CALIBRATION OF THE OBSIDIAN BUTTE HYDRATION RATE AND ITS IMPLICATIONS REGARDING LATE PREHISTORIC EXCHANGE

A Thesis

Presented to the

Faculty of

San Diego State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

in

Anthropology

by

Debra Ann Dominici

Fall 1984

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Approved by:

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Although the above-mentioned individuals contributed in various ways, the author accepts full responsibility for the structure, content, and conclusions of this thesis.

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CHAPTER I

INTRODUCTION

Obsidian dating has been used by California archaeologists to establish the chronology of many prehistoric archaeological sites. Criticism concerning the use of the obsidian dating method exists because of the lack of thorough evaluation by these same archaeologists of the proposed obsidian hydration rates which are the basis of the age determinations. An unpublished Ph.D. dissertation by J. E. Ericson (1977) and a subsequent article summarizing some of his findings, stand as one of the most comprehensive examinations of obsidian hydration dating (Meighan 1983:800). Along with a number of proposed hydration rate equations, Ericson (1978) discusses several cautions and qualifications for researchers using the obsidian dating method. Ericson (1978:45) hoped that his work would stimulate concern among scholars with the practical and the theoretical nature of obsidian dating. Unfortunately, little attention has, thus far, been given to these aspects of the field.

One such example of this lack of "careful evaluation" concerns the proposed hydration rate for Obsidian Butte material. Obsidian Butte served as the primary source of obsidian used prehistorically throughout the Far Southwest (San Diego and Imperial Counties in southern California, and Northern Baja California). Chace (1980) has proposed the only existing hydration rate for Obsidian Butte. He developed his rate by correlating known historic and prehistoric events, which were assumed to affect obsidian exchange, with points on the frequency curve of the 540 hydration rim measurements from 34 sites. His method has some relevance for obsidian exchange discussions, however, it does not include the correlation of data sets specifically outlined by Ericson (1977, 1978).

Ericson's studies demonstrate the need for source specific hydration rates in order for increased accuracy of the hydration technique. In order to get the best information about obsidian hydration rates for a specific source, three sets of data from a single site must be correlated: (1) identification of the source of the obsidian through chemical characterization; (2) identification of the age of some sourced samples through associated radiocarbon dates; and (3) measurement of the hydration layer (Ericson 1977; Meighan 1983:600).
In addition, a large sample of obsidian and a wide range of variability of hydration layer measurements from a

single site are needed (Meighan 1983:603). The temperature effect on a hydration rate, although important for converting hydration thickness to absolute age, is of little importance in determining the relative range of hydration measurements of chemically analyzed subsurface obsidian at one site (Friedman and Trembour 1983:545). Subsurface obsidian is essential because of the unreliability of surface obsidian due to factors such as heat exposure from brush fires.

If a site contained all the data mentioned above, it would be an excellent test case for the establishment of a source specific hydration rate. Establishment of a source specific hydration rate would involve the examination of how well the above data fit one of six hydration rates proposed for California (Ericson 1977:67, Table 1-12; 1978: Table 1).

Calibration of the Obsidian Butte hydration rate was chosen, in part, as the primary topic of this thesis due to the lack of any thorough research based on empirical obsidian data from the Far Southwest. The decision was also made because of the availability of the largest sample of hydrated and sourced obsidian (57) from a single prehistoric site (CA-SDi-5680) located in the Far Southwest. Ten radiocarbon dates were also obtained from CA-SDi-5680. This site, also known as the Nelson site, was the focus of a State of California, Department of Transportation's (Caltrans') data recovery program (Dominici n.d.). Chace (1980) incorporated 17 obsidian hydration rim measurements from the Nelson site to construct his Obsidian Butte hydration rate.

The calibration of Obsidian Butte hydration rate enables hydration analysis to be used as an archaeological dating technique for the Far Southwest. Research hypotheses concerned with archaeological and anthropological theory, can only be formulated and tested regionally once a chronology of an area is adequately understood and empirically tested. One of the major difficulties in the development of chronologies of prehistoric occupation in the Far Southwest is the absence of temporally sensitive, diagnostic artifacts with which to assess site antiquity. This is in part a function of not only the physical paucity of diagnostic materials, but also the absence of seriations for ceramics and flaked lithics which associate typological variability with differing temporal periods. The majority of prehistoric sites in this region also lack organic materials for C-14 dating. For most of the Far Southwest, however, archaeological collections do include some obsidian chipping waste which may often be the only means for dating sites.

This thesis also attempts to discern the implications of the Obsidian Butte hydration rate as it pertains to obsidian exchange in specific and Late Prehistoric exchange in general. The obsidian dating method has direct implications upon the time framework of the Obsidian Butte obsidian exchange. Once the time framework has been determined for obsidian exchange, then obsidian can be used as a tracer item in a network analysis and may be used to describe the exchange complexity (extent and direction). Secondarily, this research tests several hypotheses concerning the regional exchange system of Obsidian Butte material by synthesizing available data from the Far Southwest. The research of Ericson (1977) and Shackley (1981) served as the impetus for the development of this thesis, and provided the major hypotheses which will be tested.

The first section of this paper presents a review of literature pertinent to obsidian hydration dating in California. In addition, the research concerning the Obsidian Butte hydration rate is discussed as is the obsidian exchange pattern in the Far Southwest. From this information, a research methodology has been formulated and is presented in Chapter II. The research methodology provides a discussion of the problems and merits of the method of obsidian hydration dating as it relates to the Far Southwest. Furthermore, the research orientation of this thesis is discussed in relationship to the specific data base and explicit research questions. The last section of Chapter II discusses the parameters that should be incorporated when attempting to calibrate a source specific obsidian hydration rate. The detailed discussions in these sections and the data contained in Appendix A have been provided for future research comparisons. Frequently hydration studies lack this important information.

Chapter III synthesizes all available information concerning Obsidian Butte which is pertinent to its hydration rate calibration. This chapter also presents a description of the source before and after the numerous impacts created by modern development. Next the unique circumstances regarding Obisidian Butte availability periods are discussed. The final section of the chapter discusses the hydration rate for Obsidian Butte proposed by Chace (1980).

A brief environmental and cultural setting for the CA-SDi-5680 site complex is provided in Chapter IV. Chapter V presents the data base from CA-SDi-5680 used for this research and hypothesizes the best fitting obsidian hydration rate model for Obsidian Butte. This selected rate is then calibrated by empirical testing of all available data.

The last topic addressed is the Late Prehistoric exchange of obsidian specifically and other items generally. The focus of the chapter deals with the implications regarding the hypothesized Obsidian Butte hydration rate (presented in Chapter V) and exchange. A discussion and summary of this research, as well as suggested future research programs, are to be found in Chapter VII.

CHAPTER II

OBSIDIAN HYDRATION DATING

Review of Pertinent Literature

Within the last decade, a new method for determining the chronologies of prehistoric occupation using obsidian hydration has been tested in California (Ericson 1977, 1978; Taylor 1976). Since the introduction of this method by Friedman and Smith (1960), numerous researchers have published their findings and theories on the topic, as seen, for example, in reviews of the state of the art (Friedman and Trembour 1978; Michels and Tsong 1980). Constant evaluation and checking of published information using obsidian data, has led to series of proposed hydration rates developed primarily but not exclusively by Jonathan Ericson (1977, 1978). Relevant data are also summarized in the essays assembled by Taylor (1976).

Obsidian Hydration Dating. The obsidian hydration dating technique has been shown to be useful to archaeology (Katsui and Kondo 1965; Michels 1967, 1973; Meighan et al. 1968; Johnson 1969; Suzuki 1973; Bell 1977; Singer and Ericson 1977; Ericson 1977, 1978; Origer 1982; Meighan 1983). The hydration phenomenon involves the development of a measurable birefringence stress layer through a sequence of processes which are not totally understood.

Obsidian is a naturally occurring volcanic glass which is of rhyolitic composition. Water begins to diffuse slowly from the obsidian surface into its body as soon as a fresh surface of obsidian is exposed to the atmosphere. When the layer has reached a thickness of about one-half micrometer or more, it is detectable and measurable by conventional microscopic examination of a thin section in the laboratory. The measured thickness of the hydration layer/rim is then converted into age terms.

The rate at which the hydration proceeds must be estimated in order to convert hydration thickness into age. Two general methods have been proposed. The first involves a direct calibration of the hydration rim thickness with known radiocarbon, potassium-argon or cultural dates on materials associated with the obsidian; the second involves an experimental determination of the hydration rate.

The principal variables governing the growth rate of the hydrated layer include not only time, but also past ambient temperature of the obsidian, and its chemical composition. Discrepancies among hydration age investigations have resulted due to the failure to understand accurately the temperature and composition variables of the study pieces. The importance of these variables which influence the hydration rates have been noted by a number of scholars (Friedman and Smith 1960; Aiello 1969; Ericson 1969, 1973, 1975, 1977; Kimberlin 1971, 1976; Michaels and Bebrich 1971; Morgenstein and Riley 1973, 1975; Suzuki 1973; Layton 1973; Ericson and Berger 1976; Kimberlin 1976; Friedman and Long 1976; Ambrose 1976; Origer 1982; Friedman and Trembour 1983).

In summary, prior research has refined the obsidian hydration dating technique by determining variables of the hydration process. Researchers are still doubtful of the actual mathematical model which best fits the hydration process. The simplest rate model proposes that hydration is linear (Meighan et al. 1968) with respect to time--that is, each micron of hydration takes the same amount of time to form. All other proposed models operate on the premise that each micron will require a longer time to form the preceding micron. The differences among these various rate models relate to how much additional time is needed to form each subsequent micron of hydration (Friedman and Smith 1960; Clark 1964; Findlow et al. 1975; Kimberlin 1976; Ericson 1977). Ericson's research concluded that the "Diffusion" model of Friedman and Smith (1960): $T=dX^2$ "appears to be the best model in 5 of 14 cases" (Ericson 1978:49). On the other hand, Meighan's research suggests that the "Linear" model is the closest approximation of the hydration process (Meighan 1983:605).

Obsidian Butte Hydration Rate. Research concerning the obsidian hydration rate for Obsidian Butte was initiated by Chace (1980). Criticism of Chace's (1980) proposed linear rate was expressed by Christenson and Russell (1981). One issue raised by Christenson and Russell (1981:136), based on the research of Waters, deals with the initial availability date of Obsidian Butte. The most current work of Waters (1983) has been abstracted to show five availability periods of Obsidian Butte material within the past 2000 years.

Another criticism raised by Christenson and Russell (1981:138) is the lack of chemical characterization of the obsidian samples Chace (1980) used. It is usually assumed that obsidian recovered from San Diego County sites came from Obsidian Butte because this is the nearest available obsidian source. However, recent archaeological data in San Diego County indicate that prehistoric populations were utilizing obsidian from at least four and possibly more sources located in

California, Baja California and Arizona (Banks 1971; Christenson and Russell 1981:132-129; Shackley 1981; Bouey 1984:55).

As pointed out by Christenson and Russell (1981:137-138), the major problem with Chace's (1980) proposed rate is the lack of correlated C^{14} dates. Christenson and Russell (1981:138) also state that as C^{14} dates are obtained, the association of these dates with hydration measurements must be evaluated carefully.

Obsidian Exchange. Although obsidian exchange is not documented in any ethnographic or ethnohistoric material for the Far Southwest, Ericson (1977) and Shackley (1981) have used Obsidian Butte material to develop their hypotheses concerning Late Prehistoric exchange. The obsidian was used as a tracer item in order to describe the egalitarian exchange complexity (extent and direction).

This thesis is an attempt to synthesize available data and to empirically test Chace's (1980) Obsidian Butte hydration rate hypothesis. Secondarily it tests those hypotheses of Ericson (1977) and Shackley (1981).

Research Methodology

Problem Statement. Obsidian Butte was the primary but not only source of obsidian for prehistoric use and exchange in the Far Southwest. Archaeologists doing research in this region have relied on Chace's (1980) proposed Obsidian Butte hydration rate to date their archaeological sites based on limited unsourced obsidian samples submitted for hydration analysis. Two inherent problems exist within these practices. First, Chace's (1980) proposed rate ignored the methodology and theory presented by Ericson (1977, 1978). Secondly, researchers in the Far Southwest have not attempted to empirically test their data against Chace's (1980) rate or any of the other five hydration rates proposed for California obsidian sources. However, due to the lack of thorough examination of these issues, a large body of potentially important obsidian hydration data remains relatively useless.

The unfortunate nature of this problem is that although there has been an extensive amount of research done on the obsidian hydration dating technique, the situation has not been alleviated, and this is in light of the fact that the hydration dating method is a much needed procedure in the Far Southwest. This unique situation of the Far Southwest is due to a combination of factors. There is a general lack of diagnostic artifacts recovered from the prehistoric sites, and there is a lack of developed artifact seriations which are temporally sensitive, and lastly, there is an absence of organic material recovered which can be radiocarbon dated.

Research Orientation. This thesis is an initial attempt to solve the above stated problems. The first step of this undertaking is a careful synthesis and evaluation of all available data concerning the Obsidian Butte hydration rate. This thesis also examines the largest available sample of sourced and hydrated obsidian specimens from a single site (137 kilometers west of Obsidian Butte) in San Diego County. Ten corroborative radiocarbon dates were obtained from this site.

Data Base. The data used in this thesis are from the CA-SDi-5680 site complex. CA-SDi-5680 was proposed to be impacted by a Caltrans construction project. At the time from its initial recordation (Dominici 1980) and re-recordation of Locus A--the "Nelson Site" (Chace 1980), to the present, the author has been involved in the cultural resource management of the CA-SDi-560 site complex (Dominici 1981, 1982, 1983a,b, n.d.; Dominici and Corum 1983).

The CA-SDi-5680 site complex was identified as a Late Prehistoric Dieguenо habitation site containing a possible Early Milling Archaic component (Dominici n.d.). Sixty-seven (67) obsidian specimens from this site were submitted for sourcing and hydration. Fifty-nine (59) of these specimens were sourced to Obsidian Butte from which 57 hydration rim measurements were obtained. Ten radiocarbon dates are associated with these hydration measurements.

Research Questions. It was proposed that the data sets obtained from the CA-SDi-5680 site complex can be used to refine the obsidian hydration rate by answering the following question:

- Do those obsidian hydration rim measurements associated with C^{14} dates (chemically sourced to Obsidian Butte) from CA-SDi-5680, substantiate one of the six proposed California hydration rate models?

To this date, available ethnographic and ethnohistoric information does not mention that obsidian was exchanged. Obsidian is present in many of the prehistoric sites in the Far Southwest, but the mechanisms of how the obsidian was deposited and time framework involved are only postulated (Ericson 1977; Chace 1980; Shackley 1981). Development of an Obsidian Butte obsidian hydration rate would therefore require an understanding of the obsidian exchange system.

The research questions dealing with Obsidian Butte exchange that can be addressed with the data recovered from the CA-SDi-5680 site complex are:

- Do the frequencies of exotic materials at CA-SDi-5680 equal or exceed frequencies of exotic materials at other sites in similar cultural and natural environments along known corridors?
- Once the frequency of obsidian has been determined, how can these data compare to existing obsidian exchange network models as proposed by Shackley (1981:107-116) and Ericson (1977:199-202)?

Hydration Parameters

As stated previously, Ericson's studies (1977, 1978) illustrate the need for obsidian hydration dating research to incorporate three parameters: source, hydration, and known age. Given these parameters from a single site, it is then possible to test the six proposed California rates and determine which one best fits the data. Friedman and Trembour (1982) have emphasized the importance of the past ambient temperature of obsidian governing the growth rate of the hydration rim.

Chemical Characterization. Chemical characterization of obsidian can be described as a process or procedures which defines the chemical parameters by which a set of sources can be distinguished. Three methods of chemical analysis are used in California; X-ray fluorescence analysis and two types of instrumental neutron activation analysis (Ericson 1977:15). Instrumental neutron analysis can be either for the short or long half-life radionuclides. Using only two specimens from the Obsidian Butte source for chemical characterization and multivariate analysis, Ericson (1977:19) found Obsidian Butte obsidian to be chemically discrete from other Californian sources by the long half-life radionuclide INAA technique. However, for purposes of Obsidian Butte sourcing and other sources in the Far Southwest region, the rapid-scan X-ray fluorescence technique is adequate (Ericson 1977; Hughes 1984; Bouey 1984).

Obsidian data in this thesis that has been subjected to trace element analysis, was processed on either the Kevex 07700 X-ray fluorescence unit located at the Department of Geology, University of California, Davis (Bouey 1984:55) or at the Department of Geology and Geophysics, University of California, Berkeley, on a Spectrace 440 (United Scientific Corporation) energy dispersive X-ray fluorescence machine (Hughes 1984). The Berkeley machine is equipped with a 572 power supply (50 kV, 1mA), 534-1 pulsed tube control, 514 pulse processor, 588 bias/protection module, Tacer Northern 1221 100 mHz ADC, Tracor Northern 2000 computer based analyzer, an Rh X-ray tube and a Si(Li) solid state detector with 142 eV resolution (FWHM) at 5.9 keV in a 30mm^2 area. The X-ray tube operates at 30.0 kV, .40 mA pulsed with primary beam filter in an air path at 200 second livetime.

The elements used to differentiate the sources include rubidium (Rb), strontium (Sr), and zirconium (Zr), analyzed by a rhodium target; and iron (Fe) and manganese (Mn), analyzed by a germanium target. Values of these trace elements have been found to be the best quantitative way by which to separate sources in California (Bouey 1984:55). Results of X-ray fluorescence method are presented as trace element values expressed in parts per million by weight. This style of reporting is done in crder that the results can be compared directly to published values for obsidian sources that appear in Taylor (1976:202-204) and in Robinson, Elders and Muffler (1976:347-360).

The use of X-ray fluorescence chemical characterization method for identifying an obsidian source used in correlation with associated radiocarbon dates and hydration layer measurements, is the most important step in calibration of an hydration rate for a specific source.

Archaeological findings in the Far Southwest indicate that prehistoric populations were utilizing obsidian from at least four sources; (1) Coso, (2) Obsidian Butte, (3) San Felipe, and (4) Punta Mangles (Bouey 1984:55; Christenson and Russell 1981:132-139; Shackley 1981; Banks 1971). Three other sources are recognized in Baja California and may have also played an important role in prehistoric economies of the Far Southwest. The first is the Arroyo Matomi drainage obsidian (Douglas 1981) found just south of the location of the San Felipe material and may derive from the same source pool in the headwater mountains. Another source as reported by a local rancher (Bouey 1984) may be located in the Sierra de San Francisco, and a third apparently is in the vicinity of Mexicali (Laylander 1983). General locations of the obsidian source areas are indicated on Figure 1.

Chemical characterization work had focused on two sources in the Far Southwest, Coso and Obsidian Butte. Recently, however, Paul D. Bouey (1984) has published qualitative trace element analysis on samples from two Baja California obsidian sources, San Felipe and Punta Mangles. Bouey states that the Coso, Obsidian Butte, San Felipe and Punta Mangles sources can be distinguished on the basis of the rubidium (Rb)/strontium (Sr)/Zirconium (Zr) ratio. The Coso numbers plot in a position which

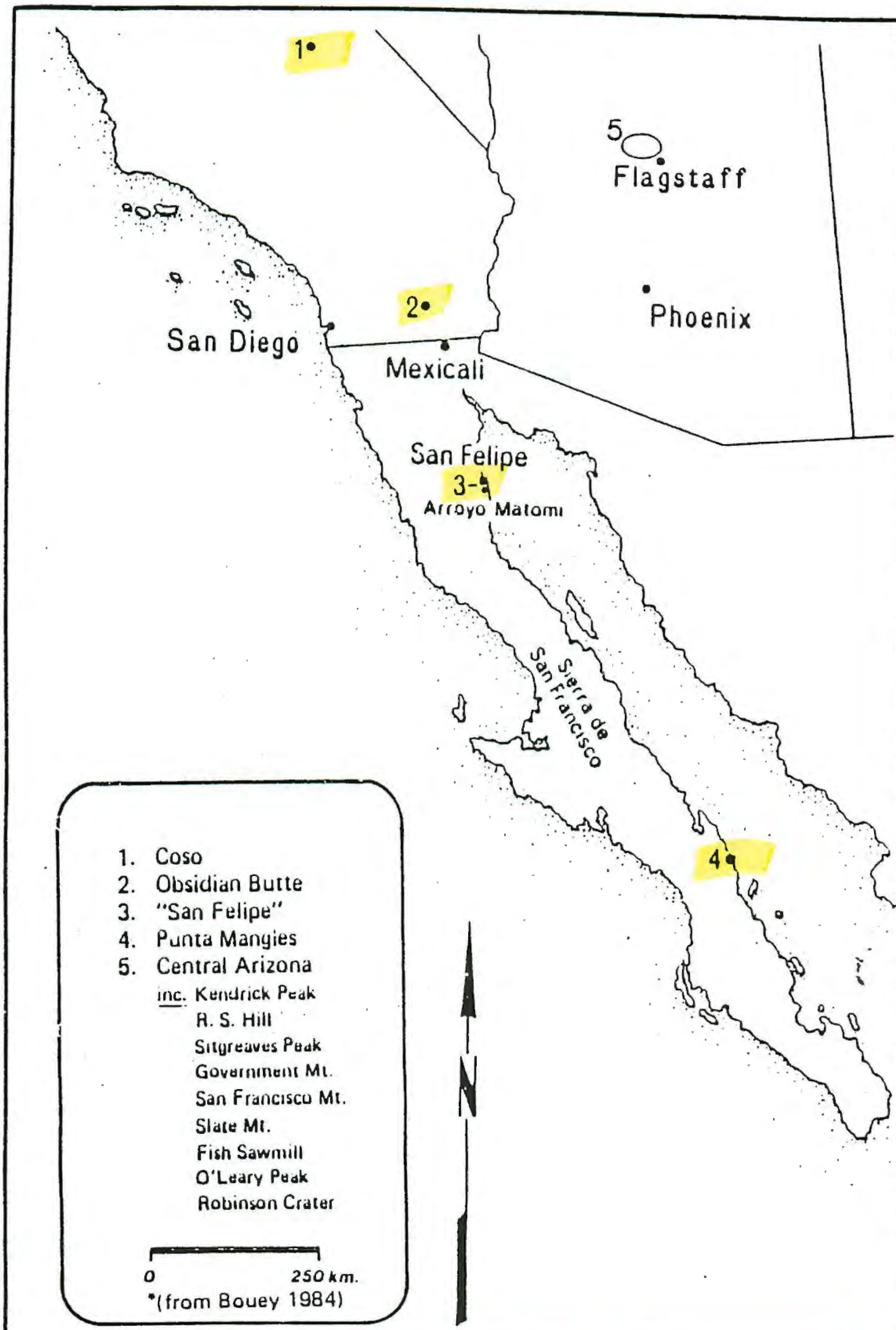

Figure 1. *Obsidian Sources of the Far Southwest

overlap with five other sources in southern California (see Taylor 1976), however using the iron (Fe)/manganese (Mn) ratio, all can be separated. Table 1 is taken from Bouey (1984:57) and included for later comparisons.

