Twenty-Five Years on the Cutting Edge of Obsidian Studies:

Selected Readings from the *IAOS Bulletin*

Edited by Carolyn D. Dillian

International Association for Obsidian Studies

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Chapter 1

Twenty-Five Years on the Cutting Edge of Obsidian Studies: Perspectives for 2014

Carolyn Dillian

Twenty-five years ago, the International Association for Obsidian Studies (IAOS) was founded to bring together obsidian researchers for the purposes of sharing data and ideas. Our membership is drawn primarily from the fields of archaeology, geology, and materials science. I am thrilled to have been involved in the IAOS for many years, and to have served as Editor of the *International Association for Obsidian Studies Bulletin* since 2004.

Our goal in putting together this collection is to highlight important contributions to obsidian studies over the past twenty-five years and to set a foundation for the future. The papers in this volume represent articles previously published in the *International Association for Obsidian Studies Bulletin.* These readings were selected to provide a range of methodological approaches to obsidian studies, including seminal research on obsidian hydration and characterization from the past twenty-five years. Case studies illustrate international examples of obsidian research by IAOS members.

The *IAOS Bulletin* has long been a forum for cutting-edge studies, works in progress, and laboratory reports. It has provided our members with insights into ongoing research as well as served as a way to solicit input from other experts in the field. As a result, it is often cited in in other scholarly journals. It is published twice per year and back issues are available on the IAOS website.

Organization of the Volume

This volume is roughly organized into three main components, focusing on obsidian hydration, obsidian characterization, and worldwide case studies, with introductory material from the first issue of the *IAOS Bulletin* by Kathleen Hull, and a prescient article by Craig Skinner on the role of the internet for data sharing in obsidian studies, to which he has provided commentary for 2014.

The brief introductory chapters are followed by the first section highlighting research in obsidian hydration. This begins with an article from the first issue of the *IAOS Bulletin* by Christopher Stevenson, Douglas Dinsmore, and Barry Scheetz that presents a comparison of hydration rim measurements from multiple laboratories and operators. This was the first to try to assess the consistency of hydration readings between laboratories, and was an important early article in the history of the IAOS. The papers that follow in this section present new methods and research in obsidian dating and conclude with a call by Ioannis Liritzis for a revival of obsidian dating, first published in 2003 and leading up to the international obsidian workshop in Melos, Greece, in the summer of 2003.

The second section of this volume is dedicated to obsidian characterization and sourcing, and opens with an article by Ellery Frahm, first published in 2012, that asks what, exactly, constitutes an obsidian "source"? This is followed by an interlaboratory comparison of characterization methods, organized by Michael Glascock, and articles devoted to a range of characterization technologies.

The third part of this volume highlights case studies from a variety of international localities, displaying the diversity of the IAOS membership's research. Finally, the volume concludes with a retrospective article by Ellery Frahm that highlights the past fifty years of obsidian sourcing studies and the work of John Dixon, Joseph Cann, and Colin Renfrew. Their work started a revolution in obsidian studies and ultimately led to the kinds of research you see in this volume.

Perspectives for 2014 and the next Twenty-Five Years

As Editor of the *International Association for Obsidian Studies Bulletin,* there are some things that I'd love to see appear in the *IAOS Bulletin* over the next twenty-five years, building on the great body of scholarship we've already accumulated in the publication. In Kathleen Hull's introduction to the first issue of the *IAOS Bulletin* (Chapter 2, this volume), she noted that much of the information published in the first issue was related to obsidian studies in California, as a reflection simply of the founding membership. Since 1989, the IAOS has grown dramatically in scope and international reach, but there are still some areas for expansion. Geographically, in this volume, we are notably lacking studies from some parts of the world where obsidian research is significant, particularly in Asia. I feel this is a weakness in this collection, given the importance of the studies taking place there, and I hope we will be able to remedy it by 2039!

