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VOLCANIC GLASS HYDRATION-RIND AGE DETERMINATIONS FOR BELLOWS DUNE, HAWAII

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Abstract

Volcanic glass hydration-rind analysis offers many advantages as a dating technique in Hawaiian archaeology. Previous results must be considered in the light of ongoing research, and it now seems clear that great care must be taken in sample collection, acquisition of provenience temperature data, and laboratory cross-checks on hydration thickness measurements. Thirty-seven specimens of basaltic-glass from the Bellows Dune, an early Hawaiian site, have now been dated. Twenty-four of the derived dates are presented here for the first time and thirteen previously published dates are reanalyzed. These figures are discussed in the context of current hydration-rind research. The substantive results allow a correlation of Bellows strata excavated in 1967 and 1975 and suggest that the Bellows occupation may not be as old as previously indicated.

INTRODUCTION

The prehistoric Hawaiian past has been chronologically controlled by the use of genealogies, artifact seriation, carbon - 14 analysis, and volcanic glass hydration-rind measurements. Within the last decade, hydration-rind analysis has become the foundation of Hawaiian chronologies, as reference to virtually every recent field report will attest.

The advantages of volcanic glass hydration-rind analysis as a technique of age determination are substantial. Nevertheless, the technique is still in its developmental stages in Hawaiian research because all of the variables relevant to hydration have not been determined and because some of the known environmental variables can only be approximated. Additionally, anomalies in rind widths create variations that need to be accounted for. We also suggest that there are several archaeological sampling problems which require more attention than generally considered.

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Many of these problems became apparent in the dating of volcanic glass from the 1975 excavations at the Bellows Dune Site, Oahu, considered the earliest known site in the Hawaiian Islands. The present paper presents the recent Bellows dates in the contexts of ongoing dating problems. The problems are considered in general terms below, followed by the Bellows material. The 1975 volcanic glass specimens and the reanalysis of previously reported 1967 and 1975 specimens (Kirch 1974; Cordy and Tuggle 1976) are presented here.

PROBLEMS IN HYDRATION DATING IN HAWAII

Recent Hydration Dating Research

The primary hydration research in Hawaii has been conducted by Morgenstein (Morgenstein and Riley 1975; Morgenstein and Rosendahl 1976; Morgenstein and Child 1977). Research on the hydration of high silica (rhyolitic) obsidian found in continental areas indicates that the hydration rate is affected by glass chemistry and by the depositional environment, especially temperature and soil pH (e.g., Ambrose 1976; Ericson 1975; Friedman and Long 1976). However, much of the Hawaiian glass is a low silica, mafic material (termed "sideromelane" by Morgenstein) whose hydration product is palagonite. Previous research suggested that the hydration of mafic glass is controlled by a linear chemical reaction whose properties vary considerably from those of obsidian diffusion. Recent research indicates that as long as the SiO_2 concentrations remain below rhyolitic levels, the chemical composition of the glass (other than the amount of connate water) may not affect the rate of hydration (Morgenstein, personal communication; Morgenstein and Child 1977), although this remains to be demonstrated experimentally.

Until recently the hydration rate of Hawaiian glass has been calculated linearly at 11.77 micrometers/1000 years, with the assumption of an island-wide effective temperature of 24°C. This rate was determined by the measurement of hydrated rinds on glass obtained from historic flows tied into a theoretical temperature curve (Morgenstein and Riley 1975). The use of this rate has produced dates which have generally correlated well with radiocarbon age determinations from comparable proveniences (Hommon 1976; Morgenstein and Rosendahl 1976). The error range appended to a hydration date has been calculated by various means in published chronological tables. Within recent months hydration-rind dating has been concerned with actual site temperatures rather than with an island-wide constant, resulting in a dating refinement (Morgenstein, personal communication). All of the dates for Bellows reported herein are based on the previously standard rate of 11.77μm/1000 yrs at 24°C.

Anomalies in Rind Widths

In addition to 'natural' variation resulting from the above factors, 'artificial' variation in hydration rind results may be produced in the laboratory by (1) thin section problems and (2) calculation problems. Thin sectioning can damage rinds, resulting in lower rind-width measurements. Thin sectioning can also cut obliquely through rinds due to improper cutting or when the specimen has a fluctuating facet. These problems will yield a few anomalous rind widths that do not reflect the age of the specimen. (In the case of improper oblique cutting, all the measurements will be inaccurate.)

Calculation problems can result from human and instrument error. For the Hawaiian material ten traverses or measurements are usually made on each specimen. In some cases, a specimen may have two flake-scars of different age with different rind widths. Unless this is recognised, measurements from flake scars of two different ages may be combined into one date. Other kinds of human and instrument error are also possible (e.g., failure to recognise the proper rind).

Once the non-temporal variables which produce variations in hydration rind widths have been eliminated, it is still necessary to keep in mind that a hydration rate remains a statistical-theoretical inference. For this reason it is argued that dates should be expressed in "HR" years (just as radiocarbon dates should be expressed as "RC" years) for the sake of clarity.