Both Baja sources can be distinguished by SR/RB ratio ranges, which are discrete from Obsidian Butte and Coso SR/RB ratios. Although the Baja sources are also discrete from Obsidian Butte and Coso using the ZR/RB ratio, the values for that ratio for San Felipe and Punta Mangles overlap. Due to the limited size of the sample, the information was presented by Bouey as an initial step in the research for chemical identification of obsidian sources in Baja California.

Hughes (personal communication 1984) has stated that the majority of San Diego County obsidian he has analyzed from non-identifiable sources, cannot be matched to Bouey's qualitative trace element analysis (for Baja Sources). It is quite likely that obsidian sources in Arizona may also have been exploited (see Figure 1). Objects manufactured from these sources may have been traded or exchanged by people moving westward (see Archaeological Reconstruction in Appendix B).

If research concerning hydration rates is to be viable, source work is a mandatory preliminary step. The origin or source of an obsidian artifact can now be

Table 1. Bouey's (1984:57) Integrated Intensity Ratios and Percentages

BOUEY'S SAMPLE	RB/RB	SR/RB	ZR/RB	E	RB %	SR %	SR %	FE/MN
SAN FELIPE								
1	1.0000	.3931	2.2947	3.6878	27.1	10.7	62.2	
2	1.0000	.3831	2.2772	3.6603	27.3	10.5	62.2	
3	1.0000	.5136	2.2111	3.7247	26.8	13.8	59.4	
4	1.0000	.4964	2.4054	3.9018	25.6	12.7	61.6	
5	1.0000	.4729	1.9748	3.4477	29.0	13.7	57.3	
6	1.0000	.3924	2.2143	3.6067	27.7	10.9	61.4	
7	1.0000	.4218	2.4839	3.9057	25.6	10.8	63.6	
PUNTA MANGLES								
1	1.0000	.7586	2.0817	3.8403	26.0	19.8	54.2	
2	1.0000	.6865	1.9365	3.6230	27.6	18.9	53.5	
3	1.0000	.8224	1.8267	3.6491	27.4	22.5	50.1	
4	1.0000	.7984	2.1633	3.9617	25.2	20.2	54.6	
5	1.0000	.7214	1.8030	3.5244	28.4	20.5	51.2	
6	1.0000	.7297	1.9543	3.6840	27.1	19.8	53.0	
7	1.0000	.6533	1.8500	3.5033	28.5	18.6	52.8	
OBSIDIAN BUTTE								
1	1.0000	.1528	4.4132	5.5660	18.0	2.7	79.3	
2	1.0000	.3551	4.3458	5.7009	17.5	6.2	76.2	
3	1.0000	.2136	4.0414	5.2550	19.0	4.0	76.9	
4	1.0000	.2437	4.1861	5.4298	18.4	4.5	77.1	
5	1.0000	.3059	4.4906	5.7965	17.3	5.3	77.5	
6	1.0000	.1814	4.2261	5.4075	18.5	3.4	78.2	
7	1.0000	.1663	3.7749	4.9412	20.2	3.4	76.4	
COSO								
1	1.0000	.0619	.8331	1.8950	52.8	3.3	44.0	57.6859
2	1.0000	.0365	.8352	1.8717	53.4	2.0	44.6	51.3715
3	1.0000	.0229	.7677	1.7906	55.8	1.3	42.9	48.7306
4	1.0000	.0317	.9012	1.9329	51.7	1.6	46.6	54.4486
5	1.0000	.0538	.8316	1.8854	53.0	2.9	44.1	56.5278
6	1.0000	.0337	.8962	1.9299	51.8	1.7	46.4	53.1629
7	1.0000	.0371	.9829	2.0200	49.5	1.8	48.7	47.9951

identified by applying three different techniques (Ericson 1977:36). For purposes of determining sources in the Far Southwest, rapid scan X-ray fluorescence technique is adequate because the available sources are chemically discrete (Jack and Carmichael 1969; Bouey 1984). The short half-life radionuclide INAA technique proposed by Ericson (1977:36) can also be used. However, the most precise laboratory procedure is available with the application of the long half-life radionuclide INAA technique of chemical characterization. This technique is used in cases where the analyst does not have the necessary information for the other two techniques.

Chemical characterization research on obsidian artifacts from prehistoric sites in the Far Southwest indicate four exploited obsidian sources. Trace element values have been published for only two of these sources, Coso and Obsidian Butte. Recently, source work on two Baja sources, San Felipe and Punta Mangles, has been presented (Bouey 1984). Three other sources are recognized in Baja California and should be considered when source work is undertaken, although chemical characterization information is not available.

After the initial identification of the source of the obsidian through chemical characterization, two tasks involved in calibrating a specific hydration rate remain.

One of these involves the age determination of some "known" samples through correlation with associated radiocarbon dates. The other is to measure the hydration layer.

Radiocarbon Dating. The organic samples used for radiocarbon dating come from CA-SDi-5680. They were processed at the Institution of Geophysics and Planetary Physics, at the University of California, Los Angeles (UCLA). All the work was done under the supervision of Dr. C. R. Berger. Each associated organic sample was given a UCLA radiocarbon number and its provenience recorded. The description of the process utilized by the UCLA radiocarbon lab is taken mainly from Ericson (1977:41-45).

First, a pre-treatment of the organic samples with 1 nitrogen sodium hydroxide which removed humic acid residues and 3 nitrogen hydrochlorines which removed residual carbonates or bicarbonates was done. Root hairs and rootlets were removed manually. The samples were then burned in a close oxygen environment. The combustion produced a gas mixture. All components of the gas mixture except carbon dioxide and radon were removed by a system of interconnected traps and catalysts.

Oxygen and other impurities were removed from the "countable" carbon dioxide. Stored in a high-pressure container for a period of four days to a month, the "countable" carbon dioxide was rid of radon. Radon has a half-life of 3.8 days. The process of combusting and cleaning usually took three to four hours, and at times required up to eight hours.

For a period of 1,000 minutes or 16 hours and 40 minutes, the β-decay of the radiocarbon or Carbon-14 was counted which was contained in the carbon dioxide gas. This was accomplished by placing the gas in a 7.5-liter Geiger counter surrounded by an array of 13 Geiger-Muller anticoincident counters. The following equation illustrates the calculations involved in determining a radiocarbon date:

$$\text{DATE (yrs.)} = 8.030\ 1^{-1}(X/Y/T)$$

where:

X = 95% oxalic acid standard cpm

Y = Carbon-14 and Radon minus Radon minus Marble background

T = Time

The value of "modern" or 95% oxalic acid pre-1950 standard was approximately 40 counts per minute. For "old" or marble or background standard the values were approximately 13 counts per minute. Depending on their age, the unknown samples ranged between 40 and 13 counts per minute. To insure the repeatability of the measurement, the counts were repeated two or three times.

The two-sigma standard deviation (± factor), is based on the counting statistics rather than repeated measurements. This is necessary due to the fact the two or three counting periods is not an adequate sample to determine the range of the means. The standard deviation is a function of the age of the sample, counting period, and dilution. The error can be minimally ± 40 years if the sample is not diluted, recent, and counted for a long duration. All dates are expressed in years BP or years before A.D. 1950.

It should be pointed out, many problems exist with the association and/or context of a given radiocarbon date. There may be numerous reasons why a piece of obsidian is not the same age as the level from which a given radiocarbon date is obtained. However, it is felt that with a large enough sample, anomalous results can be filtered out (Meighan 1981:3).

Hydration Rim Measurement. Immediately when a fresh surface of obsidian is exposed to the atmosphere, water begins to diffuse slowly from its surface into the body of the obsidian. When the layer has reached a thickness of about ½ micrometer or more, it is detectable and measurable by conventional microscopic examination.

Hydration rim measurements for the majority of data utilized in this thesis were taken by Dr. Thomas S. Kaufman at the University of California, Los Angeles. The procedures used by the UCLA Obsidian Laboratory are stated in the report that accompanied the results of the hydration measurements (see Appendix A).

The physical-chemical process of obsidian hydration remains ill-defined and not fully understood (Meighan 1981:1). Many researchers are studying this critical problem. At first it was proposed that the primary variable in the formation of hydration bands was temperature, and that other factors such as the chemical characterization of the obsidian were of lesser magnitude. Ericson (1977) presented results that the chemical nature of the varying obsidian was much more important than temperature in the formation of hydration bands. Friedman and Trembour (1983:544) have stated that the past ambient temperature of an obsidian object is equally important as chemical composition when considering the factors governing the growth rate of the hydrated layer.

Past Ambient Temperature

Friedman and Trembour (1983:544) have concluded that the hydration rate rises 10% for one degree centigrade of the effective hydration temperature (EHT) of an object based on the assumption that hydration of obsidian is a diffusion process. Elevated temperatures increase the absorption of water, while cooler temperatures inhibit absorption of water. The EHT is not the mean of fluctuating temperatures that the obsidian has been exposed to but a higher integrated value.

A beginning point for determining the EHT, is using information published regarding the mean annual air temperature (MAT) for a particular area. The MAT needs corrections, which have to do with a particular microclimate of a site, in order to use this data appropriately. Such factors which determine the microclimate of a site are:

(1) Elevation,

(2) Vegetational cover,

(3) Slope aspect in respect to isolation, and

(4) Other apparent local features.

One way to determine the EHT is to obtain the temperature of a site over a period of several years. This can be done inexpensively by use of a field temperature sensing device known as a diffusion cell (Ambrose 1976) or the Pallman cell (O'Brien 1971). However, there has never been an attempt to determine an EHT for an obsidian specimen obtained in the Far Southwest.

A word of caution is provided regarding EHTs for future research. Theoretically, higher EHTs suggest that hydration reactions should be accelerated with concomitant increased hydration thickness with all other factors being equal. However, Origer (1982:23) found that increased EHTs can result from lowered temperatures. It was stated that temperature range is the key variable in determining EHTs because those areas with broader ranges of temperatures annually, actually produced the larger EHTs (Origer 1982:24).

Another factor proposed to alter the EHT of an obsidian object is the depth below surface from which it was obtained. Unfortunately, general empirical equations which link surface air temperature as a function of depth have not been developed. One reason these equations are lacking is due to the numerous variables involved in soil temperature. A diagram taken from Ericson (1977:63, Plate 1-4) illustrates the variation of EHT relative to soil depth and MAT (Figure 2).

Surface obsidian is particularly vulnerable to the temperature factor especially in areas in which brush fires are common. Friedman and Trembour (1983:545) have done replicative tests to examine the effects of high heat (burning) on test obsidian flakes. It was found

> " . . . from laboratory heating tests that temperatures below 540°C could produce first, a deepening of a preexisting hydration layer, and

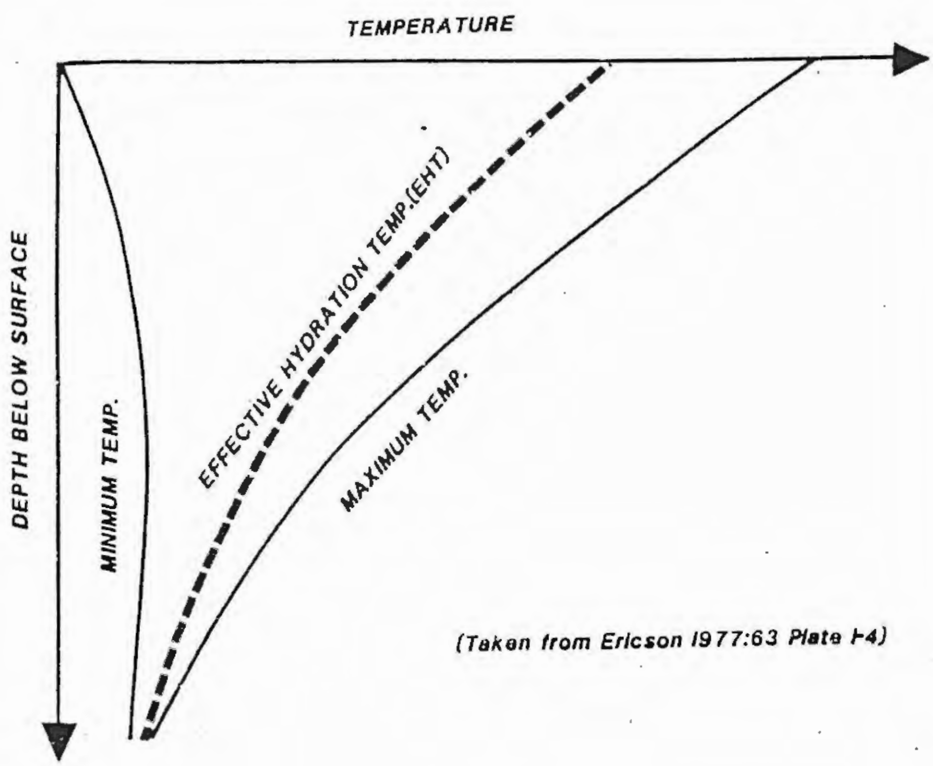

Figure 2. Diagram of Effective Hydration Temperature as a Function of Depth in Soil

> then, its disappearance due to water leaving the glass at high temperature--all before further heating above 540°C (which) produced the telltale crazing (on the obsidian flake surface)" (Friedman and Trembour 1983:545).

The surface of all specimens should be examined for evidence of heat damage in order to eliminate the possibility of inadequate results.

Another aspect of surface obsidian and their hydration rim width concerns solar radiation and its effect on the temperature of an obsidian artifact. Layton (1973) analyzed temporally sensitive projectile points from northern Nevada and found that specimens on the soil surface exposed to direct sunlight were marked by hydration measurements that were twice the thickness of their subsurface counterparts. It was concluded by Layton (1973:131) that the primary effect of direct sunlight was to greatly elevate the artifacts' temperature and thus, allow the hydration process to occur more rapidly.

The above discussion points out that besides chemical characterization and time, the effective hydration temperature will also determine the rate in which obsidian will hydrate. There are other variables also discussed in the hydration literature which may affect the rate of the obsidian hydration process or measurement of the hydration rim. These variables include: (1) erosion caused by water tumbling or blasting by windborne sediments which physically removes the hydration rim (Friedman and Smith 1960:486), (2) artifact reuse and breakage which can lead to misinterpretation of hydration measurements (Clark 1961:70), and (3) possibly geothermal activity and soil pH which may affect hydration rates (Kaufman 1980:379).

Detailed information concerning a site's microclimate, descriptions of the obsidian artifacts' morphological characteristics and meteorological data from existing references, should be applied when determining a hydration rate when the final age conversion calculation is finally made. Although the depth from which an object is found has some bearing on the EHT, the EHT will be basically the same for a series of artifacts buried at one site, where all samples had experienced the same microclimate (Friedman and Trembour 1983:546).

Conclusion

The initial phases of the study of obsidian hydration as a dating method are time-consuming and costly. Measuring the hydration rim is a relatively cheap and easy procedure. However, translating the hydration rim measurement into an age determination requires several ancillary studies and correlation of their results.

These ancillary studies, which are costly, involve neutron activation or X-ray analysis (in order to determine the specimen's chemical characterization) and a suite of radiocarbon dates (for age calibrations). Once a hydration rate is established for a specific source, this dating method will be more efficient in regard to both cost and time.

CHAPTER III

BACKGROUND INFORMATION CONCERNING OBSIDIAN BUTTE HYDRATION RATE

Introduction

The purpose of this chapter is to provide a general background of the existing data concerning hydration rate studies for Obsidian Butte.

The material presented in this chapter provides a general description of the Obsidian Butte Source. Chace's (1980) proposed hydration rate for Obsidian Butte material is also presented and discussed.

Description of the Obsidian Butte Source

Obsidian Butte is located in Imperial County, in the southern portion of the Salton Trough which is a part of the Colorado Desert. Recorded in the San Diego Museum of Man files as C-89, Obsidian Butte is located on the southeast shore of the Salton Sea, about three miles southwest of the mouth of the Alamo River (northeast ¼ of Section 32, Township 11 South, Range 13 East on the 7.5 minute U.S.G.S. *Obsidian Butte* Quadrangle)(Figure 3). The resource area consists of a central dome of pumice with several smaller obsidian hills located on its periphery (Kelly and Soske 1936; Morton 1977). The

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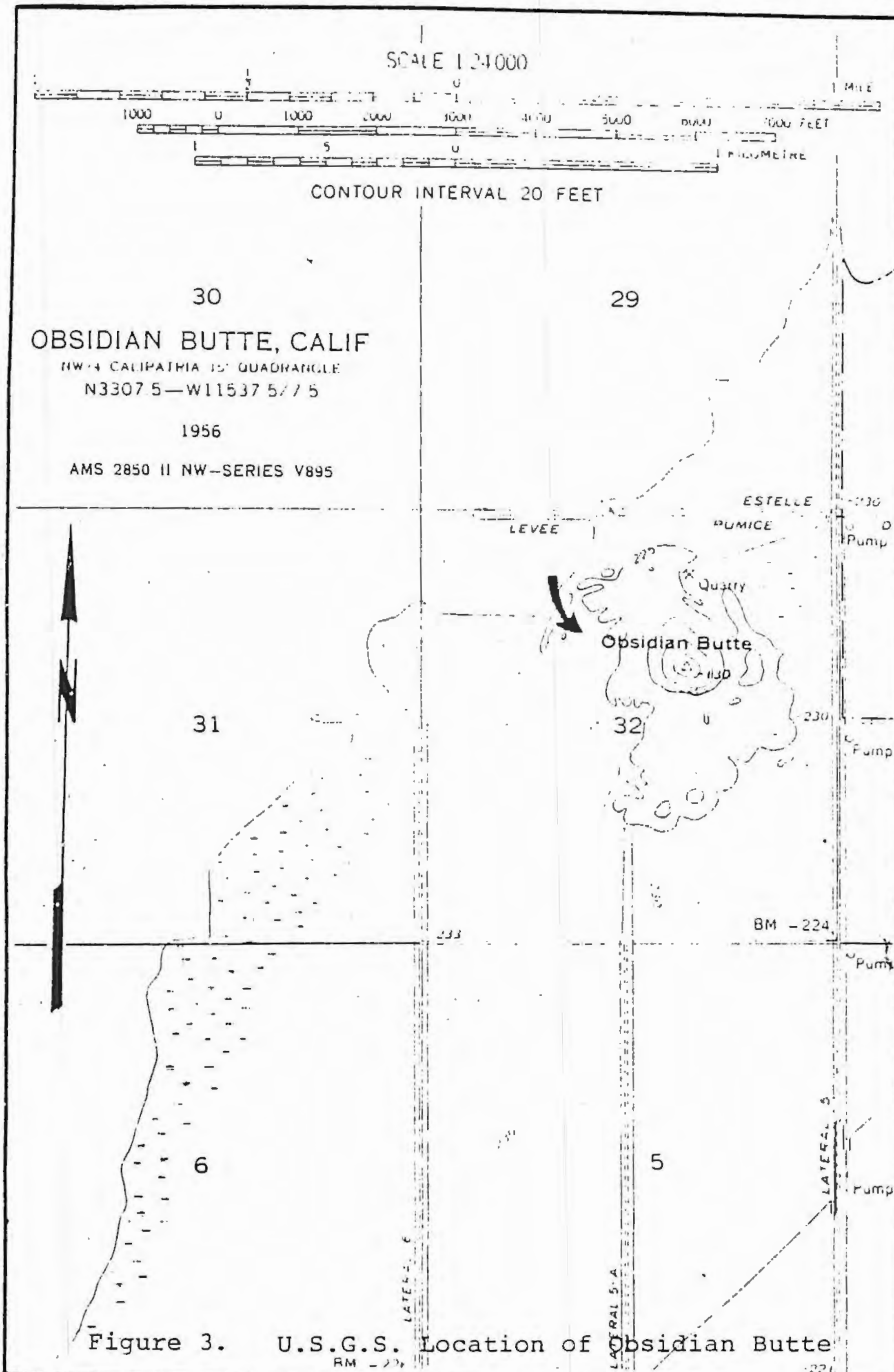


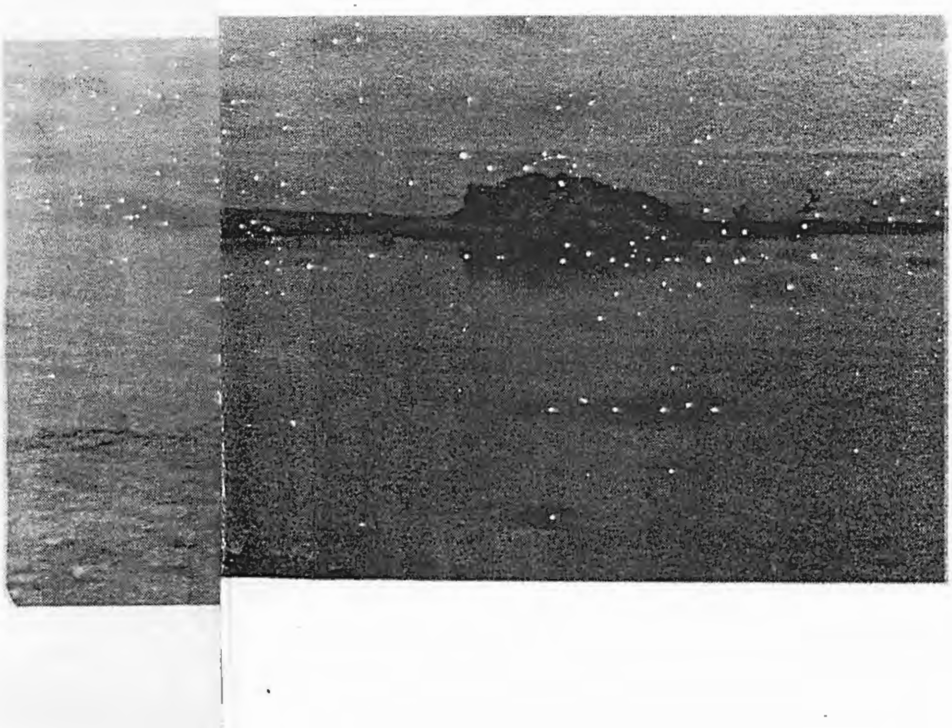
Figure 3. U.S.G.S. Location of Obsidian Butte

elevation of the peripheral buttes ranges from 185 to 200 feet below sea level. The area of obsidian exposed is estimated to be 0.5 square kilometers (Ericson 1977:199). Figure 4 shows Obsidian Buttes in 1981.

