transform Infrared Spectrometry). The analytical hypothesis they employed (and is used here) is that water mass increase as a function of time is described by

$$C_{wt} = kt^n \qquad (1)$$

where C_{wt} is the added concentration of total water in wt% after t days, n is an exponent on the order of 0.5 - 0.7, and k is a rate with units of wt%/day^n. Their data on intrinsic water content are presented in their Table 1, and water mass increase as a function of time at 90°C are in their Table 3 (Stevenson and Novak 2011:1717 and 1722, respectively).

Equation (1) can be expressed in the form

$$\ln(C_{wt}) = \ln(k) + n\ln(t) \qquad (2)$$

Making a weighted linear least-squares best fit between y = $\ln(C_{wt})$ and x = $\ln(t)$, the resulting slope S is equal to n and the y-intercept I is equal to $\ln(k)$. The rate is then k = exp(I). Stevenson and Novak (2011) used this procedure to develop an estimate of n = 0.6, and found no consistent dependence on intrinsic water content.

However, their data show that the rate itself *is* strongly dependent on intrinsic water content; Figure 1 shows there is a definite relationship between the best-fit values for k and intrinsic water content. The rate is also a function of temperature, with a dependence given by the Arrhenius equation

$$k = k_0 \exp(-E/T) \qquad (3)$$

where k_0 is the pre-exponential, E is the activation energy expressed in °K, and T is absolute temperature. Note that k_0 and k will always have the same units, since the exponential is dimensionless.

The pre-exponential k_0 can be determined by rearranging equation (3)

$$k_0 = k \exp(E/T) \qquad (4)$$

and computing E from structural water (w_s) based on data presented by Stevenson and Novak (2011:1724, Table 6). The linear best-fit equation is

$$E = 10443 - 2857w_s \qquad (5)$$

where E is in °K and w_s is total structural water content in wt%.

The values of k_0 computed by equations (4) and (5) are given in Table 1 below and plotted in Figure 2. The strong dependence of k_0 on intrinsic water is clearly visible.

Obsidian	w_s (wt%)	Slope = diffusion rate (wt%/yr$^{0.6}$ @ 90°C)	E (°K)	k_0 (wt%/yr$^{0.6}$)
TAK054	0.08	5.10E-03	10215	8.37E+09
CPQ002	0.14	4.97E-03	10043	5.09E+09
RHC02	0.36	9.18E-03	9414	1.66E+09
RHC06/08	0.49	7.51E-03	9043	4.90E+08
CVO709	0.93	1.28E-02	7786	2.62E+07
RHNM22	1.34	2.55E-02	6614	2.07E+06

Table 1. Values of pre-exponential k_0 for water mass increase. Data from Stevenson and Novak (2011: 1723, Table 4).
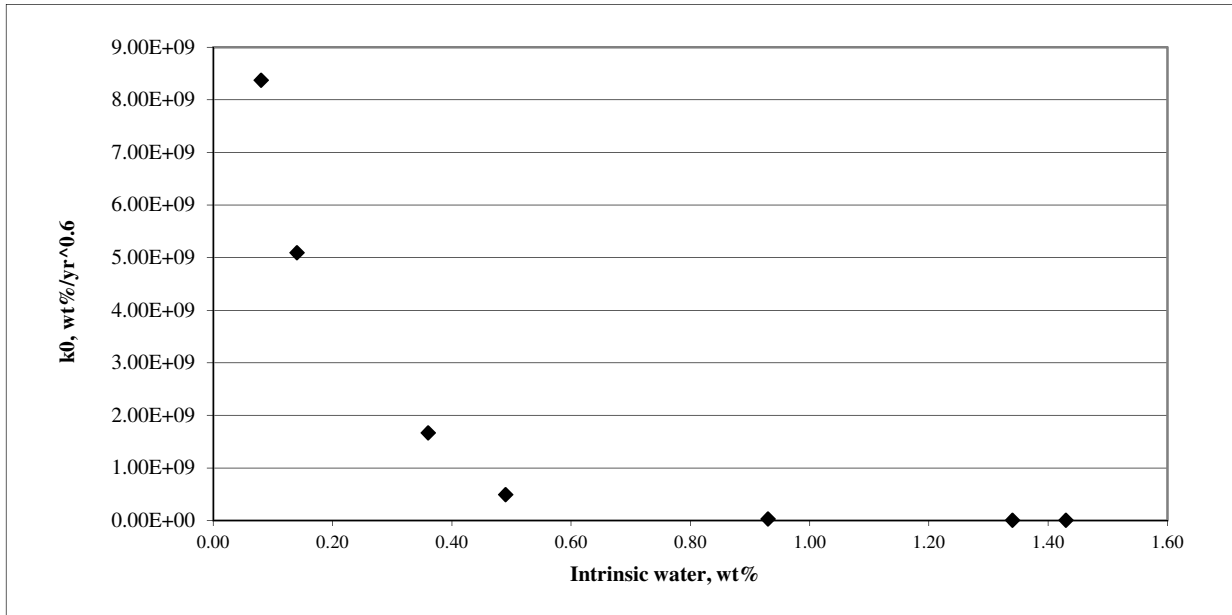
Figure 2. Dependence of pre-exponential factor A on structural water content for six obsidians (Stevenson and Novak 2011:1723, Table 4.

