IAOS

International Association for Obsidian Studies

Bulletin

Number 40 **Winter 2009**

CONTENTS

NEWS AND INFORMATION

IAOS Annual Meeting

The 2009 IAOS annual meeting will be held on Friday, April 24, 2009 from 3:00 pm to 5:00 pm in the Atlanta Marriott Marquis Hotel, the headquarters hotel for the SAA conference. Consult your SAA program for meeting room location.

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, or lab report for publication in the IAOS *Bulletin*. Articles and inquiries can be sent to cdillian@princeton.edu Thank you for your help and support!

IAOS Elections

It is election time again! Elections for the office of IAOS President will be held in advance of the 2009 IAOS annual meeting, which will occur in conjunction with the Society for American Archaeology (SAA) annual conference in Atlanta in April 2009. We have two highly qualified nominees for the position: Tristan Carter and Robert Tykot. See page 3 for information and a statement by the candidates.

The vote will be held via email. Watch your inbox in January for a ballot with votes due by Monday, March 2, 2009. The new President will be announced at the 2009 IAOS annual meeting.

NOTES FROM THE PRESIDENT

With the close of another year, IAOS is asking the membership to weigh in on two important administrative concerns. One is to select a new President, and the second addresses proposed changes to the IAOS by-laws.

We have two excellent candidates to lead IAOS: Rob Tykot at the University of South Florida, and Tristan Carter of McMaster University. Please read more about each in their candidate statements in this issue of the Bulletin and respond with your vote when the Secretary-Treasurer Colby Phillips sends out an email in January. The elected candidate will serve as President-Elect/Vice-President in April 2009, and will assume the office of President in April of 2010. For the past several years, we have been a bit out of synchronization with the succession plan indicated in IAOS by-laws; with this election we will have returned to the correct pattern.

The second vote needed from the membership is to accept or reject proposed changes to IAOS by-laws. The proposed updates were emailed to the membership last September and are available for review at our website:
(http://www.peak.org/obsidian/index.html).
Let us know if the changes in the by-laws meet with your approval.

I look forward to seeing everyone at the SAA annual meetings in Atlanta this April. Please plan to come to the IAOS annual Business meeting, to be held on Friday afternoon. And on Saturday afternoon, IAOS and the Society for Archaeological Sciences are co-sponsoring the symposium "Provenance Studies in Archaeology", organized by Mostafa Fayek and Sharon Hull. There are papers addressing obsidian geochemical analyses from Kenya, Guatemala, and Peru, and a variety of provenance analyses on an array of materials, including turquoise, chert, quartz, ceramic glazes, glass beads, and tin.

See you in Atlanta!

Ana Steffen

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IAOS Membership Renewal

Last year the IAOS transitioned all IAOS annual memberships to a Jan. 1 – Dec. 31 calendar year. So all IAOS memberships for 2009 can be renewed starting on Jan. 1, 2009, and you can renew online via PayPal on the IAOS website at http://www.peak.org/obsidian or simply use the form on the last page of this Bulletin). Renewing your membership will allow the IAOS to continue, and we appreciate your support.

Regards,
Colby Phillips, IAOS Secretary/Treasurer

PRESIDENTIAL CANDIDATES

We have two nominees for IAOS President. Below are their statements for your evaluation. The vote will be held via email. Watch your inbox in January for a ballot with votes due by Monday, March 2, 2009. The new president will be announced at the 2009 IAOS Annual Meeting.

TRISTAN CARTER

I have been working with obsidian since the late 1980's, initially using techno-typological and functional studies to discuss the social significance accorded the consumption of this material in the Neolithic / Bronze Age Aegean (the focus of my 1999 PhD from UCL's Institute of Archaeology). My geographical and temporal interests have since expanded, working on obsidian from Epi-Palaeolithic and Neolithic contexts in Anatolia, not least Çatalhöyük and Göbekli Tepe. I have also initiated a series of characterization studies in both regions, working in collaboration with labs in France (CNRS Bordeaux, Grenoble, Paris), Greece (NCRS Demokritos), the UK (Aberystwyth) and the US (Berkeley and Stanford). I am also working with Oak Ridge National Laboratory on new obsidian hydration techniques.

After a decade of temporary positions in Athens, Stanford and Bordeaux, I finally became an Assistant Professor in 2007 at the Department of Archaeology at McMaster University, Hamilton, Ontario. Here, I am aiming to establish an obsidian characterization lab to develop further the work of my colleagues and I, as well as initiate research anew on Canadian and other regions' obsidians. My primary aim in all of this is to locate our powerful data within an anthropologically aware and holistic form of material culture analysis, whereby we can re-engage with some of the discipline's 'big picture' questions.

www.socsci.mcmaster.ca/anthro/faculty/carter.cfm

ROBERT TYKOT

I have been nominated to serve as the President of the International Association for Obsidian Studies. As many of you may know, I have been involved in obsidian studies for more than 25 years, focusing at first on the sources on the island of Sardinia in the central Mediterranean. Following my dissertation (1995) on that subject, I have worked on many artifact collections in Sardinia, Corsica, mainland Italy, Malta, and Tunisia, looking at trade routes and patterns to help reconstruct socioeconomic characteristics of the cultures involved. In addition to the laboratory-based sourcing analyses, using a variety of instruments including microprobe, XRF, INAA, and ICP-MS, I have led an excavation of an obsidian workshop on the east side of Monte Arci in Sardinia. I have also expanded my work on obsidian sources with surveys on Lipari, Palmarola, and Pantelleria, with the results demonstrating that it is important to differentiate between subsources on each island in order to address prehistoric access issues and selection methods. Most of my publications on obsidian have been listed in previous issues of the IAOS Newsletter, and copies are available on my website (http://shell.cas.usf.edu/~rtykot/).

As President of the IAOS, I would continue the efforts made by our current and previous presidents in managing IAOS business activities, the website, newsletter, chairing the annual meeting session at the SAAs, and expanding our world-wide membership and audience, especially in Europe and Asia. I would always be open to suggestions/recommendations from IAOS members on other projects, activities, and service that can be done. I look forward to serving the needs and interests of IAOS members.

NEWS AND NOTES

LIGHT BOX FOR OBSIDIAN ARTIFACTS
Contributed by Ellery Frahm

I've just completed a small project -- building a portable "light box" -- that some of you could find useful for your own fieldwork.

Awhile ago, while photographing obsidian tools in the field, I found myself wishing for a way to backlight the artifacts. I looked online for a portable light box that could stand up to field use, but I couldn't find what I wanted. Many light boxes were much too large (poster-sized), others were too small (sized for photographic slides). Most of them needed electricity from a wall outlet. All used fragile fluorescent bulbs. I wanted a device that could run off batteries and stand up to dust, heat, and some abuse from traveling. I couldn't find such a device, so I got a small grant to build one, and the grant proposal included sharing this design and the details of its construction online. The total cost of the project was less than $300, and it requires only a day and a half and basic shop and electronics skills.

This portable "light box" uses 9-volt batteries (either regular alkaline or rechargeable) to power an electroluminescent sheet. Everything from the unassembled components to the final backlit obsidian photographs can be found here:

http://web.mac.com/elleryfrahm/iWeb/lightbox/

This page is somewhat graphics-heavy, and I'd recommend using the latest version of your favorite browser.

Have a look if this sounds useful to you, and if you have any questions or comments about the project, please feel free to email me.

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OBSIDIAN SESSION AT 2009 SAAs
Provenance Studies in Archaeology
Organized by Mostafa Fayek and Sharon Hull

Carolyn Dillian - Obsidian Characterization and Theories of Interaction, Koobi Fora, Kenya

Anne C. Hamilton - Palaeo-Eskimo Lithic Exploitation Strategies: Assessing Inferences of Culture Change Through Chert Sourcing on Southern Baffin Island

Rachel E. ten Bruggencate - Sourcing Quartz Quarries from Granville Lake, Manitoba, Canada using Trace Elements and Oxygen Isotopes

Alyson M. Thibodeau - Tracing Turquoise from Site to Source Using Radiogenic Isotopes

Judith A. Habicht-Mauche - Studying Glaze-Paint Production and Exchange in the American Southwest Using Lead Isotope Analysis

Mostafa J. Fayek - Fingerprinting Turquoise Provenance Regions in the American Southwest and Northern Mexico

Matthew T. Boulanger - Salvage Archaeometry: Rescue, Preservation, and Dissemination of Geochemical Data

Thomas Fenn - Early Islamic Commerce with sub-Saharan Africa: Chemical and Isotopic Analyses of Late 1st Millennium A.D. Glass Beads from Igbo-Ukwu, Nigeria

Lisa J. Molofsky - Sources of Tin in Prehistoric Bronzes: A Novel Approach

Jeffrey C. Dobereiner - Source Analysis of Obsidian from San Bartolo and Xultun, Guatemala by X-ray Fluorescence

Daniel A. Contreras - Research at the Quispisisa Obsidian Source in the Central Peruvian Highlands

Discussants: M Steven Shackley, Hector Neff, Robert H. Tykot

OBSIDIAN CIRCULATION: NEW DISTRIBUTION ZONES FOR THE ARGENTINEAN NORTHWEST

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Patricia S. Escola, CONICET, Universidad Nacional de Catamarca. Argentina.
Julián P. Gómez Augier, CONICET, Universidad Nacional de Tucumán. Argentina.
Michael D. Glascock, MURR, University of Missouri

The results reported in this work are part of research seeking a better understanding of the cultural development and social relations carried out by prehispanic peoples who inhabited the western and eastern sides of the Cumbres Calchaquíes-Sierras del Aconquija (Tucumán-Argentina) mountain range. There are two goals in the search for characteristic features in the subject: 1) Source determination by XRF of nine obsidian samples from different archaeological sites on both slopes of Cumbres Calchaquíes (Tucumán) and 2) Analyzing obsidian distribution range taking into account the findings of the first goal and comparing them with the database for other sites of the Argentinean Northwest (NOA) (Yacobaccio et al. 2002; Yacobaccio et al. 2004; Escola 2007).

The research context for the analyzed obsidian samples involves the study of prehispanic occupation on the western and eastern slopes of the Cumbres Calchaquíes of Tucumán (26º and 27º South and 66º30' West) during the Late-Formative interval (*ca.* 2200-550 BP). Since archaeological information for this zone is scarce, this survey is the first step towards a systematic investigation of obsidian circulation in the cultural process and the socio-economic relations between this and other areas.

