WHAT X EQUALS: THE ARCHAEOLOGICAL AND GEOLOGICAL DISTRIBUTION OF "SOURCE X" TUSCAN OBSIDIAN IN NORTHERN CALIFORNIA

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A friend and mentor once told me that there were five stages through which one must pass before completing any large project - enthusiasm, disillusionment, panic, punishment of the innocent, and finally, credit taken by superiors for a job well done. Although this bit of knowledge was passed on as a humorous anecdote, it has certainly proven true in my case, and has helped me to maintain perspective while enduring the many trials and tribulations which occurred during the course of this research project. It is therefore with deep appreciation that I would like to formally acknowledge those friends, colleagues and family members that in some way supported me through each and every stage, and by doing so, assisted in the completion of my endeavor.

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ABSTRACT

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A fundamental problem in hunter-gatherer archaeology consists of establishing the relationship between material remains recovered in the present and the nexus of human behaviors and societal relationships to which these remnants of the past may be attributed. With this perspective in mind, the present study has as its principal objective the gathering of relevant data regarding the archaeological, geographical, petrological and geochemical variability of artifact-quality glass derived from the Tuscan obsidian source located in northern California.

Eight previously unidentified artifact-quality glass sources were found within the Tuscan Formation as a result of this investigation. These sources were found to be relatively well dispersed over the landscape, making them

available to early hunter-gatherers in diverse environments. Moreover, significant geochemical differences were established between several of the main source groups, indicating that in addition to the original Tuscan obsidian sources identified by Richard Hughes (1983), there are at least two new chemical source groups identifiable by obsidian characterization analyses.

The data obtained as a result of the geochemical analyses were then used to add to the understanding of the changing lifeways in prehistoric northeastern California, relying upon the central concept of "mobility strategies".

The results of this analysis lend support to the view that as the northern Sacramento Valley and surrounding areas became more heavily populated during the late prehistoric period, the mobility of the aboriginal inhabitants became more restricted. These local population increases most likely resulted in competition and conflicts for available land and resources, thus possibly necessitating the use of more locally available toolstone such as the Tuscan obsidians.

CHAPTER I

INTRODUCTION

"Unidentified Source X"

> Just as the Shasta served as transmitters in trade between the Modoc and the people of the northwest coast, the Achomawi to some extent served a similar function between the Modoc and the Sacramento Valley Wintun. The Shasta also supplied obsidian and arrowheads to the Wintun to the south, but according to DuBois, "Obsidian ... was more often secured by the Wintun themselves on individual or small peaceful expeditions to Glass Mountain in the north." In a sample of artifacts from Northern Wintun sites in Trinity County, 297 (74%) are of Medicine Lake (Glass Mountain) obsidian, 1 sample is possibly from Sugar Hill/Buck Mountain, and 7 (1.8%) are not identified. The remaining 96 samples (23.9%) create a mystery as to their source. They are clearly of a single uniform chemical composition representing another source as yet unsampled and which therefore must at present be assigned to an unknown source "X"... Only further sampling of obsidian extrusions in northern California and adjacent Oregon and Nevada will solve the problem of source "X". (Jack 1976:198)

Despite the fact that California has been at the forefront of obsidian characterization studies from the very beginning, until the last 10 years, obsidian now known to originate from the Tuscan Formation was merely identified as "Source X". While trace and rare earth element analyses performed by Hughes and Hampel (Hughes 1983:324) demonstrated that Tuscan obsidian localities were, in fact, the geographic counterparts for Jack's (1976:198) "Source X" distribution, to date, no formal attempt has been made to characterize the full geographical extent and geochemical variability of obsidian sources contained within this formation.

The early research conducted by Jack (1976) and Hughes and Hampel (1983) provided archaeologists with a rough understanding of the distribution of obsidian artifacts that originated from this geological source. Viewed from a geologist's perspective, a source attribution was considered to be sufficient provided there is a correlation between the trace element composition of an artifact and the composition of a provenienced obsidian source.

While this viewpoint may provide an acceptable starting point for the archaeologist concerned with lithic production systems, in order to fully understand the attributes of lithic sources that are likely to have been important to prehistoric stoneworkers, it is necessary to first examine the raw material variation which may be present within a specific "source" from a regional perspective. As Basgall (1989:111) so succinctly points out, "Especially critical is an ability to track the spatio-temporal dimensions of stone tool use across large regions". But this cannot be done with precision unless we have the ability to recognize intrasource variations with some accuracy.

Moreover, although the use of x-ray fluorescence (xrf) analysis for the characterization of obsidian is not new, after nearly 20 years, the anthropological issues on which obsidian characterization analysis has been focused remain surprisingly few. Many archaeologists persist in viewing regional source profiles as relatively straight-forward signatures of trade, territoriality, and other behaviors which operate within a strong sociological matrix (Basgall 1989:11). Consequently, the full potential of characterization analysis has yet to be realized. Like-wise, characterizations of lithic tool assemblages utiliz-ing economic concepts which consider such issues as mobility, storage or energy costs remains under-represented in northern California studies.

With these perspectives in mind, a two-stage research program was developed. The initial and principal objective of the present study was to gather data regarding the archaeological, geographical, petrological and especial-ly the geochemical variability of artifact-quality obsidian from the Tuscan Formation. The pursuit of this objective was guided by two basic premises, the first of which focuses upon issues surrounding hunter-gatherer procurement strategies.

Although patterns of obsidian dispersion can be accounted for, in part, by prehistoric exchange systems operating within fairly elaborate socioceremonial systems, ethnographic data and archaeological research conducted by Binford (1979) and others (Kelly 1983, 1985; Meltzer 1984; and Shackley 1985, 1986, 1990) suggest that among many hunter-gatherer populations, the bulk of lithic raw materials enters the system embedded within the subsistence procurement schedule. Viewed in this manner, obsidian source profiles often relate more directly to aspects of residential mobility and group provisioning than to specialized collection forays or formalized socioceremonial exchange relationships (Basgall 1989).

However, in order for obsidian characterization studies to be useful in the investigation of such issues as prehistoric exchange networks, mobility strategies and hunter-gatherer procurement patterns, it is necessary that artifact-quality obsidian be traceable to specific quarries or, as is the case with Tuscan obsidian, "lithic collection localities". Prior to this study, Tuscan obsidian artifacts from archaeological sites were not traceable to specific locations within the Tuscan Formation range. Since the Tuscan Formation occurs over an expansive area, it is possible that there are additional previously unreported areas in which artifact-quality glass is present and that such obsidian will exhibit geochemical variability, specifically in regards to trace and rare earth element concentrations. Therefore, one component of this research will focus on the geochemical and petrological analysis of rhyolite glass from various locales within the Tuscan Formation in an attempt to determine whether or not significant geochemical differences can be detected.

The second basic premise underlying the first part of the present research assumes that the higher the quality of the obsidian, the more desirable it would have been to prehistoric flintknappers, and hence, the more widely it would have been distributed throughout the archaeological record, both temporally and spatially. It has been suggested by some researchers that compared to other obsidians, Tuscan obsidian is of lesser value since it is found primarily as small waterworn nodules. Moreover, it is suggested that the nature of the Tuscan obsidian required that different methods of lithic reduction be used (e.g., bipolar reduction) in the manufacture of stone tools from this material. Further, it has been assumed that because Tuscan obsidian was less desirable than obsidian from the Medicine Lake Highlands, this resulted in the limited temporal and areal distribution of Tuscan obsidian in the archaeological record.

While knapping and use qualities of a particular stone operate as important elements in raw material selection practices, there are other variables which may be equally important. The distribution of source areas in space and the accessibility of stone at the source are two such aspects which may have been important determinants in hunter-gatherer lithic procurement strategies (Bamforth 1992).

As observed by Bamforth (1992:133), most archaeologists would predict that prehistoric peoples exploited lithic sources close to the areas they inhabited; chose sources that produced abundant, concentrated, and easily obtainable stone; and chose material that was best suited for the kinds of tools and tasks for which it was used for. However, since stone tool users in a given region could have chosen only from the range of variation to which they had access, evaluations of the accessibility and quality of a given type of stone must be made relative to other lithic material available in the same area.

These considerations lay the basis for the second component of this research, which will focus on three aspects of lithic raw material variation in relation to the Tuscan Formation: the distribution of source areas in space, the accessibility of the stone at the source, and the knapping and use qualities of the stone. It is not likely that raw material variations were the sole determinants responsible for the lithic technological patterns seen in hunter-gatherer contexts in northern California. However, when viewed from a regional perspective, it may be possible to determine and provide an explanation for the temporal and spatial distribution of artifacts manufactured from Tuscan obsidian in the archaeological record when an examination of the raw material variation is taken into consideration.

The following study is presented in eight chapters. Chapter II provides an overview of the study area in which the reader is introduced to the essential environmental, historical and archaeological information pertaining to the area of investigation. In order to understand the human adaptation processes which were in operation in response to the prehistoric environment a brief description of the environmental setting of the region is provided, followed by a cultural-historical synopsis of the study area as it is currently understood. Chapter II concludes with a discussion of the patterns of Tuscan obsidian procurement and production over time as viewed by various area researchers. Chapter III presents the geological, geographical and geochemical descriptive data of the Tuscan Formation based on the known literature. A discussion of the previously known geological sources of Tuscan obsidian prior to this study's undertaking is presented in this chapter as well as an evaluation of the potential problems faced by archaeologists attempting to interpret the archaeological record utilizing Tuscan obsidian source data.

The methods employed in this study are discussed in Chapter IV, while Chapter V presents the results of the petrological and geochemical analyses portions of this study. Detailed megascopic descriptions of the Tuscan obsidian localities, the results of the trace and rare earth element analysis, a discussion concerning intrasource variability of the various Tuscan obsidian source locales, and observations regarding the knapping qualities of the various glasses recovered from the Tuscan obsidian source areas are all presented in Chapter V. This study indicated that some glass localities, especially the spatially distant sources, exhibit geochemical modalities along two or more trace elements. Data gathered as a result of these analyses indicate that in addition to the original Tuscan obsidian sources identified by Richard Hughes (1983), there are at least two new chemical source groups which can be identified by trace element analyses.

Chapter VI will examine the patterns in lithic procurement, technology and use of Tuscan obsidian revealed in the archaeological record by the areal distribution of Tuscan obsidian in temporal and spatial contexts. Site-specific analysis of Tuscan obsidian procurement and production through time will be examined utilizing data obtained from several archaeological sites situated within the area of investigation. To anticipate very briefly conclusions which were drawn as a result of this analysis, I argue that beginning around 700 B.P. in the southern portion of the study area and perhaps as early as 1700 B.P. in the northern portion, obsidian procurement patterns appear to have changed suggesting that the procurement ranges were becoming more circumscribed.

Chapter VII will summarize the results of the entire study and evaluate the contribution it has made. This final chapter concludes with a discussion of the data in light of the theoretical perspective undertaken and provides directions for future research.

CHAPTER II

TUSCAN OBSIDIAN: A CULTURAL-HISTORICAL OVERVIEW

Introduction

Various researchers have noted that throughout prehistory the role of toolstone source areas has varied according to changing cultural factors such as settlement-subsistence strategies, social boundaries, trade and exchange systems, and lithic technology. However, the locations and character of these same source areas have remained relatively constant.

In chapters III, IV, and V to follow, the obsidian source that is the subject of this thesis is described and located in space. This chapter presents, by way of a background briefing, information regarding the salient features of the environment to which earlier humans adapted, the nature of that adaptation as revealed in the known archaeological and ethnographic record and ideas which have been expressed regarding the use of Tuscan obsidian by prehistoric populations in the area.

First, a brief summary regarding the environmental setting of the region is presented in order to indicate the aboriginal resource availability and the general context of human adaptation which exists within the study area. The environmental section is followed by a cultural-historical synopsis of the study area as it is currently understood. The ethnographic and prehistoric descriptions provided in this section are, for the most part, a composite picture drawn from information regarding the various groups which once inhabited the region. At the heart of this chapter is a discussion regarding the changing patterns of prehistoric Tuscan obsidian procurement and production practices as hypothesized by various researchers.

Physical Setting

The study area incorporates a large expanse of land along the east side of the northern Sacramento Valley at the juncture of the Cascade Mountain Range and the Great Valley physiographic province (Figure 1). With the Sacramento River on the west, the northern boundary follows the course of the Pit River from the city of Redding east into the southern Cascade foothills towards the small community of Montgomery Creek. From this point, the boundary turns south through these mountains and their foothills along an arbitrary line to a point just north of Oroville, where it again turns to the west, terminating at the Sacramento River. The limits of the study area are defined to incorporate the various geological and cultural features which are essential to the archaeological issues at hand.

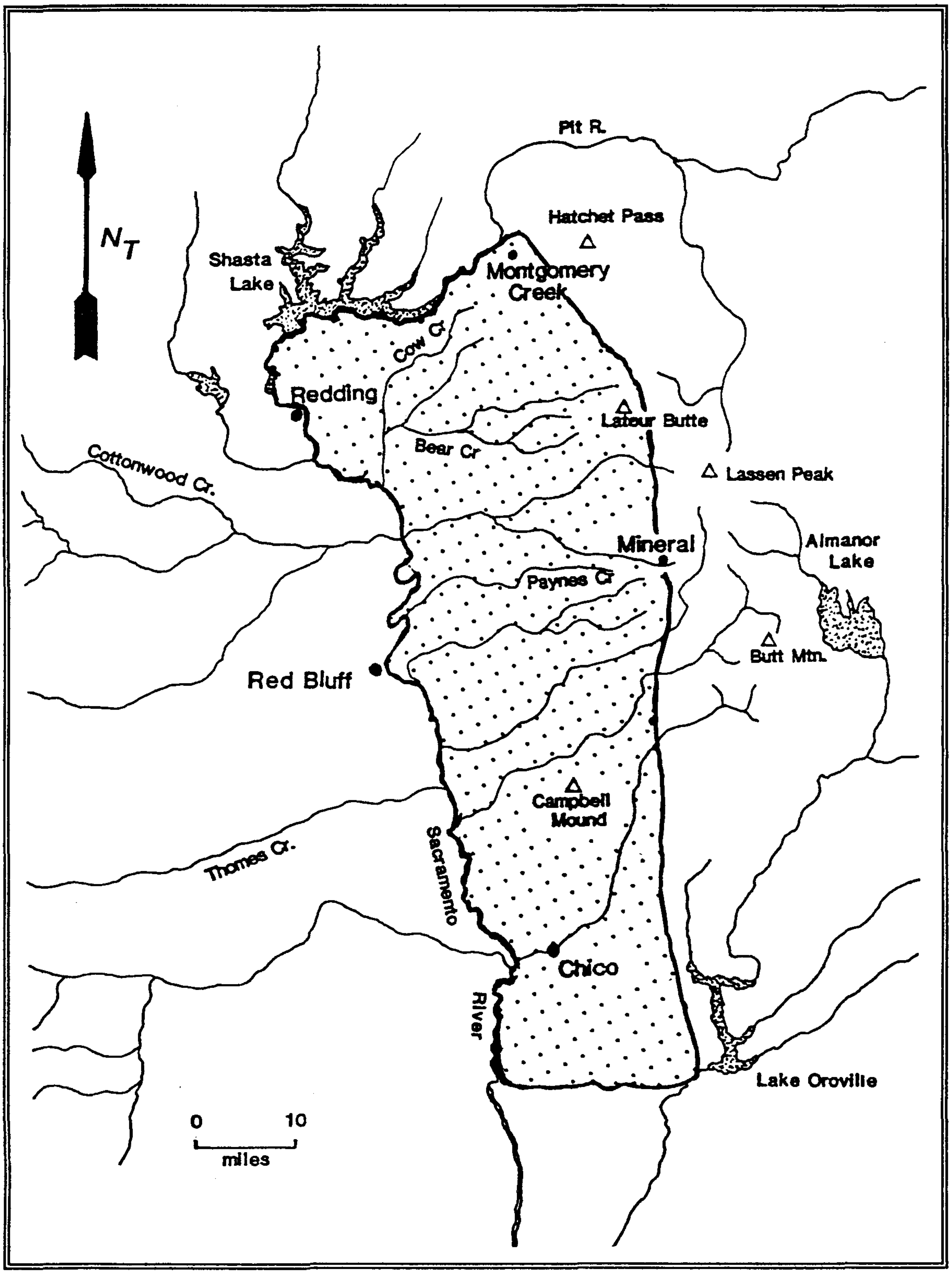

Figure 1. The Study Area.