Evidence of prehistoric quarrying activities around the butte was present several decades ago (Heizer and Treganza 1944:305), but now is sparse due to recent grading for irrigation, levee construction and inundation. Malcolm Rogers (in the 1920s or 1930s) noted the following archaeological remains when he recorded the source:

> Several small work shops located on a north terrace. The big work shop is on the south side on two different terrace levels. Most of the work seems to have been of a test and roughing out nature. No finished artifacts were found . . . (Christenson and Russell 1981: 134, notes in the San Diego Museum of Man).

An interesting fact is that no ethnographic or ethnohistoric material reference the exchange of Obsidian Butte obsidian (Christenson and Russell 1981:134). The Gabrielino received traded obsidian from the Cahuilla (Bean 1978:582), but the source of this obsidian is not known (Bean 1972:124). Control of the Obsidian Butte source has not been established due to the intermingling of Diegueno in that area with Quechan and other Yuma speakers (Almstedt 1968:10; Luomala 1978:593). However, while the Native Americans living in the desert areas



around the Salton Sea and Imperial Valley, and the Dieguено of the mountains and to the west, were tied by close social and economic bonds, but there is no ethnographic record of exchange of obsidian between the two (Davis 1961:20; Gifford 1931:17,23).

Temporal Availability of Obsidian Butte Obsidian

The availability of Obsidian Butte centers on the fact that although the Colorado River normally flows into the Gulf of California, at times in the past it was diverted into the Salton Basin or Trough, forming a large body of water called Lake Cahuilla. Four lacustral intervals have been documented for ancient Lake Cahuilla during the late Holocene, between AD 700 and 1580 (Waters 1983:373). This information was derived from a combination of C^{14} dates on charcoal, corrected C^{14} dates on shell, and sedimentation rates and associated with historical data (Waters 1983:381-382,384). (See Figure 5.)

The equilibrium high stand of the lake in these intervals was 40 feet above sea level (Weide 1976:12), which submerges Obsidian Butte outcrops under 240 or more feet of water. Drying of the lake would have taken several decades once the flow of the Colorado River into the trough stopped. Weide (1976:13) estimated a 40 year period for exposure of the Obsidian Butte outcrops and

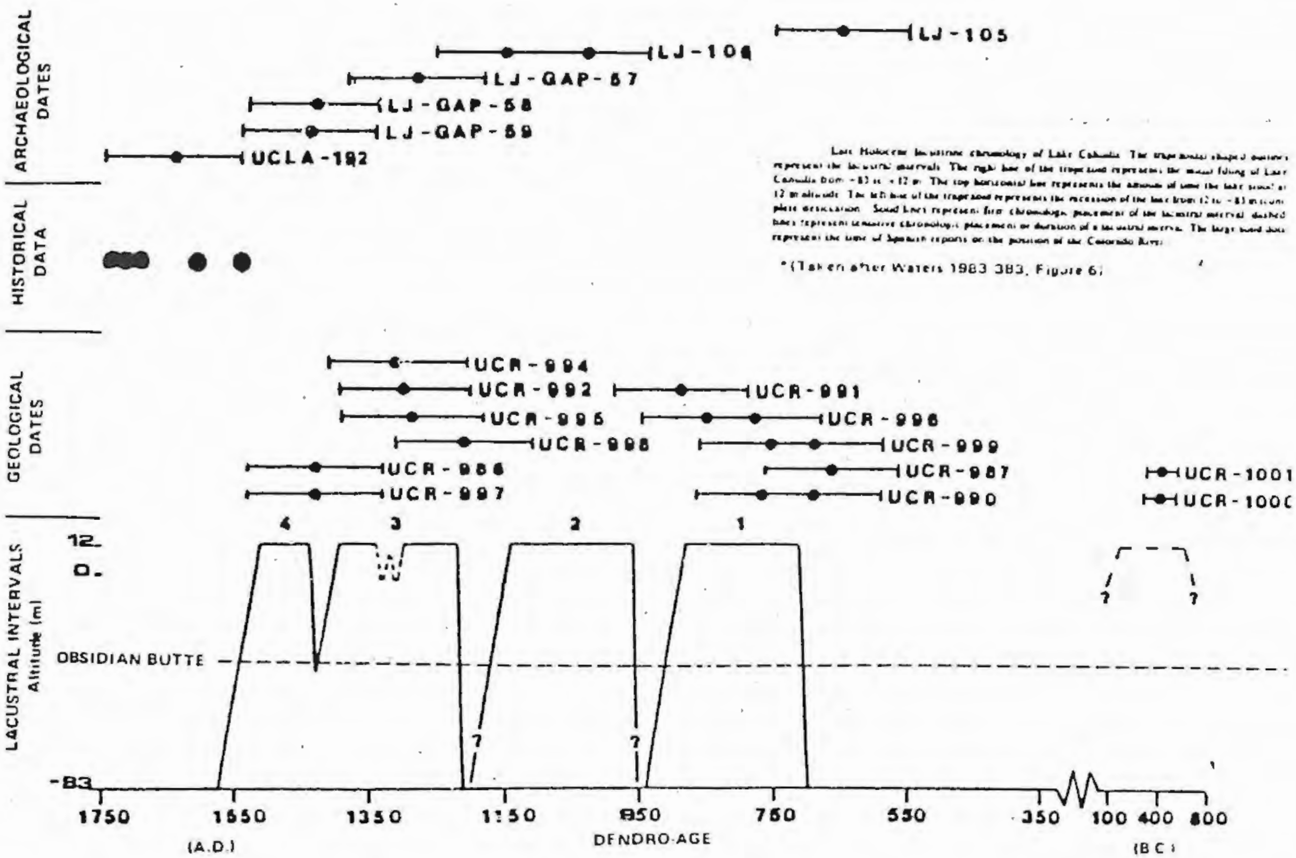


Figure 5. *Late Holocene Lacustrine Chronology of Lake Cahuilla

another six years (±) for the outcrops to be connected to the mainland. The first of the last three desiccation dates (Waters 1983:383) is approximately A.D. 940 (1044 B.P.). The next desiccation period occurred around 1210 (774 B.P.). At approximately A.D. 1420 (564 B.P.) the lake receded approximately 240 feet (Waters 1983:383), which would expose Obsidian Butte outcrops as islands and possibly a portion of these exposed outcrops may have been to the mainland. Approximately 10 years prior to the final desiccation of the lake (A.D. 1580), Obsidian Butte would have also existed as islands (A.D. 1570).

Proposed Hydration Rate

As discussed in the Introduction and Chapter II, three parameters (source, known age and hydration rim measurement) must be correlated from a single site in order to calibrate a hydration rate (Ericson 1977; Meighan 1983:600). Additionally, a large sample of obsidian and a wide range of variability of hydration layer measurements from a single site are needed (Meighan 1983:603).

An inherent problem arises when dealing with the Obsidian Butte source since it was only available for aboriginal exploitation for a relatively short period of time. Based on historical accounts and climatological research, the date for the most recent availability of the Obsidian Butte material begins about A.D. 1570-1580 (Waters 1983; Weide 1976). These dates are tied to the latest desiccation of Lake Cahuilla in which Obsidian Butte was located. During the periods when Lake Cahuilla was full, Obsidian Butte would have been inundated. Although there are data suggesting other earlier periods of Obsidian Butte availability, little archaeological evidence supports other than a relatively recent exploitation. Therefore, the limited time span (500 years) of Obsidian Butte accessibility would limit confidence in the development of any source specific hydration rate (Meighan 1983:603).

Chace's (1980) proposed Obsidian Butte hydration rate will be presented, with the above qualifications and cautions in mind. His rate was constructed from a total of 540 hydration measurements from 34 sites in or near San Diego County (Chace 1980:9). The 17 measurements from CA-SDi-5680 (Locus A) were included in this total.

Chace (1980:10) proposed that the hydration rate for Obsidian Butte material was very close to the linear rate model equation: $D = .0105t$ (Meighan et al. 1968). "D" is the thickness of the hydration rim in microns and "t" is the age in years (before 1980). Chace developed his hypothesis by correlating two types of information: (1) known historic and prehistoric events, with (2) changes in the slope of the frequency curve of the hydration measurements for the 540 samples from San Diego County (Christenson and Russell 1981:137). Chace correlated the decline in frequency of measurements at 1.4 microns with the almost complete breakdown of Native American trade systems by Anglo influence in about A.D. 1860. The point at which the hydration frequency curve begins was correlated with the time of Obsidian Butte availablility. Chace put this date at A.D. 1600 (Chace 1980:9).

In addition to the inherent problem of the proposed short time span for Obsidian Butte exploitation, Chace's work contains other weaknesses. Of the total 540 hydration measurements used in this rate construction, only 20 specimens have been correlated with C^{14} dates. Further refinement by calibration with many more radiocarbon dates would greatly strengthen the argument for the proposed rate.

The use of hydration measurements which are not source specific is also a weakness of this rate. Since the chemical composition of the source material affects the rate of hydration, only hydration measurements from samples known to be from the same source can be used to construct a hydration rate. Chace's preferred hydration rate includes only 24 artifacts which have definitely been sourced to Obsidian Butte. This includes 20 hydrated pieces of obsidian from CA-SDi-799 (White et al. 1983:95) and four artifacts from CA-Riv-643 in Riverside County (Ericson 1977:350; Christenson and Russell 1981:134,137).

The latest period of availability of Obsidian Butte obsidian was placed at A.D. 1560-1570 by Christenson and Russell (1981:136), at A.D. 1600 by Chace (1980:10), and at A.D. 1570-1580 by Waters (1983). Christenson and Russell (1981:136-138) question Chace's assumption that the rise in the frequency curve of hydration measurements represents the initial use of the Obsidian Butte source after Lake Cahuilla became desiccated for the last time. They suggest that the rise in frequency which Chace correlated with A.D. 1600 could merely represent a change in exchange systems or reflect changing patterns in technology (Christenson and Russell 1981:136-138).

A final weakness with Chace's proposed rate concerns the constants derived by using a "before 1980 date" (t) in the linear rate equation to correlate the hydration rim measurements (D) with specific major historical events presumed to have affected the obsidian exchange system (Table 2).

Table 2. Chace's (1980) Linear Hydration Rate Model Equation D = bt (b = .0105)

Formula	Hydration Measurements in Microns (D)	Historic or Prehistoric Events	Years Before 1980 (t)
3.8=b(380)	3.8	A.D. 1600 (Desiccation of Lake Cahuilla) Start of Curve	380
2.0=b(200) b=.01	2.0	A.D. 1780 (Spanish Mission-ization) Peak of Curve	200
1.4=b(120)	1.4	A.D. 1860 (Termination of Trade, Euro-American Settlement) End of Curve	120

Chace averages the three "b" values together to come up with the .0105 constant. Averaging these values actually results in a .0106 constant (by rounding the .0105555667 answer). However, this is not the major weakness in his rate determination. By using the D = bt format, Chace's quantification of the rate actually makes each b value appear more similar than they really are, thus supporting his idea that Obsidian Butte material hydrates close to a linear rate.

Christenson and Russell (1981:137) transcribed Chace's original formula into the form for the linear rates found in Ericson by using the constant "95" (b) which is the reciprocal of .0105 (1977:67, Table 1-12).

Table 3. Chace's (1980) Linear Rate Model

Linear Formula T = bx

Formula w/Adjusted Constant to Fit Chace's(1980) Data	Hydration Measurement in Microns	Historic or Prehistoric Event
380=b(3.8) b=100	3.8	A.D. 1600 (Desiccation of Lake Cahuilla) Start of Curve
200=b(2.0) b=100	2.0	A.D. 1780 (Spanish Missionization) Peak of Curve
120=b(1.4) b=85.7	1.4	A.D. 1860 (Termination of Trade, Euro-American Settlement) End of Curve

By examination of Table 3, it is evident the "b" constants are not all similar to each other. Similar constants would be needed for a linear rate model. Meighan states that the linear model appears to give the best results for hydration data from archaeological sites in California (Meighan 1983:605). However, other researchers in hydration studies believe that hydration thickness increases as the square root of time; time = constant X $(\text{thickness})^2$ (Friedman and Trembour 1983:546).

Other evidence indicates that the formation of the hydration rim is not uniform with respect to time (Ericson 1978). This suggests that the linear model does not provide an accurate mathematical description of the hydration process. For these reasons, five other hydration rate model equations have been proposed for California obsidian sources (Table 4).

Table 4. Proposed Hydration Rate Model Equations for California

Linear (Meighan et al. 1968)	Diffusion (Friedman and Smith 1960)	Squareroot (Ericson 1977)
$T=bx$	$T=dx^2$	$T=ax^{\frac{1}{2}}$
California (Clarke 1964)	Cubic (Kimberlin 1976)	Parabolic (Findlow et al. 1975)
$T=cx^{1.33}$	$T=ex^3$	$T=f(x^2-x)$

(Taken after Ericson 1977:67, Table 1-12)

In order to propose a hydration rate for Obsidian Butte, each of the above rates must be correlated with the three data sets from a single site, i.e., (1) sourcing, (2) absolute dates, and (3) a wide range of hydration measurements.

CHAPTER IV

ENVIRONMENTAL AND CULTURAL SETTING OF THE CA-SDi-5680 SITE COMPLEX

The environmental and cultural setting of CA-SDi-5680 are presented in this chapter.

Site Location

CA-SDi-5680 is comprised of five loci located on the west and east sides of State Route 67, south of the intersection of Poway Road and State Route 67, in a rural part of San Diego County, California (Figures 6, 7 and 8). CA-SDi-5680 is situated on both sides of Poway Creek, a major drainage which eventually drains into Penasquitos Creek and the Pacific Ocean.

The site is delineated on the 7.5 minute U.S.G.S. San Vicente Reservoir Quadrangle, in Township 14 South, Range 1 West, on the line between the northeast and southeast ¼, of the northwest ¼ of Section 15 (Loci A, B and C) and in the northwest ¼, of the southwest ¼ of the northeast ¼ of Section 15 (Loci D and E). The UTM (Zone II) coordinates are:

Loci A and B

(a) 502620/3646520; (b) 502710/3646620

(c) 502640/3646625; (d) 502710/3646590

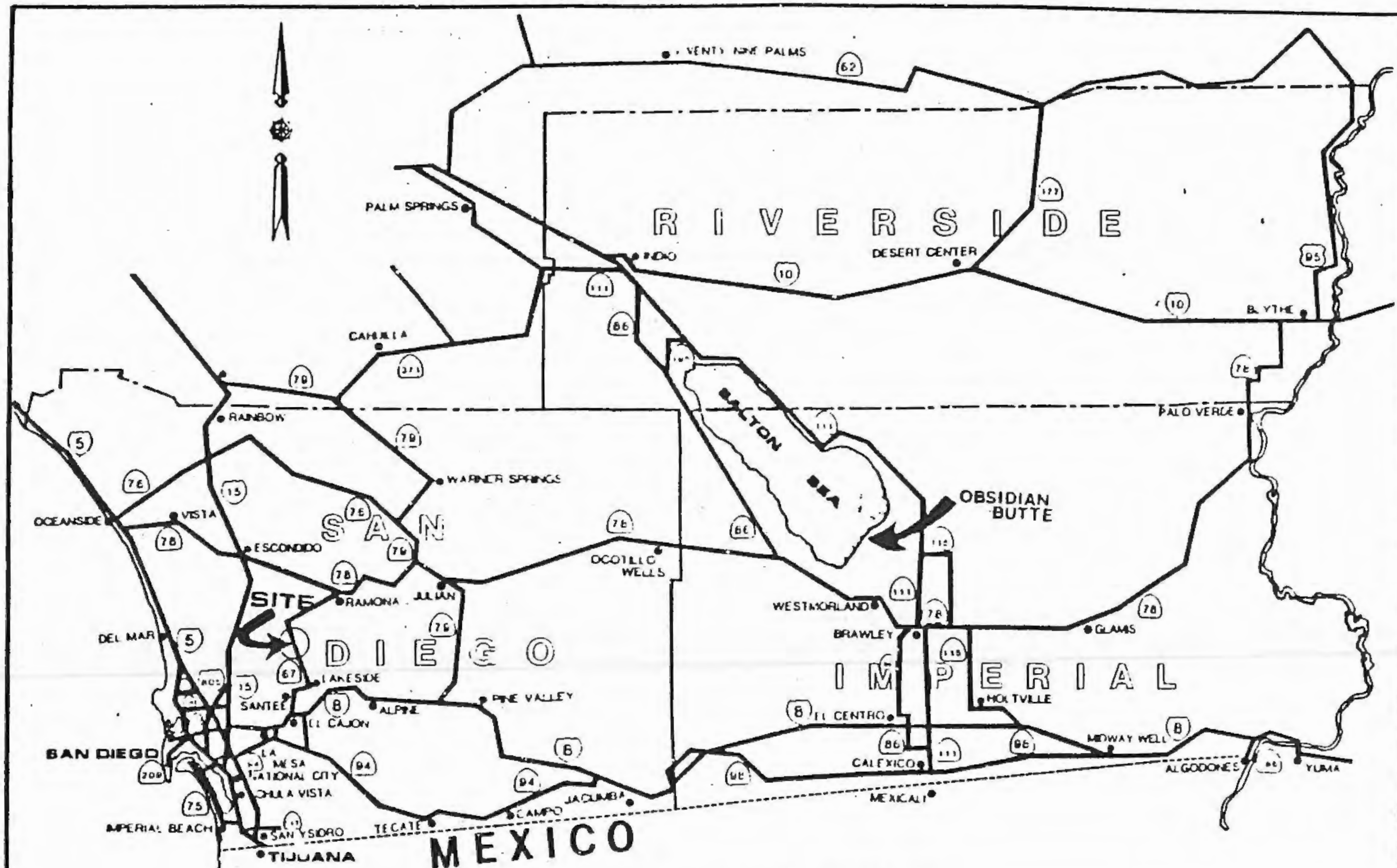


Figure 6. CA-SDi-5680 Location

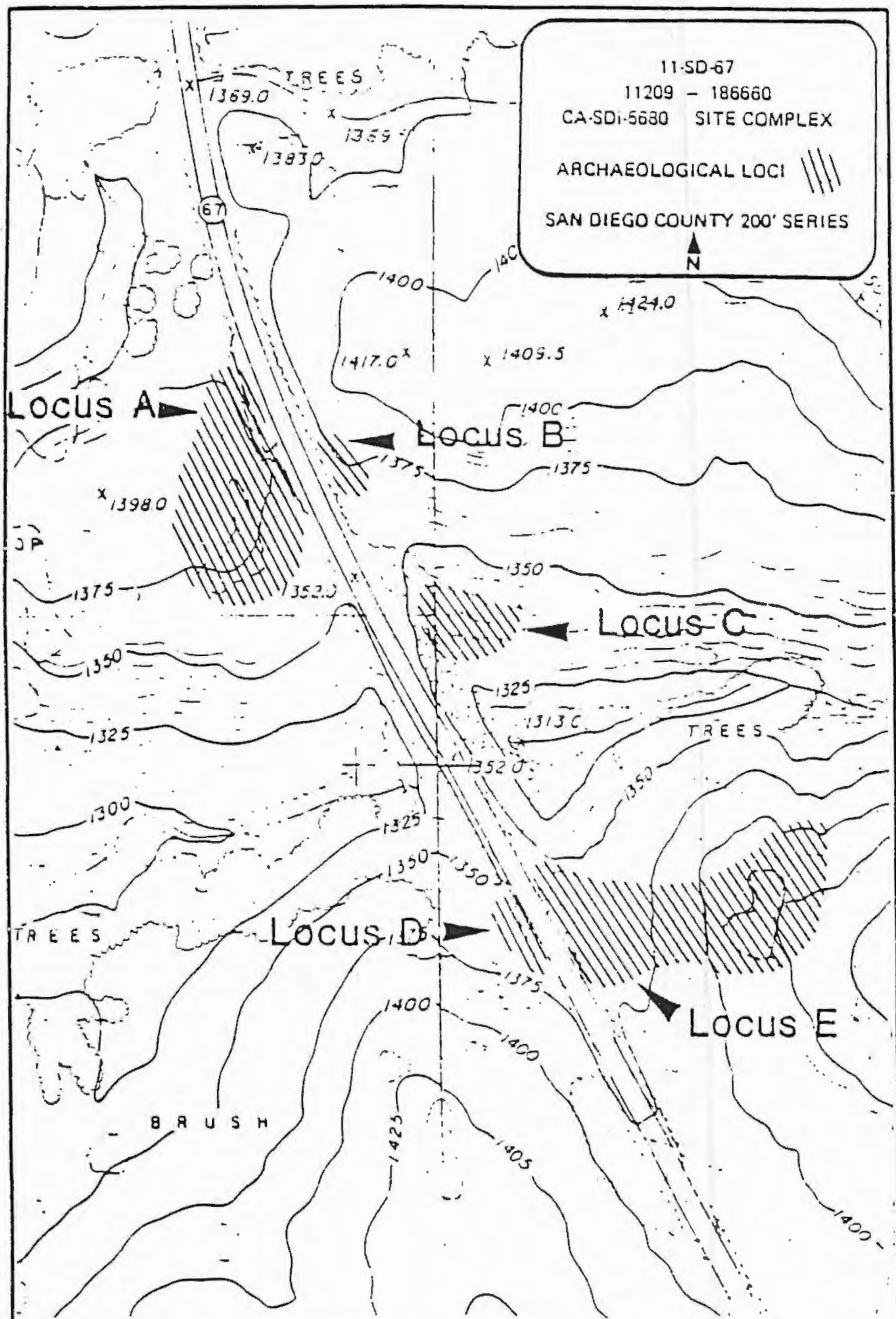


Figure 7. Topographic Location of CA-SDi-5680

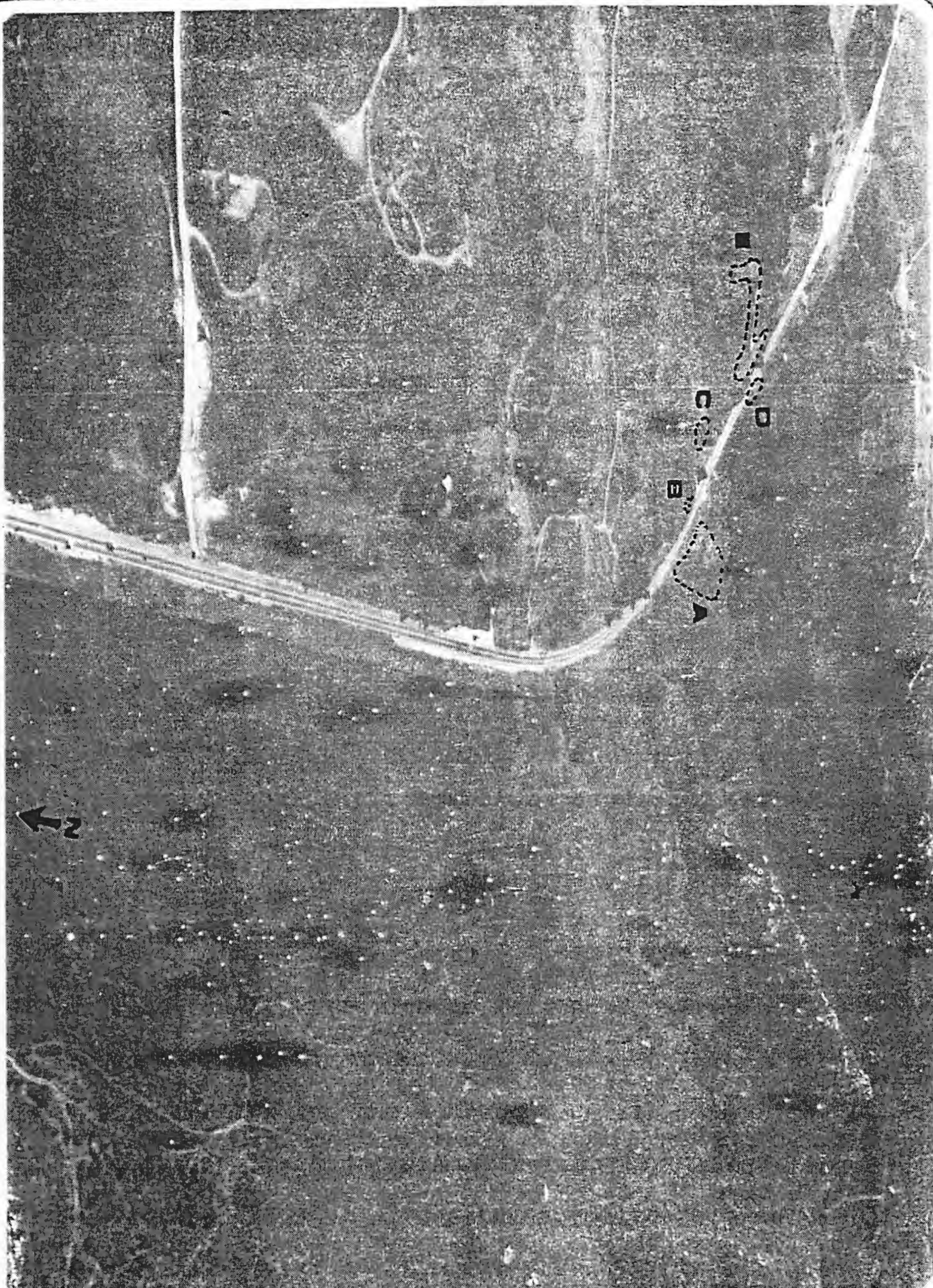


Figure 8. Aerial View of CA-SBr-5680 Site Complex

Locus C (center point)