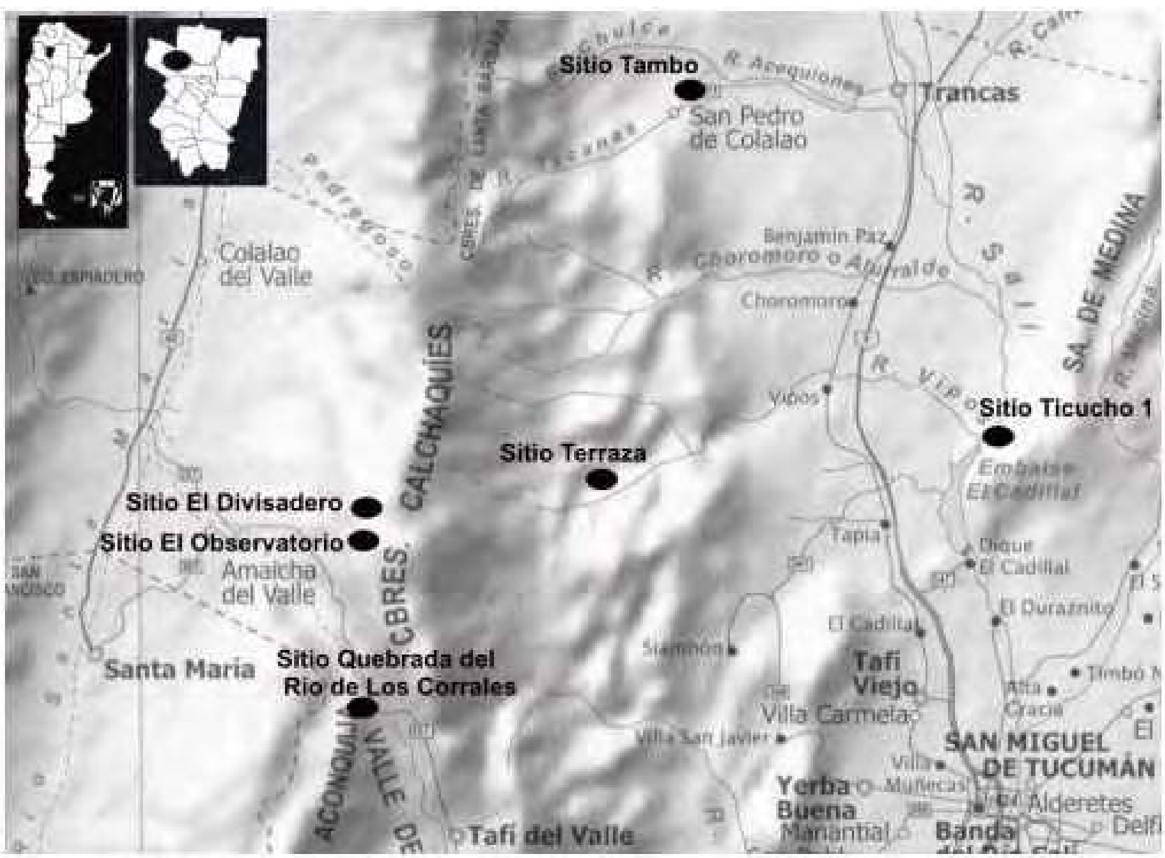

Figure 1. Location map of analyzed sites.

The region is a transitional zone between ecologically well differentiated environments: the dry and arid Santa María Valley, the pastures of the Tafí Valley to the west, and the eastern jungle slopes of the Cumbres Calchaquíes to the east in a barely 40 km wide meridian strip. The ample altitude range (between 400 and 5000 masl) allows for a remarkable study of vertical biotic zoning.

The archaeological sites where the samples were found are “Terraza”, “Tambo” and “Ticucho 1” (Figure 1) on the eastern slope of the Cumbres Calchaquíes (Tucumán).

During the Formative (*ca.* 2200-1200 BP), which includes “Terraza” and “Tambo”, the use of space was characterized by the occupation of hills and river terraces. Prehispanic groups that lived in small, semi-sedentary settlements in the foothills were hunter-gatherers with a complementary agriculture (Caria 2004, 2007). “Terraza” (Vipos) consists of five little defined, semicircular stone structures scattered on the surface of a river terrace. Some grey, polished, not ordinary ceramic potsherds were recovered along with other types of fragments. A sling stone was found among the lithic material apart from the obsidian. “Tambo” (San Pedro de Colalao) may be defined as a burial site on a glacis without surface structures and with ceramic materials characteristic of the Candelaria tradition in its Molleyaco phase (*ca.* 1500 AP) (Caria 2004).

Later, during the Late period (1200-550 BP) that comprises “Ticucho 1”, this site was influenced by entities of higher socio-political complexity. They came from the western slope (Santa María Valley), nd its occupants adapted spatially to the environmental characteristics, thus generating distinctive sites that were somewhat different from the typical ones of the Santa María Valley. “Ticucho 1” is on a glacis and it consists of circular stone structures five meters in diameter and a large quantity of grinding tools (mortars and “conanas”). A clearly defined occupation layer was found at a depth of 70 cm within one of the structures. It consisted of faunal, ceramic, and lithic (quartz, quartzite, obsidian and basalt flakes) materials. It was dated at 1020±35 BP (NSRL-12171) (Caria 2004).

The samples from the western slope of the Cumbres Calchaquíes are from “El Divisadero” and “El Observatorio” and those from the northern end of the Aconquija mountain range are from Quebrada del Río Los Corrales (Figure 1). In these areas, Formative occupations are masked by the reoccupation of large sites of semi-urban characteristics and by satellite settlements with differentiated functions typical of the Late period, which would make localization of the former occupations difficult (Gómez Augier 2005; Gómez Augier and Collantes 2006). However, some sites have been placed more recently that may be assigned to the Formative period. They show a spatial pattern of compound and separate circular structures associated with farming land.

“El Divisadero” (Ampimpa) occupies an ample section of the middle and apical portion of a wide alluvial fan at the western piedmont of the Cumbres Calchaquíes. Numerous groups of aggregate circular stone structures (“daisy pattern” type), small rock mounds and associated areas of cultivation platforms make up the main settling pattern; there are also some isolated circular structures of megalithic characteristics and menhir-like vertical stones. Some petroglyphs were detected in peripheral areas to the site. Ceramic materials corresponding to the Condor Huasi Polícromo, Ciénaga Gris Grabado and Aguada Pintado were recovered on the surface and in probing excavations. Lithic material includes flakes and artifacts of basalt, obsidian, quartz and pink quartzite. The architectural designs and ceramic and lithic materials found would identify this site as belonging to the Formative period (2200-1200 BP). The discovery of some structures and materials, however, suggest a possible occupation that would also encompass the Late period (Gómez Augier and Caria 2008).

“El Observatorio” site (Ampimpa) is strategically placed on a position of visual control towards the Santa María Valley at 2600 masl. Geomorphologically it covers an erosion glacis and mass remotion accumulation surfaces adjacent to a spring and natural pastures. Semicircular, rectangular and poligonal structures of different sizes were surveyed as well as retaining walls and leveling structures. Among the materials found on the surface and in excavations there is a clear predominance of Santamariano style ceramics (Santamariano Negro over Blanco-Famabalasto Negro Grabado) that would assign this site to the Late period (*ca.* 1000-600 BP). Abundant faunal material was found that belonged to domestic and wild camelids. This feature suggested the site may have been used as a space for camelid management, probably as a place for breeding and grazing subordinate to a population of higher importance (Gómez Augier 2005)

The site "Quebrada del Río de Los Corrales" is in Abra del Infiernillo at 3200 masl. This is a tectonic sinking zone within the northern section of the Aconquija range. Morphologically, it constitutes the northern limit of Valle de Tafí which lies on a North-South position and is limited in the South by the peaks of Ñuñorco Chico (2900 masl) and Ñuñorco Grande (3200 masl). There are three kinds of structures: 1) living enclosures (sample PAT 102 comes from it), 2) animal pens and 3) farming platforms. A cave was also found and studied where there were 14 mortars carved on the stone floor at the entrance (Caria et al. 2006; 2007).

The beginning of prehispanic occupation in "Quebrada del Río de Los Corrales" takes place *ca.* 2300 years BP according to radiocarbon dating of a *poaceae* sample that was part of a straw bed from "Cueva de Los Corrales 1" (CC1). The dating corresponding to Layer 2 (3rd extraction, C3A microsection) read 2060±200 BP (UGA-01616) (Oliszewski 2007 y Caria et al. 2007). Additionally, following Berberián and Nielsen (1988), if the presence of circular/subcircular living enclosures is taken into account, prehispanic occupation may be tentatively placed between *ca.* 2300 and 1200 years BP. Also, ceramic material collected at the site may be assigned to the styles known as Tafi and Ciénaga that belong to a time range between *ca.* 2100 and 1200 BP. Hence, until absolute dates are associated to agricultural structures, we consider that the beginnings of occupation for this area occurred *ca.* 2300-2100 BP**.** We do not know, in the light of current knowledge, when the living enclosures were abandoned. However, architectural characteristics and surface ceramics material, date occupation until *ca.* 1200 years BP.

Background

In 1990, new investigations aimed at localizing and characterizing obsidian sources and determining the provenance of archaeological samples in the Argentinean Northwest were carried out. Since then, ten obsidian sources have been identified and described (Yacobaccio et al. 2002): Ona-Las Cuevas, Cueros de Purulla, Chascón and Valle Ancho (Catamarca, Argentina), Quirón, Alto Tocomar and Ramadas (Salta, Argentina); Caldera Vilama 1 and 2 (Jujuy, Argentina) and Zapaleri or Laguna Blanca (Altiplano de Lípez, Bolivia). At the same time, eleven additional sources called Unknown Sources A, B, C, D, E, F, G, H, I, J, K and M were identified (Yacobaccio et al. 2002). Recent studies have found the location of Unknown Source B which we now know as Laguna Cavi (Escola and Hocsman 2007; Escola et al. 2007).

The geographic distribution of the different obsidian sources has two main distribution spheres. The first sphere is controlled by the Zapaleri source in the septentrional section of the Argentinean Northwest, and the second sphere is dominated by Ona-Las Cuevas source in the southern region (Yacobaccio et al. 2004). The latter has a distribution range of 340 km and it is the one this work will address. The Ona-Las Cuevas source is in Antofagasta de la Sierra (Catamarca, Southern Puna), 80-90 km away from the town of the same name. The obsidian from this source reached archaeological sites in Southern Puna, Valle del Cajón, western Aconquija slopes, Valle de Santa María and Valle de Lerma and Quebrada del Toro to the north between 2200 and 550 BP (Yacobaccio et al. 2002).

There are also some minor sources along with Ona-Las Cuevas, but only two are of interest for the purpose of this work: Cueros de Purulla and Laguna Cavi (previously known as Unknown B). Use of Cueros de Purulla occurred at the same time as Ona-Las Cuevas and it supplyied obsidian to different sites in the Catamarca Puna reaching as far as Valle del Cajón. Cueros de Purulla is 60-70 km southeast of Antofagasta de la Sierra, Catamarca (Yacobaccio et al. 2004). Laguna Cavi is located south-southwest of Volcán Galán, Antofagasta de la Sierra, 36 km away from Antofagasta de la Sierra. Like Cueros de Purulla, use of obsidian from Laguna Cavu was active at the same time as Ona-Las Cuevas, but obsidian from Laguna Cavi was distributed over a larger area than Cueros de Purulla. In fact, utilization of obsidian from Laguna Cavi has been detected at archaeological sites in the Catamarca Puna, the western slopes of the Aconquija range, Valle del Cajón, Valle de Santa María and Valle Calchaquí (Yacobaccio et al. 2002; Escola et al. 2007).

Analytical Procedures

Analysis of the artifacts in this study was performed using an *ElvaX* desktop energy-dispersive x-ray fluorescence (ED-XRF) spectrometer. The spectrometer consists of an X-ray generator, and X-ray detector, and a multi-channel analyzer (MCA). The detector is an electronically-cooled, solid-state Si-pin-diode with an area or 30 mm^2 and a resolution of 180 eV at 5.9 keV (at a count rate of 1000 counts per second). The X-ray tube is an aircooled, tungsten anode with a 140 micron beryllium end-window. The analyses were performed with an operating voltage 35 KV with a tube current of 45 microamps and a counting time of 400 seconds. Concentrations were calculated in parts per million using a regression program based on the quadratic regression model established from a series of obsidian reference samples previously characterized by neutron activation analysis (NAA) and XRF. The elements measured were K, Ti, Mn, Fe, Zn, Ga, Rb, Sr, Y, Zr, and Nb. All analyses of obsidian artifacts using this instrument were performed non-destructively.