Archaeological Sampling Considerations

As part of the archaeological dating process, the archaeologist has to consider two dimensions of sampling regarding dated specimens. The first is whether or not a provenience has yielded specimens so that its duration can be said to be adequately sampled. This is in part a matter of the chance recovery of datable materials, so the adequacy of sampling must be carefully argued by the archaeologist. The second dimension of sampling is the selection of specimens for analysis from the total collection: are these representative of the full range of temporal variation from the total collection of a particular provenience?

An additional consideration is the basic problem of all archaeological dating: establishing the relationship between the dated material and the provenience which is by inference dated. In the case of hydration dating, a "contempraneous" date must be based on the argument that dated specimens come from _in situ_ chipping and are thus not in a secondary location. If the latter is the case, it can only be argued that the provenience is later than the age of the dated specimen.

VOLCANIC GLASS SPECIMENS FROM BELLOWS: ANALYSIS

The early Hawaiian site of Bellows is a stratified dune with at least three habitation deposits. The artifact types, settlement characteristics, and antiquity have assured its importance in Hawaiian prehistory (Kirch 1974) and will not be discussed here. The original chronometric age determinations for the site, first excavated in 1967, were based on radiocarbon analysis (Pearson, Kirch, and Pietrusewsky 1971). Additional dates were obtained later from hydration analysis of volcanic glass (Kirch 1974). A second excavation was conducted in 1975, and preliminary hydration ages were reported (Cordy and Tuggle 1976). The present paper reports a reanalysis of the previously dated 1967 and 1975 specimens and an analysis of additional specimens from both excavations. The basic distributional and stratigraphic information is taken from Pearson, Kirch, and Pietrusewsky (1971) and Cordy and Tuggle (1976).

Age determination analysis was carried out with the following problems in mind:

1. correlation of strata between areas of the dune excavated in 1967 and 1975 (the intervening area was destroyed in the period between excavations; Cordy and Tuggle 1976);
2. establishment of a chronometric frame for Bellows occupation;
3. estimation of the duration of occupations and periods between occupations.

Thirty-seven dated specimens are included in this analysis (Table A). The specimens from the 1975 excavations were selected by Cordy and

TABLE A. VOLCANIC GLASS SPECIMENS FROM BELLOWS DUNE EXCAVATIONS: TOTAL NUMBER EXCAVATED; NUMBER THIN-SECTIONED AND EXAMINED FOR RIND; NUMBER WITH IDENTIFIABLE MEASURABLE RIND

1975 Excavations

PROVENIENCE	St.II	St.IV	St.IVb	Tr.9	Totals
Total:	62	9	1	2	74
No.thin-sectioned:	20	2	1	1	24
No.dated:*	14	2	1	1	18

1967 Excavations

PROVENIENCE	St.I	St. II	St.II/III	St.IIa	St.III	Totals
Total:	12	ca.200	10	3	1	ca.226
No. thin-sectioned:	2	12	2	3	1	20
No. dated:*	2	11	2	3	1	19

* thin-sectioned specimens with measurable rinds

Tuggle, and the hydration analysis was conducted by Child using the general linear rate. Subsequently, through the courtesy of Patrick Kirch, we obtained the volcanic glass collection from the 1967 excavation, and hydration analysis was carried out by Child on a selection to augment the original 1967 sample of age determinations (Kirch 1974). It was found that there was a significant discrepancy between the pattern of age determinations for the two selections of 1967 material which had been analysed: the dates were consistent within each independently dated set, but the dates between sets were not comparable.

Child reanalysed all thin-sections prepared from Bellows Dune glass -- 1967 and 1975 excavations. It was discovered that the Bellows volcanic glass had a number of rind features which made measurements difficult (e.g. cracking along the rind surface). This measurement problem had not been perceived in the original analysis. Experience working with volcanic glass in recent years enabled resolution of the problem. The original dates were considered to have resulted from improperly measured rinds; a re-analysis by Child has produced corrected measurements (Table B).

Analytical Procedures

Prior to thin-sectioning, specimens were descriptively classified and samples selected based on provenience and then, where possible, on surface regularity. Each Bellows sample was thin-sectioned: cut at 90 degrees perpendicular to the plane of the major flake scar, and then hand-polished with fine carborundum grit and mounted on a glass slide. The mounted samples were ground to 20 micrometers in thickness with a final fine hand-polishing. When the major rind was isolated under the micro-scope, ten measurements (traverses) were made. The ten traverses were averaged and a standard deviation was calculated to provide a rind width in micrometers.

The entire set of Bellows dates is presented here. The 1967 excavations' volcanic glass dates and proveniences are in Table C; the 1975 dates and proveniences in Table D; combined data are in Figure 1.

