A Physics-Based Hydration Rate for Queen Obsidian, Western Nevada

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ABSTRACT

This paper describes a computation of a hydration rate for Queen obsidian from western Nevada. The approach is to reanalyze a previously-published data set, using the best physical understanding of the hydration process. The resulting rate is 10.29 μ^2/1000 years at an effective hydration temperature (EHT) of 20°C.

Introduction

Obsidian from the Queen source in western Nevada is frequently found in archaeological sites in the northern Owens Valley area of eastern California, with decreasing amounts in more southerly sites. This paper describes a computation of a hydration rate for the Queen source.

Data Set and Analysis

Basgall and Giambastiani (1995:44) analyzed Queen obsidian artifacts from the Bishop Tablelands area, and computed a best fit equation of

$$t = 82.74 * r^{2.06} \quad (1)$$

where t is age in radiocarbon years before the present (rycbp, with "the present" understood as 1950) and r is hydration rim in microns. This equation was apparently the result of a linear best fit to obsidian-radiocarbon data pairs, in which the fit was between ln(t) and ln(r). However, the fit does not recognize the physics of the process. Hydration is a diffusion process, and hence, by definition, the exponent in the right side of the equation must be equal to 2, so that

$$t = r^2/k \quad (2)$$

where k is the hydration rate. The data set was not published, so it was not possible to re-analyze it. Instead, the analysis was based on equation (1) itself.

The analytical procedure was to select a set of hydration rim readings and compute the corresponding age by equation (1). The ages were then converted to calibrated years before 1950 (cyb1950) using Calib 6.0, and 50 years was added to adjust to the year 2000 (cyb2k). Finally, a linear least-squares best fit was made between r^2 (independent variable) and t in cyb2k (dependent variable). Table 1 presents the data used.

Table 1. Queen obsidian data, Bishop Tablelands.

rim, μ	**t, rcybp**	**t, cyb1950**	**rim ^{2}, μ^2**	**t, cyb2k**
2	345	398	4	448
4	1439	1353	16	1403
6	3317	3558	36	3608
8	5999	6850	64	6900
10	9500	10824	100	10874
12	13830	16927	144	16977
14	18999	22621	196	22671

Plotting the data results in Figure 1. The linear best fit constrained to pass through the origin yields a slope of 114.57 yrs/μ^2. The rate is the reciprocal of the slope, or 8.73 μ^2/1000 years.

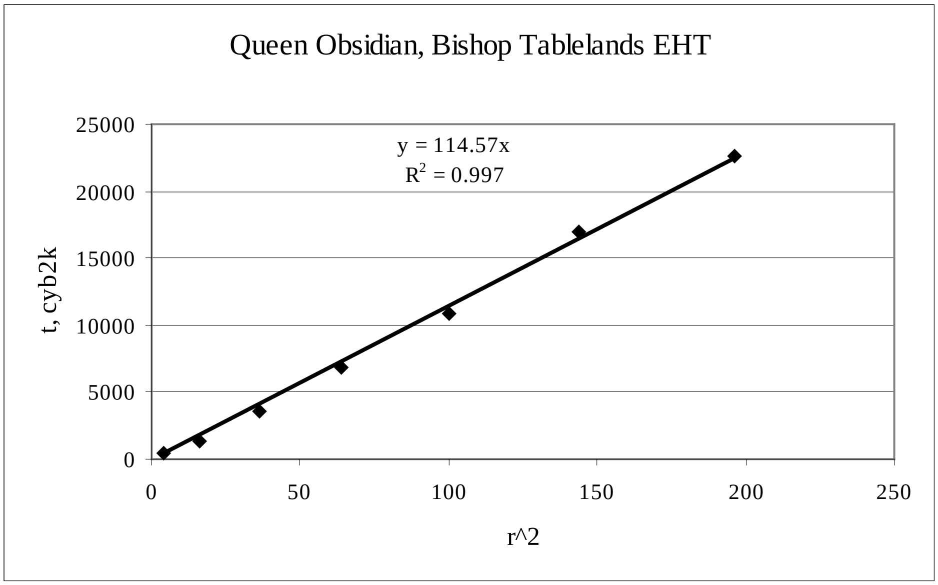

Figure 1. Linear least squares best fit, Queen obsidian. Effective hydration temperature typical of the Bishop Tablelands.

Effective Hydration Temperature Adjustment

The temperature estimation method here is based on thirteen sites in the upper Mojave Desert and desert mountains of eastern California, ranging from Baker, California, at 940 ft above mean sea level (amsl) to Mt Barcroft at 11,800 ft amsl. Details of the method are in Rogers 2008.

Most archaeological sites are not collocated with meteorological stations but temperature parameters for them can be estimated by regional temperature scaling (Rogers 2008). Such data can be down-loaded from the web site of the Western Regional Climate Center. The scaling principle is that desert temperature parameters are a strong function of altitude above mean sea level, and the best estimates of temperature are determined by scaling from 30-year data from large a number of meteorological stations.

Computation of EHT requires three climatic parameters: average annual temperature (T_a); annual seasonal variation, hot-month mean minus cold-month mean (V_a); and mean diurnal variation (V_d).

With this technique, in the northern Mojave Desert, annual average temperature can be predicted by the equation

$$T_a = 22.25 - 0.0018*h, \qquad 940 < h < 11{,}800, \qquad (3)$$

where h is altitude in feet. The accuracy of this model is 0.98ºC, 1-sigma.

The annual temperature variation can be predicted by

$$V_a = 23.14 - 0.0005*h, \qquad 940 < h < 11{,}800, \qquad (4)$$

with h defined as above. The accuracy of the prediction is 0.27ºC, 1-sigma.

The best fit between V_d and altitude is relatively poor, and, in the absence of other data about a site, the optimal estimate is

$$V_d = 15.8^{\circ}C \qquad (5)$$

for locations in the western Great Basin and deserts, irrespective of altitude. The accuracy of this estimate is 1.67ºC, 1-sigma.

The site at the Bishop Tablelands for which equation (1) was derived is at an altitude of 4500 ft, which allows computation of the temperature parameters, which were then used to construct a numerical model of the temperature history to which the obsidian was exposed. The model consists of a constant term equal to T_a, a cosine term with a period of twelve months and an amplitude of $V_a/2$, and a cosine term with a period of 24 hours and an amplitude of $V_d/2$. The effective hydration temperature was computed by numerical integration of the hydration rate over the modeled temperature history (details in Rogers 2007). Table 2 shows the temperature parameters and resulting EHT.

Table 2. Temperature parameters for the Bishop Tablelands.

Parameter	**Value, °C**
Annual average temperature, T_a	14.15
Annual (seasonal) variation of the mean, V_a	20.89
Mean diurnal variation, V_d	15.80
Effective hydration temperature, EHT	18.59

The rate is corrected for EHT by the equation

$$k_{20} = k_s * \exp(-10000/293.16 + 10000/EHT_s) \qquad (6)$$

where k_{20} is the hydration rate at 20°C (293.16°K), k_s is the rate at the EHT for the site, and EHT_s is the EHT for the site in °K (273.16 + 18.59 = 291.75). Making this correction then yields a rate of 10.29 μ^2/1000 years at 20°C.

Discussion

The rate derived here, 10.29 μ^2/1000 years at 20°C, is not computed from primary data but from a best fit thereto, and should be regarded as provisional. It yields reasonable ages in archaeological contexts, but is subject to revision. The primary cause of intra-source variability in rate is fluctuations in intrinsic water content, but unfortunately no data are available for Queen obsidian; Coso obsidian shows a variability of 15 – 20 % (Stevenson et al. 1993), so similar variations can be expected here.

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