It is difficult to speculate where we will be as a discipline in twenty-five years. Our methods, technologies, and research questions have changed dramatically, even within the past five years, so who knows where we will be? In 1989, we would have been amazed to know that twenty-five years later, portable x-ray fluorescence would bring obsidian characterization into the field. Craig Skinner, a mere twenty years ago, was heralding the rise of the "information superhighway" (see Chapter 3, this volume), and yet now we routinely share data, conduct research, and network over the internet.

What will the future bring? Will we have new computer algorithms to help us delineate source assignments or manipulate characterization data? Will new dating techniques or refined methods bring an end to any debates about obsidian hydration? Will archaeological procedures be so sophisticated that site mapping is done with a simple push of a button (we're almost there already)? I look forward to seeing what the future holds.

In the meantime, please send along your articles, news, announcements, and reports for publication in the *IAOS Bulletin*, and continue to share your research with the IAOS. We welcome your contributions!

Chapter 4

An Inter-Laboratory Comparison of Hydration Rind Measurements

Christopher M. Stevenson, Douglas Dinsmore, and Barry Scheetz

Editor's Preface [in original]

This paper reports the results of a comparison of obsidian hydration measurements between obsidian hydration technicians (operators) from several laboratories across the United States. The results are extremely promising, suggesting that measurements between operators and laboratories are generally comparable. Participating operators produced measurements for most specimens that fell with the optical limits of resolution of the measurement process. This preliminary assessment of the variables involved in measuring hydration rinds sets the stage for more formal, better-controlled experiments that should establish standards by which operators, laboratories, and researchers can evaluate the results of individual operators.

In the spring of 1988, a number of obsidian hydration technicians and interested archaeologists from across the United States met in Reno, Nevada during a Materials Research Conference. The seeds of the International Association of Obsidian Studies were planted at this meeting with the identification of a number of issues of mutual concern. Foremost among these was the problem of comparability of measurement results between laboratory operators. Meeting operators agreed to participate in a comparison of measurements between laboratories and operators. No experimental controls were established, as the purpose of the comparison was to establish interaction between the various laboratories and conduct a preliminary assessment of the variables that might be important to include in a more formal comparison. Another of the goals of the IAOS is to establish more formal procedures for interlab comparison to ensure that operators are producing measurement results of reasonable accuracy and comparability. While broad disclosure of the results was unintended, given the inception of the IAOS and the close agreement between operators, the results of the informal comparison are worth sharing.

The editor made several changes based on concerns raised by participants in the comparison. Unfortunately, the primary author could not be consulted regarding these minor changes as he was on Easter Island between submission of the paper and its inclusion in the newsletter. I hope the changes are acceptable, Chris.

Introduction

In recent years, concerns over the degree of precision and accuracy inherent in the obsidian hydration dating method have been addressed by several researchers and have focused on the ability of different operators to replicate measurements on identical thin sections (Green 1986; Jackson 1984; Schiffman 1988), measurement methods (Stevenson et al. 1987) and the theoretical limits of resolution associated with the optical microscope (Scheetz and Stevenson 1988). These concerns over the ability of different labs to produce consistent results are well founded, since small differences in the measurement of hydration rinds can in some cases produce substantial age differences. This may be especially critical in situations where the hydration rate of an obsidian is slow.

The results of the first large scale inter-laboratory comparison conducted by Green (1986) have not been published and are currently not available for analysis by other archaeologists. A second and different set of slides was circulated to many of the analysts involved in the first comparison. Six operators, from four laboratories, returned hydration rind measurements conducted on the reference set of 24 thin sections. One of the operators was unwilling to measure the hydration on several specimens due to reported problems with slide quality. The limited results of this operator were not included in the inter-laboratory comparison.

Inter-laboratory Comparison

The thin sections were prepared according to laboratory specifications presented in Michels and Bebrich (1971). The slides were selected from the available laboratory collections and included obsidians from Easter Island, Chile, the New Mexico sources of Cerro del Medio, Mule Creek, Obsidian Ridge, and Polvadera Peak, and a variety of unknown obsidians from Ecuador and Alaska. As a result, the slide set contained glasses containing a variety of optical images. The range of hydration rind widths was typical of that normally encountered in many obsidian studies and varied between approximately 1µm and 11µm (Table 1).