If the data are plotted as $\ln(k_0)$ vs. w_s, the result is a straight line (Figure 3). The best-fit equation for this curve can be computed by a weighted least-squares best fit procedure, using weight factors of $w_i = k_{0i}^2$, appropriate for a logarithmic dependent variable. (Cvetanovic et al. 1979). (Using a uniformly weighted best fit such as MS Excel provides nearly the same answer.) The linear best-fit curve is

$$\ln(k_0) = 23.334 - 6.394w_s \qquad (6)$$

Combining equations (4), (5), and (6) yields

$$k = \exp(23.334 - 6.394w_s - 10433/T + 2857w_s/T) \qquad (7)$$

where k is in $\%H_2O_t/yr^{0.6}$, T is in °K, and w_s is in wt%. The uncertainty in k can be computed by using equation (7) to predict the rates for the obsidians in Table 1 and comparing to the experimental rates; when this is done, the rms error is $0.004\%H_2O_t/yr^{0.6}$. The fit is shown graphically in Figure 4.

The form of this equation is similar to those derived by Zhang et al. (1991) and Zhang and Behrens (2000) for higher temperatures, although the values of the numerical constants are different.

Extrapolation to Optical Miscroscopy

The argument to this point has been a straight-forward, if tedious, numerical analysis, based upon two simple assumptions from physical chemistry: the mass of absorbed water grows as t^n, where n is shown to be ≈ 0.6, and the absorption (i.e. hydration) rate is sensitive to temperature and intrinsic water content. Further analysis showed that activation energy decreases with increasing intrinsic water, and the pre-exponential coefficient also decreases with increasing intrinsic water content.

At this point I am going to go out on a limb, and extrapolate the method to the case of obsidian hydration measured by optical microscopy. This is risky, because the time dependence of the position of the optical hydration front varies slightly from the time dependence of water mass increase. The hydration front is the stress zone caused by the diffusion process (water absorption). There is no fully satisfactory theory of how the stress

zone develops, but it is not surprising that the stress lags the water mass increase slightly. However, the two phenomena are related, since both are due to the same process of water absorption. For this reason *I assume the equation for optical hydration rate to be of the same form as equation (7), but with possibly different numerical coefficients*. Thus, for the present analysis the functional form of equation (7) is used to describe the behavior of the pre-exponential due to intrinsic water, but with different parameters which are adjusted empirically to give a good fit for optical microscopy:

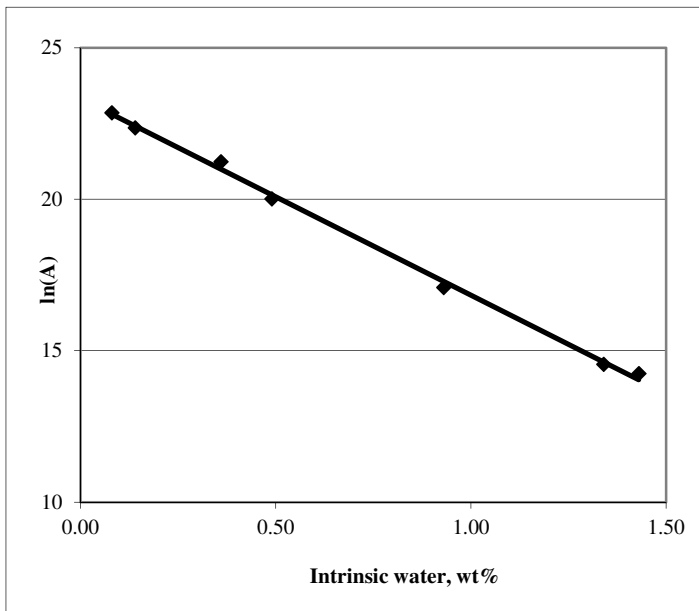$$k = \exp(A - Bw_s - C/T + Dw_s/T). \qquad (8)$$