TABLE B

ORIGINAL 1967 AND 1975 DATES & CORRECTED MEASUREMENTS

Stratum	Sq.-Id. No.	Original Measurements[1]		Corrected Measurements	
		Mean Rind Width (µm)	Mean Date HR yrs AD	Mean Rind Width (µm)	Mean Date HR yrs AD
1967 Excavations					
I[2]	B2 - 1	12.25	873 ± 50	11.33 ± 1.07	1012 ± 91
	B2 - 2	12.28	897 ± 60	11.41 ± 1.09	1006 ± 96
II	B20 - 6	14.18	767 ± 90	12.56 ± .36	908 ± 31
	B2 - 3	13.98	779 ± 100	12.36 ± .48	925 ± 41
	C4 - 1	14.44	735 ± 120	12.70 ± .24	896 ± 20
IIa	A5 - 1	15.64	618 ± 126	13.79 ± .74	803 ± 63
II/III Interface[3]	A20 - 1	14.20	683 ± 58	12.94 ± .65	876 ± 55
III	N21 - 1	19.44	323 ± 150	18.44 ± 1.23	408 ± 105
1975 Excavations					
II	39 - V1[4]	14.50	735 ± 74		
	39 - V7	10.47	1085 ± 76	10.47	1085
	25 - V3	12.61	904 ± 88	12.40 ± .63	921 ± 54
IV	39 - V8	15.43	763 ± 94	15.22 ± .52	682 ± 44
	28 - V5	14.10	775 ± 90	14.03 ± .50	783 ± 42

1. 1967 data from Kirch (1974). 1975 data from Cordy and Tuggle (1976).
2. As pointed out by Cordy and Tuggle (1976), 1967's stratus I was not a cultural layer. Apparently it is disturbed surface material.
3. The cultural meaning of II/III Interface is uncertain (see Kirch 1974).
4. The thin-section of this specimen was found to have two flake scars of different ages upon reanalysis.

TABLE C

1967 HYDRATION DATES AND PROVENIENCES

Stratum	Sq.-Id. No.	Mean Rind Width (μm)	Mean Date (HR yrs. AD)
I	B2 - 1*	11.33 ± 1.07	1012 ± 91
	B2 - 2*	11.41 ± 1.09	1006 ± 93
II	B2 - 1	11.35 ± .95	1011 ± 81
	B2 - 2	12.13 ± 1.27	944 ± 108
	B2 - 3*	12.36 ± .48	925 ± 41
	B20- 1	13.61 ± .75	819 ± 64
	B20- 3	13.32 ± .41	843 ± 35
	B20- 4	12.00	955
	B20- 5	12.60	904
	B20- 6*	12.56 ± .36	908 ± 31
	C4 - 1*	12.70 ± .24	896 ± 20
	C4 - 2	11.50 ± .75	998 ± 64
	C4 - 3	11.66 ± .94	984 ± 80
II/III	A20- 1*	12.94 ± .65	876 ± 55
	A20- 2	14.06 ± .63	780 ± 54
IIa	A5 - 1*	13.79 ± .74	803 ± 63
	A5 - 2	14.90	709
	A5 - 3	14.25 ± .45	764 ± 38
III	N21- 1*	18.44 ± 1.23	408 ± 105

*Reanalyzed specimens, originally published in Kirch (1974).
1975 = 0 BP.