(a) 502750/3646535

Loci D and E

(a) 502920/3656500; (b) 502900/3646320

(c) 502805/3646335; (d) 502770/3646420

Environment and Microclimate

The site complex is situated on the western slopes of Iron Mountain in the Foothills physiographic region (a belt of narrow winding valleys and rolling to hilly uplands). Streams in this area are seasonal and usually short-termed. They flow after heavy rainstorms which occur between the months of December and April. Precipitation in the project area ranges between 12 to 18 inches a year (U.S. Department of Agriculture 1973:45) with a mean annual air temperature between 20.1°C (U.S. Department of Agriculture 1973:45) and 24.8°C (Ericson 1977:59, Table 1-11 Ramona Fire Department). The EHT was calculated to be 25.3°C for the 24.8°C MAT.

Geologically, the site is located in a subductive fault zone (geo-suture), between a remnant island arc granite formation and the Woodson Mountain Formation (George Morgan, personal communication 1980). Santiago Peak Volcanics (andesite, dacite, rhyolite) are folded into this subductive fault area. 11-SD-67 is situated directly over an inactive fault. Poway Creek is also situated over a fault. Stream action is rapidly eroding away any surface indications of this fault. The Poway Creek fault is younger than the 11-SD-67 fault, evidenced by the unalignment (surface rupture) of the older fault due to relative tectonic movement of the younger. Perpendicularly transecting Poway Creek, the older fault is manifest by a seep (4000 meters east of 11-SD-67) and by a tributary of Poway Creek (2000 meters west of 11-SD-67), west of CA-SDi-5680 (Locus A). Santiago Peak Volcanics (resource area for aboriginal lithic material) occur east of the older north-south fault (Locus A), whereas granites are located to the west (Loci D and E).

Due to the permeability of the faults, the abundance of water resources (springs and seeps) can be explained. The availability of water from these source areas is basically year-round. This would be an important consideration for aboriginal occupation.

The site complex area can be characterized by a considerable amount of erosion. Friant soils (shallow and well drained fine sandy loams), formed in material weathered from fine-grained metasedimentary rock (tonalite and granodiorite) and metavolcanics (Santiago Peak Formation) are found on mountainous uplands in this region (U.S. Department of Agriculture 1973:45). Soils from the Escondido Series (deep, well drained very fine sandy loam) weathered in place from metamorphosed sandstones, occur on gently rolling uplands. Rock outcrop covers 2 to 10 percent of the surface in some areas. Valley areas, which were formerly wet meadows, are comprised of loamy alluvial land (poorly drained, very deep, black silt loams and sandy loams)(U.S. Department of Agriculture 1973:64).

The representative profile of the soil in the site complex vicinity is composed of two layers. The surface layer is dark-brown (10 YR 3/3) moist, fine sandy loam, with a weak, very fine and fine, granular structure. It is slightly acid (pH 6.4) and approximately 3 inches (7.62 cm.) thick. The next layer, which extends to bedrock, is heavy fine sandy loam, dark-brown (10 YR 4/3) moist, massive, slightly hard. It is also slightly acid (pH 6.2). Bedrock is either a gray metasedimentary (Locus D, occurring at a 130 cm. depth) or metavolcanic rock (Locus A, occurring at 40 cm.) that is slightly tilted.

Vegetation communities within the project locale consist of a mixed inland sage scrub and chaparral, southern oak woodland, riparian oak woodland and ruderal and exotic plantings (Thorne 1976).

Locus D of CA-SDi-5680 differs from Locus A (originally called the Nelson Site) in that it has twice the depth and is associated with a southern oak woodland, granitic outcrops and has a northwest exposure in a saddle between two knolls. Whereas Locus A is associated with a southwest exposure atop a knoll, metavolcanic outcrops and inland sage scrub vegetation.

Cultural Setting

An Early Milling Archaic component seems to be represented at CA-SDi-5680 (Locus D). However, no relative or absolute dates were obtained from any levels of Locus D that fall near 3000 B.P. (Dominici n.d.).

The presence of an Early Milling Archaic component at Locus D was based on the correlation of: cobble based lithic tools, portable milling implements, a "Pinto" projectile point basal fragment (all diagnostic of an Early Milling Archaic Horizon) with the lower levels of the cultural deposit (Table 5). However, based on the relatively low number of these artifacts, the Early Milling Archaic culture seems to be sparsely represented. There were also a few items diagnostic of the Late Prehistoric period that were found in the lower levels of the midden at Locus D. It was felt that their presence may be intrusive due to mixing mechanisms (i.e., rodent

Table 5. Distribution of Select Artifact Classes

Level	Portable Milling Implements	Ceramic Sherd Counts	Radiocarbon Dates	Other Obsidian Hydration Measurements	Projectile Points Typology (True 1970)	Production Base of Lithic Tools Other Than Projectile Points
1		63				4 Flake Based
2		Two 89	<300 yrs. BP		Type 1	2 Flake Based
3		83	<300 yrs. BP		Type 1	8 Flake Based
4		91	Two <300 yrs. BP		Type 1 Type 2	7 Flake Based
5	Metate	50	<300 yrs. BP		Type 2	10 Flake Based 5 Cobble Based
6		19	400± 160 yrs. BP <300 yrs. BP		Two Type 5s	10 Flaked Based
7		22				
8	Metate	4		(Not identifiable source) 1.3 microns	Cryptocrystalline Silicate Projectile Point Midsection	1 Cobble Based
9	Metate	3			Pinto Point	
10	2 Metates	2				2 Cobble Based
11	Metate		<300 yrs. BP	(Not identifiable source) 4.9 microns		1 Cobble Based
12		2		Coso obsidian 6.4 microns		
13						

activity, soil mechanics caused by erosion, prehistoric disturbance, etc.).

The majority of artifactual material recovered from the CA-SDi-5680 site complex was diagnostic of the Late Prehistoric (small triangular projectile points; side-notched points; projectile point made of light green glass; ceramics; stone and clay pipe fragments; steatite pendant fragment, beads, flake based tools--made from obsidian, quartz, local metavolcanic, and exotic metavolcanic; bone tools; negative flake scars on the metavolcanic outcrops; and bedrock milling features). Ecofacts included charcoal, shellfish, mammal, bird, reptile and amphibian remains. The greatest density of this material was recovered from the top 20 centimeters at Locus A and from the 30-60 centimeters at Locus D.

Cultural remains associated with the following activities (inferred from ethnographic accounts) are represented at CA-SDi-5680:

- Hunting
- Gathering and food processing (plant and animal)
- Use of ceramics
- Tool manufacture and use
- Basketry manufacturing and/or repair
- Trade or long distance travel.

Based on the above information, CA-SDi-5680 was determined to be a Late Prehistoric habitation site complex. There were year-round exploitable resources available, as indicated by the recovered faunal genera and the presence of seeps and springs at the site. Resources usable during the spring and summer seasons consisted mainly of seeds and berries. The recorded bedrock slicks would indicate processing of these vegetable foods. Concentrated fall extractive activities are likely to have been performed at the site due to the extensive oak-woodland associated with the site. Mortars and Locus A and D would indicate acorn processing was occurring. The CA-SDi-5600 site complex area was potentially available for year-round occupation. However, ethnographic accounts document semisedentary occupation of Late Prehistoric habitation sites (Spier 1923:299, 301-302; Luomala 1978:547; Almstedt 1979:18-20). This was probably the case at CA-SDi-5680.

It was found that the projectile point type percentages from the CA-SDi-5680 site complex were closer to the assemblages from two Diegueno (Cuyamaca) sites than San Luis Rey assemblages (Dominici n.d.). Therefore, based on this information and that the site complex was located in the ethnographic territory of the Diegueno, it was decided that the artifactual/ecofactual material recovered from CA-SDi-5680 belongs to the Dieguenio culture. (The reader is referred to Appendix B for a detailed Cultural Background discussion of the Far Southwest.)

CHAPTER V

CALIBRATION OF OBSIDIAN BUTTE HYDRATION RATE

Obsidian Hydration Analysis of CA-SDi-5680 Obsidian

Sixty-seven (67) obsidian specimens, including the 18 pieces recovered from Locus A by Chace (1980:8-9), were submitted for hydration measurements and sourcing analysis. Only 17 of the 18 obsidian samples from Locus A had visible hydration rims. (#519-2 had no visible hydration rim.) Additionally, 10 samples of carbonized wood recovered from Locus D were submitted for radiocarbon dating. The obsidian specimens and carbonized wood samples were sent to Dr. C. Rainer Berger, Geophysics Laboratory at the University of California, Los Angeles. The chemical source work was subcontracted to Richard Hughes of Sonoma State University; Thomas S. Kaufman performed the hydration studies at the UCLA Isotope Lab and Dr. Berger conducted the radiocarbon work. Correspondence and results of the chemical source work, hydration studies and radiocarbon analysis are provided in Appendix A.

Two different sampling strategies were used for obtaining obsidian specimens from Locus A and Locus D. Chace (1980:9) selected the 18 obsidian pieces from the lowermost and uppermost portions of the cultural deposit of Locus A, to better establish the dates of initial settlement and final abandonment of the site. One additional obsidian specimen was processed from Locus A (Dominici n.d.) due to its association with the radiocarbon dated material (Table 6).

The considerations for obsidian selection and processing for Locus D were twofold: association of as many as possible obsidian hydration measurements with radiocarbon datable material, and at least one hydration measurement from every 10 centimeter level of a single unit (see Table 6). As mentioned earlier, correlation of those sourced and hydrated specimens with absolute C^{14} dates was desired for purposes of calibration of the Obsidian Butte obsidian hydration rate. Questions of integrity and cultural/temporal stratigraphy can be addressed by obtaining hydration measurements throughout the cultural deposit.

Of the 67 obsidian specimens submitted to UCLA, 66 were chemically sourced and 65 had their hydration rim measured (17 were previously submitted by Chace 1980: 8-9). Table 6 presents the results of these studies. Fifty-nine (59) of the obsidian specimens were sourced to Obsidian Butte, four were sourced to Coso and three were unable to be identified as being from a previously

Table 6. Provenience of Obsidian Butte Specimens

CASE NO	V1	V2	V3	V4	V5	V6	V7	V8
1	15680	440	0	9	1	1	1 8	0
2	15680	441	1	9	2	1	2 2	300
3	15690	441	2	9	2	1	1 5	300
4	15690	442	1	9	3	1	2 2	0
5	15680	443	1	9	4	1	2 1	300
6	15690	443	2	9	4	1	2 1	300
7	15690	444	0	9	5	1	2 1	0
8	15690	445	2	9	6	1	2 1	0
9	15680	446	0	9	8	3	1 3	300
10	15680	447	2	9	9	1	2 0	0
11	15680	448	1	9	11	1	1 9	0
12	15690	449	0	9	12	2	6 4	0
13	15690	431	1	8	2	1	1 8	300
14	15690	432	1	8	3	1	1 9	0
15	15680	433	0	8	4	1	2 1	0
16	15690	434	1	8	5	1	2 2	300
17	15690	434	2	8	5	1	2 1	300
18	15680	436	0	8	7	1	1 8	0
19	15680	437	0	8	9	1	2 0	0
20	15680	438	0	8	10	1	1 8	0
21	15680	439	0	8	11	3	4 9	0
22	15690	457	1	11	1	1	1 9	0
23	15680	458	1	11	2	1	4 0	0
24	15680	510	1	91	5	2	2 8	0
25	15680	510	2	91	5	1	1 7	0
26	15690	509	2	91	4	1	3 3	0
27	15690	509	1	91	4	1	3 8	0
28	15680	525	0	95	4	2	3 2	0
29	15690	512	1	91	6	1	2 3	0
30	15690	508	1	91	3	1	3 6	0
31	15690	521	1	94	4	1	1 5	0
32	15680	516	1	93	3	3	4 3	0
33	15680	505	1	91	1	2	4 3	0
34	15690	505	2	91	1	1	2 5	0
35	15680	506	1	91	2	1	2 6	0
36	15680	518	1	94	1	1	2 6	0
37	15690	519	1	94	2	1	2 6	0
38	15680	519	2	94	2	1	9 9	0
39	15690	515	1	93	1	1	3 1	0
40	15690	513	1	92	1	1	3 3	0
41	15690	507	1	91	2	1	2 6	0
42	15690	511	0	91	6	1	4 6	220
43	15690	459	1	11	3	1	2 2	0
44	15680	460	1	11	4	1	2 3	300
45	15690	460	2	11	4	1	2 2	300
46	15690	460	3	11	4	1	9 9	300
47	15680	460	4	11	4	1	1 7	300
48	15680	460	5	11	4	1	1 8	300
49	15680	461	1	11	5	1	2 3	0
50	15690	462	1	11	6	1	2 0	300
51	15680	462	2	11	6	1	1 9	300
52	15680	463	1	11	7	1	2 2	0
53	15680	464	0	11	9	1	[illegible]	0
54	15680	465	1	11	10	1	1 9	0
55	15680	465	2	11	10	1	2 1	0
56	15680	466	0	11	11	1	2 4	300
57	15680	496	1	16	2	1	1 7	0
58	15680	497	1	16	3	1	3 6	0
59	15680	498	1	16	4	1	2 1	0
60	15690	499	1	16	5	1	1 9	0
61	15690	500	1	16	6	1	1 6	0
62	15690	501	1	16	7	1	2 9	0
63	15690	502	1	16	8	1	1 9	999
64	15680	502	2	16	8	1	2 1	999
65	15680	503	0	16	9	1	2 1	0
66	15690	504	0	16	12	1	2 8	0

LEGEND

- V1 - Site
- V2 - Catalogue Number
- V3 - Specimen Number
- V4 - Unit
- V5 - Level
- V6 - Source
  1. Obsidian Butte
  2. Coso
  3. Not Identified
- V7 - Hydration Rim Measurement
  - 9.9 - No Hydration Visible
- V8 - Associated C 14 Date
  - 999 - Date Not Obtained

recognized source. The hydration measurements for the Obsidian Butte sourced pieces ranged from 1.5 microns to 4.6 microns, with a mean of 2.309, a mode of 2.1, a medium of 2.125, and a standard deviation of 0.647. Table 7 gives the provenience of the Obsidian Butte specimens.

As mentioned earlier, Chace (1980:9) assumed that all 18 obsidian samples from Locus A were to be from Obsidian Butte. After chemical sourcing by X-ray fluorescence, this assumption proved to be false. Three of these 18 pieces of obsidian were sourced to Coso and one was analyzed to be from a non-identifiable source. The four obsidian specimens account for 21% of the analyzed sample from Locus A from non-Obsidian Butte sources.

From Locus D, two obsidian specimens were chemically characterized to non-identifiable sources and one sample was identified to Coso. Out of the total of 47 samples analyzed from Locus D, these three specimens account for 6% of the total non-Obsidian Butte pieces. Information concerning the trace element analysis performed by Richard Hughes for those obsidian specimens, characterized as being from non-identified sources, was compared to Bouey's (1984:57) data (Table 8). Two of the obsidian samples which have similar trace element percentages (Catalog No. 1982-10-0516-001 and 0439-000)

Table 7. Obsidian Specimens Submitted for Sourcing and Hydration Rim Measurement

* * * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * *

V5 LEVEL BY V4 UNIT NO. PRE 9=LOCUS A

CONTROLLING FOR

V6 SOURCE VALUE = 1. OBSID. BUTTE

* *

V5 (COUNT ROW PCT COL PCT TOT PCT) \ V4	8	9	11	16	91	92	93	94	ROW TOTAL
1	0 0.0 0.0 0.0	1 16.7 10.0 1.7	1 16.7 6.3 1.7	0 0.0 0.0 0.0	1 16.7 11.1 1.7	1 16.7 100.0 1.7	1 16.7 100.0 1.7	1 16.7 25.0 1.7	6 10.2
2	1 11.1 12.5 1.7	2 22.2 20.0 3.4	1 11.1 6.3 1.7	1 11.1 10.0 1.7	2 22.2 22.2 3.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 22.2 50.0 3.4	9 15.3
3	1 20.0 12.5 1.7	1 20.0 10.0 1.7	1 20.0 6.3 1.7	1 20.0 10.0 1.7	1 20.0 11.1 1.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	5 8.5
4	1 8.3 12.5 1.7	2 16.7 20.0 3.4	5 41.7 31.3 8.5	1 8.3 10.0 1.7	2 16.7 22.2 3.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 8.3 25.0 1.7	12 20.3
5	2 33.3 25.0 3.4	1 16.7 10.0 1.7	1 16.7 6.3 1.7	1 16.7 10.0 1.7	1 16.7 11.1 1.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	6 10.2
6	0 0.0 0.0 0.0	1 16.7 10.0 1.7	2 33.3 12.5 3.4	1 16.7 10.0 1.7	2 33.3 22.2 3.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	6 10.2
7	1 33.3 12.5 1.7	0 0.0 0.0 0.0	1 33.3 6.3 1.7	1 33.3 10.0 1.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 5.1
8	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 100.0 20.0 3.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 3.4
9	1 25.0 12.5 1.7	1 25.0 10.0 1.7	1 25.0 6.3 1.7	1 25.0 10.0 1.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	4 6.8
10	1 33.3 12.5 1.7	0 0.0 0.0 0.0	2 66.7 12.5 3.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 5.1
11	0 0.0 0.0 0.0	1 50.0 10.0 1.7	1 50.0 6.3 1.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 3.4
12	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 100.0 10.0 1.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 1.7
COLUMN TOTAL	8 13.6	10 16.9	16 27.1	10 16.9	9 15.3	1 1.7	1 1.7	4 6.8	59 100.0

Table 8. Bouey's (1984-57) Integrated Intensity Ratios and Percentages Compared to CA-SDi-5680 Non-Obsidian Butte Sourced Material

BOUEY'S SAMPLE	RB/RB	SR/RB	ZR/RB	E	RB %	SR %	SR %	FE/MN
SAN FELIPE								
1	1.0000	.3931	2.2947	3.6878	27.1	10.7	62.2	
2	1.0000	.3831	2.2772	3.6603	27.3	10.5	62.2	
3	1.0000	.5136	2.2111	3.7247	26.8	13.8	59.4	
4	1.0000	.4964	2.4054	3.9018	25.6	12.7	61.6	
5	1.0000	.4729	1.9748	3.4477	29.0	13.7	57.3	
6	1.0000	.3924	2.2143	3.6067	27.7	10.9	61.4	
7	1.0000	.4218	2.4839	3.9057	25.6	10.8	63.6	
PUNTA MANGLES								
1	1.0000	.7586	2.0817	3.8403	26.0	19.8	54.2	
2	1.0000	.6865	1.9365	3.6230	27.6	18.9	53.5	
3	1.0000	.8224	1.8267	3.6491	27.4	22.5	50.1	
4	1.0000	.7984	2.1633	3.9617	25.2	20.2	54.6	
5	1.0000	.7214	1.8030	3.5244	28.4	20.5	51.2	
6	1.0000	.7297	1.9543	3.6840	27.1	19.8	53.0	
7	1.0000	.6533	1.8500	3.5033	28.5	18.6	52.8	
OBSIDIAN BUTTE								
1	1.0000	.1528	4.4132	5.5660	18.0	2.7	79.3	
2	1.0000	.3551	4.3458	5.7009	17.5	6.2	76.2	
3	1.0000	.2136	4.0414	5.2550	19.0	4.0	76.9	
4	1.0000	.2437	4.1861	5.4298	18.4	4.5	77.1	
5	1.0000	.3059	4.4906	5.7965	17.3	5.3	77.5	
6	1.0000	.1814	4.2261	5.4075	18.5	3.4	78.2	
7	1.0000	.1663	3.7749	4.9412	20.2	3.4	76.4	
COSO								
1	1.0000	.0619	.8331	1.8950	52.8	3.3	44.0	57.6659
2	1.0000	.0365	.8352	1.8717	53.4	2.0	44.6	51.3715
3	1.0000	.0229	.7677	1.7906	55.8	1.3	42.9	48.7308
4	1.0000	.0317	.9012	1.9329	51.7	1.6	46.6	54.4486
5	1.0000	.0538	.8316	1.8854	53.0	2.9	44.1	56.5278
6	1.0000	.0337	.8962	1.9299	51.8	1.7	46.4	53.1689
7	1.0000	.0371	.9825	2.0200	49.5	1.8	48.7	47.9951
SAMPLES FROM CA-SDi-5680								
POSSIBLY SAN FELIPE								
0516-001	1.0000	.4368	.9559	2.3927				
0439-000	1.0000	.3437	.9299	2.2736				
POSSIBLY PUNTA MANGLES								
0446-0000	1.0000	.1241	1.9422	3.0663				
COSO								
0449-000	1.0000	.000	.4808	1.4808				
0529-000	1.0000	.0229	.5210	1.5439				
0505-001	1.0000	.0178	.5044	1.5222				
0510-001	1.0000	.0253	.4887	1.5140				

could possibly be from the San Felipe source, based on the SR/RB ratio. The values for the SR/RB ratio fall in the range given by Bouey (1984:57). However, values for the ZR/RB ratio are closer to the values presented for Coso (see Table 8).