Elevations within the study area range from a low of 300 feet along the Sacramento River near the western border to 4000 feet in the mountainous eastern sections. Generally speaking, the terrain throughout much of the study area consists of a continual series of low rolling hills and volcanic tablelands which are divided by a number of perennial and seasonal westward-flowing drainages. The eastern sections of the study area are characterized by the often rugged, mountainous terrain that is typical of the foothill and mountain regions of the Southern Cascade Mountain Range.

Although the topography significantly influences its localized manifestations, the climate within the project area largely reflects the typical Mediterranean pattern of hot, dry summers and cool, wet winters. Temperatures within the project area vary greatly with variations in elevation, terrain and exposure. The annual average temperature is 50 to 55 degrees. However, extremes of 100 degrees Fahrenheit or greater in the summer months to lows of 20 degrees Fahrenheit during winter are not uncommon (Major 1977). Although the average annual precipitation of those portions of the project area on the valley floor near Redding averages approximately 36 inches, precipitation is seen to vary inversely with the temperature, and amounts generally increase with elevation gains (Major 1977). The predominant form of precipitation below the 2000 foot elevation level is rain, while above 4000 feet snow becomes the most prevalent form.

Paleoclimatic studies for the Holocene period within the project area itself have yet to be conducted. However, West (1989:36-50) has proposed a general sequence of paleo-climatic changes for the upper Sacramento River Canyon based on the pollen record from Cedar Lake in southern Siskiyou County. West's sequence suggests that several major shifts in vegetation and climate occurred within the last 10,000 years (1989:48). Prior to 10,000 B.P. temperatures were probably considerably cooler than today. However, beginning around 10,000 years ago and lasting until 3,500 B.P. significant vegetation changes suggest that climatic conditions during this interval were warmer and drier than those preceding or following it (West 1989:49). By around 3,500 B.P. a cooler, more mesic period saw the establishment of modern-day vegetation associations and distributions. West (1989:49) noted that these changes were most likely a response to the neoglacial conditions observed elsewhere in California and Oregon by Crandall (1965) and Warhaftig and Birman (1965).

To characterize the biotic environment in the broadest terms, the major portion of the study area is situated within the Lower Sonoran or Great Central Valley Lifezone; however, portions of the project area also include the Upper Sonoran or Foothill/Chaparral Belt and Yellow Pine

Forest Belt (Storer and Usinger 1963). Potential food resources throughout the region are extremely varied, and in places, quite abundant.

Ethnographic Overview

In anticipation of the research problems which will be discussed in Chapter VI, the following section presents a brief description of the various ethnographic groups known to have inhabited the study area prior to the arrival of the Euro-Americans. Ethnographic descriptions for the Yana are given by Waterman (1918), Kroeber (1925), Sapir and Spier (1943), and Johnson (1978). The Central Wintu or River Nomlaki have been described by Goldschmidt (1978). Dubois (1935) and Vogelin (1942) have described the Wintu, and LaPena (1978) has provided a comprehensive synthesis for this group.

An examination of tribal territory maps indicates that the study area is not easily correlated with the nuclear territory of any single ethnographic group. At the time of Euro-American contact, the upper Sacramento Valley along the western shores of the river was occupied by the Penutian-speaking Wintu in the northwest and the Nomlaki or Central Wintun in the southwest. In the eastern foothills of the Southern Cascade Range were the Hokan-speaking Yana, while the various Achumawi groups occupied the upper reaches of the Pit River.

Due to differences which have arisen in the interpretation of territorial boundaries, the precise ethnographic identification of regions within the study area during the late prehistoric era remains uncertain. Although there is general agreement on the location of the Wintu peoples on the western banks of the Sacramento River, there is no singular consensus regarding the eastern shores from the mouth of Cow Creek southward. Powers (1976), Waterman (1918), and Kroeber (1925) all place the area within the territory of the Nomlaki, while Merriam (1966) assigns it to the Wintu. However, Sapir and Spier (1943) claim that the area was utilized by the Southern Yana (Figure 2).

As hinted at previously, the greatest area of uncertainty lies with the western limit of the Yana. Waterman (1918), Powell (1885), and Merriam (1966) all place the western boundary of the Southern Yana and Yahi at the 1000 foot contour interval in the foothills of the Southern Cascades. Kroeber (1925), however, disagrees with this demarcation and places the western boundary closer to the valley floor, at the 400 foot contour interval. Consistent with this placement, information gathered by Sapir and Spier (1943), Kroeber (1925), and Powell (1885) suggest that the Southern Yana and Yahi maintained permanent or at least seasonal fishing camps along the Sacramento River.

On the basis of the ethnographic data gathered by Sapir and Spier (1943) and more recently obtained

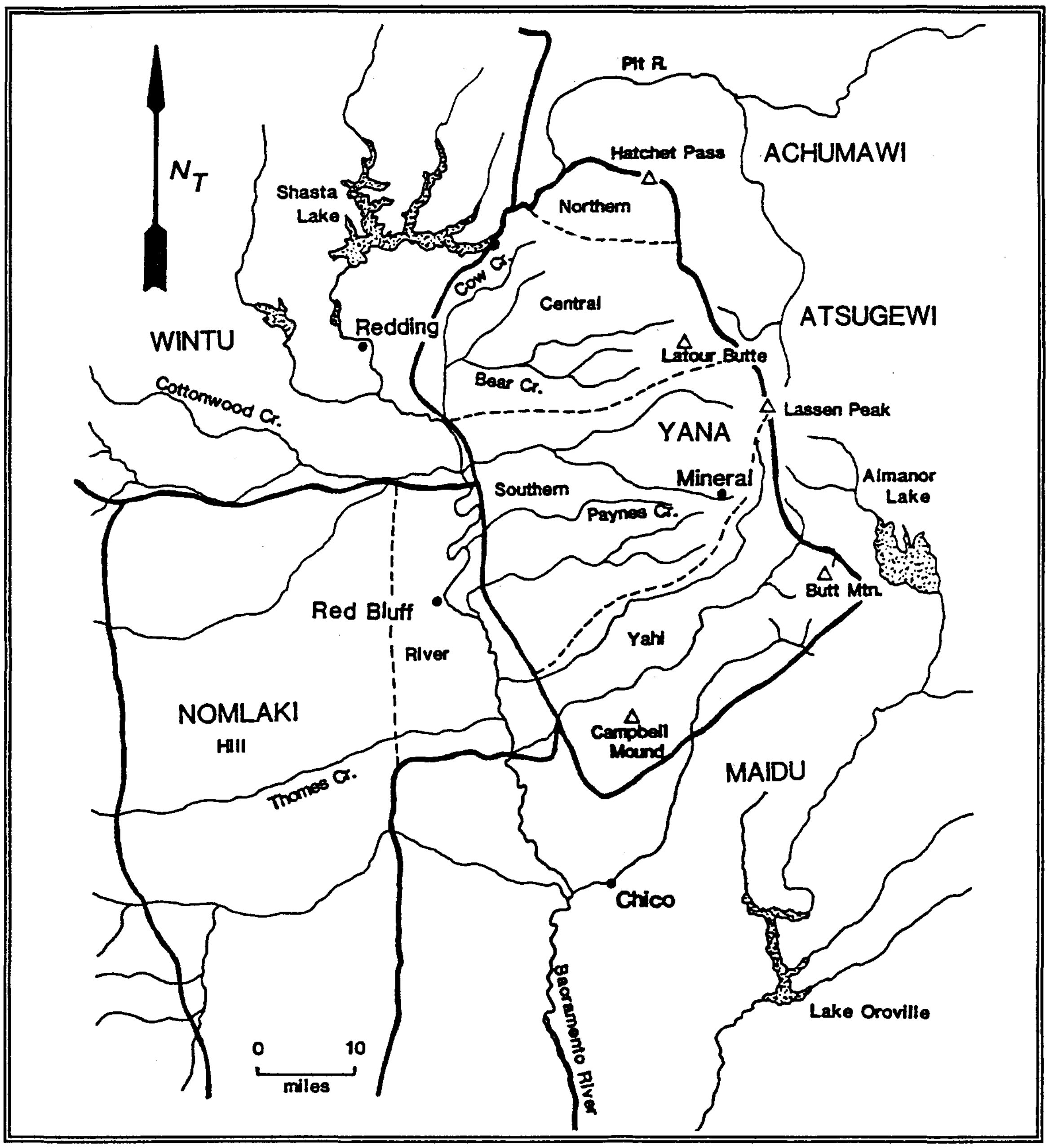

Figure 2. Ethnographic Tribal Distribution of the Northern Sacramento Valley and Adjacent Mountains.

Source: Dondero, S., and J.J. Johnson, 1988, Dutch Gulch Lake Excavations at Six Prehistoric Sites, Cottonwood Creek Project, Shasta and Tehama Counties, California. The Hornet Foundation, Department of Anthropology, California State University, Sacramento. Submitted to U.S. Army Corps of Engineers, Sacramento District, Contract No.DACW05-81-C-0094. Adapted.

archaeological information, it seems reasonable to follow Wiant (1981) in suggesting that the Southern Yana and Yahi made limited seasonal use of the region between the Sacramento River and the Southern Cascade foothills. As Johnson (1978) has indicated, the uncertainty concerning the western border most likely reflects the retreat of the Yana further into the foothills as a result of pressure exerted upon them by the neighboring Wintun groups prior to white contact and from Euro-American settlers after 1847.

The aboriginal Wintu and Yana were hunter-gatherers whose subsistence activities were based on fishing, hunting, and the gathering of plant foods. While there were differences, both groups practiced some form of seasonal transhumance for their basic subsistence strategy in order to acquire sufficient quantities of foodstuffs. In addition to hunting and fishing, a wide variety of plant foods were collected by both groups, with acorns being one of the most important of the plant food sources.

The Wintu lived in logistically-organized, self-sufficient villages which served as multifamily bases from which food procuring forays were staged. These villages formed the basic social, economic and political units of their society. In comparison, the settlement pattern of the Yana reflected a simpler socio-political organization. The Yana were politically divided into numerous tribelets. These tribelets typically consisted of the occupants of a cluster of dwellings that constituted a major village at which the principal hereditary chief and assembly house were located. These villages were occupied for the major part of the year and most likely had several smaller villages allied with them. In addition to these major villages, the Yana also had regular fishing places which were occupied during the summer fishing season as well as temporary hunting camps or "resting places" which were spots favorable for staying overnight as parties traveled between villages.

Archaeology and Prehistory

Although ethnographic and historic data provide some indication as to the manner in which post-contact, non-indigenous populations and the ethnographic-period Native Americans adapted to the northern Sacramento Valley and surrounding regions, these data are fragmentary and say virtually nothing of earlier populations in the study area. Since they fail to provide the long-term perspective useful in answering questions of origins and cultural dynamics operating through time, it falls upon archaeological research to attempt to remedy the deficiency in our understanding of the area. The following discussion reviews previous archaeological work in the study area as it pertains to issues focusing on prehistoric cultural chronology and population dispersal.

Temporally diagnostic artifacts and radiocarbon dates obtained from deeply stratified archaeological deposits such as CA-SHA-475 in the Squaw Creek drainage, indicate that hunter-gatherers began to occupy this region around 7500 to 8000 years ago (Clewett and Sundahl 1983). Although several different models have been developed to explain the changes in settlement and subsistence practices over time, all have outlined a very similar sequence of developments (see especially Basgall and Hildebrandt 1989; Clewett and Sundahl 1982; Hildebrandt and Hayes 1983; Johnson and Theodoratus 1984; and Kowta 1984).

Human occupation during the Early Archaic (6000 - 3000 B.C.) seems to have been dispersed throughout the region, and residential groups appear to have been small and relatively mobile (Sundahl 1992). Villages during this time tended to be small to medium in size and occurred mainly in the foothill zone and along major and minor streams in the northern portion of the valley, while occupation within the Southern Cascade Mountains appears to have been ephemeral (Johnson and Theodoratus 1984). Kowta (1984) surmises that between 8000 to 5000 B.P. the northern California region was lightly populated by small mobile groups which subsisted primarily on plant foods such as seeds and a very generalized hunting pattern.

However, between 5000 to 3000 B.P. there began to be a restructuring of the way of life with a greater diversification in the subsistence economy, measured by increased frequencies of milling equipment and greater use of upland habitats, the latter change presumably brought about by a mid-Holocene warming trend (Basgall and Hildebrandt 1989:68). It was at this time that the Southern Cascade Mountain Ranges began to witness an increase in occupation, with small mobile groups establishing task specific or summer base camps throughout the foothill zones. With the onset of cooler climatic conditions after 3000 B.P., the higher elevations became less productive and the overall degree of residential mobility in the region appears to have declined (Clewett and Sundahl 1982). Along with the appearance of permanent villages, adaptations appear to have centered on riverine and other lowland water sources, with the higher elevations being used primarily for seasonal or otherwise temporary purposes by logistically organized task specific groups.

With these changes in settlement practices and technology, a new era was ushered in, in which economic pursuits that relied heavily on acorn gathering, salmon fishing and hunting became the norm. For the most part, it has been assumed that the adaptational changes witnessed during the Late Archaic arose in part as a result of the arrival of Penutian-speaking populations into the northern Sacramento Valley, which encroached upon and pre-empted lands occupied by the original Hokan-speaking groups (Basgall and Hildebrandt 1989; Clewett and Sundahl 1982; Hamusek and Kowta 1991; Sundahl 1982; Whistler 1977). While it appears that in the northern portions of the study area these changes led to the complete territorial displacement of Hokan-speakers, it has been hypothesized that the Wintu encroachment on traditional Yana territory along the Sacramento River may have resulted in only a partial loss of traditional lands accompanied by adjustments in the settlement-subsistence systems (Hamusek and Kowta 1991).

With only sporadic and temporary access to the Sacramento River resources, the Yana would have been forced to accept changes in order to compensate for the loss in land. An increased use of the tributary streams for fishing and the establishment of primary summer base camps for permanent occupation sites are just two of the changes which might have occurred as a result of the Wintu intrusion (see Hamusek and Kowta 1991 for more detailed discussion of these issues).

Tuscan Obsidian Procurement Patterns: Some Suggestions and Hypotheses

Many of the ideas outlined above are difficult to evaluate with the current archaeological data base. However, important insights into the organization of hunter-gatherers groups can be gained through an evaluation of resource procurement strategies such as obsidian production systems. As a result of several significant studies which have been conducted since the 1980s, tentative patterns of obsidian procurement and exchange which can be used to address broader issues are beginning to emerge. This section discusses current insights regarding obsidian procurement strategies and is organized geographically into major zones.

Shasta County and Areas North

Sundahl's (1984a; 1985a) analysis of Shasta County sites northeast of Redding in the Squaw Creek drainage led her to suggest that during the earliest periods of occupation, the use of Medicine Lake Highland obsidians predominated, at least for the manufacture of projectile points. However, between 6000 to 2000 B.P., a change in the obsidian procurement pattern occurred in which Tuscan obsidian became the overwhelming medium used for the manufacture of projectile points. By the late prehistoric period, Medicine Lake Highland obsidians, were once again used heavily.

Sundahl (1985a:120-122) suggested that these changes stemmed first from the expansion of a single cultural group possibly the ancestors of the Okwanuchu or Achumawi-Atsugewi southward closer to Tuscan sources during the middle period. She also hypothesized that in the later period, the northward expansion of the Yana may have resulted in a cultural barrier which prevented use of the Tuscan source by groups who had previously drawn upon this source, thus forcing them to procure a greater amount of their obsidian from the Medicine Lake Highlands (Sundahl 1984a:6-7, 1985a:120-122).

The use of Tuscan obsidian in prehistoric Yana sites close to the main source areas was not unexpected given the intimate relationship that prehistoric peoples had with their environment. However, what was surprising to Clewett and Sundahl was the overwhelming preponderance of Tuscan obsidians in Wintu sites along the Sacramento River near and around Redding (1981a), a finding that was at variance with ethnographic accounts gathered by Cora DuBois (1935:25) which relate that the Wintu made expeditions to Glass Mountain to the north to collect obsidian, a location assumed to be Glass Mountain of the Medicine Lake Highlands.

Obsidian geochemical data from sites in the Whiskeytown area west of Redding suggest a pattern similar to that noted by Sundahl at both the Redding and Clikapudi localities. Baker (1984) reported that approximately 60% of the obsidian material was from the Tuscan Formation, with obsidians from the Grasshopper Flat/Lost Iron Wells/Red Switchback (GF/LIW/RS) geochemical group in the Medicine Lake Highlands comprising approximately 35% of the obsidian projectile point and core assemblage. Moreover, there are hints in the sequence which suggest that there was an increase in the amount of GF/LIW/RS obsidian later in time. Baker (1984:91) hypothesized that this apparent parallel in obsidian procurement patterns with those noted by Sundahl at Squaw Creek may correlate with a socio-political barrier at the Pit River which may have restricted procurement of Tuscan materials south of the Pit River.