TABLE D

1975 HYDRATION DATES AND PROVENIENCES

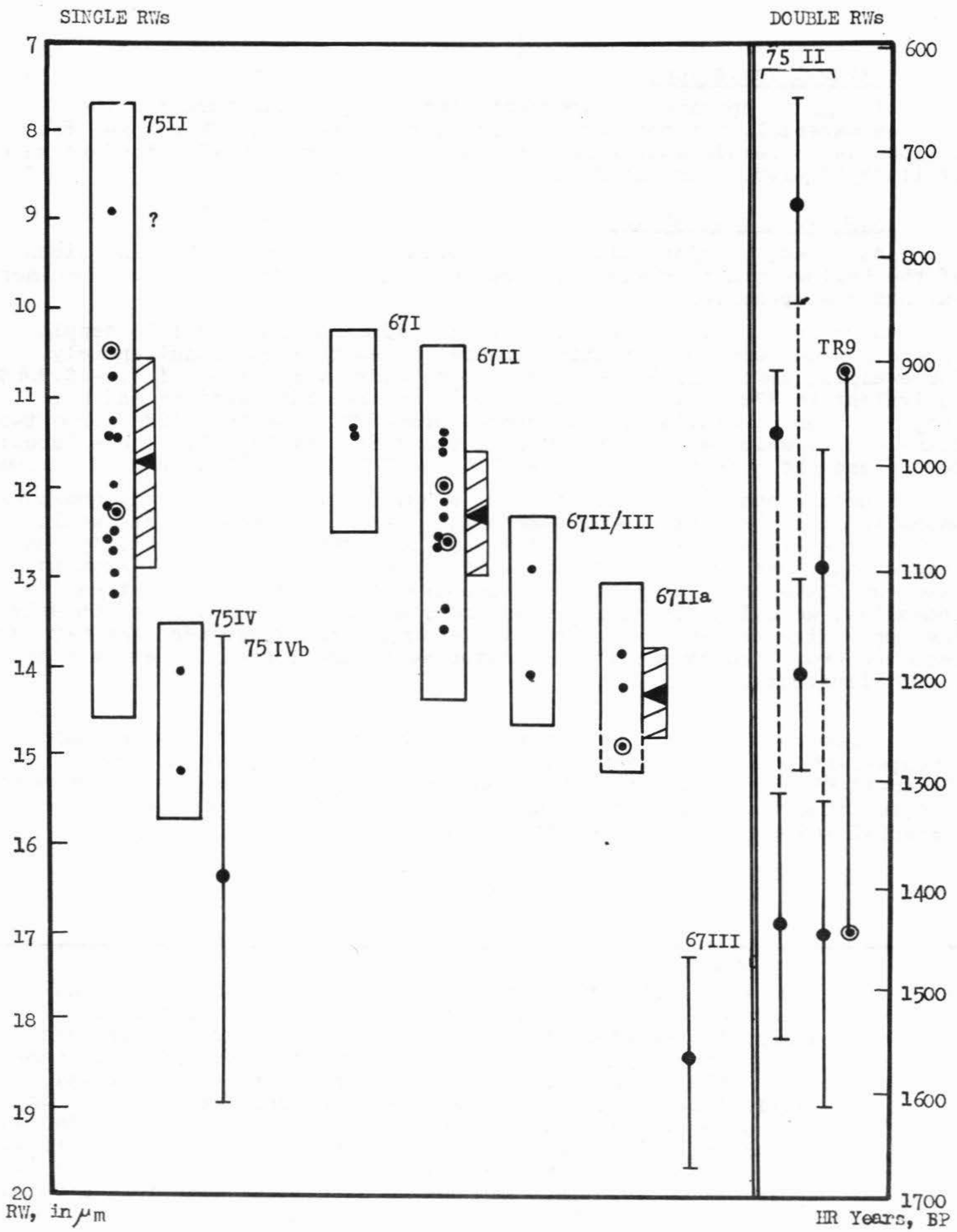
Stratum	Sq.-Id. No.	Depth (cm)	Double Date[1]	Mean Rind Width (μm)	Mean Date (HR yrs. AD)
II	04 - V1	Sc[2]	a	11.36 ± .77	1010 ± 65
	16 - V3	12	-	10.69 ± .72	1067 ± 61
	16 - V6	13	-	11.35 ± 1.33	1011 ± 113
	16 - V4	22	-	12.50 ± .56	913 ± 48
	28 - V1	Sc	-	11.88 ± 1.64	966 ± 139
	25 - V3[3]	Sc	-	12.40 ± .63	921 ± 54
	39 - V1[3]	0	a	8.80 ± 1.16	1227 ± 99
	39 - V10	13	a	12.88 ± 1.30	881 ± 113
	39 - V7A	15	-	12.17 ± 1.28	941 ± 109
	39 - V7[3]	22	-	10.47	1085
	49 - V2	?	-	12.23	936
	74 - V1	7	-	13.11 ± 1.40	861 ± 119
	32 - V3	Sc	-	12.67 ± 1.02	899 ± 87
	32 - V2	8	-	11.14 ± 1.06	1029 ± 90
IV	28 - V5[3]	Sc	-	14.03 ± .50	783 ± 42
	39 - V8[3]	4	-	15.22 ± .52	682 ± 44
IVb[4]	28 - V2	3	-	16.30 ± 2.68	590 ± 228
Unknown	Tr 9		a	10.70	1066
	39 - V1[3]	-	b	14.96 ± 1.09	704 ± 93
	04 - V1	-	b	16.83 ± 1.40	546 ± 119
	39 - V10	-	b	17.80 ± 1.73	480 ± 147
	Tr 9		b	17.00	531

1. The earlier dates from "double date" specimens (the "b" dates) are placed in the Unknown Stratum category, for their provenience at the time of original deposition is unknown. Both of Trench 9's dates are in this category because the relation of Trench 9's stratum to the major 1975 stratum is unknown.
2. Sc = Screen (specimens were recovered in the screen during sifting).
3. Reanalyzed specimens, originally published in Cordy and Tuggle (1976).
4. Stratum IVb is a third cultural stratum located in square 28. As noted in Cordy and Tuggle (1976: 218-220), a third cultural stratum was indicated in three excavation units (squares 28 and 74, Trench 3). However, excavation was not extensive enough to determine if the layers in these units are connected.

1975 = 0 BP.

Fig. 1. Rind width (RW) distribution by provenience: mean and standard deviation of rind widths.

Each column is a graphic presentation of the hydration-rind measurements of volcanic glass specimens by stratum/year of excavation. Each dot is the average reading based upon ten traverses of the hydration-rind of a single specimen. The open bar containing the dots represents the total range of standard deviations for the specimens within that provenience (dots with circles did not have standard deviation data available). The hatched bars represent the mean and standard deviation for all of the averages (dots) of the contiguous bar. A dot with a vertical line is the mean and standard deviation for a single specimen from a provenience. Double rind widths are explained in the text. Note that the upper specimen in 75II may not be associated with this stratum; it has been excluded from the dating synthesis.