The other obsidian specimen not sourced to either Obsidian Butte or Coso (Catalog No. 1982-10-0446-000), could possibly be from the Punta Mangles source based on the ZR/RB ratio value. However, the SR/RB value is much lower than Bouey's (1984:57) Punta Mangles material value for that ratio.

All possible Far Southwestern obsidian sources are shown on Figure 1. The three obsidian samples, one from Locus A and two from Locus D, could possibly be from any of the Baja sources. However, these obsidian samples could also be from Arizona obsidian sources. Additional studies are needed concerning chemical characterization of the Baja sources before definitive conclusions can be drawn.

Results of the radiocarbon dating procedures indicate that the material analyzed is all less than three hundred years old except for one carbonized piece of wood dated 400 ± 160 years B.P. from the 50-60 centimeter level of Unit 8 at Locus D (see Appendix A). The best date was obtained from a piece of carbonized wood submitted by Paul G. Chase and Associates to Radiocarbon Laboratory of the University of California, Riverside (see Appendix A). The radiocarbon determination was 220 ± 70 years for a sample recovered from the 50-60 centimeter level of Unit 91, Locus A. The range in age for that sample would be 290 to 150 years B.P.

Analysis of specific hydration rim measurements, correlated with absolute dates and interpretations concerning dating methods, are discussed in the next section.

Calibration of the Obsidian Butte Hydration Rate

Of the 67 obsidian specimens submitted for sourcing and hydration analysis from the CA-SDi-5680 data recovery program, 59 were chemically sourced to Obsidian Butte, and 57 of these specimens had their hydration rims measured (see Table 6). Fifteen of the Obsidian Butte sourced specimens are associated with radiocarbon dates of less than 300 years B.P. (One piece was destroyed during sourcing analysis.) The range of hydration rim measurements associated with that date is 1.5 microns to 2.4 microns. One of the Obsidian Butte specimens from Locus A is associated with a radiocarbon date of 220 ± 70 years B.P. Table 9 presents this data with provenience information.

Table 9. Obsidian Butte Obsidian Hydration Rim Measurements and Associated Radiocarbon Dates with Provenience from CA-SDi-5680

Hydration Rim Measurement	Unit	Level	Radiocarbon Date Years B.P.
2.4	11	11	300 (A.D. 1650)
2.3	11	4	300
2.2	9	2	300
2.2	8	5	300
2.2	11	4	300
2.1	9	4	300
2.1	9	4	300
2.1	8	5	300
2.0	11	6	300
1.9	11	6	300
1.8	8	2	300
1.8	11	4	300
1.7	11	4	300
1.5	9	2	300
4.6	91	6	220±70 (A.D. 1660-A.D. 1760)

Due to the late radiocarbon dates and the fact that they are associated with a broad range of hydration readings, correlations of these data could not be used to calibrate any obsidian hydration rate for the Obsidian Butte obsidian. Because of the lack of good radiocarbon dates, correlations were made of known historic and prehistoric events with changes in the slope of the frequency curve of the hydration measurements for the 57 samples from CA-SDi-5680 sourced to Obsidian Butte. This approach for establishing a hydration rate for Obsidian Butte obsidian was originally proposed by Chace (1980:9).

The obsidian hydration rim measurements associated with dates of these known historic and prehistoric events are then tested in each of the six proposed hydration rate model equations for California. Figure 9 is a histogram illustrating the frequencies of the hydration readings for the Obsidian Butte material.

Examination of the frequency histogram (Figure 9) of Obsidian Butte hydration rim measurements shows:

(1) 4.6 microns = Start of the curve

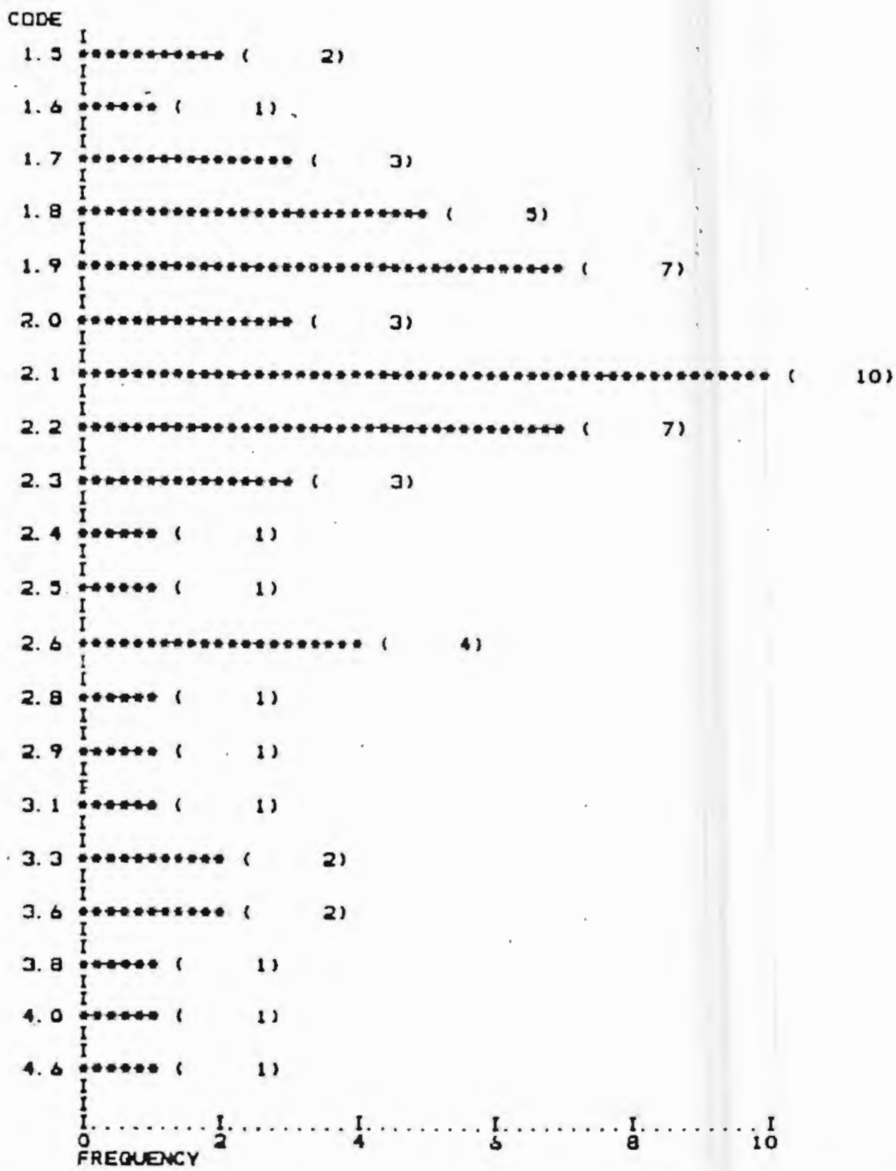
(2) 2.1 microns = Peak of the curve

(3) 2.0 microns = Drop off of the curve

(4) 1.5 microns = End of curve

Before discussing any specific hydration rate model equation, information concerning the date for the start of Obsidian Butte obsidian exchange system must be discussed.

Chace (1980:9) proposed that the obsidian ". . . trade began when the lake dried and initially exposed the obsidian deposit . . ." at approximately A.D. 1600 (384 B.P.). The 3.8 micron reading was correlated to this date which was the assumed beginning of local trade from Obsidian Butte. Chace (1980) argued that measurements beyond 4.0 microns do not represent use of Obsidian Butte obsidian, but are either original flow surface measurements or obsidian from other sources.



MEAN	2.309	STD ERR	0.086	MEDIAN	2.125
MODE	2.100	STD DEV	0.647	VARIANCE	0.418
KURTOSIS	2.612	SKEWNESS	1.638	RANGE	3.100
MINIMUM	1.500	MAXIMUM	4.600		

VALID CASES 57 MISSING CASES 2

Figure 9. Frequency Histogram of Obsidian Butte Hydration Rim Measurements from CA-SDi-5680

Refinement of Chace's proposed onset of obsidian trade/exchange involves the dates previously presented and which were derived from the research of Waters (1983:81-382,384) and Weide (1976:12-13). These dates (A.D. 940, A.D. 1210, A.D. 1420 and A.D. 1570/A.D. 1580) are correlated with the beginning of the periods of Obsidian Butte availability. Christenson and Russell (1981:138) have stated that the point at which the frequency curve of hydration measures increases ". . . need not represent initial use of Obsidian Butte after drying up of Lake Cahuilla--that is only one of several possible events that could have resulted in this change." Some possible events that would cause an increase of obsidian, as proposed by Christenson and Russell (1981:138), are changes in patterns of technology or exchange, especially at sites located quite a distance from the source. The only way to understand the exchange system is to determine the production system at the source (Christenson and Russell 1981:139). Unfortunately, Obsidian Buttes have been heavily impacted by grading, levee construction and inundation within the last three years. Studies at Obsidian Buttes would be greatly compromised due to these factors.

For purposes of testing Chace's (1980) hypothesis, the A.D. 1420 date has been set as the maximum age in maximum age in which any hydration measurement for Obsidian Butte material can be associated during the Late Prehistoric period. The widest hydration rim measurement obtained from CA-SDi-5680 was 4.6 microns. However, the widest hydration rims recorded for an Obsidian Butte specimen in San Diego County are 9.7 microns and 8.9 microns from CA-SDi-813 located near Ocotillo Wells (Dallas 1984: Table 1). Obsidian specimens obtained from the flow surfaces of Obsidian Butte had a hydration rim measurement of 5.2, 8.1 (rough) and 4.3 microns (Meighan and Russell 1981:29). Three utilized flakes from Obsidian Butte have hydration rim measurements of 5.8, 5.5 and 4.9 microns (Van Camp 1979:45). An obsidian specimen sourced to Obsidian Butte recovered from CA-SDi-674, located in the foothill region of the county, had a relatively large hydration measurement of 6.7 microns obtained from the dorsal side of a flake (3.3/3.8 microns from the ventral side)(Rosen 1984:110). Correlating the 9.7, 8.9, 6.7 hydration rim measurements with the A.D. 1420 date and most recent Obsidian Butte availability (A.D. 1575 averaged from the A.D. 1570-1580 date) during the Late Prehistoric period, constants were determined for each of the proposed hydration rates for California sources (Table 10).

Table 10. Proposed Hydration Rate Models for California Correlated with Obsidian Butte Availability and Widest Hydration Measurements Recorded from San Diego County Sites

HYDRATION RATE MODEL EQUATION	X= 9.7	X= 8.9	X= 6.7
Linear T=bx			
T=564 B.P. (A.D. 1420)	b= 58.14*	b= 63.4*	b= 84.18
T=409 B.P. (A.D. 1575)	b= 42.16*	b= 45.96*	b= 61.05*
Diffusion $T=dx^2$			
T=564 B.P.	d= 5.99*	d= 7.12*	d= 12.56*
T=409 B.P.	d= 4.35*	d= 5.16*	d= 9.11*
Square Root $T=a(x)^{1/2}$			
T=564 B.P.	a= 181.09	a= 189.05	a= 217.89
T=409 B.P.	a= 131.32	a= 137.1	a= 158.01
California $T=C(x)^{1.33}$			
T=564 B.P.	c= 27.47*	c= 30.8*	c= 44.94
T=409 B.P.	c= 19.92*	c= 22.34*	c= 32.59*
Cubic $T=e(x)^3$			
T=564 B.P.	e= 0.62*	e= 0.80*	e= 1.88*
T=409 B.P.	e= 0.45*	e= 0.58*	e= 1.36*
Parabollic $T=f\ (x^2-x)$			
T=564 B.P.	f= 6.68*	f= 8.02*	f= 14.77*
T=409 B.P.	f= 4.85*	f= 5.82*	f= 10.71*

* Constants considered not viable based on the 1.1 micron hydration measurements associated with 84 B.P. (A.D. 1900) termination date for use of Obsidian Butte obsidian.

The microclimates of CA-SDi-674 (inland from Oceanside), CA-SDi-5680 (foothill region), CA-SDi-813 (desert floor) and Obsidian Butte (Salton Trough) are quite different. However, their effective hydration temperatures (EHTs) do not vary substantially. Effective hydration temperatures determined by Ericson (1977: 49,58,59) for weather stations near or in similar environments as the above listed sites were used. These locales and EHTs are as follows: Oceanside - 18.1°C, Ramona Fire Department - 25.3°C, Palm Springs - 22.0°C, and Obsidian Butte - 24.5°. The difference between the two extreme EHTs (18.1°C and 22.0°C) is 6.1°C. Origer (1982:97) found that even though the difference between the two extreme EHTs for Sonoma County prehistoric sites used in his study was 5.6°C, the temperature was relatively homogeneous in the study area and had no effect on the hydration process. Although additional verification of this phenomenon is needed, for purposes of this study it was assumed that the hydration measurements obtained from subsurface obsidian specimens recovered from the sites above are comparable.

Very few hydration measurements for obsidian sourced to Obsidian Butte and recovered from San Diego or Imperial Counties are larger than or equal to 5.0 microns (Hughes 1984). Therefore, it is suggested that Obsidian

Butte obsidian exchange was expanding in a period correlated with the 5.0-5.8 micron measurements, but began at a time associated with the 9.7-6.7 micron readings.

The previous discussion and Table 10 have focused on the accessibility of Obsidian Butte and possible start of the Obsidian Butte obsidian exchange system. Turning to the termination date of the obsidian exchange system, several obsidian hydration rate models and constants can be dismissed.

Based on ethnohistoric information, Chace (1980:9-10) and others (Christenson and Russell 1981:137) feel Euro-American influences eliminated obsidian trade at approximately A.D. 1860-1880. The minimum hydration readings recorded for Obsidian Butte material in San Diego County are around 1.1 $\pm$ 2 microns (White et al. 1983:94). The hydration rim measurements represent the last flaking episode, and not the time when the obsidian was quarried (direct access) or exchanged. Allowing for some lag, the date of A.D. 1900 is believed to be the latest possible time with which the minimum hydration rim measurement could be associated. The hydration rim measurement of 1.1 microns was substituted for "x" in each of the hydration rate model equations. Those equations or constants (see Table 10) that produced values for "T" that were less than 84 B.P. (A.D. 1900) were dismissed.

Based on the above restrictions, two of the six proposed hydration rate equations (Linear and Square Root) remain viable alternatives for the best approximations of the Obsidian Butte obsidian hydration rate. However, some comment is needed for the Square Root hydration rate model.

The "T" values (age in years B.P.), derived for the Square Root model equation using the 1.1 micron hydration measurement and the constants provided in Table 10, range from 138 (A.D. 1846) to 229 (A.D. 1755). These dates appear to be too old for the last use of obsidian based on the available data from San Diego County prehistoric sites and the data obtained from CA-SDi-5680. For example, the narrowest hydration rim measurement (1.5 microns) from CA-SDi-5680 (and for the majority of San Diego County sites,) would correlate with A.D. 1752 date when "a" equals 189.05 or the A.D. 1717 date when "a" is 217.89. These dates do not seem realistic based on ethnohistoric information (Hill 1972: App. 1:187) that reported Diegueno Villages in the CA-SDi-5680 vicinity as late as A.D. 1849. It has been proposed that Spanish Missionization, which began in A.D. 1780, may have disrupted obsidian exchange but did not eliminate it

(Chace 1980:9). Therefore, the Square Root hydration rate equation remains a possible but unlikely model for the Obsidian Butte obsidian hydration rate.

Only one constant determined for the Linear hydration rate equation (b = 84.18) remains viable for the Obsidian Butte hydration rate. This constant was derived by correlating the 6.7 micron measurement with the A.D. 1420 date. Using the "b" constant of 84.18, a 9.1 micron reading would correlate to the A.D. 1210 (774 B.P.) Obsidian Butte availability date; a 12.4 micron reading would correlate to the A.D. 940 (1044 B.P.) desiccation period; and a 4.9 micron reading would be associated with the final desiccation of Lake Cahuilla. These proposed micron readings are within the range previously discussed. Constants derived by using the actual hydration measurements in the Linear hydration rate equation correlated to the last three availability periods are as follows:

(1) 9.7 = X, and 774 = T, then b = 79.79

(2) 6.7 = X, and 564 = T, then b = 84.18

(3) 5.8 = X, and 409 = T, then b = 70.5

Averaging the "b" constants, the value of 78.16 is derived. It was determined that this value for "b," calibrated for the Linear model, was the closest

Table 11 presents the data obtained from CA-SDi-5680 incorporated in the "Linear" hydration rate for Obsidian Butte derived by this research. Each value of "x", listed below, correlates with a point on the hydration measurement frequency curve (see Figure 9). The widest hydration rim measurement, 4.6 microns, correlates to the start of the curve. The peak of the curve, at 2.1 microns, is associated with measurement with the greatest number of occurrences. The measurement on the curve where the number of occurrences begin to diminish is 2.0 microns. The smallest hydration measurement, 1.5 microns, represents the end of the curve. Using the "Linear" hydration rate T = 78.16(x), each hydration measurement is given an equivalent age in years before present.

Table 11. The "Linear" Hydration Rate Model Equation Correlated With CA-SDi-5680 Hydration Measurements

Hydration Rate Model Equation	Constant	T (years B.P.) when x equals: 4.6	2.1 (middle of interval)	2.0	1.5
Linear T=bx when b equals:	78.16	360	164	156	117

(All hydration rim measurements have a ±0.2 factor)

Using the uncertainty factor ± 0.2 microns, the range of dates obtained from CA-SDi-5680 obsidian is 375 B.P. to 102 B.P. (A.D. 1609-1882). This range is consistent with the radiocarbon dates.

The Linear hydration rate (b = 78.16) dates the peak of hydration measurement frequency curve from CA-SDi-5680 (X = 2.1) at A.D. 1804-1835 (T = 136) with ending point (X = 1.5) dated at A.D. 1851-1882 (T = 117). This model is plausible for describing use of Obsidian Butte at CA-SDi-5680 during the Late Prehistoric period.

The first adobe was built in Poway Valley in A.D. 1859 (Van Dam, personal communication 1979). Dieguenos (Iipay) inhabited the valley, at least into the land boom of the 1880s. A valley rancheria was reported occupied as late as 1889 (Kear 1965:45). Based on the ethnohistoric information concerning North American settlement and the encroachment of Euro-Americans into the Poway Valley, it seems likely that the upland areas would be inhabited as late as the 1890s. Also, Shipek (1978:610-611) has proposed that the more rugged areas in San Diego County (like the CA-SDi-5680 vicinity) remain relatively undisturbed until A.D. 1870 and some until as recently as A.D. 1910. Therefore, it is proposed that obsidian was used at CA-SDi-5680 until the site was abandoned.

The termination date for occupation of CA-SDi-5680 was given an upper limit of A.D. 1900. At that time a historic homestead was built a little more than a mile upstream on Poway Creek from CA-SDi-5680. A proposition that obsidian present at sites may have been used for only a small portion of the entire occupation span (Christenson and Russell 1981:138) may also explain the obsidian exploitation at CA-SDi-5680. In this case, according to the "Linear" model, use of obsidian would have ceased at the time Euro-Americans were settling in the valley. Glass, which is very similar to obsidian, was used to manufacture tools. A glass projectile point was recovered at Locus A. Glass, in the form of discarded bottles, would be available at Euro-American homesteads in the valley beginning about A.D. 1859. Metal was also available and traded to the Native Americans by Euro-Americans for tool use.

The "Linear" hydration rate, $T = 78.16x$, has been correlated with the data obtained from CA-SDi-5680. Several questions revolving around Chace's (1980) hypotheses concerning the development of Obsidian Butte exchange can now be addressed. The first of these questions is, Does the 2.0 micron measurement correspond to the calendrical date of A.D. 1780 (170 B.P.) as proposed by Chace (1980)?

For the "Linear" hydration rate, 2.0 microns correlate to 156 years B.P. (A.D. 1828). The "Linear" rate model does not justify Chace's hypotheses that Spanish Missionization (A.D. 1780) disrupted obsidian trade. However, the correlation of the drop in frequency of a specific hydration measurement, with the time period when obsidian exchange was disrupted, needs to be justified with further testing.

The 3.8 micron measurement that Chace (1980) proposed and which corresponds to A.D. 1600 has previously been discussed. That correlation was based on the initial availability of the Obsidian Butte source and the widest hydration measurements found in San Diego or Imperial Counties. It was determined that Obsidian Butte outcrops were exposed at A.D. 940, A.D. 1210, and then as islands at approximately A.D. 1420, with inundations occurring between these dates. The most recent exposure and final desiccation of Lake Cahuilla occurred at approximately A.D. 1570-1580.