Operator	**Instrument**	**Magnification**	**Numeric Aperture**	**Resolution**	**Residual Error**
1	*IM-SP	800X	0.65	0.42	1
2	Filar	500X	0.65	0.42	1
		750X	0.85	0.32	
3	Filar	563X	0.65	0.42	0.8
4	Filar	450X	0.66	0.41	0.9
5	Filar	325X	0.85	0.32	2.1
6	Filar	325X	0.85	0.32	2.1

Table 1. Operator measurement conditions.
*IM-SP=Watson image-splitting measurement instrument.

Each laboratory also supplied a description of the measurement instrument that included the numeric aperture of the objective and the level of magnification used in the measurement process (Table 2). Using these data we have calculated the theoretical optical resolution associated with each measurement system.

During the measurement process, each of the operators evaluated the quality of the thin section. Although the rating method was not standardized, descriptions of "unacceptable" or "disqualified" were used as a basis for eliminating certain thin sections from the set of hydration rinds. The remaining slides were classified as either "good" or "adequate[i]." On the basis of these criteria, the authors excluded two of the 24 thin sections from the statistical analysis.

Lab No.	Operator 1		Operator 2		Operator 3		Operator 4		Operator 5		Operator 6	
	OH	**C**	**OH**	**C**	**OH**	**C**	**OH**	**C**	**OH**	**C**	**OH**	**C**
87-012	4.38		4.3	V	4.86		4.4		4.5		NR	
87-019	2.43		2.4	S/D	2.49		2.4	V/F	2.3		NR	
87-188	2.63		2.5/6.9	V/D	3.29/7.29		2.9/7.4	F	3.1/7.2		NR	
87-243**	5.91		6.7	S/D	6.5	V/D	6.1	P	6		NR	
87-248**	9.89		9.8	V	10.66	V/D	9.9	P/V	NR		NR	
87-261	3.92		3.9		4.19	V	4.2		3.5		NR	
87-317	2.87		3.1		3.38	V	3.1-4.3	V/F	3.9		NR	
87-361	4.28		3.7/6.2		4.35/6.52	S/V	3.8/6.3		4		NR	
87-346	5.69		5.3		5.72		5.1		4.3		NR	
87-343	7.07		6.8	V	7.2	P/V	6.6	D	7.7		NR	
87-337	3.19		3.4		3.53		3.2		3.7		2.6	
87-385	1.72		1.6		1.8		1.8		1.6		1.8	
87-391	1.2		1.5	S	1.91	S	1.5		1.3		NR	
87-390	1.08		1	S	1.25	S	1.3		1.5		NH	
88-220	7.2		7.2	S/V	7.72/9.61	P	7.6	D	7.3		9	D/I
88-242	3.14		3.1/2.2		3.22/2.48		3.4/2.4		2.8		NR	
88-257	3.6		4.4	S/D	3.6/4.6	S/V	3.8	F	4.1		4.5	P
88-287	2.39		2.2	S	2.14	D	2.4		2.4		NR	I
88-304	2.63		2.3/2.9	V	2.57	S	2.6	D	2.7		2	
88-309	1.77		2	V	2.54		2.1	D	1.6		1.8	
88-173	10.56		10.3	V	10.51		9.6	V/F	10.4		11.4	
88-150	1.54		1.5		1.64		1.6		1.3		NR	
88-188	8.65		9.1	V/F	9.81	V/F	8.9	F	9		8.1-8.7	
88-170	5.19		5.1		5.36	P	4.8		5.6		NR	
88-333*	NR		2.7	V	2.55		2.5		2.9		NR	

*The smaller of the two reported rinds were used for the analysis

**Eliminated from the statistical analysis

D=Discontinuous
S=Single Surface
OH=Obsidian Hydration Measurement
I=Inclined
P=Poor Edge
V=Vague
F=Faint, Vague
C=Comments