Figure 3. Pre-exponential of Figure 2 plotted as natural logarithm.

The data set to be fit is from the Coso volcanic field. Stevenson et al. (1993) and Rogers (2008) developed statistics for the intrinsic water content of four obsidian source flows in the Coso field, based on source-flow definitions of Hughes 1988. Rogers (2013) computed source-specific hydration rates for these sources. These data are summarized in Table 2.

Source Flow	Intrinsic water w_s, wt%	Hydration rate @ EHT = 20°C, μ^2/1000 yrs
West Sugarloaf	0.62	18.16
Sugarloaf Mountain	1.02	29.87
West Cactus Peak	1.01	29.58
Joshua Ridge	0.81	23.72

Table 2. Coso obsidian parameters

Numerical fitting and adjustment of constants yields the equation

$$k=\exp(37.76-2.289w_s-10433/T+1023w_s/T) \quad (9)$$

Here A = 37.76 and is simply a scale factor; B = 2.289/wt%, which expresses a temperature-independent variation with water concentration; C = 10433°K, the basal activation energy of dry obsidian; D = 1023°K/wt%, and represents the variation of activation energy with both temperature and water concentration. In making the numerical fit to the data of Table 2, C was assumed to be the same for water mass increase or for the optical hydration front, and the B and D coefficients were adjusted to give the best fit, with the ratio between them held constant. Here again w_s is total intrinsic water in wt %, T is effective hydration temperature in °K, and k is hydration rate in μ^2/1000 yrs.

Source Flow	Data from Table 2	Equation (9) model	Error
West Sugarloaf	18.16	18.47	0.31
Sugarloaf Mountain	29.87	29.86	-0.01
West Cactus Peak	29.58	29.50	-0.08
Joshua Ridge	23.72	23.21	-0.51

Table 3. Agreement between equation (1) and Coso data for hydration rate @ EHT = 20°C, in μ^2/1000 yrs.

The agreement is reasonably good, as summarized in Table 3 and Figure 5. The overall rms error in prediction is 0.27 µ2/1000 yrs, or approximately 1%. However, it must be kept in mind that the range of values for the intrinsic water is quite limited (0.62 – 1.02 wt%); a greater range of intrinsic water
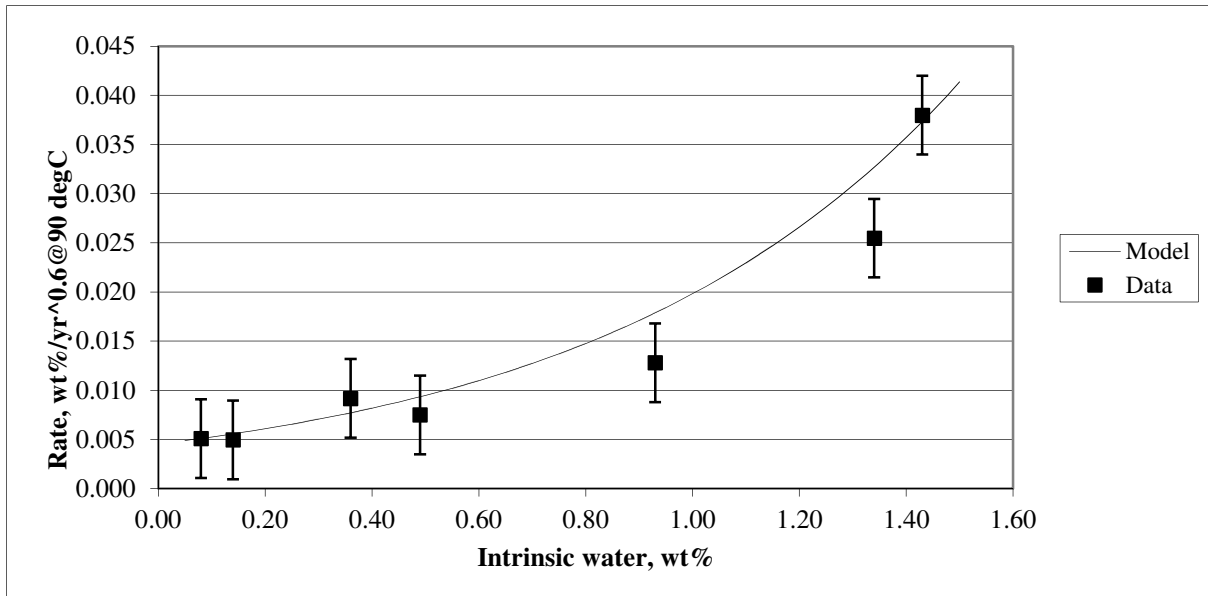
Figure 4. Fit between model and data for water mass increase. The model represents equation (7), data are in Table 1