A final concern regarding the Obsidian Butte hydration rate is the correlation of the 1.4 micron measurement with the calendrical date of A.D. 1860 (124 B.P.) as proposed by Chace (1980). Using the "Linear" hydration rate equation, T = 78.16x, the 1.4 micron measurement corresponds to 109 years B.P. (1875). It is logical that the termination of obsidian exchange would correlate to the period of Euro-American encroachment into Diegueño territory. However, this event happened at various times in different areas. As mentioned previously, the more remote areas of San Diego County remained relatively unaffected by Anglo-American encroachment until A.D. 1870 and until A.D. 1910 in some areas (Shipek 1978:610-611). Therefore, it is possible that obsidian trade continued to some extent until the turn of the century. More individual site comparisons from various locations are needed in order to test Chace's (1980) hypotheses.

Conclusions

The "Linear" hydration rate model proposed by Friedman and Smith (1960) was determined to be the best model for the Obsidian Butte hydration rate. The constant, calibrated by use of the Obsidian Butte specimens' widest and narrowest hydration rim measurements from San Diego County prehistoric sites, was 78.16(b). Use of the "Linear" hydration rate model and the constant 78.16(b) produced relative dates for the hydration rim measurements from CA-SDi-5680 that agree with the absolute radiocarbon dates obtained from the site.

The hypothesis dealing with the availability periods of Obsidian Buttes can be tested by the examination of the frequency distribution of recorded Obsidian Butte hydration measurements. If the hypothesis is correct, the frequency distribution of Obsidian Butte hydration readings should exhibit little or no evidence for the 7.0-7.5 and 6.2-6.5 micron ranges. However, large numbers of obsidian measurements sourced to Obsidian Butte from single sites are needed to construct such a frequency distribution. At this time these data are not available.

Choice of the "Linear" rate model, T = 78.16(x), assumes that: (1) the hydration readings close to 9.7 microns are associated with the Obsidian Butte availability date of A.D. 1210; (2) those hydration readings around 7.0 microns correlate to the A.D. 1420 date when Obsidian Butte existed as an island (possibly connected to the mainland); and (3) hydration readings around 5.2 are associated with the latest availability date of Obsidian Butte. Additional research is needed in order to test the reliability of the "Linear" rate model, T = 78.16(x) against archaeological data from a large sample of sites.

CHAPTER VI

IMPLICATIONS OF THE OBSIDIAN BUTTE OBSIDIAN HYDRATION RATE REGARDING LATE PREHISTORIC EXCHANGE

Introduction

The ethnographic literature does not contain any information concerning the trade/exchange of obsidian. However, obsidian is one of the most common exotic materials mentioned as an exchanged resource in archaeological sites in the Far Southwest. Ericson (1977:199-202) and Shackley (1981) have used Obsidian Butte as the central source for their Late Prehistoric exchange system models. This paper does not review these models but does test their applicability in light of the data generated by this project.

This chapter emphasizes the relationship between Obsidian Butte obsidian hydration rate and local obsidian exchange. The first topic discussed is the time framework of Obsidian Butte obsidian availability and exchange. The second goal of this chapter is to describe the Obsidian Butte exchange system diachronically by examining the spatial distribution of hydration measurements. Such an approach is usually ignored by existing exchange system models.

Exchange Items of CA-SDi-5680

The presence of exotic material at the CA-SDi-5680 site complex indicates that these items were either exchanged or directly acquired. Shackley (1981) states there are four possible ways the Diegueno exchanged goods and ideas, and procured exotic resources:

1. Seasonal Transhumance
   A. pooling resources in the Peninsular Ranges)
2. Direct Access
3. Premeditated Exchange Journeys
4. Incidental Traders (Kwitxal movement)
   (Shackley 1981:26)

Each of the above assume that a well-established trade or travel corridor (trail) facilitated these ways of exchange or direct access. A network of these corridors/ trails has been documented ethnographically (Davis 1961; Shackley 1981). The majority were used by Euro-Americans initially for exploration, then trade and travel, and eventually (and still) for commerce.

The diary of Fra. Juan Mariner states that he and his party went up Sycamore Canyon (situated southwest, with its headwaters located one mile south of CA-SDi-5680) to Santa Ysabel (situated ca. 20 miles northeast of CA-SDi-5680) in September 1849 (Hill 1927: App. 1:187). Another north/south trail, which is situated in Wildcat Canyon (two miles east), was documented by Tom Lucas (Diegueno) to have existed during the historic period.

However, no ethnographic accounts state or show that CA-SDi-5680 was situated on a trade or travel corridor.

Mission records have been used to document the association of habitation sites along travel/trade corridors and lineage affiliation. Autonomous, exogamous, patrilineal lineages were basic to the social organization of the Diegueno. Marriages were arranged on the basis of economic as well as kinship considerations. They served to establish a strong reciprocal relationship between families and wider kinship groups. Therefore, if two habitation sites are separated by a considerable distance, but situated on the same drainage and occupied by the same lineage, it can be proposed that the natural corridor was used for trade/travel. Such documentation exists for the village of Paguay in Penasquitos Canyon (to which Poway Creek is a tributary), and a site at the coast where Penasquitos Canyon ends (Richard Carrico, personal communication 1983).

Models proposed for the Obsidian Butte exchange network are based on the assumption that the relative frequency of obsidian in a lithic assemblage of a site will decrease as the distance from the source increases (Ericson 1977; Shackley 1981). In these models, distance is not measured directly between two points, but along plausible trade/travel corridor networks (Shackley 1981:100-115).

CA-SDi-5680 was compared with three other sites located on travel/trade corridors and analyzed by Shackley (1981:101). These sites (CA-SDi-161, 2537 and BW-9) are Kumeyaay (Southern Diegueno) sites and are located in Carrizo Gorge on ancient alluvial terraces, dominated by a mesquite plant community. Obviously, these sites differ from CA-SDi-5680 in their cultural and natural contexts. However, ideal comparisons were not possible because the data did not exist. Table 12 presents the data.

Table 12. Exotic Resources Comparison of CA-SDi-5680 With Other Sites on Trade/Travel Corridors

	CA-SDi-5680	CA-SDi-161	CA-SDi-2537	BW-9
Colorado Buffware %	0	19	7	14
Tizon Brown Ware %	100	81	93	86
Cryptocrystalline Silicates (% of Total Debitage)	1.4	10.0	10.0	20.0
Obsidian (% of Total Debitage)	2.7	2.24	2.0	5.0

Based on this small sample, there is a probability that CA-SDi-5680 is located along a travel corridor. The high relative frequency of cryptocrystalline silicates

(10 to 20%) at the sites in Carrizo Gorge, compared to that at CA-SDi-5680, may be explained by the fact that most of the cryptocrystalline silicate sources are closer to the Carrizo Gorge sites. It is postulated that cryptocrystalline silicate material was not as important as obsidian for tool manufacturing purposes. Cryptocrystalline silicate material can be worked a little easier than the local metavolcanic material available at CA-SDi-5680, but obsidian far surpasses both types of the lithic material for ease of flintknapping.

The higher frequency of Colorado Buff Ware at the Carrizo Gorge sites and lack of it at CA-SDi-5680 may be explained by the type of clay used for the manufacture of ceramics. Colorado Buff Ware is made of sedimentary clays which are found in former lake bottoms and alluvial deposits of the Colorado Desert in Imperial County into which the Carrizo Gorge empties. Residual clays, from which Tizon Brown Ware is made, are found mainly in the mountain and coastal areas of San Diego County. It is more probable that those traveling and living along the Xakinimis Trail (Carrizo Gorge), located in the escarpment between the mountains and the desert, would more likely be manufacturing and using Colorado Buff Ware. It is unlikely that the ceramics would be exchanged. Therefore, one would not expect to see a high frequency of

Colorado Buff Ware at mountain or foothill sites located some distance from the desert.

To test the Ericson (1977) and Shackley (1981) network models of obsidian exchange, the relative frequencies of obsidian in the total lithic assemblage and of Buff and Brown Wares at CA-SDi-5680 were compared with other sites examined by Shackley (1981:101,107) in San Diego County. The results are presented in Table 13.

Table 13. Relative Obsidian and Ceramic Frequencies and Distance to Obsidian Butte for Sites in San Diego County

Site No.	Obsidian	Buff Ware	Brown Ware	Distance From Source
*SDi-5017	.02	0	1.0	152 km
*SDi-5680	.03	0	1.0	137 km
*SDi-4606 (Village of Paguay)	.09	0	1.0	135 km
*SDi-5669	.03	-	-	130 km
SDi-8762	.008	-	-	125 km
W-417	.003	-	-	123 km
*SDi-7116	-	0	1.0	121 km
SDi-8762	.008	-	-	120 km
W-2237	0	-	-	114 km
SDi-860	-	.02	.98	
SDi-161	.02	.19	.81	73 km
SDi-2537	.02	.07	.93	70 km
BW-9	.05	.14	.86	66 km

* Northern Diegueno (Ipaay) sites based on San Diego River territorial boundary

Examination of the above data does support Renfrew's (1977) "monotonic decrement model" (frequency decreases as distance from source increases) for Colorado Buff Ware sherds. However, the relative frequencies of obsidian do not support the monotonic decrement model.

A difference between Northern and Southern Diegueno sites exists. This difference is based upon the relative frequencies of both obsidian and ceramics. Buff Ware is not recorded for any Northern Diegueno site. There is a drop in obsidian frequency as distance from Obsidian Butte increases for Southern Diegueno sites. However, Northern Diegueno sites do not produce similar data. In fact, the village of Paguay situated in the valley near CA-SDi-5680 had the greatest relative frequency of all the sites. Conclusions cannot be based on such a small sample of sites. However, it is suspected that village areas (i.e. SDi-4606) would have greater relative frequencies of exchange items due to ceremonial gatherings of a number of inter-tribal groups at those locales. Such gatherings and consequent exchange of goods have been documented for the Diegueno in regard to their economic importance for redistribution (Graham 1981:106-110).

The differences observed in Table 13 may be due to the type of trade/travel corridor where a particular site was located. The extensive aboriginal trail system ranged from simple paths linking neighboring villages to major inter-tribal trails (Cline 1979:17-19; Heizer 1978:692). It would be expected that sites along inter-tribal trail/travel corridors would have the greatest frequencies of exotic goods. Additional studies are needed to test these postulations.

Time Framework of Obsidian Butte Obsidian Exchange

Based on the data presented herein, it is suggested that aboriginal exploitation of Obsidian Butte obsidian began at approximately A.D. 1210. Using the "Linear" hydration rate equation, T = 78.16(x), the 9.7 and 8.9 micron readings from CA-SDi-813 (Dallas 1984: Table 2) have been correlated with the A.D. 1210 (774 B.P.) period. The possibility exists that Obsidian Butte obsidian was exploited earlier than A.D. 1210; however, no hydration rim measurements (sourced to Obsidian Butte) have been recorded that are greater than 9.7 microns. If hydration rim measurements in excess of 9.7 are once documented, those near 13.4 microns would correlate to the A.D. 940 (1044 B.P.) availability period, and those larger than 16.4 microns would correlate to the period of availability prior to A.D. 700 (1284 B.P.).

Diachronic Implications of Late Prehistoric Exchange

The initial desiccation of Lake Cahuilla in the Late Prehistoric period at A.D. 940 (1044 B.P.) does agree with Luomala's proposed date for Yuman migration. Increased aridity in the desert areas contributed to the evaporation of Lake Cahuilla. Due to the desiccation of this large body of water and overall increased aridity, a few Yuman groups may have migrated west over the mountains to eventually form the nucleus of later Dieguenо groups. It has been proposed that this occurred at approximately 950 B.P. (Luomala 1978:594).

Migrations to the Peninsular Ranges of these Yuman lacustrine adapted groups probably increased through time. This may be especially true during the desiccation periods of Lake Cahuilla. Archaeological evidence suggests that the Dieguenо were well established in their ethnographically recognized territory by A.D. 1500. It has also been suggested that they might have occupied some portions as early as A.D. 700-800 (Berryman 1981; True 1970). For those groups remaining at Lake Cahuilla, the lacustrine habitat may have been only part of a transhumant pattern that was carried on after the final desiccation of the lake. Agriculture was subsequently added to the subsistence pattern of lake shore groups (M. Weide 1976).

It is impossible to discern if the Dieguено living in the Peninsular Ranges and west (in the Far Southwest) actually practiced transhumance or even periodically traveled to the Salton Trough area. According to Shackley (1981:13), the possibility exists that both groups may have been seasonally exploiting areas on both sides of the Peninsular ranges as early as 700-800 A.D. These early dates suggest that the desiccation of Lake Cahuilla may not have been entirely responsible for the late prehistoric occupation of the Peninsular Range Province. Further research is needed to test these hypotheses regarding the effect of the desiccation of Lake Cahuilla.

The available ethnographic and archaeological data suggest that physical, linguistic and cultural relationships existed between the groups in Imperial Valley (Salton Trough) and the Peninsular Range Province at least as early as 1500 A.D. and possibly 700 years earlier (Shackley 1981:15). It is suggested that the relationships between these two groups continued up to, and after, Euro-American contact (Shackley 1981:15-25).

The date of A.D. 1210 was correlated with the start of Obsidian Butte obsidian exchange based on the very limited amount of data for the widest hydration rim measurements (8.9 and 9.7 microns). These obsidian hydration rim measurements were from specimens recovered from CA-SDi-813 (between 110 and 150 cm. below surface). CA-SDi-813 is located approximately 45 kilometers (28 miles) northwest of Obsidian Butte. In those sites located in and west of the Peninsular Ranges, the majority of Obsidian Butte obsidian hydration rim measurements are 5.0 microns or less (Dominici n.d.; Rosen 1984:110; White et al. 1983:94). Therefore, it is proposed that Obsidian Butte obsidian exchange may have operated locally A.D. 1210-1590 and then expanded at A.D. 1593 to regions west of the Peninsular Ranges. The A.D. 1593 date was derived from the "Linear" hydration rate model T = 78.16(x), when "x" is equal to 5.0 microns.

At this point it should be mentioned that unsourced hydration measurements in excess of 5.0 microns have been recorded from San Diego County (Chace 1980:10; Olmo 1981:173; Christenson 1981; Graham 1981:120). However, it has been assumed that these specimens are from the original flow surfaces of Obsidian Butte or from other obsidian sources (i.e. Coso) and, as such, have been disregarded from discussions by Far Southwestern archaeologists when presenting their hydration analyses. The justification given for these practices is that Coso obsidian exchange began much earlier than Obsidian Butte exchange. Also Coso obsidian hydrates more quickly than Obsidian Butte material (Ericson 1977). Hydration rim measurements from original flow surfaces of Obsidian Butte do not imply prehistoric exploitation. Of particular interest to the hypothesized start of Obsidian Butte obsidian exchange, are those unsourced hydration rim measurements in excess of 9.7 microns (Norwood 1981:31). Based upon available data, it seems likely that Obsidian Butte obsidian exploitation started prior to A.D. 700.

The major implications of the Obsidian Butte hydration rate proposed in this thesis is that it dates Obsidian Butte obsidian exchange almost 400 years earlier (A.D. 1210) than was previously documented (A.D. 1580). Furthermore, it disputes the idea that Spanish Missionization disrupted obsidian exchange. In addition, there are indications obsidian exchange continued after Euro-American encroachment of the Far Southwest. Finally, these data date the termination of obsidian exchange at about A.D. 1900. These implications could also be applied to Late Prehistoric trade in general. Available ethnographic and archaeological data would support these findings.

CHAPTER VII

DISCUSSION AND SUMMARY

Obsidian Butte Obsidian Hydration Rate

This research has shown that the "Linear" hydration rate model was the best approximation of Obsidian Butte obsidian hydration rate. This rate was determined by correlating the widest Obsidian Butte obsidian hydration rim measurements (8.9 and 9.7 microns) in the Far Southwest with the availability of Obsidian Butte obsidian dates (based on desiccation periods of Lake Cahuilla) (Waters 1983:383) and the narrowest hydration rim measurements (1.1 microns) in the Far Southwest with the termination date of Obsidian Butte obsidian exchange (Chace 1980:9-10; Christenson and Russell 1981:137). The "Linear" hydration rate model equation, $T = b(x)$, was calibrated by the data obtained from CA-SDi-5680 which derived an approximate constant for "b" of 78.16.

Choice of the "Linear" rate model, $T = 78.16(x)$, assumes that the hydration readings close to 9.7 microns are associated with the Obsidian Butte availability date of A.D. 1210. The assumption is also made that those hydration readings around 7.0 microns correlate to the A.D. 1420 date when Obsidian Butte existed as an island (possibly connected to the mainland). The final assumption is that those hydration readings around 5.2 are associated with the latest availability date of Obsidian Butte. The hypothesis dealing with availability periods of Obsidian Buttes can be tested by examining the frequency distribution of Obsidian Butte hydration measurements. If the hypothesis is correct, the frequency distribution of Obsidian Butte hydration readings should have little or no instances of the 7.0-7.5 and 6.2-6.5 micron ranges. However, large samples of obsidian measurements sourced to Obsidian Butte from single sites are needed to construct such a frequency distribution, and such is not the case.

Additional research is also needed to determine what the range of hydration measurements from each site represents before the hydration dating method is viable for the Far Southwest. The hydration data may represent the time framework of Obsidian Butte obsidian exchange for the site vicinity. However, the range of measurements from a single site may represent a discrete unit of time of obsidian utilization within the total occupation period of a site. It is also possible that the hydration rim measurement range may indicate the entire occupation period for an individual site. Again, the only way one can clearly understand what the hydration measurements represent is to compare numerous adequate samples of sourced and hydrated obsidian obtained from single sites.

Implications Regarding Late Prehistoric Exchange

The available ethnographic and archaeological data suggest physical, linguistic and cultural relationships existed between the groups in Imperial Valley (Salton Trough) and the Peninsular Range Province. These may have begun as early as 1500 A.D. and possibly started even 700 years earlier (Shackley 1981:15). It was previously suggested that the relationships of these two groups continued until and even after Euro-American contact (Shackley 1981:15-25).

The date of A.D. 1210 was correlated with the start of Obsidian Butte obsidian exchange based on the very limited amount of data presented in this thesis for the widest hydration rim measurements sourced to Obsidian Butte (8.9 and 9.7 microns). However, the possibility that Obsidian Butte obsidian was exploited prior to A.D. 1210 exists on a combination of factors. Such factors are recorded unsourced hydration rim measurements from the Far Southwest in excess of 9.7 microns (Chace 1980:10). Also, an earlier exploitation date is possible due to five availability periods of Obsidian Butte obsidian in the last 2000 years (Waters 1983:383; Weide 1976:13). Finally, ethnographic and archaeological data suggest exchange networks prior to 1210 (Shackley 1981:15-25).

The primary implications of the proposed Obsidian Butte obsidian hydration rate linear equation, T = 78.16(x), concerns the temporal framework of the exchange system of obsidian. The major implications of the Obsidian Butte obsidian hydration rate and the available hydration data are as follows:

1. Dates Obsidian Butte obsidian exchange almost 400 years earlier (A.D. 1210) than was previously documented (A.D. 1580);
2. Disputes the idea that Spanish Missionization disrupted obsidian exchange;
3. Indicates obsidian exchange continued after Euro-American encroachment of the Far Southwest; and
4. Dates the termination of obsidian exchange around A. D. 1900.

The time framework of Obsidian Butte obsidian most likely correlates with Late Prehistoric exchange of other goods.

Suggested Research Programs

It is hoped that this thesis will serve to be to be an impetus for further testing of the obsidian hydration dating method and theory in the Far Southwest. The thesis also proposes hypotheses that can be rigorously tested.

The program proposed is not exhaustive of questions pertinent to obsidian hydration dating and exchange research. Each explanation carries its own set of problems and further questions. It is hoped that archaeological test programs will be designed so that the results will include at least the level and types of data needed to build a regional synthesis concerning obsidian hydration dating and exchange.

To directly test the proposed obsidian hydration rate for Obsidian Butte material as presented in this thesis, large samples (100 = N) of sourced and hydrated obsidian must be processed from a single site. These obsidian specimens should be associated with at least 10 radiocarbon dates. In addition, the effective hydration temperature should be determined for the site. As the number of site samples containing these data increases, the following questions can be posed:

1. What are the percentages of non-Obsidian Butte obsidian and from which source were they obtained?

2. What is the frequency distribution of Obsidian Butte obsidian hydration rim measurements?

3. Do the Obsidian Butte obsidian hydration rim measurements associated with a radiocarbon date substantiate the proposed T = 78.16(x) formula?

4. Do the effective hydration temperatures substantially affect the Obsidian Butte obsidian hydration rate?

5. Are there Obsidian Butte obsidian hydration measurements that correlate with the Obsidian Butte accessibility dates?

6. A corollary question of Number 5 is, does the frequency distribution of Obsidian Butte hydration rim measurements show interruptions of obsidian exchange which would correlate to the lacustral intervals of Lake Cahuilla?

7. Does the spatial distribution of the Obsidian Butte obsidian measurements show equal distribution throughout the Far Southwest through time?

8. Do the relative percentages of obsidian and Colorado Buff Ware show a differential ranking of trade/travel corridors (i.e. those used inter-village as compared to inter-tribal)?

9. Do the relative percentages of obsidian indicate site type?

10. Do the minimum hydration rim measurements of Obsidian Butte material correlate with the date of A.D. 1900?

Once the answers to these questions are determined, then Late Prehistoric exchange can be examined in a manner proposed by Shackley (1981:123-127). Such a diachronic approach is necessary when testing propositions dealing with egalitarian economic theory.

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APPENDICES

APPENDIX A

Results From Ancillary Studies

ENVIRONMENTAL analysis

Debra A. Dominici
State of California
Department of Transportation
District 11
2829 Juan Street
P.O. Box 85406
San Diego, CA 92138-5406

November 8, 1983

Regents of the University of California - gy24
Dr. C. Rainer Berger
Geophysics Laboratory
University of California, Los Angeles
405 Hilgard Ave.
Los Angeles, CA 90024

Dear Dr. Berger,

I am sending 67 obsidian specimens (49 for sourcing and hydration 18 for sourcing only) and 10 charcoal samples. Additionally, 5 charcoal samples plus associated obsidian are being sent in the event that the charcoal samples choosen can not be processed. All work will be performed under the commercial service contract #T-11, 150. As mentioned over the phone, please invoice prior to December 31, 1983 which is the expiration date. If you have any questions, please call me (ATSS 631-6992 or 619-237-6992).

Debra A. Dominici
District Archaeologist

DAD/ea
Attachment
cc:Env. File
Arch. File

UNIVERSITY OF CALIFORNIA, LOS ANGELES

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Institute of Geophysics and Planetary Physics
Los Angeles, California 90024

March 29, 1984

Ms.Debra A. Dominici
District Archaeologist
Cal Trans
San Diego,CA 92138

CONTRACT No. T-11,150

Dear Ms. Dominici:

Here are the radiocarbon dating results for SDi-5680, the Nelson Site.