Table 2: Operator hydration rind measurements

Statistical Analysis of the Hydration Rind Measurements

An analysis of variance was conducted to compare the results from each of the five operators over all of the samples. Each operator was used as the dependent variable and the hydration rind measurements as the independent variables. An inspection of the results indicated that there is a very high degree of correlation between individual operator results and the least squares regression line computed from the results of the entire group. The total variability accounted for by the independent variables taken together (i.e., the range of hydration rind thicknesses between specimens) was very high, with the coefficient of determination, R^2, exceeding 0.99 each time. This implied that on an overall basis, the set of operators were measuring the same optical image.

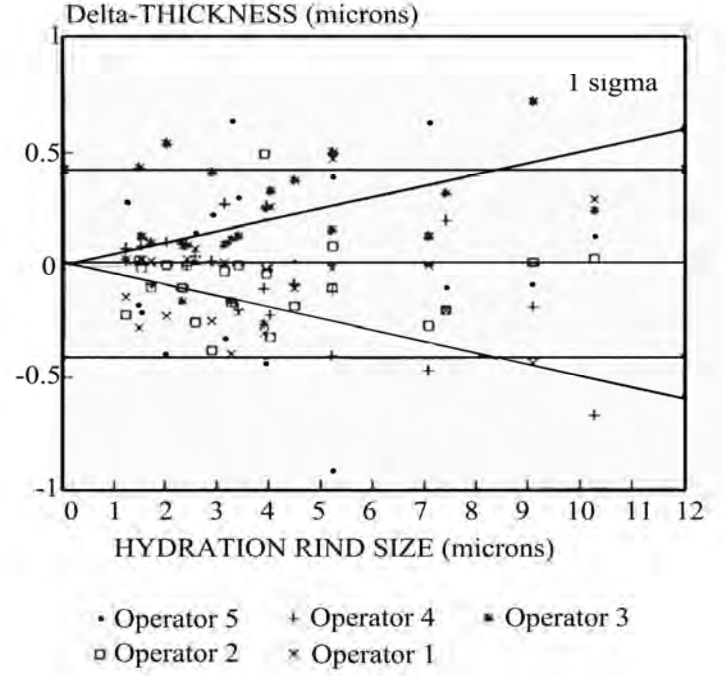

Figure 1. Delta-T vs. Rind Thickness, aggregate for all observers. Resolution limit +/- 0.5µm, based on 550nm “green”.

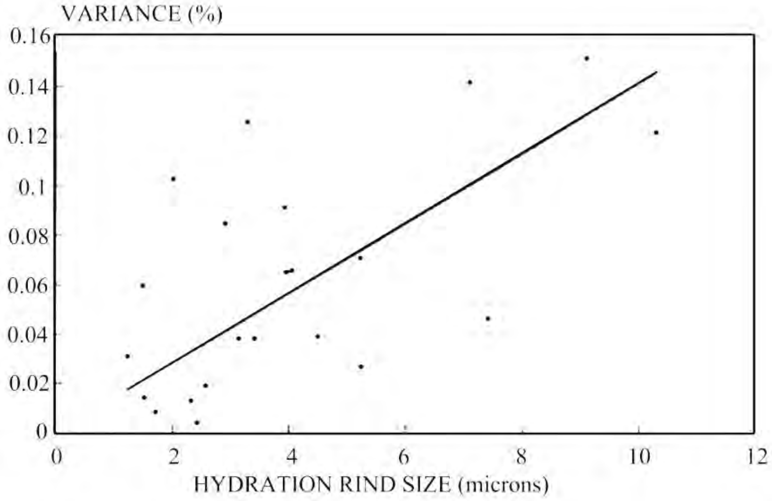

Figure 2. Variance vs. average size, aggregate for all observers.