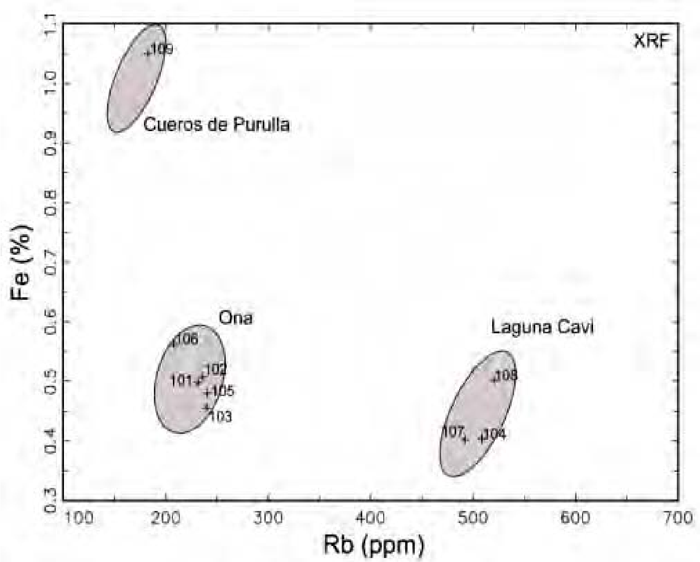

Figure 2. Bivariate plot of Fe and Rb.

Results

Analysis of the nine samples by XRF showed the following results as summarized in Table 1, Table 2 and Figure 2.

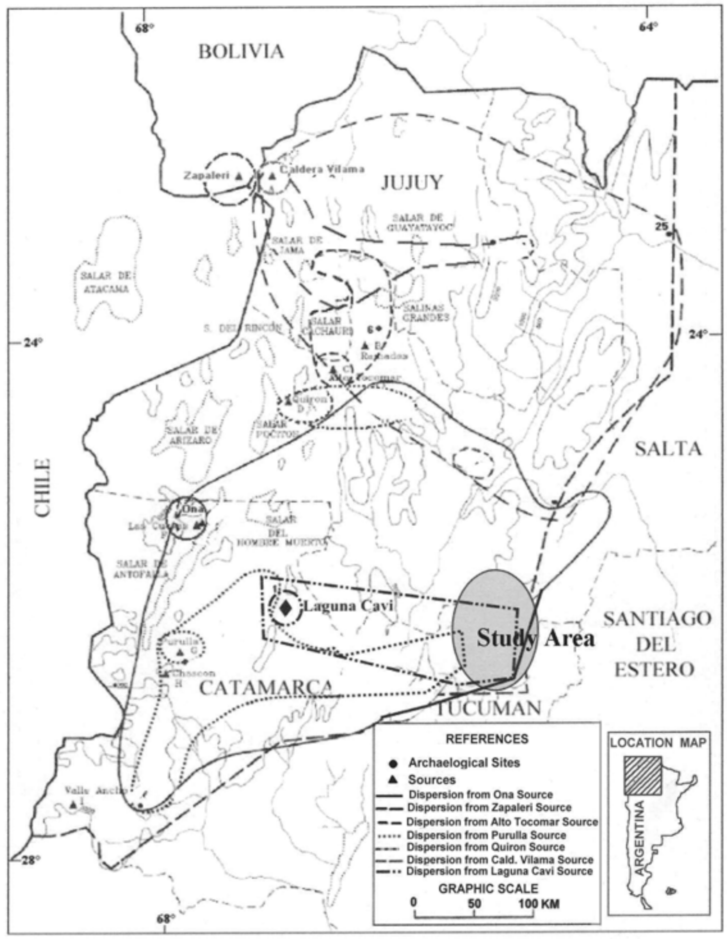

Figure 3. Obsidian distribution map (modified from Yacobaccio et al. 2004).

Conclusions

Based on the results obtained and the goals set forth, we may conclude that:

1) The original sources of the obsidian samples in archaeological sites on both slopes of the Cumbres Calchaquíes (Tucumán) belong to Ona-Las Cuevas, Laguna Cavi and Cueros de Purulla, all in the Catamarca Puna. Thus, this section of the Cumbres Calchaquíes was a constituent participant in the trade between Punean prehispanic groups and those of the eastern high valleys. In this sense, it is interesting to point out that recent XRF tests of the site El Médano (Belén, Catamarca) have detected artifacts from the sources previously mentioned in the archaeological record. This is remarkable because this strategically located site on prehispanic trade routes between the Puna and the eastern valleys has been identified as a caravan camp (Escola et al. 2007).

Table 1. Detail of analyzed samples and source identification

Site name	Sample origin	Sample number	Chronology	Sample description	Obsidian source identification
Ticucho 1 (Ticucho)	Structure 1 – Layer 2	PAT 101	1020±35 AP (NSRL-12171)	Arrow tip	Ona
Quebrada del Río de Los Corrales (El Infiernillo)	Surface collection	PAT 102	Formative	Flake	Ona
Tambo (San Pedro de Colalao)	Surface collection	PAT 103	Formative	Flake	Ona
Tambo (San Pedro de Colalao)	Surface collection	PAT 104	Formative	Flake	Laguna Cavi
Terraza (Vipos)	Surface collection	PAT 105	Formative	Flake	Ona
El Observatorio (Ampimpa)	Probing Excavation II-Level 4	PAT 106	Late	Flake	Ona
El Observatorio (Ampimpa)	Probing Excavation IV-Level 2	PAT 107	Late	Flake	Laguna Cavi
El Divisadero (Ampimpa)	On-ground collection	PAT 108	Formative-Late	Flake	Laguna Cavi
El Divisadero (Ampimpa)	Structure 1-Probing Excavation 1-Level 1	PAT 109	Formative-Late	Arrow tip	Cueros de Purulla

2) The distribution sphere of the southern section the Argentine Northwest related to the source Ona-Las Cuevas, is now spread in its southernmost portion to the low lands of Tucumán (Figure 3). Thus, the western piedmont of the Cumbres Calchaquíes (sites “El Observatorio” and “El Divisadero”), the north end of the Sierras del Aconquija (site “Quebrada del Río de los Corrales”), the eastern piedmont of the Cumbres Calchaquíes (sites “Tambo” and “Terraza”) and the Valley of Trancas (“Ticucho 1”), all in Tucumán, are included in this distribution zone.

Use of obsidian from Cueros de Purulla, stretched from the Catamarca Puna to the Valle del Cajón (Yacobaccio et al. 2002) and eastward into the western piedmont of Cumbres Calchaquíes (site “Divisadero”). The same may be said of the source at Laguna Cavi, including in this case a distribution that covers the eastern (site “Tambo”) and western (sites “Divisadero” and “El Observatorio”) piedmonts of the Cumbres Calchaquíes.

Likewise, it is interesting to observe some tendencies in this survey. Fifty-six percent of the artifacts belong to the source Ona-Las Cuevas, thus keeping the predominance already observed in previous studies of the meridional section of the Argentinean Northwest (Yacobaccio et al. 2002, Yacobaccio et al. 2004). Additionally, a parallel utilization of Ona-Las Cuevas and Laguna Cavi can be observed in two of the sites (“Tambo” and “El Observatorio”) while the same may be noticed in the site “Divisadero” where there is a parallel use of the minor sources at Cueros de Purulla and Laguna Cavi. However, a larger survey should be carried out at other sites in order to reach more definite conclusions.

The most remarkable finding from this first investigation is the inclusion of the eastern low lands in the distribution zone for obsidian from the Catamarca Puna.

Aknowledgments. Analyses were supported by the Project, 26/G333 Tucumán State University Research Council (CIUNT).

Table 2. Chemical elementary concentrations for the samples analyzed

Samples	*K*	*Ti*	*Mn*	*Fe*	*Zn*	*Ga*	*Rb*	*Sr*	*Y*	*Zr*	*Nb*
PAT101	38418.8	805.2	391.2	4973	28.8	18.7	231.5	141.6	23.5	85.4	14.2
PAT102	42512	847.8	374	5076.8	19.9	22.3	235.8	151.3	23.7	105.8	15.9
PAT103	40261.9	740.4	376.7	4548.2	22.1	20.7	239.6	130.6	21.6	84.2	14.6
PAT104	34893.2	247.1	809.2	4035.3	56.2	17.6	508.4	12.6	62.3	38.3	56.7
PAT105	39736.4	781.1	354.9	4800.5	26.4	19.8	240.5	138.4	24.3	84	17.4
PAT106	39408.2	939.8	373.4	5615	35.9	18.5	208.1	200.6	42.1	100.7	18.4
PAT107	28047.3	211.6	785.8	4018.3	33.9	21.8	492	3.3	44	90.6	22.5
PAT108	38960.8	310.6	831.7	5017.1	41.6	34.9	520.9	8.8	50.8	110.8	33.2
PAT109	41587.5	1737.4	574.8	10499.9	52.8	10.9	182.6	334.8	81.8	181.2	22.2

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AN EVALUATION OF OBSIDIAN HYDRATION DATING AS A CHRONOMETRIC TECHNIQUE, BASED ON DATA FROM ROSE SPRING (CA-INY-372), EASTERN CALIFORNIA

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Abstract

This paper reports an analysis of obsidian hydration dating (OHD) compared to radiocarbon dating, based on data from Rose Spring (CA-INY-372), southern Inyo County, California. OHD was performed using the latest mathematical techniques for effective hydration temperature (EHT) and a rigorously-derived age equation for Coso obsidian. The analysis concludes that for EHT computation, meteorologically-derived air temperatures give a better approximation to ground temperatures than reconstructed surface temperatures do; corrections for EHT will not reduce the intra-sample variation caused by obsidian chemistry; EHT-corrected obsidian hydration dates for temporally-sensitive artifacts agree reasonably well with expectations; OHD of obsidian artifacts, especially debitage, does not yield reliable indicators of the age of strata at the site. The combination of OHD and radiocarbon dates gives insights into site formation processes.

Introduction

Obsidian hydration dating (OHD) is a method whose time has come and gone several times (see, e.g. Anovitz 1999; Hull 2002; Friedman and Smith 1966; Ridings 1996; Rogers 2007a, 2008a). It was originally introduced with the promise that it would allow direct dating of artifacts, avoiding the association issues that plague radiocarbon and dendrochronology, but at times seems to have sunk to the status of a poor cousin, a technique of last resort when materials for other techniques are unavailable. Eerkens et al. (2008b) reported good results in applying OHD to sites on the south coast of Peru, but Ridings had very little success in New Mexico (Ridings 1996). Recent advances in mathematical means to correct for temperature history (Rogers 2007, 2008) hold promise, but just how good is OHD as a chronometric technique?

To address this question, a case study was performed based on the obsidian and radiocarbon data from Rose Spring, CA-INY-372, in southern Inyo County, eastern California. This site has three advantages for such an analysis: it is exceptionally well documented (Lanning 1963; Yohe 1994, 1998), has a well-defined radiocarbon age profile, and has a large (published) data sample of obsidian rim values and associated burial depths. The radiocarbon age vs. depth curve is anchored by features which are not likely to migrate stratigraphically. The data set includes 215 time-sensitive projectile points with known stratigraphy.

Five specific research questions related to obsidian hydration dating are discussed based on the Rose Spring data set. The first two are technical questions pertinent to obsidian hydration dating techniques, and the other three relate to archaeological implications:

1. Temperature Baseline: All effective hydration temperature (EHT) computations require determining three temperature parameters based on temperature history. Only meteorological data can provide a sufficiently long run of data to ensure the data are representative (of the order of 30 years), and meteorological temperatures as reported are air temperatures. Obsidian is exposed to surface temperature, suitably adjusted for depth. Surface temperature can be approximated in two ways, by using air temperature as a proxy, or by adding offsets to air temperatures. Which gives more reasonable answers in obsidian analysis? As a corollary, does on-site recording of ground temperatures for shorter time spans (1 – 3 years) yield more representative temperature results than using meteorological data?
2. Hydration Rim Variation: Hydration rims, even from specimens from the same source and the same recovery provenience, typically exhibit a spread of values. What is the source of this variability, and can EHT corrections reduce its magnitude?
3. Accuracy of Obsidian Hydration Ages: How well does obsidian hydration dating agree with expected ages of temporally-sensitive artifacts?