SINGLE RWs
DOUBLE RWs
75II
?
75IV
75 IVb
67I
67II
67II/III
67IIa
67III
75 II
TR9
7
8
9
10
11
12
13
14
15
16
17
18
19
20
RW, in μm
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
HR Years, BP

Natural Variations

The glass specimen environment, including temperature for the Bellows material, has not yet been adequately studied. Therefore, the Bellows dates remain approximations based on the previously standard rate of 11.77 μm /1000 years at 24°C.

Anomalous Rind Widths

As noted, a major calculation problem in measuring the rind widths of the Bellows glass originally occurred in the analysis of 1967 specimens, but has been resolved.

However, the traverses of several specimens from the 1975 sample showed a wide range of variation indicating another potential anomaly. For example, sample 1975-04-VI had a rind width variations of 9.7-18.8 μm equivalent to 773 HR years. In these cases the thin sections and cut fragments were reexamined, and several proved to have two rinds (from two flake scars) which are interpreted as two different "ages". These "double-dates" are shown in the Table D as "a" and "b" in the "Double Rind" column.

Further analysis indicated that a number of specimens had anomalies among their 10 traverses. For example, 1 or 2 rind measurements would be much narrower than the other 8 or 9. We considered the possibility that this anomaly was due to rind damage, for the specimens did not seem to have two flake scars suggestive of double-dates. To eliminate these anomalies, we calculated a new mean and standard deviation based on only the upper five traverse measurements (assuming the lower readings may have resulted from rind damage.) The measurements are listed in Tables E and F and illustrated in Fig. 2.

These measurements make the dates 62 years older on the average (range=0-182 HR years older) and produce a drop in the error range (mean=40 HR years; range=7-121 HR years). They are considered more reliable estimates of the "true" age of each specimen in the Bellows material and are used in the dating analysis.

Fig. 2. Rind width (RW) and distribution by provenience: mean and standard deviation of upper rind widths. Each column is a graphic representation of the hydration-rind measurements of only the upper 5 measurements from the total of 10 traverses. This was done on the assumption that the lower (i.e., smaller) measruements may represent an error factor based on rind damage. These data were not available for all specimens, so the number of specimens is smaller than that shown in Fig.1. All of the symbols are the same as Fig. 1. Note that the upper specimen in 75II may not be associated with this stratum; it has been excluded from the dating synthesis.