The residuals were plotted in relation to the least squares regression line (Figure 1). An inspection of this plot indicated that approximately half of the measurements were within +/- one standard deviation of the group mean. Very few measurements were outside the resolution limit of the optical systems used by each of the operators (Table 1). Their occurrence however indicated that other causes of variation (mechanical, judgmental) were also involved[ii]. Each operator had at least one measurement that was greater than the resolution limit from the group mean. The distribution also revealed a tendency for the variation in hydration rind measurements to increase in magnitude as the hydration rinds increased in size. This trend was illustrated by a plot of the variance versus hydration rind size (Figure 2). In this analysis the variance is low and approximates 15%.

In order to determine how each operator contributed to the total variance, the residuals for each technician were plotted and inspected. These plots (Figures 3, 4, and 5) graphically portray the differences between the observed rind measurements reported by each operator and the overall group mean calculated from all measurements contributed by the five operators included in the analysis.

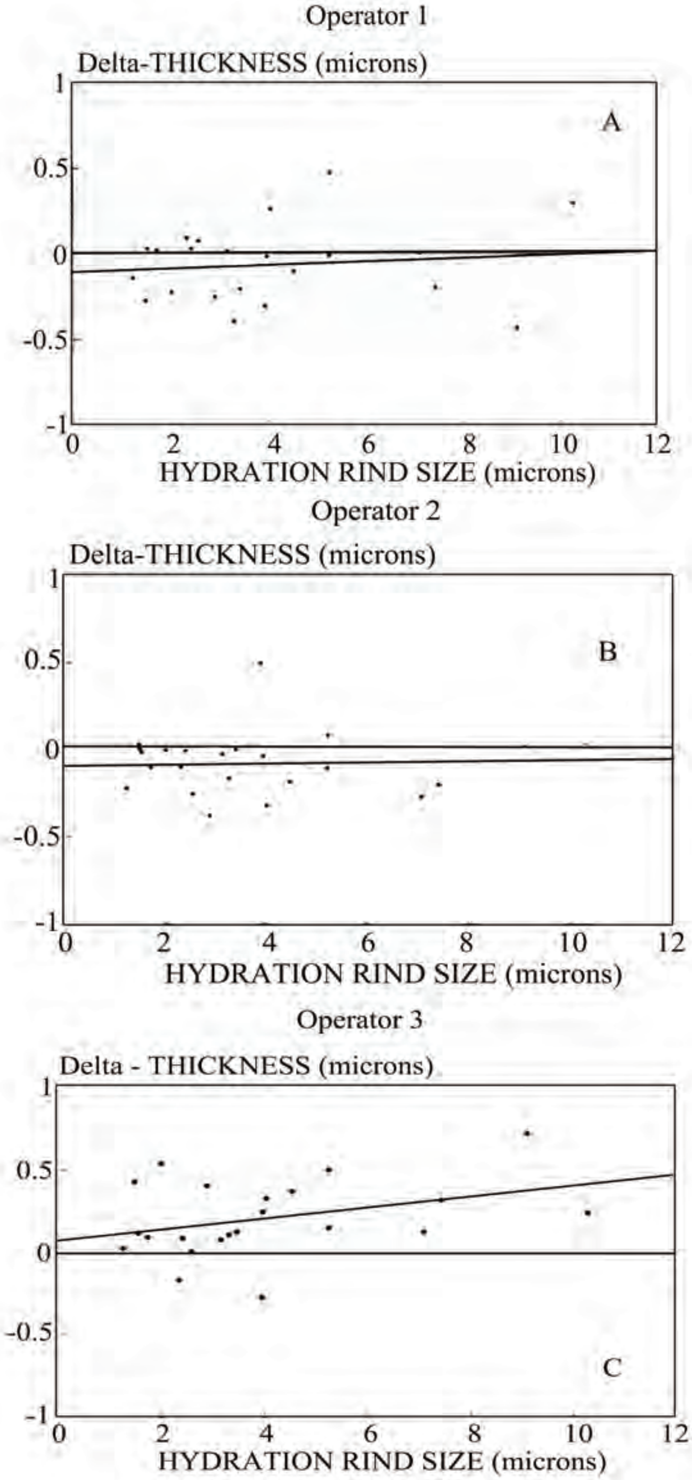

Figure 3. Delta-T vs. rind thickness. Solid line shows trend in readings.