To the north, within the Sacramento River canyon, the use of Tuscan obsidian remained secondary throughout the occupation sequence (Basgall and Hildebrandt 1989). In the canyon, GF/LIW/RS glass dominated all components. The fact that Tuscan glass representation was insignificant in all phases and at all sites tested as part of the Interstate 5 Highway project suggested to Basgall and Hildebrandt (1989:455) that one of three factors was involved:

> ... 1) that settlement systems were consistently oriented toward the northeast and minimally involved with the rim of the Upper Sacramento Valley; 2) that there was selection for Medicine Lake glass, specialized procurement forays geared to the northeast more than to the Tuscan area; or 3) that formalized trade relationships were better established with groups controlling glass sources situated to the northeast.

Basgall and Hildebrandt (1989:456) hypothesized that given the apparent spatio-temporal constancy in obsidian acquisition patterns throughout the region, obsidian source profiles at the sites they investigated provide little insight regarding changes in exchange and social inter-action. They feel that socially mediated processes had only minimal effect on obsidian dispersion in north-central California, and instead, suggest that changes in the structure of subsistence/settlement systems may have been the paramount determinants (Basgall and Hildebrandt 1989:456).

<u>Tehama County and Areas South</u>

At CA-TEH-290, located in the Southern Cascade Range, Dondero and Johnson (1988:91) note that approximately 60% of the obsidian found in the collection is Kelly Mountain glass, while 40% is Tuscan. The Kelly Mountain geochemical source appears to have been used more extensively earlier in time; however, beginning around 3500 to 2000 years ago, Tuscan obsidian use intensified and continued to dominant the site assemblages throughout the late prehistoric period (Dondero and Johnson 1988:91).

On the Middle and North forks of Cottonwood Creek, south and west of the main Tuscan source areas, it appears that between 3500 to 2000 years ago a high percentage of obsidian projectile points and debitage may have come from the GF/LIW/RS source (Dondero and Johnson 1988). The lone older widestemmed point from CA-TEH-748 and some of the large corner- and side-notched points of Tuscan obsidian indicate that this source was also known and utilized during these earlier time periods.

Beginning around 2000 years ago in the Cottonwood Creek drainage, however, an apparent shift occurred away from a more intensive use of GF/LIW/RS obsidian to one that relied on the locally available Tuscan material (Dondero and Johnson 1988:100). Dondero and Johnson (1988:99) hypothesized that the apparent preference for artifacts from the more distant source of obsidian suggests closer contact with that area, perhaps through populations not being restricted by more rigid boundaries. As the northern Sacramento Valley and surrounding areas became more heavily populated within the last 2000 years, freedom to easily move from one area to another may have become restricted as conflicts arose over competition for available land and resources, thus necessitating the use of more locally available toolstone materials.

Tuscan Obsidian Use Beyond the Sacramento Valley

The use of Tuscan obsidian for flaked stone tool manufacture is a pattern also well-documented in the Trinity River region (Nilsson 1990:91). Gunther Barbed projectile points fashioned from Tuscan obsidian commonly occur within late period site contexts; however, older, non-Gunther Barbed point styles are dominated by GF/LIW/RS obsidian and cryptocrystallines, suggesting perhaps that differential raw material use patterns were in place during the later prehistoric period (Nilsson 1990:91). It has been advanced by some researchers that the use of Tuscan obsidian for the manufacture of Gunther Barbed projectile points, as well as the points themselves, represent the intrusion of the Wintu into the Trinity River drainage system (Sundahl 1985b).

Beyond the Sacramento River Valley, the use of Tuscan obsidian appears to follow Renfrew's (1977) Law of Monotonic Decrement. Renfrew (1977:72) noted that when a commodity such as obsidian is available only at a highly localized source, its distribution in space frequently conforms to a very general pattern. In other words, the frequency of occurrence of a particular material declines with distance from the source (Renfrew 1977:72). This point has been well illustrated in the recent research conducted by Markley and Day (1992) whereby they discovered a correlation between site location and the relative frequencies of different obsidian sources represented in northern Sierra Nevadan archaeological sites. For instance, Tuscan obsidian was present in only minor amounts in one site assemblage in the northernmost portion of the Sierra Nevadan Range and was absent in site assemblages from the central and southern portions of the range. By far the greatest amount of obsidian found in northern Sierra Nevada archaeological assemblages derives from the Bodie Hills source (Markley and Day 1992:178).

Summary

While it is one thing to determine the geographic source area for a commodity, it is quite another matter to infer the social mechanisms which are responsible for the occurrence of that material at an archaeological site. Perhaps Graeme Ward (1977) expressed it best in his paper entitled: "On the Ease of 'Sourcing' Artefacts and the Difficulty of 'Knowing' Prehistory". Determinations of how an 'exotic' material comes to rest in archaeological contexts is much more difficult that determining the source of the material from which it was produced (Ward 1977).

This chapter has reviewed several hypotheses regarding Tuscan obsidian procurement patterns revealed at different sites situated throughout the region. Unfortunately, the obsidian geochemical data obtained from the majority of these sites focused on formed tools such as projectile points and bifacial cores, and geochemical characterization of debitage constituted only a minor percentage of the total number of artifacts subjected to this type of analysis. Recent research has shown that finely crafted bifacial tools can fulfill several different roles in hunter-gatherer technology (Kelly 1988); hence, their presence in archaeological assemblages often indicates items that were heavily curated, thus introducing an additional process to be accounted for in the analysis of cultural change and variation. In contrast to formed tools, debitage is the direct result of tool manufacture and/or core reduction, and the presence of different material types can be more directly linked to production activities such as local raw material procurement (Shackley 1990).

On the other hand, despite this short coming, there appears to be an emerging regional pattern in obsidian use in which during the earliest periods of occupation within the study area there was a dependency on obsidians from the Medicine Lake Highlands, which shifted at some point in time during the later prehistoric periods to an emphasis on the Tuscan obsidians. While Baker (1984) and Sundahl (1985a) both hypothesized that in the late prehistoric period the northward expansion of the Yana resulted in a cultural barrier which prevented procurement of Tuscan obsidians by groups which had previously drawn upon this source, the changes witnessed in obsidian procurement patterns might also be explained in terms of a change in mobility ranges without population replacement due to environmental conditions which forced the use of previously unexploited sources.

Assuming a large procurement range for early hunter-gatherers, it seems likely that most of the obsidian would have been procured directly as part of annual movement of the groups or individuals of the group. In the case of the earliest of these mobile groups, exchange was not likely the most common method used to procure raw material. However, as population levels began to increase within the northern Sacramento Valley and surrounding areas during the late prehistoric period, competition and conflicts for available land and resources likely resulted in more circumscribed procurement ranges. Thus, the use of more locally available toolstone material would have become necessary.

Moreover, the discrepancy which has been noted between DuBois' (1935:25) accounts of Wintu obsidian procurement practices and the picture that is currently emerging from recent obsidian geochemical analyses is not surprising when one considers that early ethnographic observations described a period of time when the aboriginal cultures had already become significantly altered due to white contact. Post-contact ethnographic descriptions give only a distorted account of the actual lifeways of the prehistoric populations which inhabited the region, and prehistoric obsidian procurement ranges reconstructed on the basis of ethnographic accounts can lead to erroneous inferences. In chapter VI these topics will be explored at greater lengths in light of several archaeological site assemblages situated within the study area.

CHAPTER III

TUSCAN FORMATION: GEOLOGICAL, GEOGRAPHICAL AND GEOCHEMICAL DESCRIPTIVE DATA

Introduction

Lahars, also known as volcanic mudflows, are a common feature of many ancient and historically active volcanoes. They are formed when water and coarse-to-finely broken volcanic rock combine as masses of mud that travel downslope under the influence of gravity. As Lydon (1968:443) notes, ordinarily lahars are restricted in areal extent and can be attributed to locally favorable conditions such as the extrusion of lava flows or hot pyroclastic debris during heavy rains or onto masses of ice or snow. However, what are not as readily explainable are the extensive accumulations of laharic and associated deposits such as tuff breccias, which may cover thousands of square miles and span several million years in time.

The research focus of this study is the distribution and utilization of artifact-quality obsidian derived from one such widespread laharic deposit, the Tuscan Formation, which is situated within the southernmost portion of the Cascade Range in California (Figure 3). The following

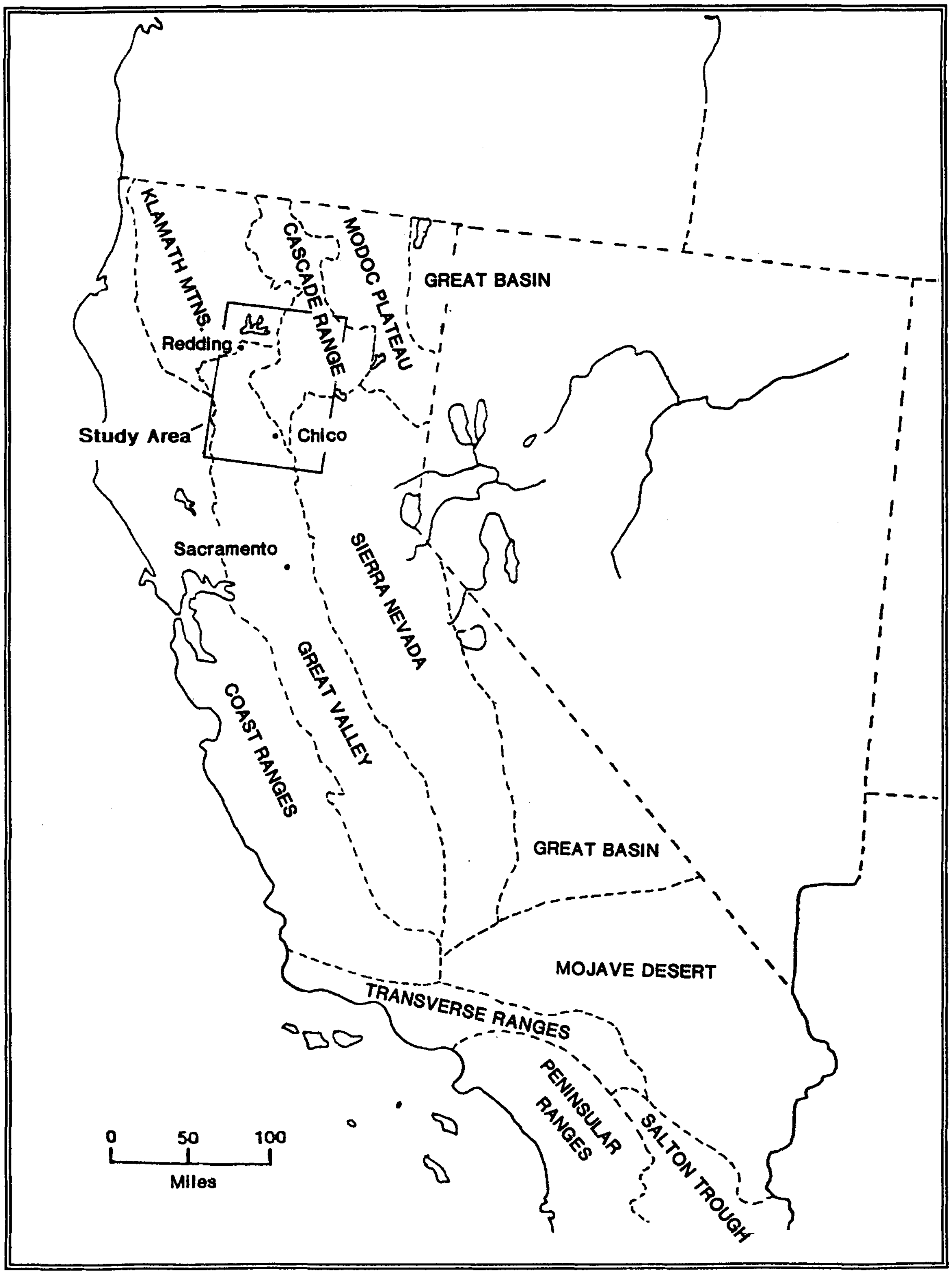

Figure 3. Geological Provinces of California and the Location of the Study Area.

sections of this chapter describe the geological context in which obsidians from the Tuscan Formation occur, describe the known geological occurrences of artifact-quality glass, and discuss the relevance this data to the archaeology of the region.

The northern portion of the Cascade Range in California is very similar in geological structure to that of the Cascade Range throughout much of Oregon. For most of its extent, the Western Cascade Range trends slightly east of north; however, the trend abruptly changes to southeastward at Mount Shasta. Although coeval with that of the High Cascade Range further north, the building of the Cascade Range south of Mount Shasta appears to be associated more closely with the history of the uplift of the Sierra Nevada, than with the history of the northern portion of the Cascade Range (MacDonald 1966).

In the region northwest of Mount Lassen, the basic geology consists of Pliocene Tuscan formations resting directly upon Cretaceous and Eocene sedimentary rocks; Western Cascade volcanics are absent (MacDonald 1966:66). The lower part of the High Cascade sequence in California consists primarily of pyroxene andesite and basalt, with smaller amounts of hornblende andesite, and dacite. Although the original topography of the area has been largely destroyed by erosion, these andesite lavas appear to have built a broad ridge possessing few, if any, large cones. These andesite lavas rest directly on the Tuscan Formation.

Although the Pliocene Tuscan Formation is thought to span a relatively small segment of geologic time, research has revealed that it is discontinuously exposed throughout an area of approximately 2,000 square miles along the east side of the northern Sacramento Valley (Figure 4). Originating largely from a belt of isolated eruptive centers in the southernmost Cascade Range, the Tuscan Formation consists principally of tuff breccias formed by lahars, or volcanic mudflows, in beds ranging from 40 to 100 feet thick. The entire eastern accumulation reaches 1000 feet in thickness (Anderson 1933:223). Erosion of the formation has resulted in the removal of the finer materials, leaving behind a surface concentration of the larger blocks to form the broad stony plains so characteristic of the foothill region east of Red Bluff and Redding.

Following the convention established by Lydon (1968:44), the term "tuff breccia" is used in this study to indicate a type of volcanic rock in which breccia blocks are surrounded by a tuffaceous matrix of fine fragments (less than 4 mm in diameter) that comprises from 25 to 75 percent of the rock by volume. "Lahar", defined as a mudflow or landslide of broken volcanic debris, may contain a subordinate admixture of nonvolcanic material, may be of pyroclastic origin, and may be either wet or dry (Lydon

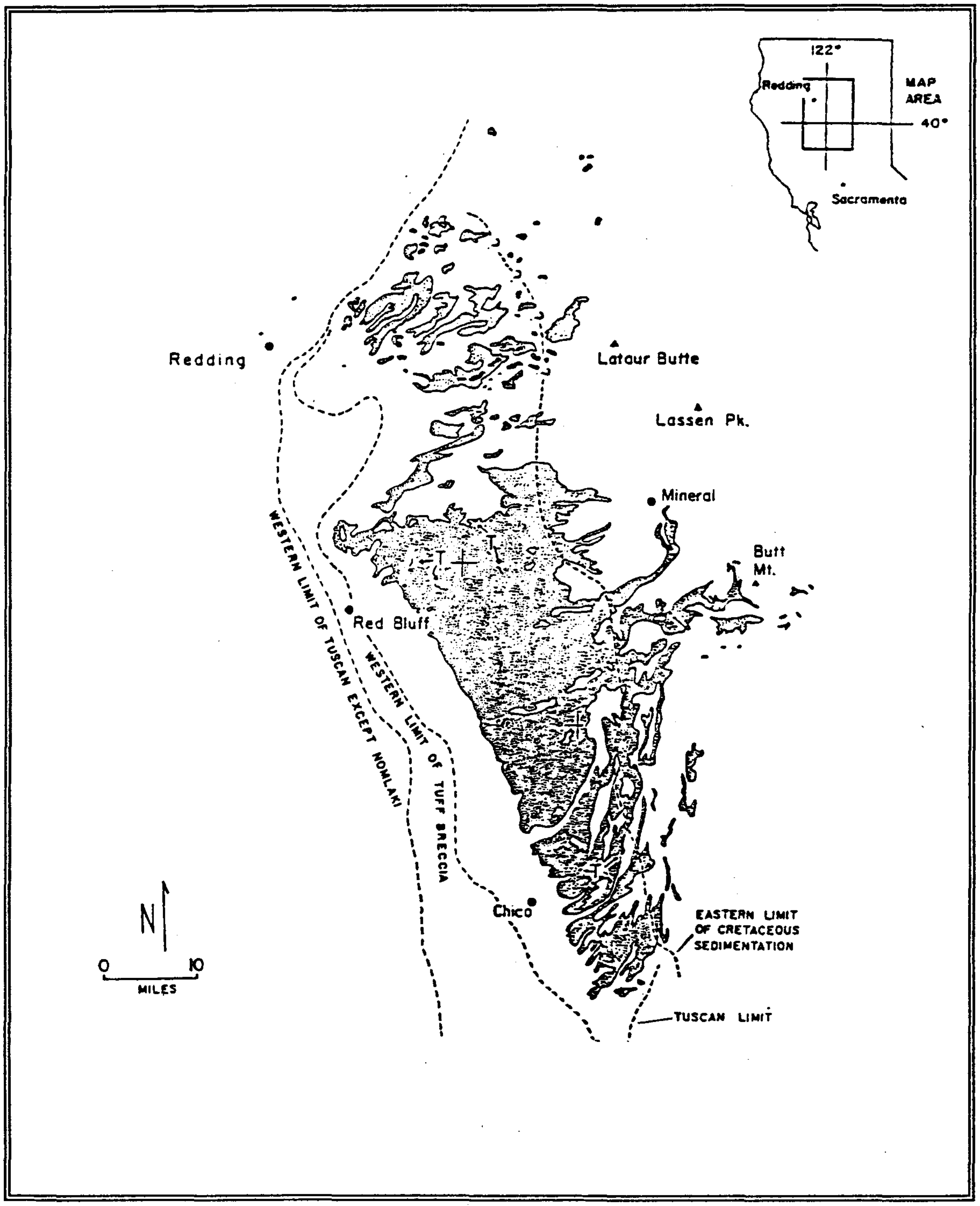

Figure 4. Generalized Distribution of Tuscan Formation.

