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Obsidian hydration dating on the South Coast of Peru

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Abstract

We compare over 230 obsidian hydration readings from 30 individual site components from the Southern Nasca Region (SNR) with independent age estimates based on radiocarbon dates and temporally diagnostic artifacts. Although there are problems with small sample sizes, and readings must be adjusted for elevation, a very strong relationship accounting for nearly 90% of the total variation in the data set is found. This suggests that obsidian hydration dating (OHD) works in the SNR and is a viable means of independently estimating age. Residual values from our regression suggest that hydration age estimates are usually within 15% of the radiocarbon estimates. Finally, we present an equation other scholars can use to estimate age for Quispisisa obsidian in the SNR.

Keywords: Obsidian; Hydration dating; Effective hydration temperature (EHT); Nasca; Peru

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1. Introduction

Obsidian hydration was developed as an archaeological dating technique in the 1960s and has seen slow development over the ensuing 40 years. It has become a mainstay in archaeometric dating in some areas, such as the western Great Basin of North America (e.g. Bettinger, 1980, 1989; Jones et al., 2003), has run into difficulties in others, such as Mesoamerica (e.g. Braswell, 1992), and has been largely ignored in still others.

For a variety of reasons, the latter situation has been true of Andean archaeology. Only a few studies have attempted to include hydration as a means of estimating site or activity age (e.g. Bell, 1977; Bonifaz, 1985; Lynch and Stevenson, 1992; Mayer-Oakes, 1986), and results have not been without controversy (Lynch, 1990:p. 23). This is certainly not for a lack of obsidian artifacts. In most regions, obsidian is a common, though not always dominant, material present in archaeological sites. Instead, the availability of less expensive and more precise dating techniques, especially ceramic seriation, and less focus on archaic-period sites where alternative dating techniques might be more useful, likely account for the lack of hydration studies in the Andes. Furthermore, recent high-profile articles, such as Ridings (1996) and Anovitz et al. (1999) have questioned the utility and accuracy of the technique. Although others have come to the defense of hydration (e.g. Hull, 2001; Rogers, 2007), the "negative press" may have resulted in a reluctance on the part of Andean scholars to utilize the technique.

In this paper we test whether obsidian hydration produces consistent and predictable dating estimates using a new data set from the Southern Nasca Region (SNR) of Peru. We compare nearly 240 source-specific hydration measurements from

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archaeological contexts with independent chronological information, including radiocarbon dates and diagnostic pottery.

2. Background

Obsidian hydration operates on the principle that like all volcanic glasses, obsidian absorbs water. This diffused water is typically visible under a microscope using high-power magnification (typically 40–80×) and appears as diffusion fronts from the exposed surface of an artifact. By measuring the thickness of these diffusion fronts (or bands or rinds), hence the amount of water absorbed, this principle can be used to determine if one artifact is older than another (relative dating). However, if the rate at which water diffuses into glass can be determined, the technique allows for more useful calendrical age estimates (absolute dating). We focus on the latter approach.

In general, the relationship between time and diffusion front thickness is described by Eq. (1):

$$\text{Age} = DX^2 \tag{1}$$

where age is generally measured in years, D is a constant (though see below), and X is the hydration rind measured in microns. In short, the age increases as the square of the hydration rind thickness.

Other than time, at least three other factors affect the rate of hydration, including temperature, water vapor pressure, and glass chemistry (Friedman and Smith, 1960; Friedman and Obradovich, 1981; Jones et al., 1997; Michels and Tsong, 1980). These factors are generally expressed as a constant and subsumed into the term D in Eq. (1). However, recent research has sought to replace D with a more dynamic function that includes at least some expression of these factors (Hull, 2001; Rogers, 2007; Stevens, 2005).

While easy to control under laboratory conditions (e.g. Mazer et al., 1991; Stevenson and Scheetz, 1989), temperature is quite dynamic in real world situations, fluctuating diurnally, seasonally, and over longer time scales as well. Instead of modeling these factors independently, archaeologists have employed a solution comprising a single term, referred to as the Effective Hydration Temperature (EHT), to model the effects of temperature on hydration. For example, Rogers (2007) has expressed EHT as a function of annual mean temperature, annual temperature range, and diurnal temperature range. A depth correction factor is also occasionally used to account for the temperature of buried artifacts (Ridings, 1991; Rogers, 2007), under the assumption that underground conditions are significantly different than surface ones. However, as we discuss below, a problem in applying this correction is the lack of research on temperature with depth, and more specifically, how this affects hydration bands. Moreover, the correction tends to impose order on an assemblage in precisely the manner expected naturally in a stratified deposit. Thus it is difficult to evaluate whether depth corrections improve the analysis because depth significantly affects hydration, or whether it improves because it reinforces stratigraphic differences. In any case, we follow Rogers (2007) and construct an EHT factor for the SNR based on altitude to correct hydration measurements. We briefly examine the effects of burial depth, but ultimately leave that for future research.

The effects of water vapor pressure have not been studied as intensively. While important in controlled laboratory settings, in practice variation in water vapor pressure might not vary enough from location to location within a geographic region to have serious effects on relative rates of hydration. In the Andes, both temperature and water vapor pressure are likely to be mainly controlled by elevation. Thus, in our application of the hydration model, both these factors are subsumed under a single term.

The effect of the glass chemistry on hydration is less well understood. Empirical data indicate that certain obsidians hydrate faster than others within the exact same depositional environment (Ericson, 1989; Findlow et al., 1982; King, 2004). The way archaeologists generally deal with this is through the construction of separate hydration curves for different obsidians using empirical data (e.g. Bettinger, 1989; Ericson, 1989; Meighan, 1976). These effects are then summarized into a constant, expressed as part of D in Eq. (1). As we show below, this does not prove to be a large problem in the SNR because obsidian comes predominantly from a single geochemical source.

An issue related to glass chemistry is the intrinsic water content of obsidian (e.g. Stevenson et al., 1993, 2000). Studies indicate that the amount of water within obsidian can vary even within obsidian nodules from a single source, and that this water content can significantly affect age estimates. To our knowledge, this factor has not yet been addressed in the Andes and its effects are, as yet, unknown.

3. Sample

Our sample of hydration measurements comes from 237 individual obsidian artifacts from the SNR. Of these, 158 artifacts are from 15 radiocarbon-dated site components. Site components are defined as stratigraphically or spatially restricted areas (e.g. individual houses) of sites that date to relatively narrow windows of time. Nine site components come from the stratified site of Upanca (Vaughn and Linares Grados, 2006). Two additional components come from Marcaya (Vaughn, 2004; Vaughn and Glascock, 2005), two from Pajonal Alto (Conlee, 2003), and one each from Higosñoc and Uchuchuma (Vaughn, 2005). All of these samples come from excavated contexts. All radiocarbon dates were calibrated using the on-line version of the Calib 5.0 program (Stuiver and Reimer, 1993).

An additional 79 obsidian artifacts were surface collected from 15 different sites or site loci in the SNR recorded by one of us (KS) during the Proyecto Nasca Sur (for a summary of the surveys see Schreiber and Lancho Rojas, 2003). All these loci represent single-component locations, where diagnostic ceramics representing only one time period were located. For dating purposes we used the median age for traditionally recognized culture historical periods (see Table 1). In