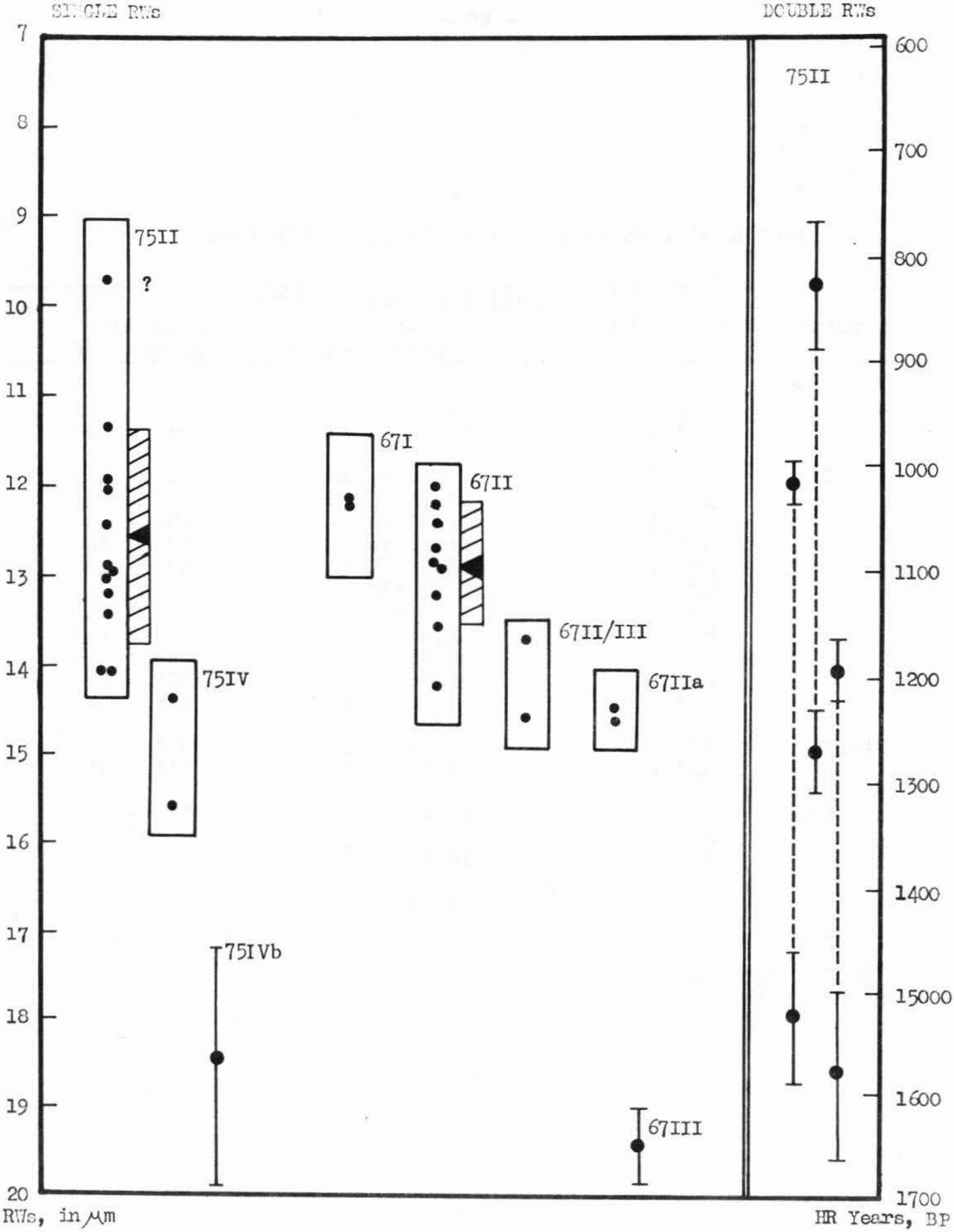

SINGLE RWs
DOUBLE RWs
7
8
9
10
11
12
13
14
15
16
17
18
19
20
RWs, in μm
600
700
800
900
1000
1100
1200
1300
1400
15000
1600
1700
HR Years, BP
75II
?
75IV
75IVb
67I
67II
67II/III
67IIa
67III
75II

TABLE E

1967 HYDRATION DATES: FIVE LARGEST RIND WIDTHS

Stratum	Sq.-Id. No.	Mean Rind Width (um) of Five Largest Traverses	Mean Date HR yrs. AD
I	B 2-1	12.12 ± .66	945 ± 56
	B 2-2	12.24 ± .81	935 ± 69
II	B 2-1	12.16 ± .44	942 ± 37
	B 2-2	13.16 ± .76	857 ± 65
	B 2-3	12.70 ± .21	896 ± 18
	B20-1	14.18 ± .53	770 ± 45
	B20-3	13.58 ± .14	821 ± 12
	B20-4	NA*	NA
	B20-5	NA	NA
	B20-6	12.84 ± .16	884 ± 14
	C 4-1	12.85 ± .10	883 ± 8
	C 4-2	11.96 ± .20	959 ± 17
	C 4-3	12.40 ± .42	921 ± 36
II/III	A20-1	13.74 ± .25	808 ± 21
	A20-2	14.58 ± .36	736 ± 31
IIa	A 5-1	14.42 ± .36	750 ± 31
	A 5-2	NA	NA
	A 5-3	14.62 ± .31	733 ± 26
III	N21-1	19.44 ± .43	323 ± 37

*NA = not available
1975 = 0 BP.

TABLE F

1975 HYDRATION DATES: FIVE LARGEST RIND WIDTHS

Stratum	Sq.-Id. No.	Depth (cm)	Double Date	Mean Rind Width (μm) of Five Largest Traverses	Mean Date HR yrs. AD
II	04-V 1	Sc	a	11.94 ± .22	961 ± 19
	16-V 3	12	-	11.34 ± .36	1012 ± 31
	16-V 6	13	-	12.42 ± 1.04	920 ± 88
	16-V 4	22	-	12.98 ± .36	872 ± 31
	28-V 1	Sc	-	13.02 ± 1.55	869 ± 132
	25-V 3	Sc	-	12.86 ± .20	882 ± 17
	39-V 1	0	a	9.72 ± .68	1149 ± 58
	39-V10	13	a	14.04 ± .30	782 ± 25
	39-V 7A	15	-	13.22 ± .89	852 ± 76
	39-V 7	22	-	NA*	NA
	49-V 2	?	-	NA	NA
	74-V 1	7	-	14.04 ± .12	782 ± 10
	32-V 3	Sc	-	13.44 ± .42	833 ± 36
	32-V 2	8	-	12.04 ± .63	952 ± 54
IV	28-V 5	Sc	-	14.34 ± .39	757 ± 33
	39-V 8	4	-	15.60 ± .32	650 ± 27
IVb	28-V 2	3	-	18.44 ± 1.26	408 ± 107
Unknown	Tr 9		a	NA	NA
	39-V 1	0	b	14.96 ± .47	704 ± 40
	04-V 1	Sc	b	17.96 ± .76	447 ± 65
	39-V10	13	b	18.58 ± .82	396 ± 70
	Tr 9		b	NA	NA

*NA = not available.
1975 = 0 = BP.

Sampling

Two points suggest that the glass flakes at Bellows are in a primary depositional context of flake production. First, none of the 1975 flakes were utilized, indicating that there is no positive argument for their having been transported from locale of manufacture to a locale of use. Secondly, the material from 1967 B20 includes several cores and many unutilized flakes, evidence for a primary chipping area. If these points are sufficient, it may be concluded that the dates of the flakes are thus applicable to the associated deposit.