UCLA No.	Unit No.	Depth	Age
2545A	8	10-20cm	less than 300 years
B	8	40-50cm	"
C	8	50-60cm	400 ± 160 years
D	9	10-20cm	less than 300 years
E	9	30-40cm	"
F	9	70-80cm	"
G	16	70-80cm	sample too small to run
H	11	30-40cm	less than 300 years
I	11	50-60cm	"
J	11	110-120cm	"

If there are any questions please do not hesitate to call me at 213-825-1469.

Sincerely yours,

C.R. Berger

C.R.Berger
Professor

UNIVERSITY OF CALIFORNIA, LOS ANGELES

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO — SANTA BARBARA • SANTA CRUZ

Institute of Geophysics and Planetary Physics
Los Angeles, California

1/30/84

Debra A. Dominici
District Archaeologist
State of California
Department of Transportation
San Diego, CA. 92138

Dear Ms. Dominici:

Enclosed are the results for 49 SDi-5680 obsidian specimens you submitted for hydration analysis. A description of the analytical procedure and report format is also enclosed.

Hydration bands were acquired on 47 of the 49 specimens. Quality was generally fair to poor with most thin sections exhibiting moderate band thickness variation along a single hydration surface. Specimens for which this effect was severe have been designated by the term "varies" in the remarks column of the hydration data table. Five specimens were destroyed during thin section preparation. These are designated by the latter "D" in the data table. At least 14 of the thin sections also exhibited hydration bands inside of cracks. Where measurable these hydration bands have been reported in the data table. Such readings are normally slightly larger than surface readings on the same thin section.

While I do not yet have a copy of Hughes' source report he has informed me that most of this assemblage derives from the Obsidian Butte (Salton Sea) source. Microscopic examination of the thin sections indicates that specimens 0431-001, 0439-000, and 0462-001 appear to differ in composition from the remainder of the assemblage.

The hydration readings themselves are characteristic of a late assemblage. Values ranged from 1.3 to 6.4 microns with all but four of the readings occurring between 1.[illegible] and 3.6 microns. Most readings cluster even more tightly in the 1.8 to 2.3 micron range.

Superficial examination of the data table does not indicate much in the way of increased hydration with increased depth in site, although specimens 0431 through 0434 might suggest evidence for some kind of trend. Measurement error precludes pushing these data too far. Specimens with hydration readings in the 3.6 to 6.4 micron range could indicate the presence of an earlier component providing that they hydrate at the same rate as the bulk of the assemblage.

I would be glad to answer any questions you may have regarding this analysis.

Sincerely;

Thomas S. Kaufman

Thomas S. Kaufman Ph.D.

REPORT OF OBSIDIAN HYDRATION ANALYSIS

(all readings ±0.2 microns)

CA-SDi-5680

Specimen#	OTS Lab#	Hydration (microns)	Remarks
all 1982-10-			
(Unit 8)			
0431-001	3045	1.8	slide 2, fair, dark obsid.
0432-001	3046	1.9	fair, varies
0433-000	3047	2.1	fair, varies
0434-001	3048	2.2	good
0434-002	3049	2.1 surface/2.5 crack	both vary greatly
0435-000	3050	NHV	D
0436-000	3051	1.8	slide 2, very poor, D
0437-000	3052	2.0	varies
0438-000	3053	1.8	poor, varies
0439-000	3054	4.9	varies greatly, different obsidian
(Unit 9)			
0440-000	3055	1.8	poor
0441-001	3056	2.2	good
0441-002	3057	1.5	fair
0442-001	3058	2.2 surface/2.1 crack	slide 2, both good
0443-001	3059	2.1	fair, varies

Specimen#	OTS Lab #.	Hydration (Microns)	Remarks
0443-002	3060	2.1	fair, has crack
0444-000	3061	2.1	fair, varies
0445-002	3062	2.1 surface/2.1 crack	slide 2, surface good, crack poor
0446-000	3063	1.3	fair
0447-002	3064	2.0	good, varies
0448-001	3065	1.9	poor, varies
0449-000	3066	6.4 surface/3.6 crack	surface good, crack fair both vary, D
(Unit 11)			
0457-001	3067	1.9	poor
0458-001	3068	4.0	good, varies
0459-001	3069	2.2	varies, has small crack
0460-001	3070	2.3	varies, has small crack
0460-002	3071.	2.2	slide 2, fair, varies, D
0460-003	3072	NHV	possible small band, D
0460-004	3073	1.7	poor, has small crack
0460-005	3074	1.8	good, varies
0461-001	3075	2.2 surface/ 3.1 crack	both good
0462-001	3076	2.0	poor, varies, dark obsid
0462-002	3077	1.9	good, varies
0463-001	3078	2.2	good
0464-000	3079	2.2 surface/ 2.5 crack	both good
0465-001	3080	1.9	fair
0465-002	3081	2.1	varies
0466-000	3082	2.4 surface/ 3.0 crack	surface good, crack poor

Specimen#	OTS Lab#	Hydration (microns)	Remarks
(Unit 16)			
0496-001	3083	1.7	fair
0497-001	3084	3.6	excellent
0498-001	3085	2.1	good
0499-001	3086	1.9 surface/2.2 crack	both fair
0500-001	3087	1.6	varies
0501-001	3088	2.9	good, varies
0502-001	3089	1.9	varies
0502-002	3090	2.1 surface/2.4 crack	both vary
0503-000	3091	2.1 surface/2.5 crack	both vary
0504-000	3092	2.8 surface/3.1 crack	both vary
(Unit 1)			
0511-000/ 339	3093	4.6 surface/4.9 crack	both vary, both good, many cracks

D= Specimen destroyed

Later research conducted by Kaufman (1980) indicates that variation well in excess of ±0.2 microns can often occur on a single hydration surface. The extent of this variability can depend upon the obsidian source and depositional environment. Hydration bands which vary excessively along a single hydration surface are designated by the term "varies" in the remarks column of the hydration data table. In such cases the reported hydration value is that which is most representative of the hydration surface.

In addition, many obsidian thin sections exhibit more than one good quality hydration band. Based upon data by Kaufman (1980:65) if these readings are ≤0.55 microns apart they are considered to be the same hydration value. In cases where more than one significant hydration value is obtained the readings are reported as a multiple hydration band in the format x.x/x.x with the ventral surface appearing to the readers left in the hydration data tables. Hydration readings appearing in cracks or on cortical surfaces are labeled as "crack" or "cortex" in the data tables.

Dr. Thomas S. Kaufman
10596 Wilkins Avenue
Los Angeles, CA 90024

January 28, 1984

Dear Tom:

Enclosed please find xerox copies of data sheets detailing the results of x-ray fluorescence analysis of 66 obsidian artifacts from the Nelson Site (CA-SDi-5680), San Diego County, California. This analysis was completed pursuant to your letter of authorization of November 21, 1983 under Sonoma State University Academic Foundation, Inc., Account 6081-A1, Job 115-83.

The analysis was completed at the Department of Geology and Geophysics, University of California, Berkeley, on a Spectrace 440 (United Scientific Corporation) energy dispersive x-ray fluorescence machine equipped with a 572 power supply (50 kV, 1 mA), 534-1 pulsed tube control, 514 pulse processor, 588 bias/protection module, Tracor Northern 1221 100 mHz ADC, Tracor Northern 2000 computer based analyzer, an Rh x-ray tube and a Si(Li) solid state detector with 142 eV resolution (FWHM) at 5.9 keV in a 30 mm2 area. The x-ray tube was operated at 30.0 kV, .40 mA pulsed, with a .04 mm Rh primary beam filter in an air path at 200 seconds livetime. All trace element values on the accompanying data sheets are expressed in parts per million by weight; consequently, they can be compared directly to published values for obsidian sources that appear in Robert N. Jack (1976), "Prehistoric Obsidian in California I: Geochemical Aspects", pp. 202-204 in R.E. Taylor (ed.) Advances in Obsidian Glass Studies: Archaeological and Geochemical Perspectives, Noyes Press. Park Ridge, New Jersey, and P.T. Robinson, W.A. Elders and L.J.P. Muffler (1976), "Quaternary Volcanism in the Salton Sea Geothermal Field, Imperial County, California", Geological Society of America Bulletin 87. pp. 347-360.

Of 66 specimens analyzed, all but seven were fashioned from obsidian of the Obsidian Butte (Salton Sea) geochemical type. Of these seven, four (Cat. nos. 449-0, 525-0, 505-1 and 510-1) were manufactured from Coso Hot Springs source material, while the remaining three (446-0, 516-1 and 439-0) could not be matched with any of the source standards presently in my obsidian source inventory. Trace element concentration values suggest that these latter three specimens represent two different source groups; 516-1 and 439-0 in one "unknown" group, and 446-0 in the other.

As you know, some of these specimens were extremely small. Consequently, the counting error estimates on the smaller objects are greater than those associated with measurement of specimens ca. a centimeter or so in diameter. In order to reduce the threshold of counting error uncertainty for extremely small objects to a level comparable to larger specimens (ca. 2.5 - 4.5 ppm) it would be necessary to double, or perhaps triple, the counting time (livetime) per analysis. I realize that tiny obsidian flakes are sometimes all that occur in many southern California sites, and that it is therefore often difficult to select specimens of "ideal" physical size for analysis. Regardless, "tiny" specimens yield comparatively large counting error estimates, and this is something to keep in mind if you anticipate submitting correspondingly small samples for analysis in the future.

I hope this information will assist you in your analysis of the Nelson Site material. If I can be of further assistance, please contact me.

Sincerely,

Richard Hughes

Richard E. Hughes, Ph.D.
Senior Research Archaeologist
Sonoma State University
Rohnert Park, CA 949_3

(P/C CONC (PPM))
(PPM ST DEV)

	CHSQ	PB	TH	RB	SR	Y	ZR	NB
W-1 F	9.0	12.0 +- 1.8	0.0 +- 0.0	21.5 +- 2.0	190.4 +- 3.7	23.8 +- 2.6	114.1 +- 3.1	15.6 +- 2.2
431-1	6.9	22.9 +- 4.6	25.9 +- 9.2	114.9 +- 6.3	9.4 +- 4.6	93.3 +- 6.9	217.8 +- 7.4	28.9 +- 4.7
432-1	5.7	23.7 +- 3.1	27.6 +- 6.6	134.6 +- 4.8	22.3 +- 3.4	110.8 +- 5.3	306.3 +- 6.1	29.3 +- 3.5
433-0	5.3	30.7 +- 5.0	33.9 +- 9.7	118.6 +- 6.5	15.4 +- 4.9	91.8 +- 7.2	233.3 +- 7.8	24.6 +- 4.9
434-1	6.9	21.2 +- 2.2	33.4 +- 4.8	144.1 +- 3.7	18.9 +- 2.5	120.8 +- 4.1	297.7 +- 4.6	30.9 +- 2.7
434-2	2.8	30.6 +- 4.3	0.0 +- 0.0	120.1 +- 6.0	18.0 +- 4.4	100.5 +- 6.5	269.6 +- 7.4	22.0 +- 4.4
435-0	2.1	50.0 +- 8.0	27.6 +- 13.6	100.3 +- 8.4	23.8 +- 6.6	84.1 +- 9.4	209.9 +- 9.7	25.0 +- 6.4
436-0	1.3	28.3 +- 7.4	0.0 +- 0.0	126.3 +- 8.4	23.7 +- 6.4	106.2 +- 9.2	246.7 +- 9.7	17.9 +- 6.3
437-0	3.6	42.8 +- 6.5	42.3 +- 11.6	98.3 +- 7.6	9.1 +- 5.6	86.0 +- 8.3	226.6 +- 8.9	22.1 +- 5.7
438-0	10.5	23.6 +- 3.3	17.3 +- 7.0	116.6 +- 4.9	23.3 +- 3.7	104.2 +- 5.4	284.4 +- 6.3	23.8 +- 3.6
510-2	9.3	20.7 +- 1.6	23.7 +- 3.7	140.1 +- 2.9	25.8 +- 2.0	117.1 +- 3.1	334.4 +- 3.8	27.0 +- 2.1
510-1	4.4	46.1 +- 3.4	43.2 +- 6.5	296.5 +- 5.8	7.5 +- 2.8	57.6 +- 4.4	144.9 +- 4.3	39.4 +- 3.3
509-1	5.3	21.9 +- 2.6	21.9 +- 5.6	131.4 +- 4.2	24.5 +- 3.0	109.4 +- 4.6	311.0 +- 5.3	24.6 +- 3.0
509-2	5.5	22.3 +- 2.9	25.2 +- 5.9	135.0 +- 4.4	42.2 +- 3.4	102.5 +- 4.8	343.2 +- 5.9	27.2 +- 3.2
508-1	5.8	19.3 +- 2.4	27.2 +- 5.2	132.5 +- 3.8	38.2 +- 3.0	104.5 +- 4.2	362.4 +- 5.2	26.0 +- 2.8
511-0	5.2	27.6 +- 4.9	45.7 +- 9.2	98.4 +- 6.1	14.9 +- 4.6	79.9 +- 6.8	229.1 +- 7.4	26.5 +- 4.7
439-0	12.9	26.5 +- 1.6	18.5 +- 3.1	141.4 +- 2.5	48.6 +- 2.0	37.2 +- 2.2	131.5 +- 2.4	16.1 +- 1.7

(P/C CONC (PPM))
(PPM ST DEV)

	CHSQ	PB	TH	RB	SR	Y	ZR	NB
502-2	2.0	50.1 +- 6.7	18.1 +- 12.9	110.2 +- 8.5	11.3 +- 6.5	96.1 +- 9.5	266.2 +- 10.6	29.2 +- 6.5
503-0	8.3	20.6 +- 3.0	24.3 +- 6.9	120.6 +- 4.9	16.8 +- 3.5	104.9 +- 5.5	230.6 +- 5.9	26.9 +- 3.7
504-0	8.6	21.0 +- 2.6	24.0 +- 5.7	141.6 +- 4.3	35.0 +- 3.1	109.1 +- 4.6	319.2 +- 5.4	32.0 +- 3.1
457-1	19.0	19.3 +- 1.6	24.4 +- 3.6	125.4 +- 2.6	19.2 +- 1.9	114.6 +- 3.1	280.3 +- 3.5	31.1 +- 2.0
458-1	6.4	22.1 +- 2.0	30.6 +- 4.6	136.0 +- 3.5	19.7 +- 2.3	112.7 +- 3.8	295.4 +- 4.4	29.1 +- 2.5
459-1	8.4	25.6 +- 2.8	33.5 +- 6.1	131.6 +- 4.5	17.4 +- 3.1	116.3 +- 4.9	260.9 +- 5.4	26.6 +- 3.3
460-1	3.8	24.7 +- 3.3	27.6 +- 6.9	123.1 +- 5.0	18.3 +- 3.6	101.4 +- 5.5	275.3 +- 6.1	21.[illegible] +- 3.[illegible]
460-4	4.9	29.4 +- 4.3	38.5 +- 9.0	132.9 +- 6.2	16.9 +- 4.6	115.9 +- 6.8	301.[illegible] +- 7.7	26.6 +- 4.5
460-2	3.7	30.8 +- 5.0	33.5 +- 9.2	103.5 +- 6.2	14.9 +- 4.6	80.6 +- 6.9	237.9 +- 7.7	23.0 +- 4.8
460-3	2.0	35.1 +- 6.4	42.2 +- 12.4	142.6 +- 8.1	21.9 +- 6.2	98.5 +- 8.8	279.0 +- 9.6	22.9 +- 5.9
460-5	2.9	34.8 +- 5.6	28.5 +- 10.9	126.7 +- 7.2	21.6 +- 5.4	103.1 +- 7.8	242.6 +- 8.3	24.1 +- 5.3
461-1	5.5	31.6 +- 4.9	38.4 +- 9.2	107.8 +- 6.2	13.8 +- 4.6	81.1 +- 7.0	233.4 +- 7.6	29.0 +- 4.7

(P/C CONC (PPM))
(PPM ST DEV)

	CHSQ	PB	TH	RB	SR	Y	ZR	NB
U-1 A	7.5	12.2 +- 2.1	0.0 +- 0.0	18.8 +- 2.2	178.9 +- 4.0	26.1 +- 2.9	109.4 +- 3.4	12.4 +- 2.4
440-0	7.2	21.7 +- 3.6	34.2 +- 6.7	115.2 +- 4.8	13.1 +- 3.5	100.5 +- 5.4	243.5 +- 6.0	34.9 +- 3.6
441-2	5.3	22.9 +- 2.8	29.4 +- 6.3	134.4 +- 4.8	20.9 +- 3.4	119.3 +- 5.2	297.2 +- 6.0	25.0 +- 3.5
441-1	6.2	22.0 +- 2.9	30.6 +- 6.3	127.0 +- 4.7	10.3 +- 3.2	114.1 +- 5.1	286.3 +- 5.9	25.1 +- 3.4
442-1	5.0	26.3 +- 4.4	37.8 +- 9.8	109.4 +- 6.7	12.9 +- 4.9	94.5 +- 7.4	239.1 +- 8.0	32.0 +- 5.0
443-1	5.1	25.5 +- 3.7	26.0 +- 8.0	134.3 +- 5.8	16.7 +- 4.1	106.4 +- 6.3	268.2 +- 7.0	29.4 +- 4.2
443-2	2.2	36.7 +- 5.3	15.9 +- 10.8	106.1 +- 7.4	18.1 +- 5.5	80.8 +- 8.3	229.7 +- 9.0	25.4 +- 5.7
444-0	4.9	26.2 +- 3.7	19.4 +- 7.6	112.9 +- 5.5	14.6 +- 3.9	96.1 +- 6.2	252.6 +- 6.9	27.0 +- 4.2
445-2	3.0	23.7 +- 4.1	21.5 +- 8.8	136.7 +- 6.3	25.5 +- 4.5	109.6 +- 6.9	268.1 +- 7.7	22.5 +- 4.6
446-0	5.0	17.1 +- 5.4	22.2 +- 11.3	83.0 +- 7.3	10.3 +- 5.7	61.4 +- 8.3	161.2 +- 8.7	24.6 +- 5.8
447-2	2.1	31.1 +- 6.2	26.5 +- 12.6	118.0 +- 8.5	12.8 +- 6.5	95.9 +- 9.4	238.2 +- 10.0	22.6 +- 6.4
449-0	2.1	54.3 +- 7.5	44.7 +- 14.6	221.7 +- 11.2	0.0 +- 0.0	51.2 +- 9.4	106.6 +- 8.8	27.7 +- 6.9
448-1	4.1	27.8 +- 3.7	21.2 +- 7.6	121.3 +- 5.5	21.7 +- 4.0	95.2 +- 6.1	268.6 +- 6.9	29.9 +- 4.1

	CHSQ	PB	TH	RB	SR	Y	ZR	NB
496-1	5.1	24.4 +- 4.2	37.5 +- 9.1	101.0 +- 6.3	8.3 +- 4.8	81.8 +- 7.0	209.9 +- 7.7	25.7 +- 4.8
497-1	5.2	22.6 +- 2.7	29.1 +- 6.2	135.1 +- 4.7	20.2 +- 3.1	120.3 +- 5.1	276.9 +- 5.6	26.2 +- 3.3
498-1	4.9	18.3 +- 2.3	12.7 +- 5.1	135.8 +- 4.0	24.4 +- 2.7	118.3 +- 4.3	304.6 +- 5.0	28.1 +- 2.8
499-1	10.6	22.1 +- 3.1	36.6 +- 7.0	110.6 +- 5.1	11.3 +- 3.6	90.4 +- 5.6	223.4 +- 6.2	26.5 +- 3.8
500-1	4.7	25.1 +- 2.4	23.0 +- 5.3	122.7 +- 4.1	30.1 +- 3.0	106.6 +- 4.5	323.5 +- 5.4	23.4 +- 3.0
501-1	7.5	23.4 +- 3.2	31.0 +- 7.0	133.2 +- 5.1	19.9 +- 3.7	111.4 +- 5.6	285.3 +- 6.4	32.5 +- 3.7
502-1	10.2	25.7 +- 3.0	28.7 +- 6.8	121.8 +- 4.9	13.0 +- 3.4	100.7 +- 5.4	239.0 +- 5.9	26.1 +- 3.6
462-2	6.1	32.2 +- 3.8	35.6 +- 7.6	123.4 +- 5.1	23.6 +- 3.9	103.4 +- 5.8	287.0 +- 6.7	25.1 +- 4.0
462-1	5.4	32.9 +- 3.9	25.6 +- 7.7	126.9 +- 5.4	21.0 +- 3.9	103.0 +- 5.9	279.6 +- 6.6	23.3 +- 4.0
465-1	10.4	25.2 +- 2.9	37.4 +- 6.4	135.7 +- 4.6	29.2 +- 3.5	103.0 +- 5.0	327.9 +- 6.0	28.6 +- 3.3
465-2	5.8	32.2 +- 5.4	23.7 +- 10.3	107.9 +- 6.8	5.2 +- 5.0	94.8 +- 7.5	231.0 +- 7.9	26.7 +- 5.1
464-0	2.3	37.0 +- 6.7	22.3 +- 11.9	102.6 +- 7.5	15.8 +- 5.9	87.6 +- 8.4	252.2 +- 9.3	18.8 +- 5.8
463-1	5.3	26.2 +- 3.2	30.7 +- 7.0	141.1 +- 5.0	21.0 +- 3.5	122.2 +- 5.5	288.3 +- 6.1	29.7 +- 3.6
466-0	6.8	24.3 +- 2.8	30.5 +- 6.1	128.4 +- 4.4	20.4 +- 3.1	111.8 +- 4.8	275.8 +- 5.4	26.8 +- 3.3

(P/C CONC (PPM))
(PPM ST DEV)

	CHSQ	PB	TH	RB	SR	Y	ZR	NB
U-1 E	9.8	14.6 +- 1.8	0.0 +- 0.0	21.6 +- 2.0	186.2 +- 3.6	24.1 +- 2.6	107.8 +- 3.1	14.8 +- 2.2
525-0	6.4	35.3 +- 4.0	13.1 +- 8.0	209.4 +- 6.4	4.8 +- 3.5	42.4 +- 5.2	109.1 +- 5.0	29.8 +- 3.9
521-1	4.8	36.7 +- 4.3	24.5 +- 8.5	130.0 +- 6.0	18.9 +- 4.3	117.7 +- 6.6	260.4 +- 7.1	21.2 +- 4.4
519-2	14.7	23.1 +- 2.5	32.2 +- 5.5	129.5 +- 4.0	26.9 +- 3.1	96.7 +- 4.4	304.7 +- 5.3	28.1 +- 3.0
519-1	5.8	24.8 +- 3.2	22.0 +- 6.6	132.1 +- 4.8	34.2 +- 3.6	103.0 +- 5.2	330.4 +- 6.2	22.9 +- 3.5
518-1	4.6	22.2 +- 2.9	32.8 +- 6.0	132.0 +- 4.4	37.2 +- 3.3	106.3 +- 4.8	337.2 +- 5.8	23.0 +- 3.2
507-1	8.1	25.1 +- 3.0	30.9 +- 6.2	121.7 +- 4.5	36.8 +- 3.5	103.8 +- 5.0	322.5 +- 5.9	26.0 +- 3.3
506-1	20.6	18.9 +- 1.7	21.8 +- 4.0	120.3 +- 3.0	28.1 +- 2.2	100.6 +- 3.3	314.4 +- 4.0	29.7 +- 2.2
505-2	6.7	29.6 +- 3.6	23.2 +- 7.4	103.9 +- 5.1	25.0 +- 4.0	89.1 +- 5.6	283.5 +- 6.7	20.0 +- 3.8
505-1	6.2	40.3 +- 2.7	46.4 +- 5.6	206.9 +- 5.0	5.1 +- 2.4	58.2 +- 3.9	144.7 +- 3.8	39.9 +- 2.8
516-1	5.0	29.9 +- 2.7	18.2 +- 5.3	136.0 +- 4.1	59.4 +- 3.3	35.3 +- 3.7	130.0 +- 3.9	17.2 +- 2.8
515-1	7.8	22.3 +- 2.2	27.7 +- 5.1	136.2 +- 3.8	27.1 +- 2.7	113.9 +- 4.2	309.3 +- 4.9	27.1 +- 2.8
513-1	6.2	19.8 +- 2.8	24.9 +- 6.0	122.9 +- 4.4	24.1 +- 3.1	110.5 +- 4.8	303.0 +- 5.6	24.3 +- 3.2

APPENDIX B

Cultural Background

Cultural Background

Introduction

The following provides the cultural background for the CA-SDi-5680 site vicinity specifically and the Far Southwest generally. The majority of the discussion was extracted from Dominici (n.d.).