values, hydration rates, and temperatures would lead to more confidence in the model

Discussion and Caveats

The models in equations (7) and (9) give a simple method for estimating hydration rate if the intrinsic water content is known. The functional form is similar to the equations derived by Zhang et al. (1991) and Zhang and Behrens (2000), although the numerical constants are different. Equation (9) gives reasonable hydration rates for archaeological temperatures, which the equations of Zhang et al. (1991) and Zhang and Behrens (2000) do not.

Clearly the rate k is a strong function of intrinsic water (Table 1). The dependence of activation energy on intrinsic water content has already been shown (Zhang et al. 1991, 1997; Zhang and Behrens 2000), and the
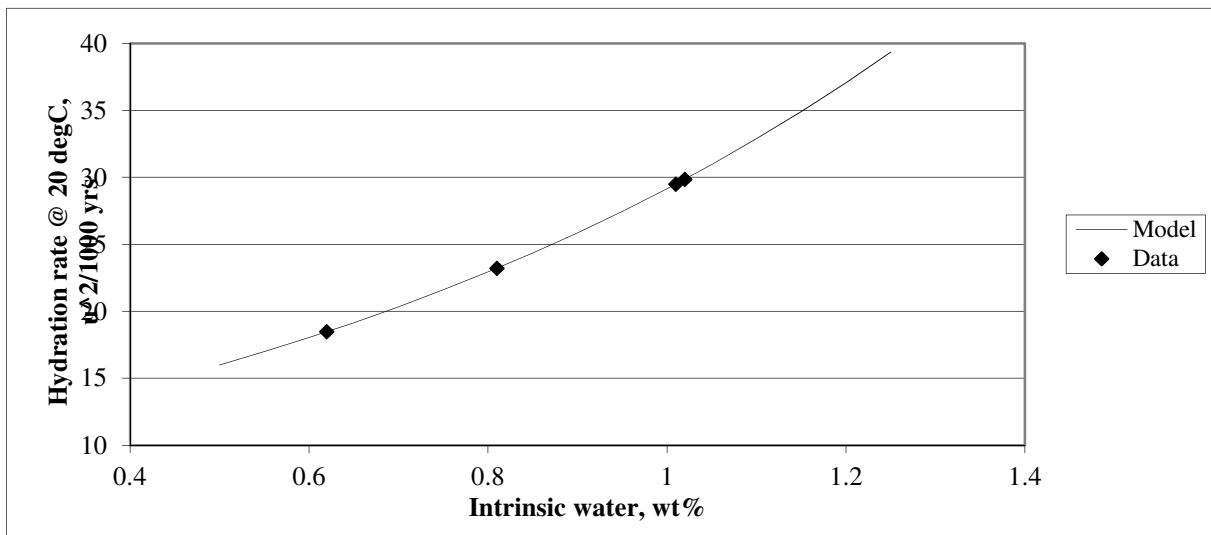

Figure 5. Agreement between equation (9) model and measured data for Coso obsidian.

specific functional form in equation (5) is based on data by Stevenson and Novak (2011). In addition, the data in Table 1 and Figure 2 show a strong relationship between the pre-exponential k_0 and intrinsic water content. Surprisingly, the pre-exponential decreases with increasing intrinsic water, which is somewhat counter-intuitive. Since the intrinsic water content is usually viewed as a proxy for the openness of the glass matrix, one would expect k_0 to decrease with increasing water content. However, since the model is purely empirical it is difficult to relate the form of Figure 2 to physical phenomena.