Given the above, the adequacy of sampling must be considered. It should first be pointed out that the horizontal area of the site has not been delimited by excavation (Cordy and Tuggle 1976), so the material may be a clustered sample and not representative of a total layer. However, the dates from the upper two layers are close but do not significantly overlap, indicating that the dating of the transition may not be unrepresentative.

There is no strong argument that there is adequate evidence for estimating the duration of each stratum. Only 1967 II and 1975 II have a relatively large number of available dates (but even here the dates within the same square are not always stratigraphically consistent - e.g. 1975 sq 39), and are the best candidates for well-dated units.

The consideration of whether the specimens from each layer were representatively sampled for dating must also be addressed. In the two layers where numerous specimens were recovered, 32% (1975) and 6% (1967) were dated. The latter could be an unrepresentative sample. However, many of the specimens are from one area (B20) of essentially contemporaneous flaking, which reduces this problem. The high consistency of the dates also suggests the sample is representative. In the other layers, high percentages of the specimen collections were sampled (range=22-100%, mean=74%). Thus, the specimen collections can be considered representatively sampled in all cases (except perhaps in 1975's Stratum IV).

DISCUSSION OF BELLOWS DATING RESULTS

Prior to discussing the results in cultural terms, we would like to offer some interpretive placements of double-dates and anomalous dates. The 1967 dates are consistent, but our prior analysis of Layer IIa (Cordy and Tuggle 1976: 211) indicated that it was no longer separated from Stratum II in the northern squares (e.g., the 2, 1, 20, and 21 series). Layers II and IIa were still stratigraphically distinct in these squares (along with several other internal layers in Layer II), but we are not sure this distinction was maintained by the excavators as stratigraphic depth of specimens was unreported. The oldest dates for Layer II come from the northern squares (e.g., B20) and this overlaps with 11A's range from southern squares (A5). The same is true for the II/III interface dates. Thus, for considerations here, we ignore the overlap between the 1967 Strata II and IIa's dates and attribute it to excavation uncertainty.

The 1975 excavations have several anomlous dates. In Stratum II, 39-VIa is outside the standard deviation of the layer, and probability figures suggest it is not part of the layer. We suggest, as it was a surface artifact, it was deposited after the abandonment of Layer II. We also suggest the double dates can be placed into different layers based on their dates (Table G). This is based on the assumption that the earlier flaking occurred at the Bellows locale. Tr 9-a seems to match the Layer II range. Specimen 39-VIb seems to match the Layer IV range. The remaining cases (04-VI-b, 39-VI0-b, Tr 9-b) seem to match an earlier deposit contemporaneous with the poorly defined Layer IVb. This earlier deposit is now termed Cultural Layer 3, including Stratum 28-IVb as well as the original context of the double dates. The third cultural layer in Square 74 and the lowest layer in Trench 3 may also belong to this deposit, but further excavation is needed to verify this.

Correlation of Strata from the 1967 and 1975 Excavations

One of the major questions arising from the 1975 excavation results was correlation between the 1967 strata and those found in 1975. It was argued that 1975's Cultural Layer 1 (Stratum II) and 2 (Stratum IV) matched 1967's Stratum II and IIa, respectively (Cordy and Tuggle 1976). It is now further suggested that Cultural Layer 3 (Stratum IVb in Square 28) matches 1967's Stratum III. The dates presented in this report support these correlations. The 1967 and 1975 strata II's dates are highly consistent, as are the dates from IIa (1967) and IV (1975). More important, the dates from 1967's Layer III and 1975's IVb (and double dates) seem to match. These arguments in turn increase the sampling representativeness of the site (more specimens per layer and more dated).

TABLE G

PLACEMENT OF DOUBLE DATES INTO DIFFERENT STRATA

Specimen	Ranges of Dates Per Stratum (HR yrs. AD)					
	II		IV		IVb	
	Means (782-1012)	Ranges (757-1042)	Means (650-757)	Ranges (623-790)	Means (408)	Ranges (301-515)
39-V 1-b			704	664-744		
04-V 1-b					447	382-512
39-V10-b					396	326-466

Trench 9-a and Trench 9-b were not analyzed for their five largest traverses. However, if Table D (which uses all 10 traverses) is referred to, it will be seen that Trench 9-a's mean date falls within Stratum II's range of the means. Also Trench 9-b's mean date closely approximates that of Stratum IVb.

Chronometric Frame for Bellows Occupations

We suggest the dates for Bellows Sand Dune's three cultural layers (called here Cultural Layers 1, 2, 3 - most recent to oldest - to avoid confusion among 1967 and 1975 layers) lie somewhere within the following figures, with the recognition that the evidence for the duration of Layers 2 and 3 may not be adequate.