4. Stratigraphic Analysis: How well do obsidian ages of debitage agree with radiocarbon dates from the same strata? To turn the question around, to what extent can ages derived from obsidian debitage be used for stratigraphic dating?
5. Site Formation: What can be inferred about site formation from the concurrent use of obsidian and radiocarbon dating?

The analysis reported herein involved performing the necessary corrections for effective hydration temperature (EHT) for the obsidian data set, computing ages, and comparing with radiocarbon and with expected ages based on projectile point typology. Debitage and chronologically-sensitive projectile points are considered as separate cases.

ROSE SPRING (CA-INY-372)

Site Description

The Rose Spring site is famous as the type-site for the Rose Spring projectile point. It is located in southern Inyo County in eastern California, just west of the Sierra Nevada escarpment, with the Coso Volcanic Field adjacent to the southeast. The site is located in a high desert valley, at an altitude of 3,584 ft above mean sea level (amsl). The prevailing vegetation is creosote scrub, and the fauna are those typical of the desert.

The site consists of six loci (Figure 1), although most of the investigation has been carried out at locus 1, located in a deep draw at the foot of a south-facing basalt cliff. Locus 1 was excavated by Francis Riddell in 1951, and subsequently by the University of California in 1956 and 1961 (Lanning 1963). Further excavations, using more modern techniques, were conducted in 1987 by Robert Yohe (Yohe 1994, 1998). The combined studies resulted in over 300 projectile points, 215 of which are temporally-sensitive; furthermore, Yohe developed a detailed radiocarbon profile of Locus 1 with 17 radiocarbon dates (five of which have $\delta^{13}C$ corrections), extending to a depth of 300 cm. It is this careful documentation of data which makes this analysis possible.

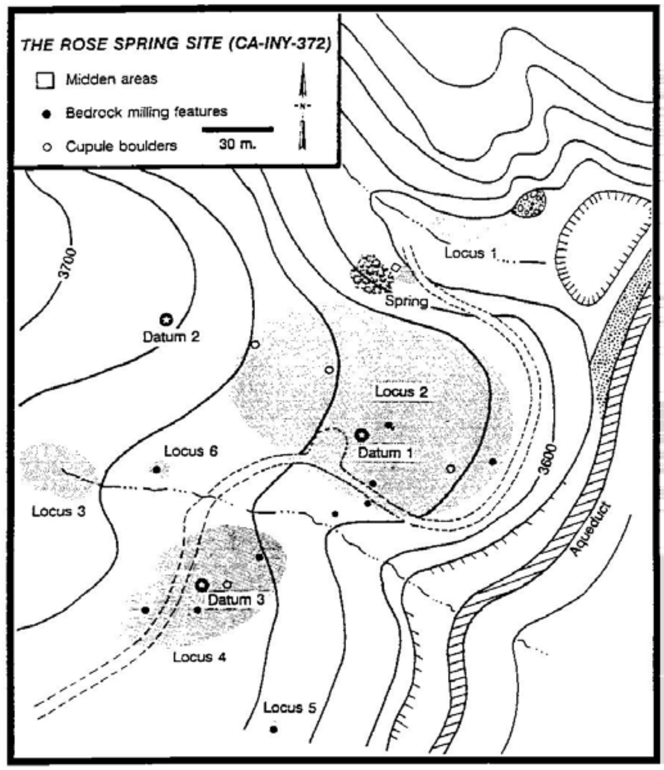


Figure 1. Map of the Rose Spring site. Artifacts analyzed in this paper were from Locus 1. (Yohe 1992:90, Figure 6; 1994; 1998).

Data Sources

Radiocarbon

The radiocarbon data cover a span of ages from 5460 rcybp to the proto-historic period, and are summarized in Table 1 (from Yohe 1998:31, Table 1). The data set includes data collected by Yohe, as well as data from earlier researchers. The depths range from 50 to 300 cm. A plot of uncorrected radiocarbon age vs. depth shows a straight line, as shown in Figure 2, indicating a remarkably uniform deposition rate at the site.

The ages from other researchers are reported without a $\delta^{13}C$ correction, although Yohe's data points did include $\delta^{13}C$ corrections (five of the data points in Table 1). The age correction is computed from the $\delta^{13}C$ measurement:

$$t_c = t_m + 16(\delta^{13}C + 25) \text{ years} \quad (1)$$

where t_c is the corrected age, t_m is measured age, and $\delta^{13}C$ is the measured or inferred value of $\delta^{13}C$ in ‰ (Bowman 1990:21). If the $\delta^{13}C$ value is larger (i.e. less negative) than -25, the corrected age is older.

Table 1. Radiocarbon data from Rose Spring (Yohe 1998:31, Table 1)

Depth, cm	Uncorr Age, rcybp	Std Dev, rcybp	Delta 13C, 0/00	Corr Age, rcybp
50	110	50		
70	280	50	-27.02	248
45	330	50		
100	330	60		
65	590	60		
85	1360	70	-11.66	1573
140	1400	50	-11.66	1613
205	2070	190		
160	2240	145		
195	2900	80		
230	3240	60	-19.77	3324
220	3520	80		
250	3580	80		
285	3900	180		
275	4030	100		
265	4460	110		
300	5460	80	-18.84	5559

The corrected ages are presented in Table 1, and the age vs. depth curve based on the corrected ages is plotted in Figure 2. It can be seen that the curves based on corrected and uncorrected ages are nearly coincident, and the difference may be due to the small sample size for the corrected curve. A χ^2 test of the slope and y-intercept of the two curves shows that the differences are not statistically significant at the 95% confidence level (Taylor 1982:159). In the analysis below, the corrected curve is used.

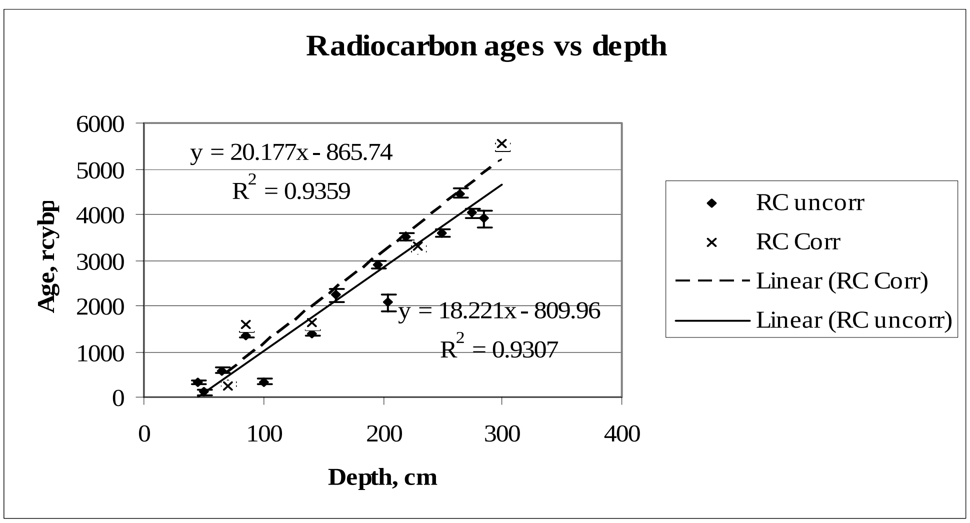


Figure 2. Rose Spring radiocarbon ages plotted against depth.

Table 2. Projectile point stratigraphy at Rose Spring (from Yohe 1998:40, Table 7). MWD is mean weighted depth of each type, in cm.

	CT	DSN	RS	ELK	HUM	GYP	PIN
0-30	11	5	33	-	3	-	-
30-60	10	4	48	2	2	-	-
60-90	3	-	32	4	2	-	-
90-120	1	-	12	2	3	-	-
120-150	-	-	3	3	6	2	-
150-180	-	-	3	10	1	-	-
180-220	-	-		6	-	2	2
MWD	38	28	55	142	93	168	195

Typed Projectile Point Stratigraphy

The stratigraphic position of chronologically sensitive projectile points was reported by Yohe (1998:40, Table 7), and is summarized in Table 2 herein. In Table 2 the weighted depth of each point type is also computed, and is shown at the bottom of the table; the order of the points is seen to be approximately correct, suggesting the stratigraphy is relatively intact.

Figure 3 presents the projectile point data as a cumulative distribution of the count of each point type as a function of depth. Again, visual inspection shows the sequences to be approximately as expected, with the possible exception of the extreme longevity of the Rose Spring type. A Kolmogorov-Smirnov analysis performed on the vertical distribution of points (confidence level = 95%) shows that within the class of arrow-size points (Rose Spring, Desert Side-Notched, and Cottonwood), the vertical distribution of individual point types cannot be distinguished, which again confirms the longevity of the Rose Spring point type in this case. On the other hand, the Elko and Humboldt type distributions can be distinguished both from the arrow points and from each other at the same confidence level. The sample size for Pinto and Gypsum is too small to draw meaningful conclusions, although both occur only a significant depths, as expected.

Table 3 summarizes the Kolmogorov-Smirnov results; “Max Delta” indicates the maximum difference between the respective distribution curves in Figure 2, while “Th 0.05” and “Th 0.10” denote the threshold value for distinguishability at confidence levels of 0.05 and 0.10 respectively.

Obsidian Hydration Data

Hydration data were reported for both debitage and projectile points. Table 4 (from Yohe 1998:48, Table 10) summarizes the published hydration data for the points, and Table 5 (from Yohe 1994:284-286, App. II) presents the data for the debitage. Debitage measurements were made by two different laboratories, and the data sets for 160-170, 170-180, 180-190, 190-200, 200-210 cm overlap. Before being summarized in Table 5, the overlapping data sets for each level were tested for statistical independence between the two laboratories, and those that were not statistically distinguishable at the 95% confidence level were merged; data for all levels except 180-190 and 190-200 cm were merged.

All obsidian artifacts were sourced to the Coso field, but not to specific flow (Yohe 1994).

Obsidian Hydration Analysis

ANALYTICAL MODELS AND TECHNIQUE

Hydration Models

Hydration of obsidian has both a physical and a chemical aspect, and is known as a diffusion-reaction process (Doremus 1994, 2000, 2002). All that is known of the physics and chemistry of the process suggests the relationship between age and rim thickness should be quadratic, i.e. of the form

$$t = k\,x^2 \qquad (2)$$

where t is age in calendar years, x is rim thickness in microns, and k is a constant, the hydration coefficient (e.g. Ebert et al. 1991; Zhang et al.

1991; Doremus 2000, 2002; Stevenson et al. 1989, 1998). Doremus demonstrated the quadratic form experimentally (Doremus 1994), as did Stevenson (2000). No other form of functional dependence is currently suggested by theory; Haller argued, based on the physical chemistry of diffusion, that if any dependence other than quadratic is found, "it is more likely the fault of the experiment rather than any inherent feature of the diffusion process" (Haller 1963:217). When obsidian data are expressed in radiocarbon years before the present (rcybp, by convention referenced to 1950), the quadratic form is still the best fit, giving the smallest overall error in age estimation, but with a different rate constant (Rogers 2006).

Table 3. Results of Kolmogorov-Smirnov analysis of stratigraphy.

	CT-DS	CT-RS	RS-EL	RS-HUM	EL-HUM	CT-EL	CT-HUM
Max Delta	0.16	0.22	0.66	0.45	0.53	0.77	0.55
Th 0.05	0.53	0.30	0.29	0.35	0.42	0.38	0.43
Th 0.10	0.47	0.27	0.26	0.31	0.38	0.34	0.38

"Max Delta" is maximum difference between curves in Fig. 2.
"Th 0.05" and "Th 0.10" are threshold values for distinguishability.