Ethnographic Background

When Spanish explorers and missionaries entered the San Bernardo and Poway areas, many large native villages or rancherias were encountered. The knolls and valleys were densely populated by a Yuman-speaking group of the Hokan language stock, whom the Spanish called Diegueno after Mission San Diego de Alcala (Kroeber 1925:749). Bounding Diegueno territory on the north were the Luiseno, Cupeno, and Cahuilla, Shoshonean-speaking groups (Kroeber 1925:709). Barrows (1900) placed the northern boundary of the Diegueno at Warner's Ranch where he found the population to be mixed Diegueno and Cahuilla. On the coast, Diegueno territory extended from Agua Hedionda Lagoon on the north, south to Ensenada, 60 miles into Baja California (Hedges 1967:1; Kroeber 1925:709). For the east and interior south, no precise limits can be set; ownership of the desert areas around the Salton Sea and Imperial Valley has not been established due to the intermingling of Dieguenо with Quechan and other delta Yuman-speakers (Almstedt 1968:10; Luomala 1978:593).

The Diegueño have been subdivided into groups on the basis of dialectic and geographic differences. Although some differences in custom between these subdivisions are known, much of the available information concerns all of them jointly. CA-SDi-5680 is within the territory of the Northern Diegueno (Kroeber 1925:710). Today the preferred designation for these peoples is "Iipay" (Luomala 1978:592). Iipay territory extended from San Felipe on its northeastern borner to Agua Hedionda and San Diego on the coast. The areas of San Pasqual, Pamo Valley, Ramona, Mesa Grande, Santa Ysabel, and Julian are included within this territory (Luomala 1978:592).

Ken Hedges (1975) identified the Southern Diegueno as Kumeyaay. Bordered on the north by Northern Diegueno, Cupeno and Cahuilla, the Kumeyaay were west of the Quechan (Yuma) and north of the Cocopa. Hedges (1975) and True (1974) have stated that pictographic differences (composite vs. geometric) can be utilized to distinguish the boundary between Northern and Southern Diegueno.

Diegueno practiced a hunter-gatherer subsistence economy, with a pattern of settlement characterized by shifting locations during the year to take advantage of seasonally available resources (Luomala 1978:599). This type of system is often referred to as the "seasonal round" (Steward 1938), where groups return to known exploitation territories year after year. Smaller special purpose campsites would be tied into a main habitation area. Each campsite would be the focus of specialized activities including: plant gathering, processing acorns or seeds, butchering animals, quarrying for lithic materials, ritual sites. The following paragraph summarizes possible local prehistoric settlement and subsistence patterns.

Aboriginal groups began gathering within the lower canyons and river bottoms and moved progressively to higher elevations throughout the year, as plant resources became available. In the spring, gathering took place in the lower reaches of the territory. Bulbs, greens and agave were then ready for harvest. In summer, berries, fruits and seeds of the chaparral-covered slopes ripened and were gathered. The acorn was unquestionably the most important food source. Excursions to mountain oak groves were made from October to November. During winter, when few resources were available, populations subsisted on stored food and faunal resources. (Wirth Associates 1978:47-51).

The village/campsite settlement system provided almost all resources necessary for group survival. This system consisted of a central main habitation area and outlying campsites where the bulk of food and other raw materials were gathered (True 1970; May 1975). It has been estimated for the Cahuilla that 80% of all goods were obtainable within a 10 km. radius from the main habitation area (Bean 1972:73-74). Subsistence patterns for the Diegueno and Cahuilla are not that dissimilar, so it is reasonable to assume "catchment regions" were of similar sizes.

The local hunter-gatherer diet has been estimated to consist of 56% game, fish and other maritime animals (Bean 1978; White 1963), with 20-25% probably being the average amount (Rosen 1984:58). The remainder of the diet was represented by various forms of plant seeds, greens, bulbs, roots and fruits.

Diegueno exchange or direct access of certain goods is reported to have occurred primarily during the winter (Weide and Barker 1974:33). Two specific trails, Maricopa and Yuha-Yuma, are reported between San Diego County Diegueno and the Imperial Valley desert Kamia (Shackley 1981:28-33). The Maricopa was the northerly east-west trail which ran southerly from San Bernardino to Pala, east through Harper's Well near the confluence of Carrizo Creek and San Felipe Creek, and across the desert to the Colorado River, in the Picacho and Tumco vicinity. The southerly east-west trail, Yuha, Yuma, ran somewhere west of Campo, through Jacumba Valley, In-ko-pah Gorge and Mountain Spring to Yuha Spring and then to Indian Wells and then ran east (Gifford 1931). Another north-south trail, Xakwinimis, branched off the Yuha Trail and joined the Maricopa Trail, probably near San Sebastian. A network of trails, transversing the mountains and eventually ending at the coast, connected the Maricopa, Yuha-Yuma and Xakwinimis trails with the rest of Diegueno territory.

The ethnographic literature suggests that the Diegueño were relatively self-sufficient, requiring virtually no exotic resources. Table 14 lists the resources exploited intraregionally. The only materials procured outside the linguistic area were gourds and seeds probably imported from the Quechan and Mohave (Davis 1961).

Diegueno material culture will be briefly discussed. The Diegueno lived in dome to tent shaped huts, made of poles, pulled together and then thatched to protect the occupants from the elements (Lee 1978:59-60); Luomala 1978:597; Kroeber 1925:721; Spier 1923:338-339). The insides were slightly sunken and support poles were set into the ground (Luomala 1978:597; Spier 1923:338-

Table 14. Ethnographically Recorded Resources Exchanged

Resource	Zone Procured	Reference
Steatite	Jacumba Mountains	Gifford (1931)
Hematite	Jacumba Mountains	Gifford (1931)
Manganese	Jacumba Mountains	Gifford (1931)
Limonite	Andrade, N. Baja Calif.	Rogers (1936)
Granite	Jacumba Mountains	Gifford (1931)
Clay	Mason Valley Manzanita Imperial Valley (lacustrine)	Rogers (1936)
Sandstone	W. Imperial Valley	Holmes (1902)
Salt	Salton Sink Indian Wells, Imperial Co.	Drucker (1941)
Acorns	Peninsular Ranges	Gifford (1931) Spier (1923) Cuero (1968)
Tobacco	Peninsular Ranges	Gifford (1931)
Agave	Desert Foothills	Gifford (1931) Cuero (1968)
Yucca fibre sandals	Desert Foothills	Gifford (1931) Spier (1923)
Baskets and carrying nets	Peninsular Range lineages	J. Davis (1961)
Eagles and feathers	Desert Foothills	Spier (1923) Gifford (1931)
Mesquite beans	Imperial Valley	Cuero (1968) Hicks (1963)
Pinon nuts	Torrey Pines Desert Foothills	Cuero (1968)
Gourds and seeds	Quechan and Mohave	Gifford (1931) J. Davis (1961)
Shells	Pacific Coast and Gulf of California	Gifford (1931) Cuero (1968)
Dried seafood	Pacific Coast	Cuero (1968)
Dried greens	Western Foothills	Cuero (1968)
Honey	Peninsular Ranges and Imperial Valley	Cuero (1968) (after contact)

(*After Shackley 1981)

339). During warmer weather or seasons, no enclosure was used.

Milling features consisted of slicks, basins and mortars set into bedrock outcrops (Kroeber 1925:passim; Spier 1923:335). Portable varieties of these also were common. They were used to prepare acorns, plant seeds and small animals for consumption (Cuero 1968:32-33; Sparkman 1908:198). The associated grinding implement for shallow milling surfaces was the mano, which may exhibit one or more ground surfaces from use (Spier 1923:335). Pestles were used in association with mortars.

For hunting, bows and arrows were used as discussed under hunter practices. The bows were generally made of mesquite, willow or mountain ash (Curtis 1926:25; Hooper 1920:358; Kroeber 1925:704; Sparkman 1908:205; Spier 1923:350); the string of fiber or sinew; the arrow of wormwood (Kroeber 1925:704 or arrowwood (Curtis 1926:25; Spier 1923:352) for a single construction arrow, or of cane and greasewood (Curtis 1926:25; Sparkman 2908:205), or arrowwood and chamise (Spier 1923:352) if the construction was a composite arrow.

Other hunting gear included wooden, flat, curved throwing sticks (Kroeber 1925:652,817; Sparkman 1908:198; Spier 1923:337; Curtis 1926:9) for small game and birds, while thick cylindrical wooden clubs (Heizer 1974; Kroeber 1925:704; Spier 1923:354) were used less frequently for hunting.

Many other perishable utilitarian goods were manufactured by the Dieguено. While these remains would not be recovered in the typical archaeological investigation, their documented use in the ethnographic literature is important for providing clues to prehistoric ecological adaptations. Articles made of fibrous materials included: twined and coiled baskets of many designs and uses; basketry carrying caps; milkweed sacks and wallets; fur and fiber clothing; wooden cooking implements and containers.

Preservable utilitarian goods included numerous stone tools; ceramic bowls, dishes, ollas and ladles (cf. Wirth Associates 1978:74-77 for discussion and references).

Other preservable items of an aesthetic or nonutilitarian nature included beads and ornaments made of shell, bone and stone.

Archaeological Reconstruction

Prehistoric. The prehistoric cultural sequence for San Diego County includes three major periods: Paleo-Indian; Early Milling Archaic; and Late Prehistoric.

This sequence corresponds closely to the general chronology suggested by William J. Wallace for the entire southern California coastal region (Wallace 1955:228). Cultural complexes associated with these periods in San Diego County include the San Dieguito (Rogers 1966), La Jolla and Pauma (Warren and True 1961), and Cuyamaca and San Luis Rey I and II (True 1970). See Table 15.

Paleo-Indian. The San Dieguito Complex, first identified and described by Malcolm Rogers in the 1920s (Rogers, 1929), is generally accepted as the earliest documented occurrence of man in the San Diego area. The initial date for this complex has been established at about 11,000 B.P. (Moriarty 1969:4). Several investigators, however, have hypothesized the existence of an earlier complex, based on highly disputed lithic assemblages from the Texas Street site and from Buchanan Canyon (Carter 1957). A controversial date beyond the "carbon-14 range of 35,000 B.P." was obtained from a Texas Street hearth (Carter 1957:318).

In addition to the Texas Street/Buchanan Canyon date, dates of 23,000 and 48,000 B.P. have been obtained from skeletal material collected at Del Mar (Bada, Carter and Schroeder 1974). These dates have been received with much skepticism by the general scientific community and await final verification. An article in the San Diego

Table 15. San Diego County Prehistoric Chronology

TIME	CULTURAL SETTING	STAGE	CLIMATE
A.D. 1876	Reservation Period		Medithermal: Moderately warm; arid & semi-arid
1850	Anglo-European Era		
1822	Mexican Era		
1769	Hispanic Era	Historic	
1542	Spanish Era	Protohistoric	
1000	(Yuman & Shoshonean Cultures) Cuyamaca & San Luis Rey I and II Complexes	Late Prehistoric	
B.P. 3000	La Jolla Complex termination		
4000			Altithermal: Arid, warmer than present
6000			
7500	La Jolla/Pauma Complexes	Early Milling	
8000			Anathermal: Climate like present but growing warm, humid and subhumid
9500	San Dieguito Complex	Paleo-Indian	
10,000			End of Glaciations
21,000	Yuha Man (?)	Early Man (?)	
48,000	Del Mar Man (?)	Early Man (?)	

* (After Westec Services 1980)

Union presents an excellent discussion of the local "Early Man" debate (Baskin 1980).

Of three phases defined by Rogers for the period of San Dieguito occupation (Rogers 1966:25), only San Dieguito II and III have been identified west of the Laguna Mountain watershed (Rogers 1966:79-81). According to Rogers, in San Dieguito II times, a westerly movement took place from the Colorado Desert into southern California following a course through the Jacumba Pass near the International Border. During this migration people spread out both to the north and the south--"to the northwest as far as the San Luis Rey River and perhaps beyond" and into Baja California (Rogers 1966:81).

Early Milling Archaic. The inclusion of milling stones within a few assemblages attributed to San Dieguito III, has led several investigations to suggest a transitional phase between the Paleo-Indian and Milling Archaic periods (Moriarty 1967:553-556); Kaldenberg 1975). In general, the Milling Archaic is viewed as a period in which fairly sedentary populations, adapting to warmer and drier climatic conditions, migrated from interior regions to the coast (Warren, True, and Eudey 1961:28; Moriarty 1967:553-556; Kowta 1969:36; Warren 1968:2). The technological innovation of milling equipment and the predominance of this element in Milling Archaic assemblages suggests that vegetal resources, particularly small seeds, were an important part of the diet. The typical tool inventory is characterized by the following: deep-basined milling stones (metates), unshaped manos, heavy cobble based tools, various tools made of flakes from cobbles, small well-made domed scrapers, and occasional ornaments or special purpose items such as perforated stones ("donuts stones") and shell beads (Warren, True, and Eudey 1961; Owen, Curtis and Miller 1964; True and Waugh 1981:102). Burials tend to flexed, heads oriented north, under stone cairns (Rogers 1939, 1945; Warren, True and Eudey 1961).

Late Prehistoric. The most common and well-defined sites in the vicinity of CA-SDi-5680 belong to the Late Prehistoric period and to the ancestors of the Yuman-speaking Dieguenos who occupied the region when the Spaniards arrived in 1769. A preceramic Yuman horizon appears at certain La Jollan sites along the coast by 2,000 B.P. (Warren 1968:2; Moriarty 1969). It has been suggested that a cultural continuum exists between the La Jollan and Yuman complexes (Moriarty 1969; True 1966:xvi). True notes that although the Late Prehistoric cultural pattern may have developed from the earlier Milling Archaic substratum, due to in situ adaptation to environmental changes, this development was modified by numerous influences from the north and from the desert regions to the southeast (True 1966:xvii).

Environmental reconstructions (Waters 1983) indicate increased aridity in the desert areas contributed to the evaporation of Lake Cahuilla (located in the Salton Trough). Due to the desiccation of this large body of water, a few Yuman groups may have migrated west over the mountains to eventually form the nucleus of later Diegueno groups at approximately 950 B.P. (Luomala 1978:594). References to the drying up of a large body of water are made in the Diegueno origin myth (Spier 1923:329, 331).

In the Late Prehistoric period milling technology shifted from portable equipment to permanent bedrock outcrops and increased numbers of deep basins and mortars (Fulmer 1977:17). However, deep basin and slab metates have also been associated with Late Prehistoric complexes (Owen, Curtis and Miller 1964; True and Waugh 1981:102). Burial patterns changed from inhumation to cremation; small triangular projectile points, clay and stone pipes, shell beads, and a variety of chopping/scraping tools, and unpainted ceramics were characteristics of this period (True 1970:53-54).

Historic

The beginning of this period is marked by the first contact between Native Americans and Europeans (A.D. 1542). There was miniman contact between the two groups until the time of the establishment of the San Diego Mission in A.D. 1769.

The village of Poway (Paguay, Spanish spelling) was a major Northern Diegueno (Iipay) village which was repeatedly noted in early Spanish and Mexican documents. As they traversed northward toward Ramona and Julian, Spanish and Mexican travelers visited Paguay (Location of Village from CA-SDi-5680). The village was called "the Rancheria with the permanent running water" (Englehardt 1920:222). Paguay or Poway is an Indian word which means the "place where the valley ends" (Stein 1975:100). Erwin Gudde (1959:272) cited Kroeber as stating that both Luiseno and Diegueno called the area Pawai, which E. D. French (Elliot 1888:178) recorded as meaning "it is finished" or "end of the valley." The Diegueno word Pawaiiy signifies "arrowhead" or point of convergence (Couro and Langdon 1975:146).

Euro-Americans came into the Poway area in the late 1800s as homesteaders (Van Dam, personal communication 1979). Philip Crosthwaite was the first documented Euro-American to reside in Poway. Portions of the Crosthwaite adobe, which was constructed in 1859, are still present at the Haley Trailer Park (Van Dam, personal communication 1979).

Dieguenos (Iipay) inhabited the valley at least into the land boom of the 1880s. A rancheria, approximately a mile and a half southeast of Poway (McKee 1970:14), was reported occupied as late as 1889 (Kear 1965:45). It is unknown how long the Dieguenos inhabited the upland areas of the CA-SDi-5680 site vicinity. A homestead built at the turn of the century is located approximately one mile from CA-SDi-5680 up Poway Creek. It is unlikely that any Native Americans were living contemporaneously with Euro-Americans in such close proximity. However, the glass projectile point tip found at Locus A would suggest that CA-SDi-5680 was occupied into the Historic period.

ABSTRACT

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Obsidian dating has been used by California archaeologists to establish the chronology of a number of archaeological sites in the Far Southwest (Imperial and San Diego Counties). Criticism concerning the use of the obsidian dating method exists because of the lack of thorough evaluation by these same archaeologists of the proposed obsidian hydration rates which are the basis of the age determinations. Therefore, a thorough examination and evaluation of all available data was performed in order to determine which California obsidian hydration rate best fits the Obsidian Butte obsidian data (a regional source of obsidian).

It was determined that the Linear obsidian hydration rate model equation best described the hydration rate of Obsidian Butte obsidian (located in the Salton Trough). The Linear rate equation, $T = 78.16(x)$, where "T" is age in years before present and "x" is the obsidian hydration rim measurement in microns, is proposed. The constant of 78.16(b) was primarily calibrated by the three sets of data that were obtained from a Caltrans data recovery program of the CA-SDi-5680 site complex located 137 kilometers (85 miles) west of Obsidian Butte. These three sets of data are: (1) 59 Obsidian Butte obsidian specimens sourced by chemical characterization; (2) 10

radiocarbon dates, ranging from 560 to less than 300 years B.P.; and (3) 57 hydration rim measurements for the Obsidian Butte obsidian which ranged from 1.5 to 4.6 microns, with a mean of 2.309, a mode of 2.1 and a standard deviation of 0.647.

Obsidian Butte obsidian exchange has a proposed starting date of approximately A.D. 1210, based on: (1) the available Obsidian Butte obsidian hydration data, (2) the proposed Obsidian Butte obsidian hydration rate (T = 78.16(x)), and (3) the desiccation dates of Lake Cahuilla (which formerly filled the Salton Trough). There is a good possibility that exploitation of Obsidian Butte obsidian could have occurred as early as 600 years prior to A.D. 700 (the first lacustral interval in the past 2000 years). However, no recorded Obsidian Butte obsidian have hydration rim measurements that could be associated with any time earlier than A.D. 1210.

Implications of the proposed Obsidian Butte obsidian hydration rate, using the recorded obsidian hydration rim measurements (from that source), suggest that Late Prehistoric exchange of this material was not affected by Spanish missionization. However, Euro-American encroachment did affect obsidian exchange which terminated at approximately A.D. 1900.

Hydration Dating Procedure and Report Format

Specimens for hydration dating were prepared in the same manner as employed by the UCLA Obsidian Laboratory. Samples were cut on a water cooled Lapcraft trim saw using a 4" diamond charged blade of 0.12" thickness. Two parallel cuts were made in each analysed specimen to a depth of 2-5mm and spaced 1-2mm apart. The resulting obsidian wedge was removed from the specimen and mounted on a 27X46mm petrographic slide using Lakeside #70 thermoplastic cement heated to 125°C. After cooling the obsidian wedge was ground and polished on a glass plate using slurrys of Buehler 400 grit silicon carbide and 600 grit aluminum oxide abrasives. The slide was then washed, reheated, and the obsidian wedge turned to expose the opposite surface. The above grinding and polishing procedure was repeated, bringing the wedge to a thickness of approximately 30-50 microns. After a final washing the specimen was again reheated to 125°C and a glass cover slip 22mm^2 and .017mm thick was affixed to the slide with Canada Balsam.

Obsidian hydration measurements were obtained using an American Optical polarizing microscope. Optics consisted of an American Optical 44X strain-free achromatic objective and an American Optical 10X filar micrometer eyepiece which resulted in an effective magnification of 440X.

All hydration readings reported here are expressed in microns. Measurements were made on each hydration surface observed on the prepared thin section as well as on surfaces appearing inside cracks. All hydration readings were made at the location which exhibited the widest continuous parallel band of good quality. Each hydration value represents the average of five measurements from the same location on the hydration band. Up to three thin sections were prepared for each obsidian specimen in order to locate a hydration band. If still no reading could be obtained the specimen is reported as NHV (no hydration visible).

All readings are reported with a measurement error of ±0.2 microns. This figure was originally reported by Friedman and Smith (1960:481) as the measurement error made by two observers using duplicate measurements at three different locations on the same thin section. Friedman and Smith report smaller errors for measurements made by a single observer.