Source: Lydon, P.A., 1968, Geology and Lahars of the Tuscan Formation, Northern California. Studies in Volcanology, Geological Society of American Memoir 116. Adapted.

1968:44). "Welded tuff" or "ignimbrite" refers to a glass-rich pyroclastic rock that has been indurated by the welding together of its glass shards under the combined action of the heat retained by particles, the weight of overlying material, and hot gases (Bates and Jackson 1984:561).

Previous Literature

Although he ascribed no name to the unit, one of the earliest references to the Tuscan Formation was made by J.D. Whitney in the 1865 report of the Geological Survey of California (1865:205-209). In subsequent publications, J.S Diller provided several extensive descriptions of the unit, referring to it as the "Tuscan formation" (1892, 1894, 1895) or "Tuscan tuff" (1894, 1906). In the years following, there were several studies of note which described the Tuscan Formation as it appeared in specific areas (Bryan 1923; Hamlin 1920; Lawson 1920; Lindgren 1911:84-93; Russell and VanderHoof 1931; Turner 1896:540-542). However, it was C.A. Anderson (1933) who has given the most detailed description of the unit to date, thereby stabilizing the nomenclature as the Tuscan Formation. In recent years, the most work done on the Tuscan Formation has been conducted by Philip Lydon (1961, 1968) and the discussion to follow draws heavily on Lydon's research.

While all of these early workers speculated on the source of origin of the Tuscan Formation, none was to write of it until Anderson and Russell (1939:231) observed that

"... the source of the Tuscan formation must have been old volcanoes in the vicinity of Lassen Peak or farther east". Subsequent work examining the difference in the prevalent rock type among the blocks suggested to Lydon (1961) that there must be different sources for the breccias of the southern and northern areas. Because of these differences in rock type, Lydon (1961:463-466) believes that three major and at least four lesser source areas provided laharic debris to the Tuscan Formation.

Major contributions are thought to have come from two Pliocene composite volcanoes, Mount Yana, which is centered a few miles southwest of Butt Mountain and Lake Almanor, and Mount Maidu, which was centered over what is now the town of Mineral. The laharic deposits of Mount Yana are continuous with those of the main part of the Tuscan Formation and clearly form one of its principal sources (Lydon 1968:463). Although the relationship of the Tuscan Formation to the remnants of Mount Maidu are less clear than in the case of Mount Yana, research has shown that "... at least the earlier phases of activity of Mount Maidu itself must have contributed substantial debris to the Tuscan Formation" (Lydon 1968:465).

Subordinate volumes originating from an area of indefinite structure situated north of Latour Butte constitute another major source for the Tuscan Formation (Lydon 1968). It is in this area that more than 1000 feet of Tuscan Formation deposit consisting chiefly of interbedded flows of andesite, beds of tuff breccia, and welded tuffs is clearly exposed. Unfortunately, the immediate source area of this deposit lies just to the east where it is covered by later volcanic flows, so that nothing can be said of the mechanisms of formation and emplacement (Lydon 1968:465).

Minor sources include an obscure area near Hatchet Mountain Pass, which may turn out to be the most significant source area for this study. Scattered outcrops of andesitic tuff breccia and associated thick accumulations of dacitic ash-flow pumice tuffs, some of which are welded, have been observed here (Lydon 1968:465). As observed at Latour Butte, thick successions of the latest Pliocene and early Pleistocene andesitic flows have obscured the details of the origin of the Tuscan Formation at this locality (Lydon 1968). Of interest to note is the fact that most of the previously reported sources of artifact quality Tuscan obsidian can be found within this region.

Other minor and/or possible sources of the Tuscan Formation include tuff-breccia dikes south and southeast of Inskip Hill along State Highway 36 and possibly the Campbell Mound north of Chico. Although the morphology of the Campbell Mound suggests some sort of dome-like feature, whether it represents upwarping beds above a shallow intrusion, a primary laharic vent, or a source of secondarily mobilized tuff breccia cannot be stated with certainty at the present time (Lydon 1968).

Lithology, Structure and Age

In general form, the Tuscan Formation constitutes a great wedge-shaped mass which tilts and thins southwestward (Lydon 1968:461). Superimposed upon this form are several folds, numerous fractures with small to negligible offsets, and local disruptions that are situated adjacent to post-Tuscan plugs. Dominant among the larger structures is the prominent Chico monocline located at the edge of the Sacramento Valley. This monocline accounts for the relatively straight western contact of the Tuscan outcrops between Chico and Red Bluff (Lydon 1968). Lydon (1968:461) notes that beginning abruptly along a line between Red Bluff and Tuscan Springs and extending north to Bear Creek, the Tuscan structure is dominated by a series of east-northeast trending anticlines and synclines. Known as the Battle Creek Fault, the most conspicuous fault lies at the foot of Shingletown Ridge, close to the North Fork of Battle Creek in Shasta County. Along Mill and South Fork Battle creeks, south and west of the town of Mineral, the upper surface of the Tuscan Formation is relatively flat and appears to lack the magnitude of regional dip found throughout the remainder of the formation.

It appears that the local structures within the Tuscan Formation are the result of forceful emplacement of small basaltic and/or andesitic volcanic plugs which include Tuscan Buttes (Lydon 1967), three plugs along South Fork Antelope Creek about 10 miles southwest of Mineral, and Black Rock and Savercool Place on Mill Creek, approximately 12 miles south-southwest of Mineral (Lydon 1968:462).

The major constituents of the Tuscan Formation include tuff breccia, lapilli, tuff, volcanic conglomerate, volcanic sandstone and siltstone. Subordinate rock types consist of dacitic ash-flow tuff, flow breccia, flows of andesite and/or basalt, and clay (Lydon 1968:451). While volcanic sediments are prominent along the western margin of the unit, geological field surveys have revealed that tuff breccia comprise more than three-quarters of the exposed bulk of the formation.

Except for a few tonguelike extensions situated between Chico and Vina, the dominant subsurface constituents of the Tuscan Formation are generally volcanic sediments. Cross-sections of these extensions indicate that super-imposed narrow, thick tongues of tuff breccia apparently followed preferred paths to their present position (Lydon 1968:451). However, the overlying volcanic sediments commonly have a sheetlike form, which suggests to Lydon (1968:452) that contemporaneous erosion and water transport were not restricted to well-defined channels.

Sedimentary units of the Tuscan Formation are exclusively volcanic in character, consisting predominantly of coarse, massive or lenticular conglomerate and well-bedded coarse sandstone. Thinly laminated claystone and siltstone are also common. Nonvolcanic constituents are prominent in the sediments of some basal portions of the formation and nonmarine diatomaceous rocks are only present in insignificant amounts.

Dacitic or rhyodacitic pumice tuffs are sparingly exposed in the Tuscan Formation south of Battle Creek in the walls or at the bottoms of a few stream canyons (Lydon 1968). However, farther north, between Redding and Latour Butte, a more continuously exposed welded tuff can be found. Although there are exceptions, by far the most widespread tuff in the Tuscan Formation is a grayish, rhyodacitic welded tuff that is exposed between Redding and Latour Butte. The welding in this tuff ranges from attainment of a hard, glassy character in the eastern exposures to simple fusion of adjacent undeformed glass shards in the western part (Lydon 1968:454). Lydon (1968:454) believes that this tuff originates from the large exposure of the Tuscan Formation northwest of Latour Butte.

Flows of basalt and andesite are sparsely distributed among the tuff breccias, and when present, they rarely are more than 100 feet thick. Olivine basalt and pyroxene andesite are the most commonly occurring rock types to be found within the formation. Flow breccias are a very minor constituent of the formation and are generally found near the main source areas such as Mount Yana, Mount Maidu and Latour Butte. Blocks of flow breccias are monolithologic in contrast to those of lahars, which in the same regions tend to be multilithologic (Lydon 1968:455).

As noted by Lydon (1968:455), gray, purplish, or brown andesitic or basaltic tuffs, which contrast with the lighter-colored acidic tuffs, comprise a subordinate, yet ubiquitous, part of the Tuscan Formation. These tuffs, more prominent in the western portion of the formation, represent reworked laharic debris which most likely have been deposited by water (Anderson 1933). The tuffs consist of fine, broken, subangular fragments of volcanic rock and/or of crystals that are derived from such rock.

The most common constituents of the Tuscan Formation are the unsorted and weakly stratified tuff breccias and lapilli tuffs. Clasts, or fragments of rock, in the tuff breccias average between 3 to 6 inches in length, however, many of the clast occur as blocks 3 feet or more in diameter. Although some of the tuff-breccia units contain relatively well-sorted clasts, the typical outcrop exhibits a chaotic mixture of all sizes (Lydon 1968). The breccia blocks and lapilli are primarily subangular in shape; however, some outcrops contain predominately angular to round to sub-round clasts.

The tuff-breccia clasts are variously colored, and most are vesicular in nature. Products of explosive volcanic activity such as bombs are rare, as are fragments of pumice, except for those which occur within the ash-flow tuffs. Porphyritic rock types are dominant among the tuff-breccia clasts (Lydon 1968:457). Phenocrysts of plagioclase, clinopyroxene, hypersthene, olivine, and hornblende in various combinations and proportions normally comprise between 15 and 60 percent of the clasts. Groundmass composed primarily of glass is unusual. Instead, the matrices are typically dominated by plagioclase, with intergranular, trachytic and intersertal textures (Lydon 1968:457).

Chemical analyses of the flow rocks of Mount Yana, which are petrographically identical to clasts that occur in the main portion of the Tuscan Formation, show silica contents of 52 to 60 percent (Lydon 1968:458). Therefore, many of the Tuscan clasts must be classified as andesites and basaltic andesites. Silicic andesites or dacites are uncommon except in portions of the Tuscan Formation north of Battle Creek (Lydon 1968:457).

The emplacement of these thick sequences of tuff breccia most likely do not represent a single enormous episodic mudflow event. Rather, it is more likely that the sequences resulted from the deposition of a number of lahars of nearly identical consistency over a period of less than a million years (Lydon 1968). From sources near the crest of the Cascade Range, it appears that the lahars moved southwestward across a surface of moderate relief, following the existing drainage patterns. Most of the earlier mudflows probably had the shape of long tongues (Crandall 1957) and as the plain of debris submerged the earlier topography, the lahars assumed a lobe-like or sheetlike shape that extended from their points of origins.

Evidence to date indicates that volcanic activity associated with the formation of Tuscan lahars proceeded in point of time from south to north. The late Pliocene age of the Tuscan Formation originally proposed by Russell and VanderHoof (1931) was based on the presence of a Blancan fauna found in the Tehama Formation 10 feet above the Nomlaki Tuff Member near Flournoy, California, and the assumption that the Nomlaki Tuff Member is a basal unit of both the Tuscan and Tehama Formations.

Potassium-argon dates performed on the rhyodacitic tuff at Bear Creek Falls in Shasta County support the late Pliocene age proposed by Russell and VanderHoof (1931). This rhyodacitic tuff, which is underlain by 400 feet and overlain by 200 feet of Tuscan Formation deposit, has been given an age of 3.3 million years (Everden et al. 1964:180). Moreover, an early Pleistocene date of 1.5 million years was obtained from a rhyolite flow that immediately overlies the Tuscan Formation west of Mineral (G.H. Curtis, in Wilson, 1961). Although the 3.3 million year potassium-argon date on the rhyodacitic tuffs from Bear Creek Falls area does not provide a lower age limit for the Tuscan Formation, at the present time, there is no convincing evidence that would suggest that the formation is considerably older than late Pliocene.

"Source X"

For geochemical purposes, an obsidian "source" is defined as a trace element group in close geographical and chemical proximity (Shackley 1986:3). Prior to this study, Hughes (1983:322-324) had located and described four individual exposures of obsidian falling within the geographical confines of the Tuscan Formation within the study area. The names of the chemical types analyzed by Hughes are Backbone Ridge, Cow Creek, Oat Creek, and Buzzard Roost (Figure 5). Within this particular geographic area, Hughes determined that it was possible to recognize similarities in their trace element chemistry which allowed all four exposures to be grouped into one chemical type (Hughes 1983:294). In this fashion obsidian previously ascribed to "Source X" was finally attributed to a specific geological source, the Tuscan Formation.

The following paragraphs summarizes Hughes' (1983) characterization of the formation's exposures. Situated between the Pit River and Little Cow Creek drainages in the easternmost portion of the study area, the Backbone Ridge source is described as an exposure of obsidian nodules which occur in a wide variety of colors. Obsidian nodules that

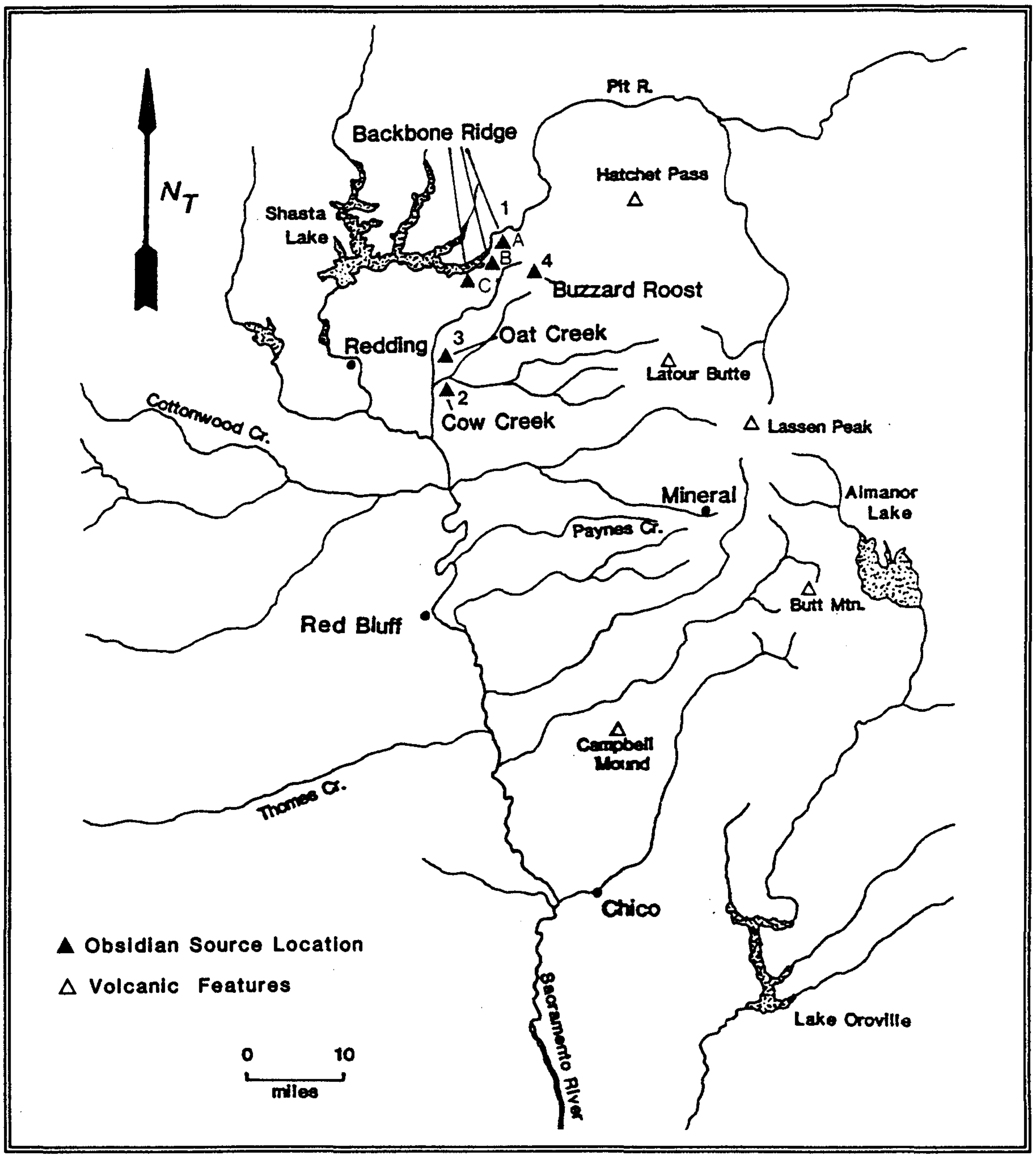

Figure 5. Tuscan Obsidian Source Localities.