The age equation for Coso obsidian derived by Rogers (2008b), and used herein, is

$$t = 38.34x^2, \quad (3)$$

where x is rim thickness in microns and t is age in rcybp. Equation 3 was derived from a data set of 26 data points from 10 sites in the northern Mojave Desert, all corrected for effective hydration temperature. Other equations have been proposed by Basgall (1990) and Pearson (1995), but are not used here. All give similar results for "young" obsidian, especially ages less than about 3,000 years. The estimates diverge significantly for older obsidians, with Basgall's equation giving ages which are too old and Pearson's giving ages which are too young; the ages from equation 3 fall between the other two.

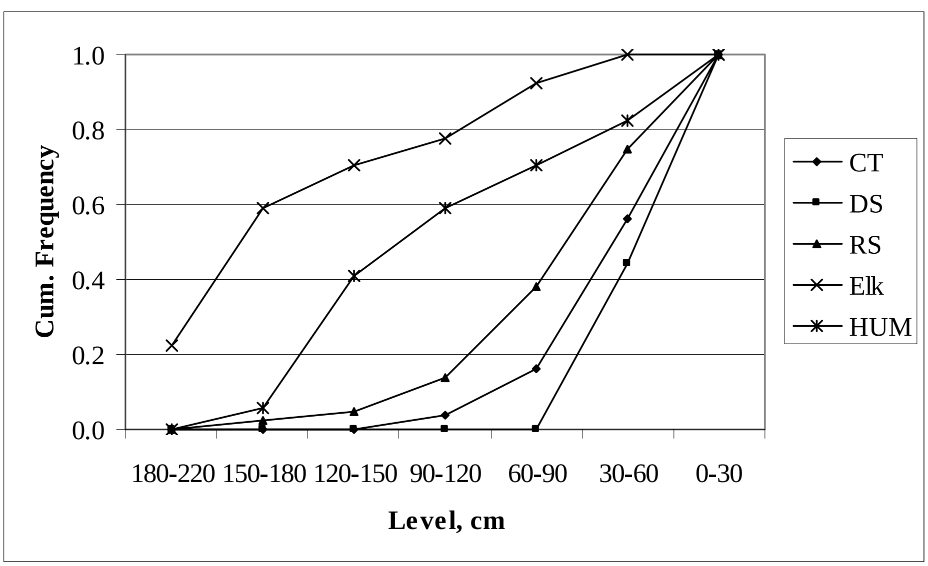


Figure 3. Cumulative distributions of point type as a function of depth, Rose Spring. The three arrow-size point types are statistically indistinguishable at the 95% confidence level; other point types are distinguishable.

Table 4. Obsidian hydration data for projectile points from Rose Spring (Yohe 1998:48, Table 10)

Cat. No.	Type	Cut No.	Depth, cm	Rim, u	Remarks
131-G1-121	DSN		0	2.3	Disturbed context, depth uncertain
131-B5-160	CLS	1	0	5.0	Disturbed context, depth uncertain
131-B5-160	CLS	2	0	7.6	Disturbed context, depth uncertain
131-FS-21	CWT		45	3.6	
131-N0-19a	RSCN	1	5	5.1	
131-N0-19a	RSCN	2	5	7.2	
131-N0-19b	RSCN	1	5	5.2	
131-N0-19b	RSCN	2	5	7.0	
131-W1-65	RSCN		45	3.7	
131-N0-80	RSCN	1	55	5.8	
131-N0-80	RSCN	2	55	18.3	Outside valid range of age equation
131-X2-74	RSCN		35	3.4	
131-XX7-72	RSCN		65	5.7	
131-F5-36a	HBN		0	6.7	Disturbed context, depth uncertain
131-F5-36a	HBN		0	6.6	Disturbed context, depth uncertain
131-W1-98a	HBN		65	6.0	
131-W1-98b	HBN		65	6.0	
131-E5-59	EL		155	7.9	
131-E5-100a	EL		165	7.6	
131-E5-100b	EL		165	7.7	

The hydration coefficient varies with EHT (see e.g. Hull 2001; Onken 2006; Ridings 1996; Rogers 2007a; Stevenson et al. 1989, 1998, 2004), with relative humidity (Friedman et al. 1994; Mazer et al. 1991; Onken 2006), and with structural water concentration in the obsidian (Ambrose and Stevenson 2004; Friedman et al. 1966; Rogers 2008c; Stevenson et al. 1998, 2000).

The analysis reported here controls for EHT by the time-dependent diffusion technique (Rogers 2007a), which specifically accounts for average annual temperature, annual variation, diurnal variation, and burial depth. The equation for EHT:

$$EHT = T_a\times(1-Y\times3.8\times10^{-5})+.0096\times Y^{0.95} \quad (4)$$

where T_a is annual average temperature, and the variation factor Y for surface artifacts is defined:

$$Y = V_a^2 + V_d^2 , \quad (5a)$$

in which V_a is annual temperature variation (July mean minus January mean) and V_d is mean diurnal temperature variation. All temperatures are in degrees C. For buried artifacts, V_a and V_d represent the temperature variations at the artifact depth, which are related to surface conditions by

$$V_a = V_{a0}\exp(-0.44z) \quad (5b)$$

and

$$V_d = V_{d0}\exp(-8.5z) \quad (5c)$$

where V_{a0} and V_{d0} represent nominal surface conditions and z is burial depth in meters (Carslaw and Jaeger 1959:81). This dependence of temperature variation on depth is well attested in physics, geology, and soil science. The numerical parameters determining attenuation with depth were determined by experiment in desert conditions, and the resulting thermal diffusivities agree well with the published values for sand (Carslaw and Jaeger 1959; App. 4). In the analysis that follows, V_{a0} and V_{d0} are referred to as "baseline" temperature parameters.

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:

$$RCF = \exp[-0.06(EHT-EHT_r)] \quad (6)$$

Table 5. Obsidian hydration data on debitage from Rose Spring, 5 to 155 cm. (from Yohe 1994:284-286, App. II)

			Uncorrected rims, u			
Depth, cm	**Level, cm**	**Uncorr rim, u**	**Mean**	**SD**	**CV**	**Sample N**
5	0	7.1				
5	0	8.5				
5	0	4.4	6.7	2.08	0.31	3
15	10	8.7				
15	10	9.3				
15	10	5.8	7.9	1.87	0.24	3
25	20	8.2				
25	20	6.2				
25	20	5.3	6.6	1.48	0.23	3
35	30	7.1				
35	30	5.3				
35	30	6.2	6.2	0.90	0.15	3
45	40	4.5				
45	40	4.4				
45	40	2.8	3.9	0.95	0.24	3
55	50	9.1				
55	50	5.9				
55	50	6.2	7.1	1.77	0.25	3
65	60	7.0				
65	60	7.0				
65	60	6.9	7.0	0.06	0.01	3
75	70	4.1				
75	70	6.5				
75	70	7.2	5.9	1.63	0.27	3
85	80	6.3				
85	80	6.3				
85	80	5.4	6.0	0.52	0.09	3
95	90	8.1				
95	90	4.5				
95	90	6.2	6.3	1.80	0.29	3
105	100	8.1				
105	100	7.1				
105	100	7.2	7.5	0.55	0.07	3
115	110	7.0				
115	110	7.0				
115	110	7.0	7.0	0.00	0.00	3
125	120	5.8				
125	120	7.1				
125	120	8.6	7.2	1.40	0.20	3
135	130	7.2				
135	130	7.5				
135	130	7.1	7.3	0.21	0.03	3
145	140	7.2				
145	140	6.4				
145	140	8.0	7.2	0.80	0.11	3
155	150	7.1				
155	150	8.8				
155	150	5.8				
155	150	8.0	7.4	1.29	0.17	4

Table 5 (continued). Obsidian hydration data on debitage from Rose Spring, 165 to 255 cm. (from Yohe 1994:284-286, App. II)

			Uncorrected rims, u			
Depth, cm	**Level, cm**	**Uncorr rim, u**	**Mean**	**SD**	**CV**	**Sample N**
165	160	7.1				
165	160	6.6				
165	160	8.0	7.2	0.71	0.10	3
165	160	6.4				
165	160	6.4				
165	160	6.5	6.4	0.06	0.01	3
175	170	10.6				
175	170	9.0				
175	170	7.3	9.0	1.65	0.18	3
175	170	5.6				
175	170	6.6				
175	170	7.2	6.5	0.81	0.12	3
185	180	6.1				
185	180	7.1				
185	180	8.7				
185	180	6.4				
185	180	7.7				
185	180	7.6	7.3	0.95	0.13	6
195	190	9.3				
195	190	7.0				
195	190	7.0				
195	190	5.6				
195	190	5.5				
195	190	8.0	7.1	1.45	0.20	6
205	200	6.8				
205	200	7.2				
205	200	5.9				
205	200	5.7				
205	200	8.1	6.7	0.98	0.15	5
215	210	9.0				
215	210	8.2				
215	210	8.1	8.4	0.49	0.06	3
225	220	8.3				
225	220	7.8				
225	220	8.3	8.1	0.29	0.04	3
235	230	8.4				
235	230	5.2				
235	230	5.9	6.5	1.68	0.26	3
245	240	7.3				
245	240	7.0	7.2	0.21	0.03	2
255	250	6.7				
255	250	7.8				
255	**250**	**8.3**	**7.6**	**0.82**	**0.11**	**3**

where EHT_r is effective hydration temperature at the reference site. The EHT-corrected rim value x_c is then

$$x_c = RCF \times x \quad (7)$$

The value of EHT_r for Coso obsidian is conventionally taken to be that of Lubkin Creek, or CA-INY-30 (20.4ºC, per Rogers 2007a; the EHT for this site cited in Gilreath and Hildebrandt 1997 is incorrect). Since most Coso work uses CA-INY-30 as a reference, correcting the rim to these conditions allows direct comparison of EHT-corrected rim data with other published data.

All the samples were assumed to have been exposed to the same relative humidity, and to a depth-corrected EHT. It has been shown that depth correction for EHT is desirable, even in the presence of site turbation (Rogers 2007b), because the depth correction, on the average, gives a better age estimate. Of course, nothing can be said about any individual artifact, because its degree of turbation is unknown. Furthermore, implicit in equation 5 is the assumption that the baseline temperature parameters refer to the surface of the ground (a point also emphasized by Onken 2006). The question of how to estimate baseline temperatures is discussed further below.

Since climate has not been stable over the periods of archaeological interest, the effects of resulting temperature changes should be included. West et al (2007) presented a graph of mean temperature fluctuations over the past 18,000 years. Data from this graph have been used to model the effects of climate change on obsidian hydration (Rogers 2007c) computed as a weighted average of effective diffusion rates over time. The maximum paleoclimatic correction is of the order of ±7% of age, and is generally smaller, so for convenience of analysis the paleoclimatic correction is omitted from the present study.

<u>Temperature Parameter Estimation</u>

Site temperature parameters were estimated from data for 13 sites in the southwestern Great Basin and northern Mojave Desert, using 30-year meteorological data reported by the Western Regional Climate Center. Based on data for this region, it has been shown that the annual average temperature decreases by 1.8ºC/1000 ft altitude increase, and to be predicted by the equation:

$$T_a = 22.25 - 1.8x \quad (8)$$

where T_a is in °C and x is altitude in thousands of feet. The accuracy of this model is 0.98ºC, 1-sigma (Rogers 2007d).

The annual temperature variation was found to decrease by 1.7ºC/1000 ft. altitude increase, and to be predicted by

$$V_a = 1.65 + 0.94T_a \quad (9)$$

with T_a defined as above. The accuracy of the prediction is 0.27ºC, 1-sigma (Rogers 2007d).