Stevenson and Novak (2011) published a simple procedure for determining intrinsic water content from absorbance measured by IR spectrometry. Taken together with equation (7), the result is an algorithm to compute age of an obsidian artifact based on IR absorbance data at 1630 cm^{-1} and 5570 cm^{-1}. It is still necessary to perform a separate computation of effective hydration temperature, however. For the case of optical microscopy equation (9) can be used to estimate the expected hydration rate for any obsidian whose water content can be measured.

A significant caveat is that the model in equation (9) is based on a very small data set with a limited range of intrinsic water values. Further, in development of the model the assumption was made that the functional form of equation (7), derived for water mass increase, is also valid for optical microscopy. There is also a tacit assumption that the activation energy measured by water mass increase is also appropriate to characterize the optical hydration front. The model in equation (9) should therefore be used with caution.

References Cited

Anovitz, L.M., J.M. Elam, L.R. Riciputi, and D.R. Cole (1999) The Failure of Obsidian Hydration Dating: Sources, Implications, and New Directions. *Journal of Archaeological Science* 26(7): 735-752.

Anovitz, L.M., J.M. Elam, L.R. Riciputi, and D.R. Cole (2004) Isothermal Time-Series Determination of the Rate of Diffusion of Water in Pachuca Obsidian. *Archaeometry* 42(2): 301-326.

Anovitz, L.M., D.R. Cole, and M. Fayek (2008) Mechanisms of Rhyolitic Glass Hydration Below the Glass Transition. *American Mineralogist* 93: 1166-1178.

Crank, J. (1975) *The Mathematics of Diffusion*. Oxford University Press.

Cvetanovic, R.J., D.L. Singleton, and G. Paraskevopoulos (1979) Evaluations of the Mean Values and Standard Errors of Rate Constants and their Temperature Coefficients. *Journal of Physical Chemistry* 83(1): 50-60.

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., and R. Smith (1960) A New Method of Dating Using Obsidian; Part 1, the Development of the Method. *American Antiquity* 25: 476-522.

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

Karsten, J.R., and J.L. Delaney (1981) Ion Microprobe Studies of Water in Silicate Melts: Concentration-Dependent Water Diffusion in Obsidian. *Earth and Planetary Science Letters* 52: 191-202.

Karsten, J.L., J.R. Holloway, and J.L. Delaney (1982) Ion Microprobe Studies of Water in Silicate Melts: Temperature-Dependent Water Diffusion in Obsidian. *Earth and Planetary Science Letters* 59: 420-428.

Newman, S., E.M. Stolper, and S. Epstein (1986) Measurement of Water in Rhyolitic Glasses: Calibration of an Infrared Spectroscopic Technique. *American Mineralogist* 71: 1527-1541.

Riciputi, L.R., J.M. Elam, L.M. Anovitz, and D.R. Cole (2002) Obsidian Diffusion Dating by Secondary Ion Mass Spectrometry: A Test Using Results from Mound 65, Clalco, Mexico. *Journal of Archaeological Scienc*e 29: 1055-1075.

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. (2013) Flow-Specific Hydration Rates for Coso Obsidian. *Proceedings of the Society for California Archaeology* 27: 281-294.

Rogers, A.K. (2012) Temperature Correction for Obsidian Hydration Dating, In *Obsidian and Ancient Manufactured Glasses*, edited by I. Liritzis and C. Stevenson, pp. 46-56. University Of New Mexico Press, Albuquerque.

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.

Silver, L.A., P.D. Ihinger, and E. Stolper (1990) The Influence of Bulk Composition on the Speciation of Water in Silicate Glasses. *Contributions to Mineralogy and Petrology* 104: 142-162.

Stevenson, C.M., and B.E. Scheetz (1989) Induced Hydration Rate Development of Obsidians from the Coso Volcanic Field: A Comparison of Experimental Procedures. In *Current Directions in California Obsidian Studies,* edited by R.E. Hughes, pp. 23-30. Contributions of the University of California Archaeological Research Facility No. 48, Berkeley.