Cultural Layer	Range of Means (HR yrs AD)	Range of Ranges (HR yrs AD)
1 (1975 II, 1967 II)	770-1012	725-1042
2 (1975 IV, 1967 IIa)	650-757	623-790
3 (1975 IVb, 1967 III)	323-447	286-515

At this point it should be mentioned that the 1967 data show several distinct stratigraphic subdivisions in Layer II. They were not apparent in 1975 data. Also, there is some evidence for more that 3 layers, but no dates are available. Further, we have postulated that the Bellows Sand Dune site extends a short distance inland into Area 1 (Cordy and Tuggle 1976). Test pits in Area 1 found one cultural deposit with one layer which has had exploratory excavations and dating (Table H). This indicates even later occupation at the Bellows Dune than formerly considered. 39-VI-a's date falls into this later range. Area 1 has not yet been closely analysed, so we are unsure whether lower parts of the cultural deposit in this area are contemporaneous with other layers in the dune itself.

TABLE H

AREA 1 DATES

Location/Specimen	Depth (cm)	Dates (range) (HR yrs AD)
TE 76/511-V3	18	1374±200(1174-1574)
TE 76/511-V4	34	1100±190(910-1290)

Layer Duration and Nature

A generally coeval accumulation over the area of each cultural layer is suggested by the lack of any horizontal clustering of dates.

Estimation of actual occupational duration per layer is hampered by insufficient data, particularly for Cultural Layers 2 and 3. Cultural Layer 1 has an estimated duration of 240 HR years based on the range of mean dates. Cultural Layers 2 and 3 have mean HR year ranges of 107 and 124 respectively. The dating ranges generally correlate with the thicknesses of the layers, but the duration figures cannot be taken literally due to the inadequate sampling and due to the possible inherent error in the dates themselves. Further, the duration of occupation does not necessarily mean continuous occupation throughout the given period.

The delineation of an occupational hiatus faces the same difficulties as those related to the estimation of curation. The difficulties are further compounded by an incomplete analysis of the natural deposition of the dune. Sterile sand strata do not represent significant periods of abandonment. Possible erosion of the surfaces of cultural deposits also complicates the picture. At the moment it may be noted that on the basis of the dating alone, there is no evidence for a major break in occupation betweeen Cultural Layers 2 and 1, while a hiatus of some 200 HR years between Cultural Layers 3 and 2 may be possible.

SUMMARY

Volcanic glass hydration-rind analysis can provide a solid basis for making age determinations with a high degree of reliability. However, basic problems exist which must be solved. Natural variables create variation in hydration rates. Anomalies in rind widths also arise from thin-sectioning and calculation problems. Lack of representative sampling and misinterpretation of specimen disposal and association may skew results.

For the Bellows material the dating conclusion remain tentative awaiting refinement of general hydration dating, analysis of the depositional history of the dune, and collection of dune environmental data. At present the "dates" are based on a generalised hydration rate formula of 11.77 micrometers/1000 years at a temperature of 24 degrees C. Two types of anomalies in rind widths have been considered. Two clusters of rind widths from single specimens have been found to be due to two flake scars, thus yielding two possible dates. Some anomalies are thought to be due to thin-section damage and these have been compensated for by using only the five largest rind widths per flake scar. Rind width figures are given as an average and 1 standard deviation of these five measurements. Finally, the sampling problems specific to Bellows have been outlined.

Given these reservations, the following statements may be made regarding Bellows dating: (1) the 1967 and 1975 layers correlate and have been identified as Bellows Cultural Layers 1, 2, and 3; (2) duration of occupation falls around 100 HR years for Cultural Layers 2 and 3 and around 200 HR years for Cultural Layer 1, based on the range of the means; (3) a significant cultural hiatus appears likely to have occurred only between Cultural Layers 3 and 2, while final abandonment of the site did not occur until after about HR year A.D. 1000 and perhaps as late as HR years 1300's; (4) the chronometric sequence derived from present data is as follows (given as the range of the means followed by the range of the standard deviations):

Area 1 Occupation	HR yrs A.D. 1100-1374 (905-1569) (2 specimens)
Cultural Layer 1	HR yrs A.D. 770-1012 (725-1042) (24 specimens)
Cultural Layer 2	HR yrs A,D. 650-757 (623-890) (5 specimens and 1 "double date")
Cultural Layer 3	HR yrs A.D. 323-447 (297-515) (2 specimens and 2 "double dates")

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ADDENDUM

Although the results in this paper are provisional, I think it important to publish them in the light of the importance of the Bellows site. New material will be available within a year or so. Some will involve new research at Bellows (although on a very limited scale), but much will be derived from ongoing glass research. The Department of Anthropology of the University of Hawaii has established a laboratory for the analysis of Hawaiian volcanic glass and has initiated a research program on the dating and sourcing of this glass. We are exploring the variables relevant to glass hydration, determining the major and trace element variability of Hawaiian glass, attempting independent dating with thermoluminescence, exploring source characterisation through thermoluminescence, and monitoring environmental variables of achhaeological sites and geological source areas. Morgenstein is also continuing primary research and several geologists are working on hydration/alteration of glass as a means of dating volcanic flows.

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