The best fit between V_d and altitude is relatively poor, and, in the absence of other data about a site, the best estimate is 15.8ºC for locations in the western Great Basin and deserts. The accuracy of this estimate is 1.67ºC, 1-sigma (Rogers 2007d).

Based on these considerations and an altitude of 3,584 ft amsl, the meteorological air temperature parameters for the site were computed to be as shown in Table 6. Surface temperatures are generally higher in the daytime, due to absorption of solar radiation, and cooler at night (Johnson et al. 2002). Analysis of high-resolution temperature data from the Amargosa Desert Research Site (ADRS), reported in Johnson et al. (2002) showed that, for ADRS conditions, the surface temperatures could be characterized by offsets from the air temperatures (Rogers 2008a). These offsets were stable over a period of six years (Rogers2008a). Based on general topographical and climatic similarity, the offsets for a ADRS were taken to be representative of surface temperatures at Rose Spring, and are summarized in Table 6.

In the context of this analysis, therefore, the following nomenclature applies: "air temperature" refers to the use of meteorological air temperature from Table 6 as the baseline temperature for obsidian hydration analyses; "surface temperature" implies the use of the offsets in Table 6 added to air temperature to estimate baseline temperature. In practical terms, "air temperature" is probably a good estimate of surface temperatures for sites with intermittent shade, and "surface temperature" would apply to sites which are devoid of shade (such as ADRS).

Table 6. Temperature parameters for Rose Spring site, deg C.

Parameter	Air Temp	Surface Temp Delta	Surface Temp
Ta	15.80	3.30	19.10
Va	16.50	6.80	23.30
Vd	15.80	9.90	25.70
EHTz	19.15	-	26.33

For this analysis, no attempt was made to include the effects of cold-air pooling, solar radiation reflection from the south-facing cliff adjacent to the site, or shading.

Data Analysis

Analytical Process

Effective hydration temperature was computed for each specimen based on equations 4 and 5 above and the parameters of Table 6. Following this, the rim thickness for each sample was corrected for EHT by equations 6 and 7 above, and age estimates were then computed by equation 3; corrections were made separately for air temperature and for surface temperature. For the debitage samples, the readings at each depth were grouped and treated as a sample of varying sample size; the projectile points were treated individually. The resulting ages are presented in Table 7 for the projectile points and Table 8 for the debitage.

Table 7. Obsidian ages for projectile points at Rose Spring.
No paleotemperature correction.

					Air Temp Corr		Surf Temp Corr		
Cat. No	Type	Cut No.	Depth, cm	Uncorr rim, u	Rim, u	Age, rcybp	Rim, u	Age, rcybp	Remarks
131-G1-121	DSN	1	0	2.3	2.5	236	2.5	231	Depth uncertain
131-B5-160	CLS	1	0	5.0	5.4	1114	5.3	1090	Depth uncertain
131-B5-160	CLS	2	0	7.6	8.2	2573	8.1	2518	Depth uncertain
131-FS-21	CWT		45	3.6	4.4	743	5.1	1015	
131-N0-19a	RSCN	1	5	5.1	5.8	1298	6.2	1495	
131-N0-19a	RSCN	2	5	7.2	8.2	2587	8.8	2979	
131-N0-19b	RSCN	1	5	5.2	5.9	1349	6.4	1554	
131-N0-19b	RSCN	2	5	7.0	8.0	2445	8.6	2816	
131-W1-65	RSCN		45	3.7	4.5	785	5.3	1072	
131-N0-80	RSCN	1	55	5.8	7.1	1952	8.4	2695	
131-N0-80	RSCN	2	55	18.3	-	-	-	-	Age equation invalid*
131-X2-74	RSCN	1	35	3.4	4.1	654	4.8	883	
131-XX7-72	RSCN	1	65	5.7	7.1	1906	8.3	2657	
131-F5-36a	HBN	1	0	6.7	7.2	1999	7.1	1957	Depth uncertain
131-F5-36a	HBN	1	0	6.6	7.1	1940	7.0	1899	Depth uncertain
131-W1-98a	HBN	1	65	6.0	7.4	2112	8.8	2944	
131-W1-98b	HBN	1	65	6.0	7.4	2112	8.8	2944	
131-E5-59	EL	1	155	7.9	10.1	3914	12.3	5787	
131-E5-100a	EL	1	165	7.6	9.7	3640	11.9	5404	
131-E5-100b	EL	1	165	7.7	9.9	3736	12.0	5547	

* Outside valid range of age equation (eq. 3).

Table 8. Obsidian ages for Rose Spring debitage.
No paleotemperature correction.

Depth, cm	Uncorr rim, u Mean	SD	N	Air Temp Corr EHT corr rim, u	Age, rcybp	Surf Temp Corr EHT corr rim, u	Age, rcybp
5	6.67	2.08	3	7.61	2218	8.16	2554
15	7.93	1.87	3	9.43	3408	10.70	4388
25	6.57	1.48	3	7.91	2400	9.12	3188
35	6.20	0.90	3	7.53	2175	8.75	2935
45	3.90	0.95	3	4.77	872	5.57	1191
55	7.07	1.77	3	8.69	2898	10.21	4000
65	6.97	0.25	3	8.62	2848	10.17	3969
75	5.93	1.63	3	7.38	2086	8.75	2934
85	6.00	0.52	3	7.49	2154	8.92	3054
95	6.27	1.80	3	7.86	2369	9.40	3385
105	7.47	0.55	3	9.40	3390	11.28	4878
115	7.00	0.25	3	8.85	3001	10.65	4346
125	7.17	1.40	3	9.09	3167	10.97	4613
135	7.27	0.25	3	9.24	3276	11.19	4797
145	7.20	0.80	3	9.18	3234	11.14	4760
155	7.43	1.29	4	9.50	3458	11.55	5112
165	7.23	0.71	3	9.27	3297	11.30	4895
165	6.43	0.06	3	8.25	2608	10.05	3872
175	8.97	1.65	3	11.52	5089	14.07	7585
175	6.47	0.81	3	8.31	2647	10.14	3945
185	7.27	0.95	6	9.36	3356	11.44	5020
195	7.07	1.45	6	9.12	3186	11.17	4781
205	6.74	0.98	5	8.71	2908	10.68	4377
215	8.43	0.49	3	10.91	4567	13.41	6894
225	8.13	0.29	3	10.54	4260	12.97	6447
235	6.50	1.68	3	8.44	2728	10.39	4138
245	7.15	0.21	2	9.29	3309	11.45	5031
255	7.60	0.82	3	9.89	3747	12.20	5708

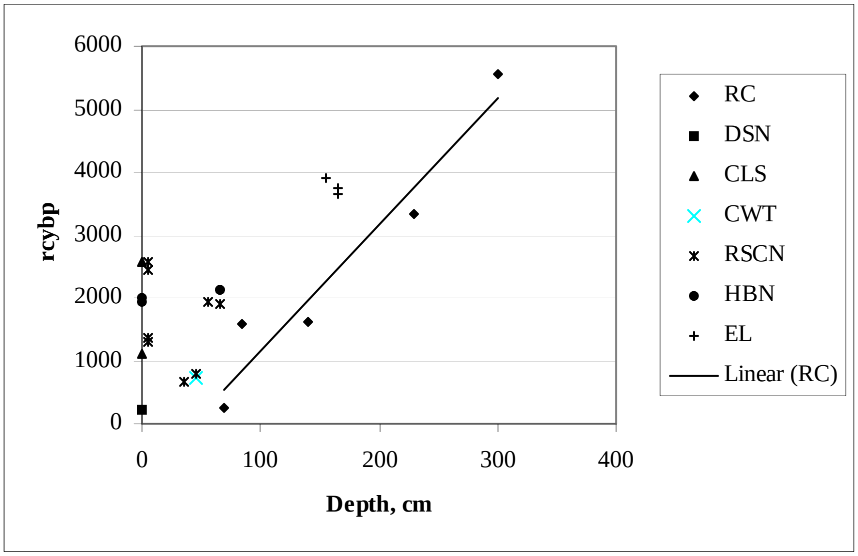
Typed Projectile Points

Considering typed projectile points first, Figure 4 shows OHD-derived ages as a function of burial depth, based on air temperatures (Fig. 4a) and surface temperatures (Fig 4b); radiocarbon ages are plotted for comparison. If the data points whose depth was uncertain (plotted near zero depth) are excluded, the result is as in Figure 5. Examination of Figure 5 shows, first, that the OHD ages are off-set at any given depth from that expected by radiocarbon, and second, that use of air temperatures gives a much better match to the slope vs. depth. The first phenomenon is probably due to site formation processes, since the projectile points are mobile while the radiocarbon ages based on features are less so. The second observation suggests that meteorologically-derived air temperatures give a better approximation to actual temperatures at the surface than reconstructed surface temperatures do. This is most likely due to the effects of intermittent shade by foliage or rocks, so the surface is not exposed to the full effects of solar radiation all day, as would be the case for a barren surface.

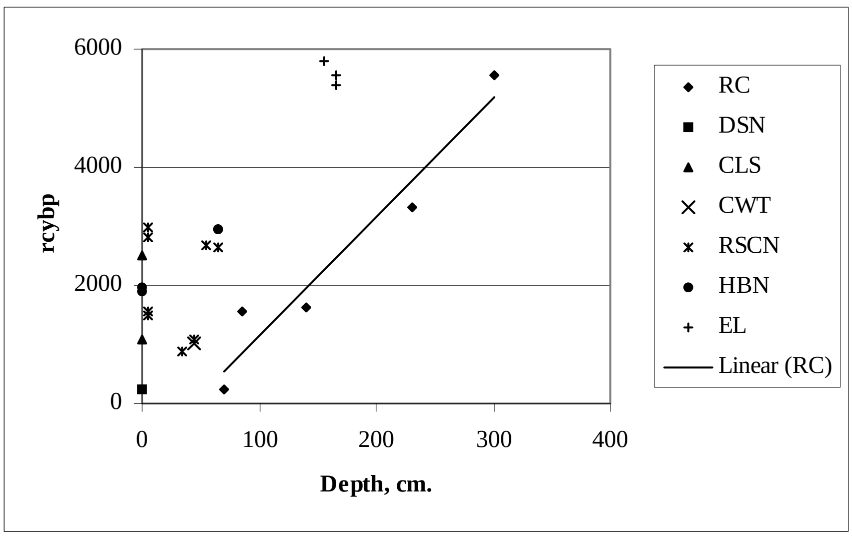
The typed projectile point age data derived from OHD can also be compared to expected values (Table 9). Here again, the ages computed based on air temperature data seem to agree better with expected values, while the ages computed from reconstructed surface temperatures (air temperature + offsets from Table 6) are too old. The case of no EHT correction is included for comparison, and yields ages which are generally too young.