Source: Hughes, R.H., 1983, <u>Exploring Diachronic Variability in Obsidian Procurement Patterns in Northeast California and Southcentral Oregon: Geochemical Characterization of Obsidian Sources and Projectile Points in Energy Dispersive X-Ray Fluorescence</u>. Unpublished Ph.D. dissertation, Department of Anthropology, University of California, Davis. Adapted.

are mahogany, red-and-black, gray, and mottled red-and-black with clear patches, can all be found along the Backbone Ridge Road, with some of the nodules approaching 7 lbs. in size (Hughes 1983:322). Hughes (1983:322) also noted that there was ample evidence of prehistoric utilization throughout this region, especially at the Seaman Gulch collection locality (see Figure 5 - 1B).

South of the confluence of Cow and Bear Creeks, obsidian nodules up to 5 cm in diameter were found eroding from the sidewalls of an unnamed tributary to the east of Cow Creek (Hughes 1983:323). Hughes observed nodules in gray, banded and mahogany colors weathering out of the strata exposed in the creek cutbank about 3 to 4 meters below the ground surface. There was no clear evidence of prehistoric reduction of this material.

Hughes' (1983:323) third source of Tuscan obsidian is situated between the Swede Creek Plains and the Millville Plains region east of Redding, California. Eroding into the Oat Creek drainage were dull gray obsidian nodules which measured up to 5 cm in diameter. Unlike the Cow Creek source, the Oat Creek source did show some evidence of prehistoric lithic reduction, albeit in limited amounts.

The fourth Tuscan obsidian source area examined by Hughes (1983:323-324) is the Buzzard Roost source, where obsidian nodules had been exposed during road grading activities. Located approximately 4.8 km southwest of Round

Mountain, nodules up to 10 cm in diameter in a wide variety of colors reminiscent of the range reported at Backbone Ridge were also found exposed in the adjacent stream channels to the south of Philips Road. Although Hughes did not specify which sites he examined, he did note that evidence for prehistoric utilization of this material has been recorded in several nearby archaeological site assemblages.

The trace and rare earth element concentration values for the Tuscan obsidian source group as identified by Hughes (1983:43) are listed below in Table 1.

Table 1: Selected Trace and Rare Earth Elements as Reported by Hughes (1983:43) for the Tuscan Obsidian Source Group.

Elements[1]									
Pb	Th	Rb	Sr	Y	Zr	Nb	Ba	La	Ce
22.3 ±5.3	7.2 ±3.6	95.5 ±6.5	95.2 ±7.5	18.6 ±2.5	66.0 ±5.3	8.0 ±3.3	1295.2 ±51.4	17.1 ±4.4	36.4 ±5.2

[1] All values are in parts per million (ppm). Pb= lead, Th= thorium, Rb= rubidium, Sr= strontium, Y= yttrium, Zr= zirconium, Nb= niobium, Ba= barium, La= lanthanum, Ce= cerium.

Discussion and Summary

Determining the location of the primary source of the obsidian nodules in the Tuscan Formation has some importance for archaeology. The Tuscan Formation occupies an area which encompasses the traditional territories of at least three different ethnographic groups, the Wintu, the Yana, and the Maidu. If these sources of obsidian were controlled by certain prehistoric groups during the later periods, then the location of the source becomes an important determinant in the reconstruction of prehistoric exchange, interaction, territory, or procurement range.

Unfortunately, the nature of the Tuscan Formation creates a special problem for archaeologists who are attempting to analyze the lithic production systems in this region. Research has revealed that the formation consists principally of tuff breccias formed by lahars, or volcanic mudflows. These volatile lahars spread over a large region during the Pliocene and the remnants of this formation today are discontinuously exposed throughout an area of approximately 2,000 square miles along the east side of the northern Sacramento Valley.

Evidence to date indicates that volcanic activity associated with the formation of Tuscan lahars proceeded in point of time from south to north with at least three major and four lesser source areas providing the laharic debris to the Tuscan Formation (Lydon 1961:463-466). Furthermore, it appears that rather than a single enormous episodic mudflow event, a number of lahars of nearly identical consistency were deposited over a period of years. Therefore, it is possible that each of these original lahar source areas might have produced a chemically distinct obsidian source depending upon the location of the volcanic vents and the period of time in which the eruptive event occurred.

The great extent of these flows prevent the possibility of pronounced internal variability so far marked by limited research. Unless such variability can be ruled out, treating Tuscan obsidian as uniform can lead to significant error in the reconstruction of past human uses of the resource. As pointed out by Shackley (1992:324), "It is not enough to discover, describe, and chemically analyze a glass source if the extent of the secondary deposits are not understood within the context of the region".

Although most of the previously reported sources of artifact-quality Tuscan obsidians were found within the northernmost portions of the study area, the depositional processes associated with these lahars indicates that artifact-quality glass may occur throughout the formation. Given the complex and incomplete geological history of the region, it will be difficult to predict where individual outcrops or localities of obsidian will occur, and to interpret how and where one source area relates to another source area. The geochemisty of the obsidians found to occur within the Backbone Ridge region and the Cow and Oat creeks areas will be examined in closer detail in Chapter V.

CHAPTER IV

METHODS OF ANALYSIS

The methods of analysis described in this chapter pertain to the two major phases of this study: the selection and field sampling of geological sources of obsidian raw material and the subsequent petrological and geochemical analyses of obsidian samples from the collection areas. In addition to the analyses of obsidian raw material derived from the Tuscan Formation, geochemical analyses of obsidian specimens from selected archaeological collections within the study area was undertaken in order to apply the results of this study to the theoretical perspectives which guided the research. Specific methods used in these analyses are described below.

Geologic Site Selection and Collection Sampling

As discussed in Chapter II, northern California obsidian studies have a long-standing history compared to other regions of the western United States (Ericson 1977, 1981; Hughes 1983; Jack 1976; Jackson 1974). However, obsidian artifacts derived from the Tuscan Formation have presented a particularly interesting set of problems in that their geological source had not been identified prior to the research conducted by Jack in the 1970s (1976). Subsequent to Jack's (1976) initial study, Hughes' (1983) pioneering research determined that trace element concentration values of the "Source X" obsidian artifacts matched those from obsidian sources found within the Tuscan Formation. In spite of this knowledge, however, there has been no formal attempt to characterize the full geographical extent and geochemical variability of obsidian sources contained within the Tuscan Formation.

Although some obsidian sources in the Tuscan Formation, such as the Backbone Ridge area, are well known to local archaeologists, only summary documentation for these locales exist (Hughes 1983). The surface geology, density, distributional extent, and evidence for human procurement at these locales have yet to be fully assessed. Since it was clear that detailed documentation and additional petrological and geochemical analyses of the artifact-quality obsidian present throughout the Tuscan Formation could provide additional information regarding the Tuscan obsidians, the decision was made to implement a field survey and sampling strategy to gather information relevant to these concerns. This survey was to include the previously known source locales of Tuscan obsidian noted by Hughes (1983) and others (e.g., Al Farber, personal communication 1992; Richard Jenkins, personal communication 1991;

Ritter 1992; Elaine Sundahl, personal communication 1990) as part of this study's sample collection .

The strategy for locating "unknown" sources followed a general pattern based on geological and topographical information. Regional geological maps were initially consulted to ascertain the location of exposed deposits of the Tuscan Formation. Rarely would obsidian be mentioned in association with the Tuscan Formation; however, special attention was given to those areas in which it was previously documented (Helley and Harwood et al. 1985). It was found that the best sources of information for locating obsidian were archaeologists, foresters, and local residents. The newly recorded sources of Paynes Creek, Paradise Ridge and Sugar Pine Camp Ridge were all located with the aid of informants.

After determining the general locality of a source, transects extending out from the central area were examined in order to ascertain the spatial extent of the deposit. Since the Tuscan Formation has been highly eroded in many places, it was often found that nodules from the exposed ridgetops would be released into the sediment load of nearby drainages, in which case an examination of the stream channels proved useful in locating additional source locales. Cow, Oat, Dry and Swede Creeks represent examples of such discoveries.

When a source area was delineated, archaeological, locational and geological information was recorded on a standardized collection form. The information on this form include exact locations down to the 1/16 quarter section, a description of the geological context and geomorphic environment of the find, general extent and density of the primary and any secondary deposits, megascopic attributes of the obsidian nodules (e.g., size, shape, color, opacity, texture, cortical, and internal variations), as well as the nature and character of any prehistoric reduction activity observed.

The terminology used for describing the various megascopic attributes of the obsidian specimens examined is modeled after a classification system developed by Craig Skinner (1992) and can be found in Appendix A. While it was recognized at the onset that some of the attributes included in this analysis may not prove to be discrimating or useful in determining intrasource variability (e.g., color), the decision was made to include all known attributes in order to provide a comprehensive description of obsidian noted at each source locale.

As stated previously, the spatial extent of the primary deposit was determined by examining the ground surface utilizing transects which radiated out from the central area of the find. In order to determine the extent of any possible secondary deposition, the adjacent drainages were examined for evidence of obsidian raw material at periodic intervals downstream from the primary deposit. Density determinations of the raw material at sample locales were made using controlled surface collection of all obsidian raw material within randomly chosen units.

For late analysis samples of raw material were collected from fifteen of the total of twenty-nine obsidian source locales investigated, the results of which are discussed in further detail in Chapter V (Figure 6). The selected sampling locales were chosen so as to represent the range of contexts in which artifact-quality rhyolitic glass were found as a result of the field investigation phase. Special attention was given to primary deposited sources which were geographically dispersed. However, secondary obsidian sources, erosionally-modified obsidian flows, obsidian-like vitrophyre from welded ash-flows and geographically proximate sources were also included within the sampling strategy. At each sampling locale an attempt was made to collect glass samples which expressed the range of physical attributes of the obsidian observed, however, no effort was made to complete a systematic sampling of a given obsidian source locality. A total of 200 obsidian specimens were collected from each of the fifteen source localities.

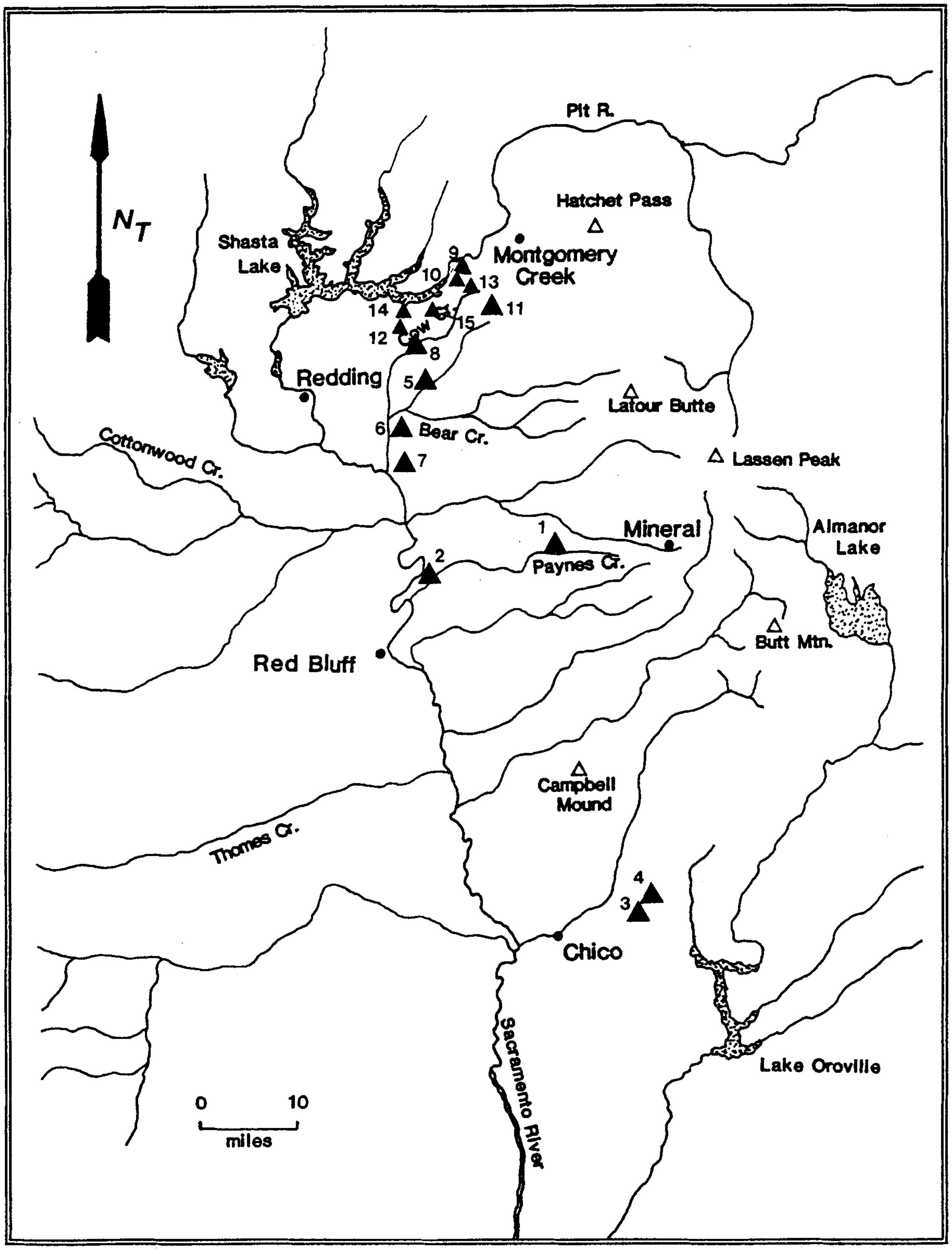

Figure 6. Sampling Locales of Tuscan Obsidian Sources.

X-Ray Fluorescence Analytical Methods

Over the last several decades a number of analytical techniques have been employed to characterize obsidian artifacts. However, the techniques most widely applied today are those which are classified as multi-element measurement techniques, namely x-ray fluorescence (XRF) and instrumental neutron activation analysis (INAA). For the purpose of this study, energy dispersive x-ray fluorescence analysis was chosen since it is relatively inexpensive, requires no special sample preparation, is completely non-destructive, and performs the analysis in a manner of minutes. Additionally, the data generated by this analysis are sufficiently precise to be usable in interlaboratory quantitative comparisons (Hughes 1983:21).

The theory and methodology of energy dispersive x-ray fluorescence spectrometry (EDXRF) and its applicability to archaeological data analyses have been examined by a number of researchers (Goffer 1980; Hampel 1984; Harbottle 1982; Hughes 1983; Jack and Carmichael 1969; Jenkins 1974; Leute 1984; and Macdonald 1980). However, a brief review of the principles of energy dispersive x-ray fluorescence would be in order here.

When an obsidian sample is irradiated with a beam of "primary" or high-energy x-rays, some of the electrons are ejected from the outer shells of the atom, thus moving them into higher energy levels or shells. This action results in an excess of energy within the atom which must be dissipated in some manner. The atom achieves this when the electrons drop back into the shells from which they originated, with the emission of secondary or fluorescent x-rays (Parkes 1987:52). These fluorescent x-rays have energies or wavelengths which are characteristic of the element from which they were emitted. Therefore, by measuring the intensity of the x-rays at different wavelengths it is possible to determine the concentrations of different elements within the sample.