An inspection of each residual plot revealed how each of the operators in the group measured obsidian hydration rinds. The analyses provided by Operator 1 (Figure 3) revealed a range in residual error of approximately 1.0µm. There also appeared to be tendency for Operator 1 to produce hydration thickness measurements slightly lower than the group mean. This pattern of lower-than-mean measurements was slightly more pronounced for Operator 2 (Figure 3). However, except for a single data point, the dispersion of residuals is much narrower than that exhibited by Operator 1.

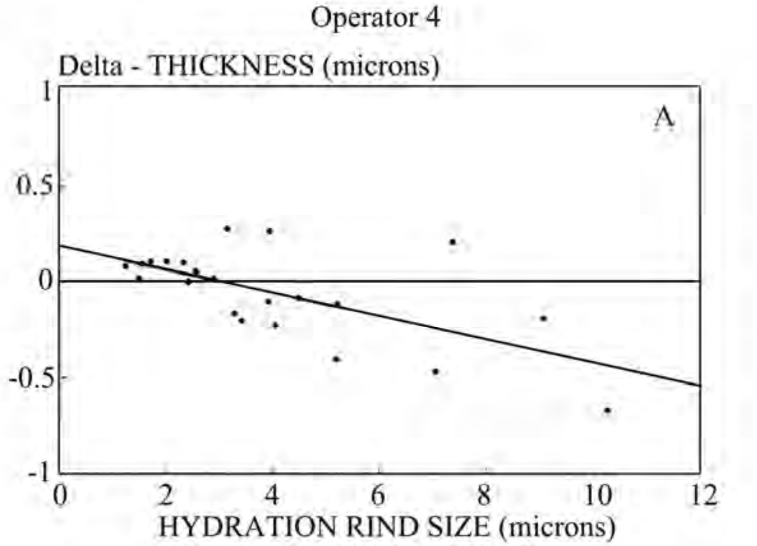

Figure 4. Operator 4, Delta-T vs. rind thickness. Solid line shows trend in readings.

Precisely the opposite pattern was identified for Operator 3 (Figure 3). Operator 3's range of measurements was approximately 0.9µm and all except two residuals were located above the group mean. The tendency for Operator 3 to produce higher-than-mean hydration rind thicknesses was not followed by Operator 4 (Figure 4). In the measurement of hydration rinds in the 1µm to 3µm range the results are very close to or slightly above the group mean. For hydration rinds greater than 3µm, there appears to be a tendency for Operator 4 to produce lower-than-mean hydration rind measurements.

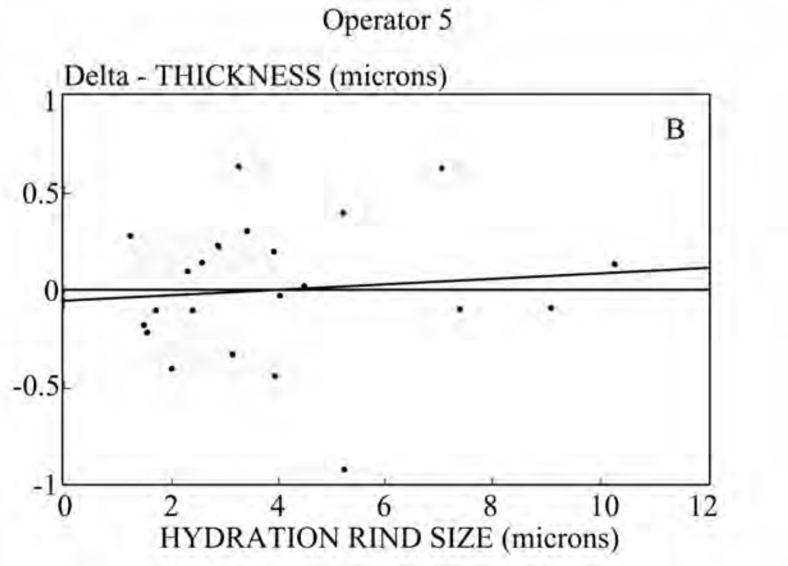

Figure 5. Operator 5, Delta-T vs. rind thickness. Solid line shows trend in readings.