Debitage

The picture is less clear with regard to ages for debitage (plotted against burial depth in Figure 6). Here neither slope agrees with the radiocarbon curve particularly well, and both show the offset to

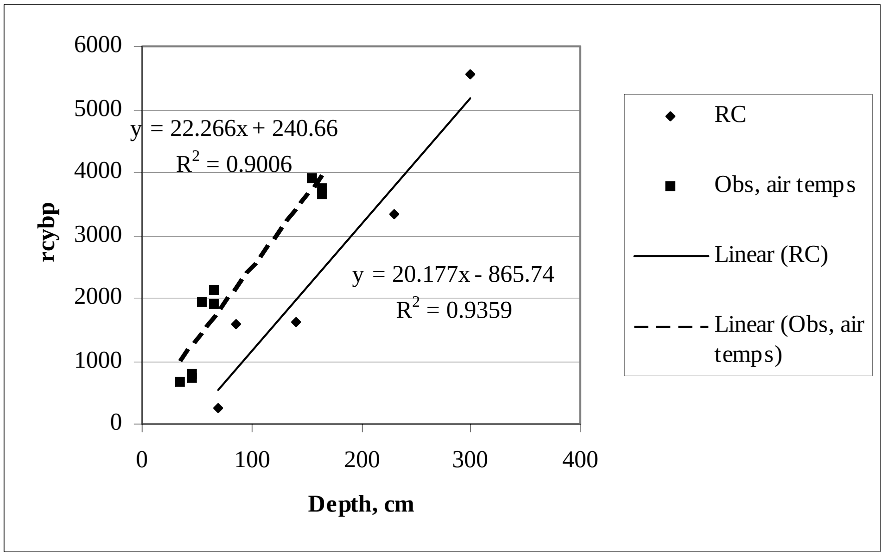


(a)

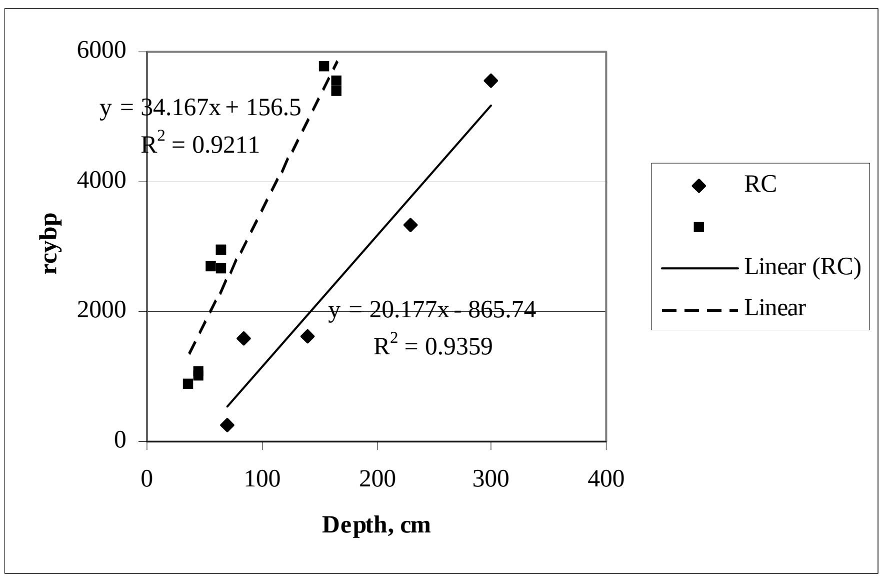


(b)

Figure 4. Projectile point hydration ages and radiocarbon ages plotted against depth. Best fit line is to radiocarbon data. (a) EHT correction based on air temperatures, (b) EHT correction based on surface temperatures.



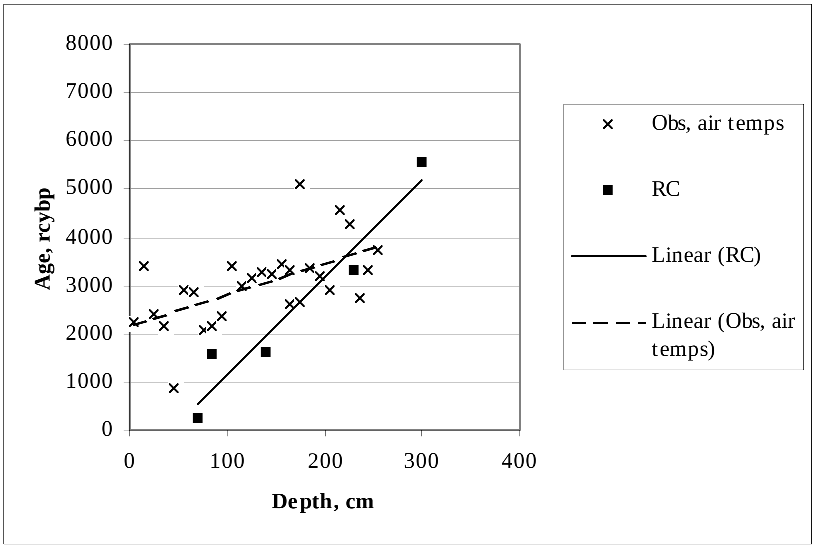
(a)



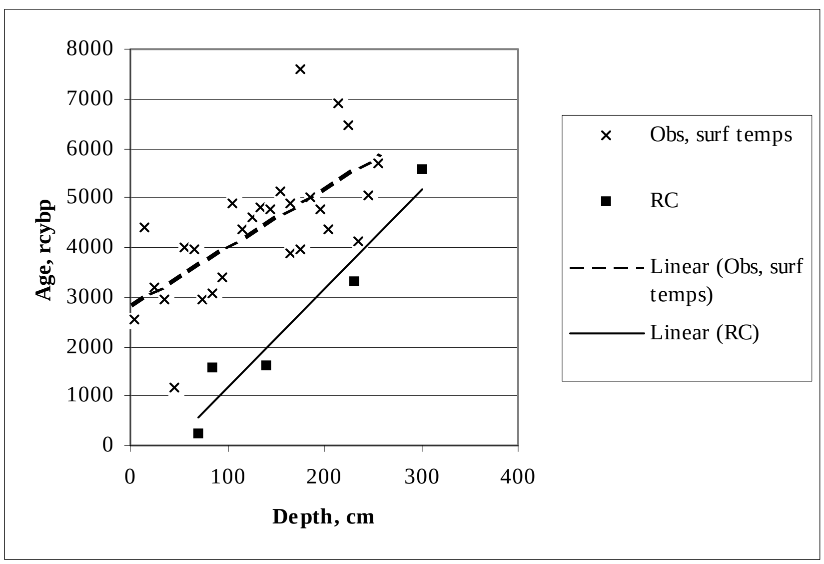
(b)

Figure 5. Projectile point hydration ages and radiocarbon ages plotted against depth. Points with uncertain depth excluded. (a) EHT correction based on air temperatures, (b) EHT correction based on surface temperatures.

younger ages as in Figure 5. The explanation probably lies again in site formation processes, especially in that later occupants of the site may have scavenged obsidian flakes to use as expedient tools. The conclusion of the analysis of the typed projectile points, that air temperatures are the preferred basis for OHD age computations, would also apply to debitage. Thus, Figure 6a is the preferred one despite the disparity in slope. The obvious conclusion here is that use of OHD-dated obsidian debitage for stratigraphic dating in inadvisable.



(a)



(b)

Figure 6. Hydration ages for obsidian debitage and radiocarbon ages plotted against depth. (a) EHT correction based on air temperatures, (b) EHT correction based on surface temperatures.

<u>Variability in Rim Thickness</u>

Examination of Table 5 shows that, for each sample of obsidian, there is significant variability in rim readings. (For this discussion, "sample" refers to the set of data points for a given 10-cm level; "specimen" refers to an individual piece of obsidian.) Although the analysis here is performed on the uncorrected rim thickness data, the results are identical when based on the EHT-corrected rim data. This is because the EHT correction, based on equations 6 and 7, is the same for all specimens of a given sample; thus the coefficient of variation (CV) for the sample is unchanged by the EHT correction.

Grouping into 10-cm levels may introduce variability, since those specimens from the top of the level were exposed to greater temperature variation than those at the bottom (per equation 5). This effect would be much more pronounced at shallow depths than at deeper ones, due to the nature of the exponential depth function in equation 5, so one would expect the CV to decrease with increasing depth. Figure 7 presents a plot of CV vs. depth, and although the CV does decrease slightly with depth, the dependence on depth is very weak; in fact, the value of R^2 (=0.1765) is so small as to be negligible, so it is not likely that this process is the cause of the variability.

Mixing of specimens between levels over the course of time is certainly probable, and could cause some of the variation. Archaeologically one would expect the mean rim thickness to increase with depth because older artifacts are typically buried more deeply, partially reduced because EHT decreases with depth. If significant mixing were occurring, the decrease with depth would be reduced or nullified. Figure 8 shows that the rim thickness does increase with depth; the R^2 value (=0.4355) is still somewhat small, but indicates a reasonable degree of correlation. Therefore, if such mixing took place, the effect is probably small, and it is unlikely that mixing is a major contributor to the observed intra-sample variation in rim thickness.

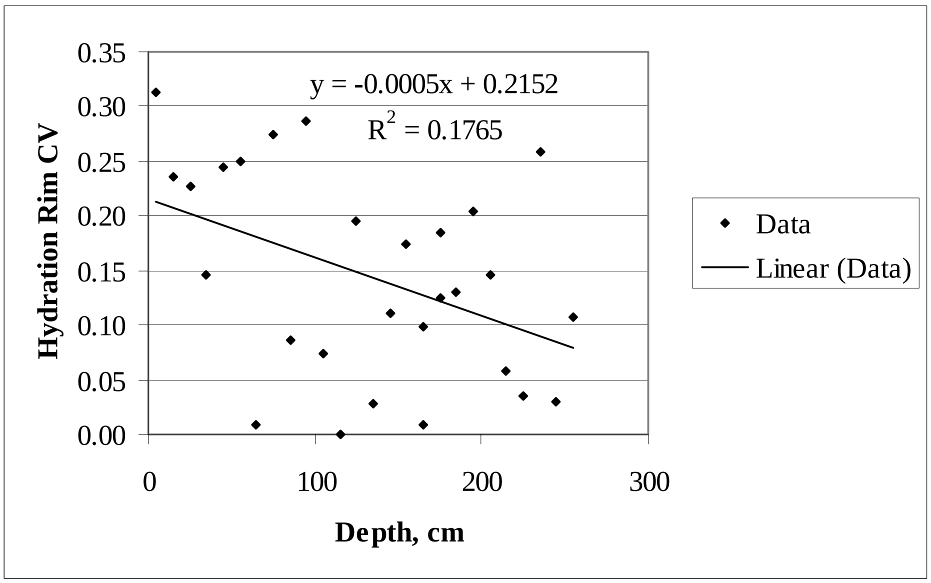


Figure 7. Coefficient of variability (CV) for uncorrected hydration rim values vs. depth at Rose Spring. Data for EHT-corrected rims are identical. R2 value is negligibly small, suggesting nearly complete lack of correlation and therefore no significance to the variation with depth.

Discussion

Examination of the radiocarbon age vs. depth curve (Figure 2) shows that the curves do not pass through the origin, but have an x-intercept at a depth of about 50 cm. The site lies in a flood channel, and this offset to the curve may suggest the magnitude of recent alluvial aggradation at the site. This conclusion is independent of any obsidian hydration results.

Key to the accuracy of obsidian hydration dating is the most suitable approximation to baseline temperature for EHT computation. The data of Table 9 show that, when meteorological air temperature is used as a proxy for baseline temperature, the ages of temporally-sensitive projectile points fall within the right ranges. The age data alone are not as conclusive, since the age data computed without EHT correction (Table 9) also fall generally within the expected range. However, the data plotted in Figure 8 show that ages computed from meteorological air temperature follow a depth trend which has essentially the same *slope* as the radiocarbon curve; they also show that ages computed without the EHT correction for depth deviate significantly from the slope of the radiocarbon curve. These lines of evidence suggest that (a) meteorological air temperature is a good proxy for baseline temperatures in EHT computations, and (b) EHT corrections by this technique yield better ages than ignoring EHT corrections (especially the effects of burial depth) altogether.

Table 9. Obsidian hydration ages of temporally-sensitive projectile points at Rose Spring, compared to expected ages.