Stevenson, C.M., J. Carpenter, and B.E. Scheetz (1989) Obsidian Dating: Recent Advances in the Experimental Determination and Application of Hydration Rates. *Archaeometry* 31(2): 1193-1206.

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. Advances in Archaeological and Museum Science*, Vol. 3, 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.

Stevenson, C.M., I.M. Abdelrehim, and S.W. Novak (2004) High Precision Measurement of Obsidian Hydration Layers on Artifacts from the Hopewell Site Using Secondary Ion Mass Spectrometry. *American Antiquity* 69(4): 555-568.

Stevenson, C.M., and S.W. Novak (2011) Obsidian Hydration Dating by Infrared Spectroscopy: Method and Calibration. *Journal of Archaeological Science* 38: 1716-1726.

Zhang, Y., and H. Behrens (2000) H_2O Diffusion in Rhyolitic Melts and Glasses. *Chemical Geology* 69: 243-262.

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., R. Belcher, P.D. Ihinger, L. Wang, Z. Xu, and S. Newman (1997) New Calibration of Infrared Measurement of Dissolved Water in Rhyolytic Glasses. *Geochimica et Cosmochimica Acta* 61(15): 2089-3100.

ABOUT OUR WEB SITE

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

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

Other items on our website include:

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

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

From the *Bulletin* Editor:

NEW EMAIL ADDRESS FOR *IAOS BULLETIN* SUBMISSIONS:

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

CALL FOR ARTICLES

Submissions of articles, short reports, abstracts, or announcements for inclusion in the *Bulletin* are always welcome. We accept electronic media on CD in MS Word. Tables should be submitted as Excel files and images as .jpg files. Please use the *American Antiquity* style guide for formatting references and bibliographies.
http://www.saa.org/Portals/0/SAA/Publications/StyleGuide/StyleGuide_Final_813.pdf

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

Deadline for Issue #54 is December 1, 2015.

Email or mail submissions to:

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

Inquiries, suggestions, and comments about the *Bulletin* can be sent to IAOS.Editor@gmail.com Please send updated address information to Matt Boulanger at BoulangerM@missouri.edu

MEMBERSHIP

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

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

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

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

NOTE: Because membership fees are very low, the IAOS asks that all payments be made in U.S. Dollars, in international money orders, or checks payable on a bank with a U.S. branch. Otherwise, please use PayPal on our website to pay with a credit card.
http://members.peak.org/~obsidian/

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

Matthew Boulanger
Archaeometry Laboratory
Research Reactor Center
University of Missouri
Columbia, MO 65211
U.S.A.
BoulangerM@missouri.edu

Membership inquiries, address changes, or payment questions can also be emailed to BoulangerM@missouri.edu

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ABOUT THE IAOS

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

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

MEMBERSHIP RENEWAL FORM

We hope you will continue your membership. Please complete the renewal form below.

NOTE: You can now renew your IAOS membership online! Please go to the IAOS website at http://members.peak.org/~obsidian/ and check it out! Please note that due to changes in the membership calendar, your renewal will be for the next calendar year. Unless you specify, the *Bulletin* will be sent to you as a link to a .pdf available on the IAOS website.

___ Yes, I'd like to renew my membership. A check or money order for the annual membership fee is enclosed (see below).

___ Yes, I'd like to become a new member of the IAOS. A check or money order for the annual membership fee is enclosed (see below). Please send my first issue of the IAOS *Bulletin*.

___ Yes, I'd like to become a student member of the IAOS. I have enclosed either an obsidian-related article for publication in the IAOS *Bulletin* or an abstract of such an article published elsewhere. I have also enclosed a copy of my current student ID. Please send my first issue of the IAOS *Bulletin.*

NAME: _____

TITLE: _____ AFFILIATION:_____

STREET ADDRESS: _____

CITY, STATE, ZIP: _____

COUNTRY: _____

WORK PHONE: _____ FAX: _____

HOME PHONE (OPTIONAL): _____

EMAIL ADDRESS: _____

My check or money order is enclosed for the following amount (please check one):
___ $20 Regular
___ $10 Student (include copy of student ID)
___ FREE Student (include copy of article for the *IAOS Bulletin* and student ID)
___ $200 Lifetime

Please return this form with payment: (or pay online with PayPal http://members.peak.org/~obsidian/**)**

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