In EDXRF a special detector which converts all the energy carried by the x-rays into electrical signals is used. These signals are fed into electronic integrating circuits so that the corresponding outputs will increase steadily as the exposure to radiation is continued over a period of time (Goffer 1980:47). The electrical signals are then translated into digital values corresponding to storage channels within the memory of the multi-channel analyzer.

The individual analytical lines in the x-ray spectrum are "filtered" or separated and the background and overlapping energy lines from other elements are subtracted prior to extracting peak region intensities for the elements of interest using a data analysis subroutine installed on the present x-ray fluorescence system (see McCarthy and Schamber 1981; Schamber 1977 for technical details). The "filtered" intensity values are ratioed to the appropriate choice of machine settings have been discussed elsewhere in detail and need not be reiterated here (Hughes 1986, 1988b; Shackley 1988, 1990, 1991). Since the same make of instrument (Spectrace) and reduction software were used for this study, the instrument methodology discussed in Hughes (1988b) are equally valid for this research project.

The trace element analyses were performed in the Department of Geology and Geophysics, University of California, Berkeley, using a Spectrace 440 (United Scientific Corporation) energy dispersive x-ray fluorescence spectrometer. The spectrometer is equipped with a Rh x-ray tube, a 50 kV x-ray generator and a Tracor x-ray (Spectrace) TX 6100 x-ray analyzer using an IBM PC based microprocessor and Tracor Super ML data reduction software.

The x-ray tube was operated at 30kV, 0.20mA, using a .127mm Rh primary beam filter in a vacuum path at 250 sec livetime to generate x-ray intensity data for elements Titanium (Ti), Manganese (Mn), Iron (Fe^{+}), Rubidium (Rb), Strontium (Sr), Yttrium (Y), Zirconium (Zr), and Niobium (Nb). A second run was performed on a smaller sample (n=5) in order to generate x-ray intensity data for high-Z and rare earth elements Barium (Ba), Lanthanum (La), Cesium (Cs), Praseodymium (Pr), Neodymium (Nd) and Samarium (Sm). Concentration values were obtained for these elements by irradiating specimens using an Americium (^{241}Am) 100 mCi radioisotope source for 300 seconds live-time in an airpath.

Trace element intensities were converted to concentration estimates by employing a least-squares calibration line established for each element from the analysis of up to 14 international rock standards certified by the U.S. Bureau of Standards, the U.S. Geological Survey, Canadian Centre for Mineral and Energy Technology, and the Centre de Recharches Pétrographiques et Géochimiques in France (Govindaraju 1989).

In order to evaluate the quantitative determinations obtained in this study, comparison with machine data were compared to measurements of known standards. Table 2 lists the standards used to calibrate the machine and a comparison between values recommended for one international rock standard, rhyolite (RGM-1). In order to insure machine calibration, the rock standard RGM-1 was analyzed during each sample run. The results shown in Table 2 indicate that the machine accuracy is quite high.

Table 2. X-Ray Fluorescence Determinations for Selected Minor, Trace and Rare Earth Element Concentrations in USGS Rock Standards Compared with Recommended Values of Govindaraju (1989)[1].

Standard	Ti	Mn	$Fe_2O_3^T$	Rb	Sr	Y	Zr	Nb	Ba
RGM-1 (G)[2]	1601	279	1.86[4]	149	108	25	219	8.9	807
RGM-1 (S)[3]	1455	245	1.98	149	106	25	222	4.9	642
	±155	±167	±.09	±2.3	±3.3	±1.7	±7.3	±6.6	±237

Table 2. Continued.

Standard	Ti	Mn	$Fe_2O_3^T$	Rb	Sr	Y	Zr	Nb	Ba
G-2 (G)	2878	248	2.66	170	478	11	309	12	1882
G-2 (S)	2695	231	2.60	167	477	12	277	12	1673
	±164	±167	±.10	±2.3	±3.7	±1.8	±7.4	±6.5	±268
AGV-1 (G)	6295	713	6.76	67.3	662	20	227	15	1226
AGV-1 (S)	7948	793	6.86	69.9	664	20	218	18	1222
	±184	±167	±.11	±2.2	±4.2	±1.8	±7.5	±6.5	±355
GSP-1 (G)	3897	310	4.29	254	234	26	530	28	1300
GSP-1 (S)	3950	283	3.96	255	234	23	454	22	1423
	±169	±167	±.09	±2.6	±3.5	±1.9	±7.5	±6.5	±292
SY-2 (G)	839	2478	6.31	217	271	128	280	29	460
SY-2 (S)	1040	2168	6.23	173	293	128	270	19	441
	±159	±169	±.09	±2.8	±3.6	±2.1	±7.5	±6.6	±236
BR-N (G)	15587	1549	12.88	47	1320	30	250	98	1050
BR-N (S)	25880	1874	15.02	48	1320	32	251	111	1581
	±267	±169	±.10	±2.3	±5.8	±2.0	±7.7	±6.7	±626
BVHO-1 (G)	16247	1301	12.23	11	403	28	179	19	12.23
BVHO-1 (S)	26616	1458	14.26	9	397	27	165	25	-
	±260	±168	±.10	±2.2	±3.9	±1.9	±7.5	±6.6	
STM-1 (G)	809	1704	5.22	118	700	46	1210	268	560
STM-1 (S)	1021	1530	5.26	116	718	47	1234	263	664
	±159	±168	±.09	±2.3	±4.2	±1.9	±8.1	±6.6	±238
QLM-1 (G)	3741	720	4.35	74	336	24	185	10	1370
QLM-1 (S)	3816	640	4.22	75	337	23	178	12	1305
	±167	±167	±.09	±2.2	±3.6	±1.8	±7.4	±6.5	±286
W-2 (G)	6355	1262	10.74	20	194	24	94	7.9	182
W-2 (S)	9441	1342	12.03	21	196	22	88	8.5	629
	±194	±169	±.10	±2.2	±3.6	±1.9	±7.4	±6.6	±377
BIR-1 (G)	5755	-	11.26	-	108	16	22	2	7.7
BIR-1 (S)	9125	1504	12.98	-	109	19	17	4.7	71.2
	±191	±169	±.10		±3.4	±1.9	±7.9	±6.8	±261
SDC-1 (G)	6055	-	6.9	127	183	40	290	18	630
SDC-1 (S)	7160	880	7.2	125	189	40	291	19	942
	±180	±168	±.09	±2.3	±3.4	±1.8	±7.4	±6.5	±336

Table 2. Continued.

Standard	Ti	Mn	$Fe_2O_3^T$	Rb	Sr	Y	Zr	Nb	Ba
TLM-1 (G)	5036	-	-	63.5	306	22	120	6.6	730
TLM-1 (S)	5977	954	8.0	64.5	298	25	133	7.7	1212
	±179	±168	±.09	±2.2	±3.6	±1.8	±7.4	±6.6	±332
SCO-1 (G)	3765	-	5.14	112	174	26	160	11	570
SCO-1 (S)	4076	429	5.22	115	168	22	163	14	285
	±163	±167	±.90	±2.2	±3.4	±1.8	±7.3	±6.5	±260

[1] - All values are presented in parts per million (ppm) except iron, expressed as total iron ($Fe_2O_3^T$) in weight percent. ± values represent counting and fitting error uncertainty at 250 and 300 seconds livetime.

[2] - Govindaraju 1989 reported values = (G).

[3] - This study reported values = (S).

[4] - Elemental Fe converted to $FE_2O_3^T$ using a 1.4297 multiplier.

Fifteen specimens were blindly selected from each source sample area for analysis. All specimens were first fractured with a rockhammer using bipolar reduction in order to obtain a relatively flat and fresh surface for analysis. The specimens were used whole and were not reduced into pellets or fused disks. Before placing in the EDXRF unit, the specimens were washed in tap water and then rinsed with distilled water and dried. Archaeological specimens were also washed in tap water followed by a distilled water rinse, before being placed dry in the EDXRF unit. Trace and rare earth element data analysis obtained from the source sample specimens are presented and analyzed in the following chapter, while chapter VI provides a discussion of the results of the trace element data obtained from the archaeological specimens.

CHAPTER V

OBSIDIAN SOURCES IN THE TUSCAN FORMATION

Introduction

Over the past ten years obsidian characterization analysis has become an increasingly important tool of archaeological research, and the significance of data obtained from these analyses has not been overlooked by areal researchers. Consequently, nearly every prehistoric archaeological research design currently written devotes a portion of the budget to performing obsidian characterization analyses. However, as noted by Fagan, Skinner and Ainsworth (1989:3), some archaeologists seem to forget that raw material is not evenly distributed over the landscape, that not all sources are equally usable by all technologies, that time and geologic events may change the nature of raw material availability, and that every time a piece of stone is removed from a quarry, extractive costs increase. Thus, in order to truly understand the human behavioral processes behind lithic technology, a thorough knowledge of the "lithic landscape" is necessary.

"Lithic landscape" can be defined as the nature of the distribution, characteristics, and availability of lithic raw materials, particularly those raw materials used to produce flaked stone tools (Fagan, Skinner and Ainsworth 1989:4). Data necessary to understand the lithic landscape of a region includes, but is not limited to the following: the location, spatial distribution and nature of the raw material deposit; the geologic context in which it is found; the accessibility of the raw material to prehistoric flint-knappers; the knapping and use quality of the material; the density or quantity of raw material at the quarry or collection site; the size range, shape, and type of cortex found on the nodules and/or boulders; and the extractive and post-extractive costs (Bamforth 1992; Fagan, Skinner and Ainsworth 1989).

One of the first difficulties which this study encountered was the fact that not all of the natural occurrences of obsidian in the region are known. Because artifact-quality obsidian is not a major concern for geologists, published reports and maps of the Tuscan Formation lack the information necessary to construct a comprehensive and detailed mapping of all potential obsidian outcrops in the area of investigation. Furthermore, since the Tuscan Formation was formed as a result of extensive Pliocene lahars or mudflows, the likelihood was high that artifact-quality glass could be found throughout the entire extent of the Tuscan Formation. Thus, the task fell upon the author to conduct a field inspection of portions of the Tuscan

Formation to ascertain the possibility of the presence of additional "unknown" artifact-quality glass sources. A detailed description of the methods utilized for this portion of the study was presented in Chapter IV and will not be reiterated here.

The discussion that follows presents detailed descriptions of the geological localities that were examined and from which obsidian was obtained for the petrological and geochemical analyses phases of this project. The areas examined were chosen so as to represent the range of contexts in which artifact-quality rhyolitic glass is found. These include primary and secondary obsidian sources, erosionally-modified obsidian flows, geographically proximate and widely-separated sources and obsidian-like vitrophyre from welded ash-flows. The results of this study suggest that artifact-quality glass from the Tuscan Formation is much more widely dispersed and accessible than previously hypothesized. Figure 7 presents the localities which were examined during the field survey portion of this study. Included within this figure are areas in which artifact-quality obsidian was observed as a result of the field investigation as well as those areas which were devoid of artifact-quality obsidian.

The terminology used for describing the various megascopic attributes of the obsidian specimens examined is modeled after a classification system developed by Craig

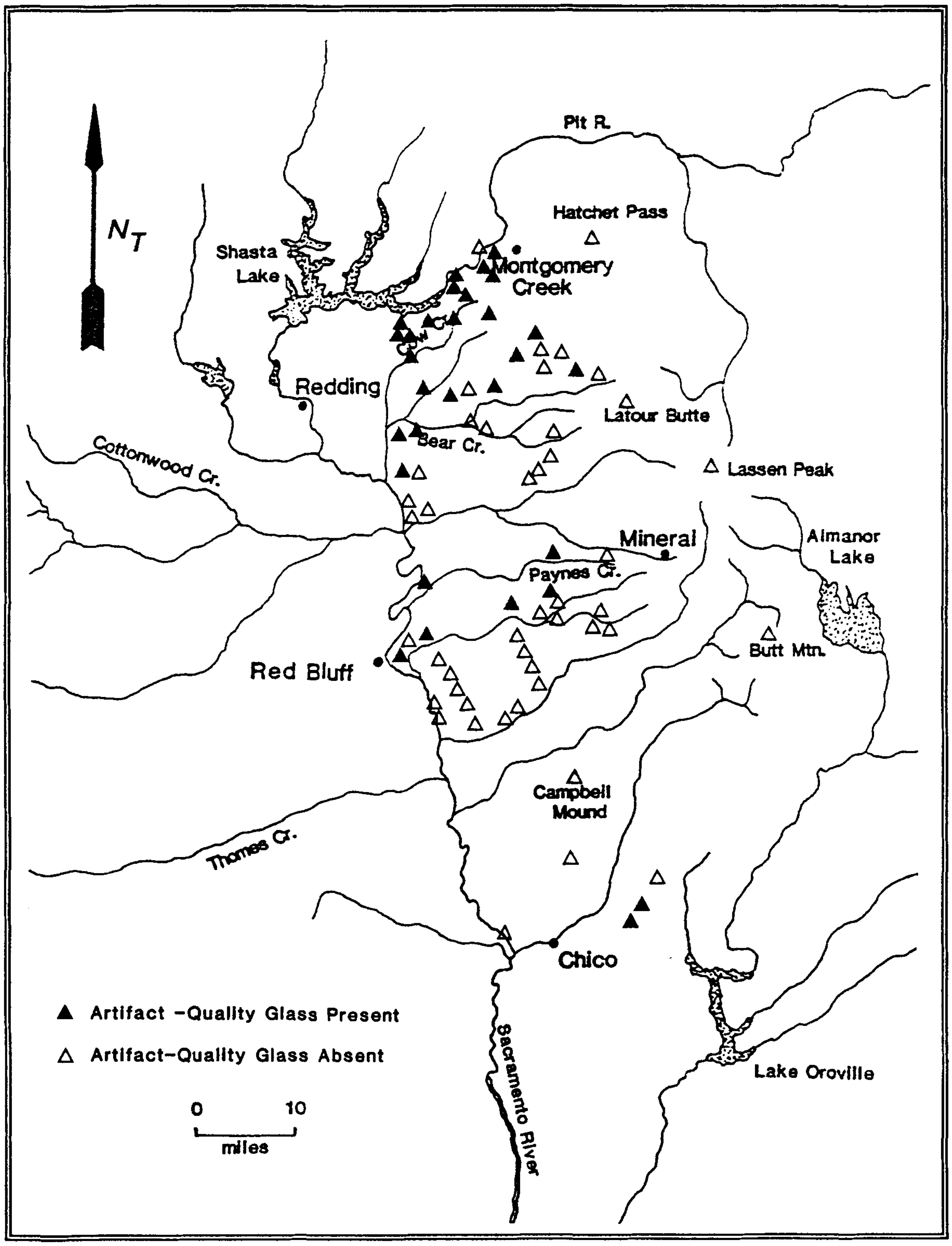

Figure 7. Localities Examined During Field Survey Phase of Study.

Skinner (1992). The results of the megascopic attribute analysis will be summarized for each obsidian source locality from which samples were obtained. Following the description of the obsidian source locales, trace and rare earth element data analyses are presented and analyzed. The chapter concludes with a discussion regarding the knapping and use qualities of the various Tuscan obsidian source materials. The raw data from the petrological and geochemical analyses are included in Appendices A and B.

Tuscan Obsidian Source Sample Localities

Paynes Creek

The Paynes Creek (PYC; see Figure 6 - Locality 1) obsidian source is located within the SW 1\4 of Section 25, T29N, R1W, USGS Finley Butte 7.5′ Quad, eastern Tehama County, California. The location of this source was noted by Richard Jenkins, CDF Region II Archaeologist on a Timber Harvest Plan inspection. This is a low density (2 specimens per 2 m^2), low quality source that is present on the surface of the slopes overlooking the upper Paynes Creek drainage. The obsidian is found within Unit D of the Tuscan Formation and is presently situated on private land. Unit D of the Tuscan Formation is thought to have originated from a major explosive event at its source volcano and consists of directed blasts or avalanche deposits, or both, pyroclastic deposits of andesitic tuff, and lahars derived from the blasts deposits (Helley et al. 1985:16).

The obsidian is highly vitrophyric and is not vitreous. Specimens are opaque and consistently black with a Munsell reading of N2/0. Most of the samples have an earthy or greasy black, hackly or flawed surface texture with megascopically visible phenocrysts. Cortex of all specimens is smooth and highly weathered. The nodules are angular to sub-rounded and spherical to sub-prismoidal in shape. Their average size range is approximately .5 cm to 6.0 cm in diameter with some larger specimens weighing over 275 grams.