	OHD Age, rcybp				
Type	No EHT correction	EHT Correction by Air Temperature	EHT Correction by Air Temperature + Offsets	N	Expected
Cottonwood Triangular	497	743	1015	1	Post 700 BP
Rose Spring/ Eastgate	1088 +/- 576	1324 +/- 543	1726 +/- 778	8	1700 - 700 BP
Elko	2293 +/- 91	3764 +/- 139	5580 +/- 193	3	3000 - 1000 BP

Determination of representative temperature parameters at a site is also an issue. Since it is well known that temperature parameters can vary significantly from year to year, the meteorological profession employs 30-year averages to obtain a representative data set ("seasonal norms", Cole 1970). Ideally one would like 30 years of temperature measurements at the archaeological site, including temperatures at depth, but archaeological sites are seldom collocated with weather stations with 30 years of data. Temperature estimation therefore requires making a choice between spatial specificity and temporal representativeness: either extrapolate from nearby sites which do possess 30 years of data, or make short-term measurements (typically one year) at the site and hope it is somehow representative.

As it turns out, Rose Spring is located within one kilometer of a long-term weather station at Haiwee Reservoir, which provides data meeting the 30-year criterion. However, the data from this station are not suitable because of the "lake effect", which lowers mean temperature and ameliorates variations relative to dry sites. Since the reservoir was only constructed in 1912, climatic data from this site are not representative of archaeological conditions. Daily temperature data measured at Haiwee Reservoir for the period 1960 – 1990 show an annual average temperature of 15.2°C, an annual temperature variation of 15.7°C, and a mean diurnal variation of 15.4°C; the respective parameters determined by scaling from desert sites are 15.8°C, 16.5°C, and 15.8°C, clearly showing the presence of lake effect.

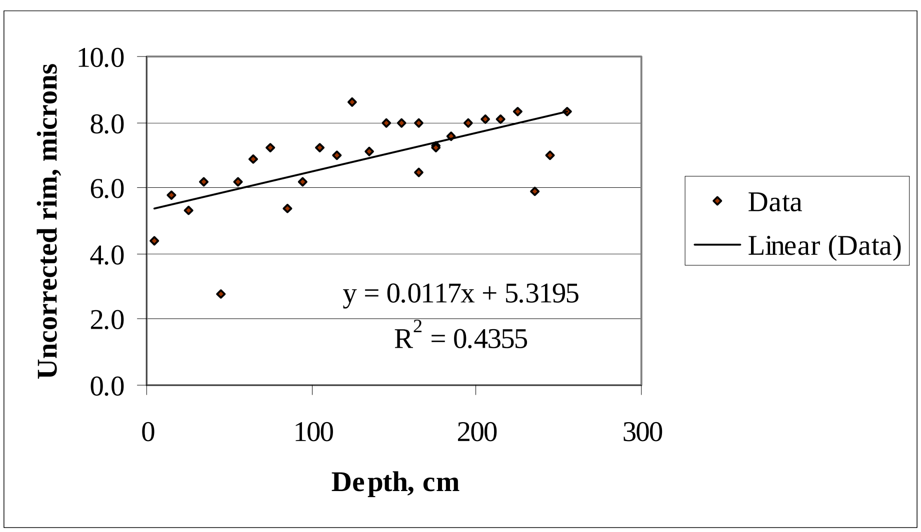


Figure 8. Uncorrected hydration rim values vs. depth at Rose Spring.

A numerical example based on the Amargosa Desert Research Site is instructive to show the effects of short-term local temperature measurement vs. use of meteorological records.

Data from ADRS (Johnson et al. 2002, plus supplemental data through 2005) showed that mean annual air temperatures varied year to year with a standard deviation of 0.7°C between 1998 and 2002; for the annual variation the standard deviation was 1.7°C, and for mean diurnal variation it was 0.9°C. These deviations caused a year-to-year variation in the computed EHT, with a standard deviation of 0.8°C, which is no better than the accuracies obtained by regional temperature scaling from meteorological data (Rogers 2007d). Therefore, for this study temporal representativeness was chosen as the criterion, and temperatures used in computing the EHT correction were based on 30-year meteorological averages, determined by regional temperature scaling.

Obsidian debitage at Rose Spring presents a more ambiguous case. When obsidian ages are computed and plotted against depth, neither approximation to baseline temperature gives a very good fit to the radiocarbon curve. In both cases the curves differ from the radiocarbon curve in both slope and y-intercept. Since the computation of age based on obsidian hydration and meteorological air temperature gives valid results for the projectile points, the lack of fit for debitage is probably due to site formation processes.

Examination of the standard deviation data in Table 8 shows that significant variability in hydration rim values exists within each level, even after correcting for EHT. In principle, such variability should not exist, since the individual specimens were exposed to essentially the same conditions and are from the same source. The fact that it does exist is probably due to one or more of four causes: the specimens were grouped into 10-cm levels and assigned a mean depth; the specimens may have been exposed to different conditions and then mixed; the specimens may not be from the same obsidian flow at Coso, and hence may exhibit different rates due to chemistry; or the variability may be due to intra-flow variations in chemistry and rate. The analysis of variability presented above showed that the first two of these possible sources of variability are unlikely to exert a large effect. This leaves hydration rate variation due to obsidian chemistry as the most probable cause of the variation in rim thickness.

The idea that rate is a function of chemical composition is not new (see e.g. Friedman and Long 1976); currently researchers in glass science generally attribute the majority of the variability to water content (molecular and hydroxyl), with anhydrous composition playing a minor role (Ambrose and Stevenson 2004; Doremus 1994, 2002; Behrens and Nowak 1997). Furthermore, Stevenson et al. (1993) have shown that Coso obsidian exhibits significant variability in water content. The effects of water variability in Coso obsidian imply a similar variability in hydration rate and hence in hydration rim thickness for a given age and temperature history (Rogers 2008c; Stevenson et al. 1998, 2000); indeed, the variability in hydration rim thickness due to variations in intrinsic water content for the Coso volcanic field as a whole has a CV = 0.21 (Rogers 2008c). For Rose Spring, the CV for the complete data set of Table 5 is CV = 0.19, which suggests the dominant factor in producing the observed variability of rim thickness at the site is obsidian chemistry, and specifically the intrinsic water (molecular and hydroxyl) content.

Since OHD provides a means for estimating the age of obsidian artifacts and radiocarbon can provide dates on features such as hearths, the concurrent use of radiocarbon and obsidian hydration age data can yield insights into site formation. For Rose Spring, the 50-cm shift in the x-intercept of the radiocarbon data suggests accumulation of at least 50 cm of alluvium overburden. The shift of projectile points to shallower depths than would be indicated by radiocarbon (Figure 5a) could indicate salvage and reuse; the fact that the shift is again approximately 50 cm may indicate that alluvial aggradation has been a long-standing process at Rose Spring, and is not confined to the recent overburden. The significantly different slope of the age vs. depth curve for debitage as compared to radiocarbon or to projectile points may indicate salvage and reuse of flakes as well as alluvial aggradation. As a cautionary point, the disparity between obsidian age vs. depth and radiocarbon age vs. depth indicates that neither obsidian debitage nor projectile points provide a reliable indication of the age of a stratum. This is probably because both of them represent moveable artifacts as opposed to stationary features, and is not due to problems with obsidian hydration dating per se.

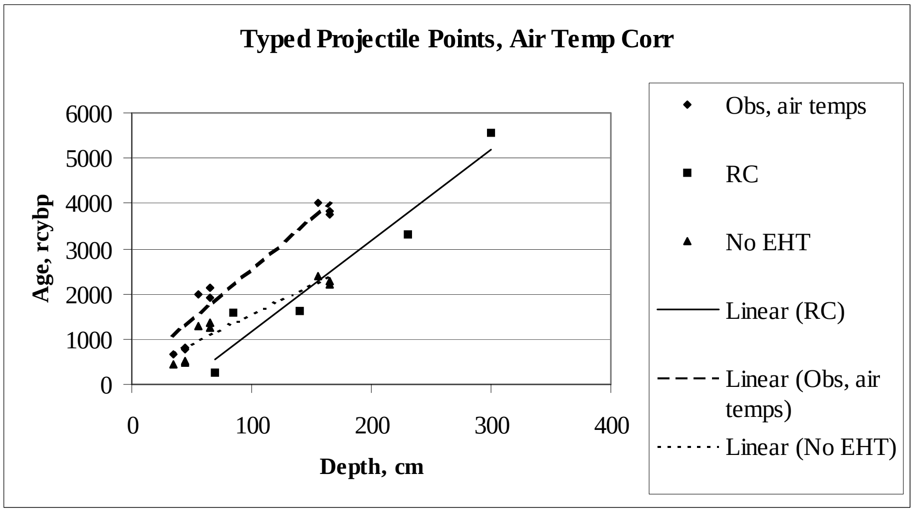


Figure 9. Trend of age with burial depth at Rose Spring, showing radiocarbon, obsidian ages with air temperature used as the baseline temperature and with depth correction, and obsidian ages with no EHT correction or depth correction.

Conclusions

The foregoing analysis provides insights to the research questions posed for this study:

Question 1. When correcting for EHT, is it better to use meteorological air temperatures as the baseline temperature, or estimate surface temperatures by adding offsets? The data on typed projectile points show that use of meteorologically-derived air temperatures gives a better approximation to baseline temperatures at the surface than reconstructed surface temperatures do. The data on typed projectile points also show the importance of applying a correction for burial depth in computing EHT, since computing ages based on uncorrected rim data, without depth correction, yields ages whose variation with depth does not agree with the radiocarbon age data. Finally, recording ground temperatures for time spans of one to three years does not improve the temperature estimates relative to using meteorological air temperatures.

Question 2. What is the source of the variability within each obsidian sample, and can the EHT correction reduce the variability? The variability within each obsidian sample is primarily due to variations in hydration rate caused by variations in intrinsic water content (molecular and hydroxyl), and it is not compensated by the EHT correction. Correction for EHT shifts the mean of the rim values and yields a more accurate mean age estimate, but it cannot compensate for chemical variations. This variability in chemistry places a limit on how well the duration of use of a site can be inferred from OHD.

Question 3. How well does obsidian hydration dating agree with expected ages of temporally-sensitive artifacts? The ages derived from OHD using air temperature correction are within the ranges expected from prior studies.

Question 4. How well do obsidian ages of debitage agree with radiocarbon dates from the same strata? Obsidian ages derived from debitage at Rose Spring do not agree well with radiocarbon ages from features at the same level. Ages derived from obsidian debitage were generally older than radiocarbon age, by approximately 1000 years. Thus, in the case of Rose Spring, obsidian ages based on debitage would not be good indicators for stratigraphic dating. The same was true of temporally-sensitive obsidian artifacts. Meaning features are a better indicator of the age of strata than are artifacts (as pointed out by Schiffer 1987).

Question 5. What can be inferred about site formation at Rose Spring from the combination of obsidian and radiocarbon? Age data derived from OHD for obsidian artifacts suggest considerable mixing of artifacts at Rose Spring. Furthermore, the mixing is not isotropic, but has an upward bias, such that obsidian artifacts at any given depth are approximately 1000 rcy older than the radiocarbon age of the stratum. Put another way, artifacts of any given age have, on the average, been shifted 50 cm upward. The mixing and resulting shift could be human, faunal, or fluvial in origin.

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ABOUT OUR WEB SITE

The IAOS maintains a website at http://www.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.

NEW: 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!

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 (available at www.saa.org/publications/StyleGuide/styFrame.html) for formatting references and bibliographies.

Submissions can also be emailed to the *Bulletin* at cdillian@princeton.edu 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 #41 is May 1, 2009.

Send submissions to:

Carolyn Dillian
IAOS *Bulletin* Editor
c/o Princeton University
Princeton Writing Program
Whitman College
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Princeton, NJ 08544
U.S.A.

Inquiries, suggestions, and comments about the *Bulletin* can be sent to cdillian@princeton.edu Please send updated address information to Colby Phillips at colbyp@u.washington.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://www.peak.org/obsidian/

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

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colbyp@u.washington.edu

Membership inquiries, address changes, or payment questions can also be emailed to colbyp@u.washington.edu

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://www.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: ____

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My check or money order is enclosed for the following amount (please check one):
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