The hydration rinds provided by Operator 5 show a relatively even distribution around the group mean (Figure 5). The range of residual error is 2.1µm, twice the range of other operators. If a single outlier was eliminated, Operator 5's range would be comparable.

The pattern for residual errors (Figure 1) was contrary to that anticipated from an analysis of the limiting factor of optical resolution (Scheetz and Stevenson 1988). In theory, the magnitude of the error should be inversely proportional to the width of the hydration rind. That is to say, thinner rinds are more difficult to identify and measure, with the error being greater relative to the rind size. Under these circumstances, operators would not be expected to return hydration rind measurements with error factors that increase with larger hydration rind widths.

Discussion

The analyses conducted here show a good agreement between persons in the field who measure obsidian hydration rinds. The high R^2 values for the correlations conducted between individual operator measurements and the low variance (15%) for all observers are gratifying. However, the outcome of the analysis raises two questions:

> 1). Why did the trend of increasing residual error contradict the pattern predicted from a consideration of the effects of optical resolution on the measurement process?
>
> 2). Why was there a tendency for operators to either produce lower-than-mean or higher-than-mean measurements of the width of the hydration rind?

At this point in time, a compelling explanation to the first question is not to be found. It is possible that the trend toward increasing residual error with greater rind width is a combination of several factors that include operator calibration, sample preparation, and the quality of the optical image. We consider the latter factor to be of greatest importance. It is our experience, for larger hydration rinds, that in some cases the intensity of the rind image may be less and that the diffusion front less clearly defined. Under such conditions, it may be difficult to locate the transition with the certainty experienced in the measurement of thinner rinds.

The criteria used by each operator to determine if a hydration rind was in focus and to define the limits of the diffusion front would appear to offer a reasonable explanation for the bias toward higher- or lower-than-mean measurement results. It has been repeatedly observed by the senior author that a hydration rind may be in focus over a narrow focal length yet at the same time, vary appreciably in width. Defining an "in focus" image is therefore in part a subjective decision. A second subjective decision is made in defining the interior limits of the hydration rind. In white light, the edge of the diffusion front is often represented by a grey band of finite thickness that may be up to 0.1μm in thickness. Deciding where to terminate the measurement process on this line may add some additional amount of variance to the process.

As noted above, the amount of variance between individual operators is approximately 15%. Reducing the variance to a lower value would involve the operator trying to make subtle variations in his measurement methods. We suggest that such a strategy could probably not be achieved because of the fine modifications in judgment required on optical images that themselves exhibit a significant amount of variation. One possible option would be to develop an "operator calibration factor" using a standard set of calibration slides. With a calibration factor, the rind measurements of the "higher-than-mean" and the "lower-than-mean" operators could be adjusted on a statistical basis to more closely approximate the group mean. Such an approach could bring the results of different labs into closer agreement if properly conducted. We see such a procedure as enhancing the credibility of obsidian hydration dating within the archaeological discipline.

Acknowledgements

We would like to thank each of the participants involved in the study for their efforts and timely return of the hydration rind measurements: Irving Friedman, Rob Jackson, Tom Origer, Kim Tremaine, and Fred Trembour.

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[i] Table 2 was modified by the editor [in original] to include all six operators' measurements and their comments. Comments made by the various operators were standardized and coded.

[ii] Editor's note [in original]: a group mean is a measure of central tendency that reflects the entire distribution. The group mean does not equate with the "correct" hydration thickness. Any of the operators, for any individual measurement, could be closer than the rest in approximating the hydration of that specimen, even if that operator's measurement is furthest from the group mean.