While there are no published references for this source location, reduced cobbles and flakes occur fairly frequently in a nearby prehistoric village site which is located on the stream terrace below.

Inks Creek

The Inks Creek (INK; see Figure 6 - Locality 2) obsidian source is located in the SW 1\4 and NW 1/4 of Section 12, T28N, R3W, USGS Bend 7.5′ Quad, of northeastern Tehama County, California. The obsidian source at this locality is very dense (108 specimens per 2 m^2), albeit of low quality. Specimens of various sizes, most of which are within the pebble and cobble range, are present on the surface of the slopes that overlook the lower portions of Paynes Creek drainage. The obsidian is found within the undivided, interbedded lahar deposits of the Tuscan

Formation and is presently situated on Bureau of Land Management (BLM) property.

The obsidian is highly vitrophyric and is not vitreous. Specimens are opaque and consistently black with a Munsell reading of N2/0. The samples exhibit a range in surface luster from an earthy or greasy black to resinous black. Despite this range in surface luster, all specimens examined possess a hackly, and often times flawed, surface texture with megascopically visible phenocrysts. Cortex of all specimens is smooth and highly weathered. The nodules are rounded to sub-angular and spherical to sub-prismoidal in shape. Their average size ranges from .5 cm to 7.0 cm in diameter.

There are no published references for this source location; however, reduced cobbles and flakes occur fairly frequently in the archaeological assemblages of the prehistoric sites located within the surrounding vicinity.

<u>Paradise Ridge 1</u>

> A very interesting geologic anomaly was discovered along the central-west edge of the parcel. This proved to be a location of obsidian needles and small pebbles, probably of the Tuscan Formation. However, no utilized obsidian was discovered, although this may be the general source (incorporating a broader zone of the ridge) of obsidian as yet unidentified from regional sites. (Ritter 1992:2)

The Paradise Ridge 1 (PR1; see Figure 6 - Locality 3) obsidian source is located within the NE 1/4 of Section 27, T22N, R3E, USGS Cherokee 7.5′ Quad. Situated near the town of Paradise in northeastern Butte County, California, this source was discovered by BLM Archaeologist, Eric Ritter, and Patricia Ritter. The obsidian was found along a ridgetop within Unit C of the Tuscan Formation. Unit C consists of several lahar deposits separated from each other by thin layers of volcanic sediments (Helley et al. 1985). Raw obsidian was not observed throughout the entire parcel; however, density estimates average 5 specimens per 2 m^2 in the area of the discovery.

The obsidian specimens are consistently black (N2/0) with dark red (2.5 YR 3/6) to dark reddish brown (2.5 YR 4/6) mottled patches and/or veins. While most of the samples are translucent and have an earthy or chatoyant surface luster, approximately one-third of the specimens are highly vitreous and transparent. Microphenocrysts were present in all but three of the specimens examined. When cortex was observable it was smooth and highly weathered. The nodules are angular and prismoidal in shape and range from 1 cm to 5.0 cm in length. As previously noted by Ritter (1992) reduced cobbles and/or flakes were not observed within the immediate vicinity of the discovery.

Paradise Ridge 2

The Paradise Ridge 2 (PR2; see Figure 6 - Locality 4) source occurs within the NE 1/4 of the NE 1/4 of Section 11 and the SE 1/4 of the SE 1/4 of Section 2, T22N, R3E, USGS Paradise East 7.5' Quad. Although an actual survey has yet to be performed, the obsidian reported upon here was discovered and collected by archaeologist Al Farber and his daughter Sarah when they were residents of the neighborhood. Cortical chunks of obsidian which were thick and irregular in shape, "none of which appeared to be culturally modified" were observed throughout the Paradise Ridge in this vicinity (Al Farber, personal communication 1992).

The obsidian occurs within the geological deposit known as the Olivine Basalt of Paradise (Helley et al. 1985:15). This formation directly adjoins the undivided Tuscan Formation deposit which is situated to the west. Although the maximum thickness of the Olivine Basalt deposit is 25 meters, it is likely that the obsidian noted here originates from exposures of the underlying and/or adjacent Tuscan Formation deposits. Unfortunately, the density of obsidian occurring at this source locality is presently unknown.

The majority of the obsidian specimens are consistently black (N2/0) with distinct reddish brown bands (5YR 4/4). The remaining specimens appear uniformly black, with some reddish brown, indistinct banding, mottling and veining also occurring. While most of the samples are translucent and have a chatoyant or earthy surface luster, approximately one-third of the specimens are highly vitreous and transparent. Microphenocrysts are present in all but three of the specimens examined. When cortex is observable, it is usually smooth and highly weathered; however, crenulated cortex was noted in two of the specimens examined. The nodules are angular to sub-angular and prismoidal to sub-prismodial in shape. They range from 1.7 cm to 5.7 cm in length, and some specimens weigh nearly 18 grams.

As previously noted by Farber (personal communication, 1992) none of the obsidian noted in this source locale appear to have been "culturally modified". However, given the vitreous nature and size of the nodules in this locale, it is likely that the Paradise Ridge obsidians were ex-ploited by prehistoric flintknappers.

Oat/Swede Creek

The Oat/Swede Creek (OSC; see Figure 6 - Locality 5) obsidian source incorporates the area originally designated by Hughes as the Oat Creek source (1983:323). The source locality described here is situated between the Swede Creek and the Millville Plains region east of Redding, California. It is located within the NE 1/4 of Section 26 and SE 1/4 of Section 23, T32N, R3W, USGS Palo Cedro 7.5′ Quad. The Swede Creek extension of this source area was discovered during an archaeological reconnaissance for a proposed firing range facility (Vaughan and McGann 1990). At that time, natural obsidian nodules were observed within the intermittent stream channels and eroding out of a mudflow layer which was exposed along the stream channel below the ridgetop's rim.

The obsidian nodules occur within the main deposit of the Tuscan Formation, which consists of interbedded lahars, volcanic conglomerates, volcanic sandstone, siltstone and pumiceous tuffs. Although obsidian pebbles and cobbles can be found in low frequencies along the ridgetops throughout this area, the main deposits of obsidian occur within the lahar layers located immediately below the ridgetops. Obsidian pebbles, cobbles and boulders are densely scattered throughout this lahar deposit, approaching 100 specimens per $5m^2$ area.

The majority of the obsidian specimens are dark grey (N3/0) to medium dark grey (N4/0) in color with small amounts of black (N2/0) and grey (N5/0) colored nodules also present. Approximately two-thirds of the specimens examined are of a uniform color texture. However, two specimens exhibit distinct banding and three specimens possess veined color textures. While most of the samples are translucent and have an earthy or greasy surface luster, approximately one-third of the sample examined is opaque. Microphenocrysts are present in all but three of the specimens examined. Cortex is consistently crenulated indicating that the obsidian from this source had been fluvially transported. The nodules are rounded to sub-rounded and sub-discoidal to spherical in shape. They range from .3 cm to 10 cm in length with some of the larger specimens weighing nearly 100 grams.

As noted by Hughes for the Oat Creek drainage (1983: 323), prehistoric lithic reduction in the form of reduced cobbles and flakes was noted along the adjacent ridgetops. However, specific lithic workshops associated with this source locality were not observed during the field investigation of this study.

Cow Creek Tributary

The Cow Creek Tributary (CCT; see Figure 6 - Locality 6) obsidian source comprises the area originally designated by Hughes as the Cow Creek collection location (1983:323). The source locality described here is situated south and east of the confluence of Little Cow and Cow Creeks on the Millville Plains, east of Redding, California. It is located within the SE 1/4 of Section 17 and SE 1/4 of SW 1/4 of Section 16, T31N, R3W, USGS Palo Cedro 7.5′ Quad.

The obsidian nodules occur within the main deposit of the Tuscan Formation, which consists of interbedded lahars, volcanic conglomerates, volcanic sandstone, siltstone and pumiceous tuffs. While obsidian pebbles and cobbles can be found in low frequencies scattered throughout the ridgetops to the east of this area, the main deposits of obsidian nodules occur within the lahar layers exposed by stream channel erosion. These lahars are located approximately 3 to 4 meters below the ridgetops and are easily accessible. Obsidian pebbles and cobbles are scattered throughout this lahar deposit, although in limited densities (3 specimens per $1m^2$). Secondary deposition of the obsidian from this locale can be found a kilometer to the west toward Cow Creek drainage.

The majority of the obsidian specimens from this source locale are black (N2/0) to grayish black (N2.5/0) in color with approximately one-third of the specimens in the dark grey (N3/0) to medium dark grey (N4/0) color range. A similar range of color texture was noted within this source sample with veining, indistinct banding, uniform color and distinct banding all being noted. The majority of the samples examined are translucent. However, approximately one-third of the remaining sample is opaque. Although two-thirds of the examined specimens exhibit a greasy surface luster, the remaining specimens were vitreous or occasionally, resinous. Microphenocrysts are present in all but one-third of the specimens examined. However, the surface texture of almost all of the specimens is consistently smooth. Cortex is consistently crenulated, revealing that the obsidian from this source had been fluvially transported. The nodules are well-rounded to rounded and sub-discoidal to spherical to sub-prismoidal in shape. They range from .5 cm to 8.2 cm in length with some of the larger specimens weighing nearly 175 grams.

According to Hughes (1983:323), prehistoric lithic reduction in the form of reduced cobbles and flakes was not observed within the immediate area.

Dry Creek

Situated between the Cow Creek and Bear Creek drainages, the Dry Creek (DCT; see Figure 6 - Locality 7) source is located within the NW 1/4 of Section 10 and SE 1/4 of Section 4, T30N, R3W, USGS Balls Ferry 7.5' Quad. Near the area known as Twin Bridges, east of Redding on the southern portion of the Millville Plains, obsidian cobbles were observed within the stream gravels of Dry Creek. Further examination of this area revealed the presence of a grayish-white pumiceous ash and mud layer which was exposed by stream channel erosion. This ash and mud layer was situated approximately 3 to 4 meters underneath the Riverbank Formation, and it contained high densities (75 specimens per $5m^2$) of obsidian pebbles and cobbles scattered throughout.

This source locale is located at the edge of the undivided Tuscan Formation and the upper member of the Riverbank Formation. It is likely that the Tuscan Formation extended further to the east and south in this area at one time and was overlain by an alluvial deposit known as the Riverbank Formation sometime during the Pleistocene. However, it is evident from the minimal amount of erosion that has occurred within the stream channel, that this source locale is not a recent origin and would have been accessible to prehistoric flintknappers. Secondary deposition of the obsidian from this locale can be found approximately one-half kilometer to the south toward Bear Creek drainage, and it is likely that nodules could be fluvially transported to the Sacramento River drainage during times of high waters.

The majority of the obsidian specimens from this source locale are dark grey (N3/0) in color with the remaining specimens in the grey (N5/0) to medium dark grey (N4/0) and black (N2/0) color range. Color texture in this source group varies between veined and uniform, except for one specimen which possesses distinct bands. The majority of the samples examined are translucent. Approximately one-third of the sample is opaque. Although two-thirds of the examined specimens exhibit a greasy or earthy surface luster, the remaining specimens are highly vitreous. Micro-phenocrysts are present in less than two-thirds of the specimens examined, with the remaining specimens being free from inclusions. One of the specimens examined possessed bubbles which are visible without the aid of a microscope. The surface texture of almost all of the specimens examined is matte-like with the remaining specimens having a smooth surface. Of interest was the observation that cortex is overwhelmingly smooth with crenulated cortex being found on only three out of the fifteen specimens examined. The presence of smooth cortex on the specimens suggests that this locale is a primary deposition area with only minor amounts of secondary deposition occurring as erosion takes place. The nodules range in shape from rounded to sub-angular and from discoidal to sub-prismoidal. They range in size from .3 cm to 4.6 cm in length with some of the larger specimens weighing approximately 34 grams.

Unlike most of the other source areas examined in this region, prehistoric lithic reduction in the form of reduced cobbles and flakes were noted at this locale. Also noted near the exposed cutbank on a gravel bar were one end-battered hammerstone/pestle fragment, a basalt scraper and a greenstone chopper. Of interest to note, the presence of end-battered groundstone artifacts such as manos, hammer-stones and pestle fragments were frequently observed at several of the various collection locales. The presence of these artifacts suggest that raw obsidian material was extracted at these locales prehistorically.

Woodman Hill

The Woodman Hill (WHR; see Figure 6 - Locality 8) source area is located within the NE 1/4 and NW 1/4 of Section 29, T33N, R2W, USGS Millville 15' Quad, Shasta County, California. The obsidian nodules occur within the main deposit of the Tuscan Formation which here consists of interbedded lahars, volcanic conglomerates, volcanic sand-stone, siltstone and pumiceous tuffs. Obsidian pebbles and cobbles can be found in low to moderate densities (10 to 56 specimens per $2m^2$) scattered throughout the ridgetops in this area.

The majority of the obsidian specimens from this source locale are dark grey (N3/0) to grayish black (N2.5/0) in color with the remaining specimens being black (N2/0) or medium dark grey (N4/0). One specimen is black with dark red (10R 3/6) mottled patches. A similar range of color texture was noted within this source sample with veining, indistinct banding, uniform color and distinct banding all being observed. The majority of the samples examined are translucent; however, approximately one-third of the sample is opaque, and a few are transparent. Although two-thirds of the examined specimens exhibit a greasy or earthy surface luster, the remaining specimens are highly vitreous. Micro-phenocrysts were present in approximately two-thirds of the specimens examined with the remaining one-third having no inclusions. Only one specimen examined from this source group possessed megascopic phenocrysts. The surface texture of the specimens examined varied from matte-like to hackly with a few of the specimens being smooth in texture. Cortex was smooth in most cases with only two specimens exhibiting a crenulated surface. The nodules range from well-rounded to sub-rounded and sub-discoidal to sub-prismoidal in shape. Almost all of the obsidian is in the pebble size range, measuring from .2 cm to 3.6 cm in length and weighing approximately 10 grams.

Prehistoric lithic reduction in the form of reduced cobbles and flakes was observed within the immediate vicinity of the source locale. Also noted were one medium sized obsidian corner-notched projectile point and one cryptocrystalline scraper.

Forest Camp

The Forest Camp Ridge (FCR; see Figure 6 - Locality 9) obsidian source incorporates the area originally designated by Hughes as one of the Backbone Ridge collection locations (1983:322). The source locality described here is the northernmost area from which samples were collected and is situated east of Redding, California, on Shasta Trinity National Forest lands. It is located within the NE 1/4 of NW 1/4 of SE 1/4 of Section 15, T34N, R2W, USGS Bollibokka Mtn. 15′ Quad.

Detailed geologic mapping has yet to be conducted on this portion of this forest, and the obsidian nodules appear to occur within what is known as the Triassic Marine deposit. However, based upon the density (300+ specimens per $1m^2$) of cobbles and pebbles containing primary cortex observed at this source locale, it is likely that a portion of the Tuscan Formation extends as far north as the Pit River drainage along the ridgetops in this region.

The obsidian specimens from this source locale exhibit a wide range of colors with black (N2/0), dark-grayish black (N2.5/0), dark grey (N3/0), medium dark-grey (N4/0) and grey (N5/0) all being noted. A similar range of color texture was noted within this source sample with veining, indistinct banding, uniform color and distinct banding all being observed. The majority of the samples examined are translucent. However, approximately one-third of the remaining sample is either opaque or transparent. More than one-third of the specimens are highly vitreous. The remaining specimens were earthy or greasy in surface luster. Microphenocrysts and/or megascopic phenocrysts were present in virtually all of the specimens examined. However, the surface texture of most of these specimens was smooth. The smooth cortical surface of all specimens examined indicate that the obsidian from this source represents a primary deposit. The nodules range from rounded to angular and sub-discoidal to sub-prismoidal in shape, with the majority of the specimens being sub-angular. They range from 1.2 cm to 5.8 cm in length with some of the larger specimens weighing nearly 100 grams. Although no evidence of prehistoric lithic reduction was observed at this source locale, its possibility can not be summarily dismissed.

Sugar Pine Ridge

The Sugar Pine Ridge (SPR; see Figure 6 - Locality 10) obsidian source locale was discovered by James Chapin, a private forester, during a timber harvest operation. Although obsidian pebbles, cobbles and boulders can be found scattered throughout the ridgetops in this area, the main deposit of this source area is located within the NE 1/4 and NW 1/4 of Section 27, T34N, R2W, USGS Bollibokka Mtn. 15' Quad. As with the Forest Camp Ridge locality, detailed geological mapping has yet to be conducted of this region. However, available information suggests that geologically this area is composed of Pliocene volcanics and pyroclastic rocks. Based upon the density (165 specimens per $2m^2$) of pebbles, cobbles and boulders containing smooth cortex, it is likely that this source area represents a primary geologic deposit associated with an unmapped portion of the Tuscan Formation. It appears that the Tuscan Formation extends north to the Pit River drainage in this region.

The obsidian specimens from this source locale exhibit a wide range of colors with black (N2/0), dark-grayish black (N2.5/0), dark grey (N3/0), medium dark-grey (N4/0) and grey (N5/0) all being noted. A similar range of color texture observed within this source sample with veining, indistinct banding, uniform color and distinct banding all present. While the majority of the samples examined are translucent, approximately one-third of the remaining sample is either opaque or transparent. Two-thirds of the specimens from this locale are highly vitreous with the remaining one-third of the specimens exhibiting an earthy or greasy surface luster. The surface texture includes smooth, flawed and matte surfaces. Microphenocrysts and/or megascopic phenocrysts were present in virtually all of the specimens examined and the presence of bubbles was noted in one specimen. As noted earlier, the cortical surface of all specimens examined was smooth, indicating that the obsidian from this source represents primary deposition. The nodules range from rounded to sub-angular and sub-discoidal to sub-prismoidal in shape. The specimens collected range in size from .4 cm to 4.3 cm in length. However, obsidian boulders up to 17 cm in length were noted but not collected during the original inspection.

Evidence of prehistoric lithic reduction was observed at this source locale in the form of reduced cobbles and flakes.

Philips Road

The Philips Road (PHR; see Figure 6 - Locality 11) obsidian source incorporates the area originally designated by Hughes as the Buzzard Roost collection location (1983:323-324). The source locality described here is situated east of Redding, California, south of the community of Round Mountain and is located within the NE 1/4 of NW 1/4 and NW 1/4 of NE 1/4 of Section 3, T33N, R1W, USGS Montgomery Creek 15' Quad.

Detailed geologic mapping has yet to be conducted of this region. However, the obsidian nodules appear to occur within what is known as a Pliocene andesite deposit. The thick sequence of andesite lava flows with minor interbedded tuff and tuff breccias was mapped in this region prior to field checks based upon adjacent sequences found further south (Helley et al. 1985:15). This source area represents a low density locality (3 to 5 specimens per $50m^2$) comprised primarily of cobbles, boulders and pebbles which contain a mix of smooth and crenulated cortical surfaces.

The obsidian specimens from this source locale exhibit a wide range of colors with black (N2/0), black with dark red mottled patches (N2/0 and 10R 3/6), dark grey (N3/0), medium dark-grey (N4/0) and grey (N5/0) all being noted. A similar range of color texture was observed within this source sample with mottling, veining, indistinct banding, uniform color and distinct banding all being noticed. The majority of the samples examined are translucent. However, approximately one-third of the remaining sample is either opaque or transparent. Approximately two-thirds of the specimens are highly vitreous, and the remaining specimens are either earthy or greasy in surface luster. Microphenocrysts and/or megascopic phenocrysts were present in approximately two-thirds of the specimens examined; one-third of the specimens were free from inclusions. The surface texture of the specimens ranged from smooth to flawed and matte-like. The nodules range from well-rounded to angular and discoidal to prismoidal in shape. They range from .5 cm to 8.2 cm in length with some of the larger specimens weighing nearly 225 grams.

As earlier observed by Hughes (1983:324), there is evidence of prehistoric lithic reduction at this source locale in the form of reduced cobbles and flakes.

Backbone Ridge-Seaman Gulch 1

The Backbone Ridge - Seaman Gulch 1 (BR1; see Figure 6 - Locality 12) obsidian source is one which Hughes included in his original investigation as the Seaman Gulch collection area (1983:322). This source area extends over a fairly large ridgetop that is located to the west of Seaman Gulch. Samples were collected from the S1/2 of NW 1/4 of SW 1/4 and NW 1/4 of SW 1/4 of SW 1/4 of Section 8, T33N, R2W, USGS Millville 15' Quad. Because this locality incorporates such a large expanse of land, a second collection sample was obtained from the general vicinity and is described below as Backbone Ridge - Seaman Gulch 2 (BR3).

As noted for the other source locales within this area, detailed geologic mapping has yet to be performed within this region. However, the obsidian nodules appear to occur within what is known as a Pliocene volcanic deposit that contains pyroclastic rocks. This source locality is a low density (8 specimens per $50m^2$) one, with cobbles and pebbles containing a mix of smooth and crenulated cortex.

The obsidian specimens from this source locale exhibit a wide range of colors with the majority of the specimens appearing as black (N2/0) with dark red mottled patches (10R 3/6). Dark grey (N3/0) and medium dark-grey (N4/0) specimens are also present in this sample. A similar range of color textures was noted within this source sample with mottling being the dominant texture. Veining, indistinct banding, uniform color and distinct banding are also present in the samples, albeit in smaller amounts. The majority of the sample examined is opaque, however, approximately one-third is transparent and a few are translucent. More than one-third of the specimens are highly vitreous and the remaining specimens are either earthy or greasy in surface luster. Microphenocrysts and/or megascopic phenocrysts were present in approximately two-thirds of the specimens examined. However, a few of the specimens were free from inclusions. The surface texture of the specimens ranged from smooth to flawed and matte-like. The nodules range from well-rounded to sub-angular and discoidal to sub-prismoidal in shape with the majority being rounded and sub-discoidal. They range in size from .5 cm to over 10 cm in length with some of the larger specimens weighing nearly 150 grams. Although Hughes noted that some of the obsidian boulders within this locality weighed as much as 7 lbs, specimens approaching this size were not observed.

Prehistoric lithic reduction in the form of reduced cobbles and flakes were noted by Hughes and are common throughout the immediate and general vicinity of the source area.

Backbone Ridge - Section 26

The Backbone Ridge - Section 26 (BR2; see Figure 6 - Locality 13) obsidian source is one which Hughes included in his original investigation as the Backbone Ridge Road collection location (1983:322). The Section 26 source locality is situated along Backbone Ridge Road near McCandless Gulch and extends approximately one kilometer in distance to the east. It is located within the NW 1/4 of SE 1/4 and N1/2 of SW 1/4 of Section 26, T34N, R2W, USGS Bollibokka Mtn. 15′ Quad. The obsidian nodules appear to occur within what is known as a Pliocene volcanic deposit with pyroclastic rocks. This source area is moderately dense (35 specimens per $2m^2$) with cobbles and pebbles containing a mix of smooth and crenulated cortical surfaces.

The obsidian specimens from this source locale range from grayish-black (N2.5/0) to dark grey (N3/0) and medium dark-grey (N4/0) in color. A few grey (N4/0 to N6/0) specimens are also present in this sample. The majority of the specimens exhibit distinct banding; however, veining, indistinct banding, uniform color and mottling are also present in the sample. While the majority of the samples examined are opaque, approximately one-third of the remaining sample is translucent and/or transparent. Unlike specimens from some of the other source locales, only a few specimens were vitreous. The bulk of the specimens are either earthy or greasy in surface luster. Microphenocrysts and/or megascopic phenocrysts were present in approximately two-thirds of the specimens examined, however, one-third are free from inclusions. The surface texture of the specimens ranged from smooth to flawed and matte-like. The nodules range from rounded to sub-angular and discoidal to sub-prismoidal in shape with the majority being rounded. They range in size from .5 cm to 3.8 cm in length with some of the larger specimens weighing approximately 30 grams.

Evidence of prehistoric lithic reduction was observed at this source locale in the form of many reduced cobbles and flakes, some of which were of cryptocrystalline materials.

Backbone Ridge-Seaman Gulch 2

The Backbone Ridge - Seaman Gulch 2 (BR3; see Figure 6 - Locality 14) obsidian source incorporates an area expanded from that which Hughes included in his original investigation. The location of this source area is within the NW 1/4 of NW 1/4 of Section 8, T33N, R2W, USGS Millville 15′ Quad. As noted for the other source locales within this area, the obsidian nodules appear to occur within what is known as a Pliocene volcanic deposit with pyroclastic rocks. This source area exhibits a slightly more dense distribution of nodules (15 specimens per $50m^2$) than BR1; however, unlike BR1 the cobbles and pebbles observed at this locale possess a cortical surface which is smooth. Crenulated cortex is only rarely encountered.

The obsidian specimens from this source locale range from primarily black (N2/0) to grayish-black (N2.5/0) and dark grey (N3/0) in color. A few black with dark red veined (N2/0 10R 3/4) specimens are also present in this sample.

The specimens exhibit a range of color textures with distinct banding, veining, and uniform color being present throughout the sample in approximately equal proportions. The surface luster is similarly varied with highly vitreous, resinous, chatoyant, earthy and greasy lusters all being observed. The majority of the samples examined are translucent; however, approximately one-third of the remaining sample is opaque and a few are transparent. Microphenocrysts were present in more than two-thirds of the specimens examined. However, three of the specimens were free from inclusions and one exhibited megascopic phenocrysts. The surface texture of the specimens ranged from smooth to matte-like or grainy. The nodules range from well-rounded to sub-angular and sub-discoidal to prismoidal in shape. They range in size from .3 cm to 6.8 cm in length with some of the larger specimens weighing approximately 170 grams.

Prehistoric lithic reduction in the form of reduced cobbles and flakes were noted by Hughes and are common throughout the immediate and general vicinity of the source area.

Backbone Ridge-Quarry Workshop

The Backbone Ridge - Quarry Workshop (BR4; see Figure 6 - Locality 15) obsidian source is located within a larger area originally designated by Hughes as the Backbone Ridge collection location (1983:322). During Hughes' original investigation into the Tuscan source, he noted three distinct source locales in which obsidian was present along Backbone Ridge in eastern Shasta County. The present study has examined all three of Hughes' original collection locales in this region, as well as one additional source location which is described here as the Quarry Workshop.

The Backbone Ridge - Quarry Workshop source locality is situated near the Sugar Pine Canyon Conservation Camp within the NW 1/4 of SE 1/4 of Section 4, T33N, R2W, USGS Millville 15' Quad. Detailed geologic mapping has yet to be conducted of this region, and the obsidian nodules appear to occur within what is known as a Pliocene volcanic deposit with pyroclastic rocks. This source area represents a low density one (3 to 5 specimens per $50m^2$) of cobbles, boulders and pebbles possessing smooth cortical surfaces. Although the overall density of obsidian cobbles and boulders is low at this source location, it should be stated that a prehistoric lithic reduction workshop, recorded as CA-SHA-1740, is situated within the collection locality boundaries.

Obsidian specimens from this source locale range from black (N2/0) to grayish-black (N2.5/0) and dark grey (N3/0) in color. A few black with dark red veined (N2/0 10R 3/6) specimens are also present in this sample. The specimens exhibit a range of color textures with distinct banding being the predominant form. Indistinct banding, veining, and uniform color are present throughout the remaining sample in approximately equal proportions. Most of the specimens are highly vitreous, however approximately one-third possess either earthy or greasy surface lusters. The majority of the samples examined are translucent. However, approximately one-third of the sample is opaque. Microphenocrysts and/or megascopic phenocrysts were present in more than two-thirds of the specimens inspected, however, three of the specimens were free from inclusions. The surface texture of the specimens was predominantly smooth. However some were flawed and/or matte-like or grainy. The nodules range from well-rounded to sub-angular and sub-discoidal to sub-prismoidal in shape. They range in size from .5 cm to 7.4 cm in length with some of the larger specimens weighing close to 200 grams.

As stated earlier, evidence of prehistoric lithic reduction was observed at this source locale in the form of many reduced cobbles and flakes. This site was formally recorded as a prehistoric lithic reduction workshop by Elaine Sundahl in 1986.

Geochemical Source Data

As discussed in Chapter IV, the trace and rare earth element analyses of the obsidian specimens were performed in the Department of Geology and Geophysics, University of California, Berkeley, using a Spectrace 440 (United Scientific Corporation) energy dispersive x-ray fluorescence spectrometer. Fifteen specimens were blindly selected from each source sample locality for EDXRF analysis. All specimens were first fractured with a rockhammer using bipolar reduction in order to obtain a relatively flat and fresh surface. Care was taken to remove all cortex from the surface to be analyzed. The specimens were analyzed whole and were not reduced into pellets or fused disks. Before placing them in the EDXRF unit, the specimens were initially washed in tap water and then rinsed with distilled water and air-dried. No other special preparation techniques were performed on the specimens to be analyzed.

Table 3 presents the selected minor, trace and rare earth element measurements determined for obsidian samples from each sampling locus. Minor, trace and rare earth element data exhibited in Table 3 are reported in parts per million (ppm), a quantitative measure by weight. The raw measurements for this data reduction can be found in Appendix B.

Since quantitative values for the element barium (Ba) have proven extremely useful for distinguishing between some chemically similar obsidians (e.g., Kelly Mountain vs. certain Medicine Lake Highlands obsidians), Ba concentrations were measured on 5 specimens from each sample group except for the Paradise Ridge 2 source. These results are also included within Table 3.

Table 3. Measures of Central Tendency and Dispersion for the Minor, Trace and Rare Earth Element Data of Tuscan Obsidians from the Study Area.

Element[1]	Mean	1st Standard Deviation	Minimum	Maximum
Paynes Creek (PYC) n=15[2]				
Ti	7381.831	702.479	6349.3	8974.75
Mn	1113.578	101.876	975.3	1337.254
Fe	52102.245	4116.074	46020.15	61298.92
Zn	105.149	8.177	89.131	116.255
Ga	18.509	2.091	13.149	21.361
Rb	44.304	3.339	38.611	50.366
Sr	353.254	17.945	324.033	381.931
Y	38.780	2.709	33.839	44.463
Zr	190.423	9.432	173.609	207.093
Nb	4.270	1.944	0.695	9.312
Ba	808.59	23.97	733.99	841.75
Inks Creek (INK) n=15$_2$				
Ti	8982.609	1160.638	7174.37	11213.2
Mn	1134.119	121.876	971.353	1385.115
Fe	60994.107	7299.596	47083.48	73296.37
Zn	110.926	10.434	95.538	127.971
Ga	19.754	3.392	13.133	25.241
Rb	44.645	3.419	40.465	50.135
Sr	361.390	20.065	331.657	394.393
Y	36.762	2.643	33.259	42.167
Zr	177.065	14.069	161.928	210.523
Nb	5.809	2.653	1.383	9.96
Ba	607.70	147.87	422.39	792.70
Paradise Ridge 1 (PR1) n=15[2]				
Ti	752.032	132.121	588.916	1101.93
Mn	363.614	34.780	294.335	426.572
Fe	8122.612	724.434	7001.917	10032.4
Zn	49.521	15.095	27.777	83.596
Ga	13.306	2.467	9.279	19.392
Rb	109.838	7.119	95.701	118.358
Sr	65.048	4.029	57.581	71.557
Y	16.234	2.739	9.96	21.431
Zr	92.481	5.778	78.509	101.226
Nb	9.786	2.259	6.93	15.545
Ba	532.66	116.29	408.37	679.04

Table 3. Continued.

Element[1]	Mean	1st Standard Deviation	Minimum	Maximum
Paradise Ridge 2 (PR2) n=12				
Ti	832.397	153.572	706.187	1074.26
Mn	353.466	34.496	303.379	401.041
Fe	8192.209	641.778	7617.157	9311.278
Zn	32.363	4.608	25.344	38.584
Ga	15.475	2.414	12.403	19.53
Rb	114.899	5.804	101.741	123.957
Sr	70.049	3.155	65.095	74.484
Y	18.562	1.009	16.784	20.064
Zr	108.906	15.404	95.4	136.237
Nb	11.551	1.341	9.805	12.935
Oat/Swede Creek (OSC) n=15[2]				
Ti	502.544	72.783	318.271	613.935
Mn	600.112	40.063	553.429	668.909
Fe	8071.731	307.221	7549.109	8636.214
Zn	45.635	5.852	37.821	54.234
Ga	16.519	2.077	14.514	19.905
Rb	94.311	2.879	88.379	98.778
Sr	100.870	3.097	96.516	106.666
Y	16.763	1.152	15.178	19.104
Zr	74.429	5.326	67.902	84.035
Nb	6.716	2.317	3.095	10.761
Ba	1445.60	239.63	1142.94	1679.09
Dry Creek Tributary (DCT) n=15[2]				
Ti	520.186	117.324	384.307	762.659
Mn	586.863	48.213	489.14	689.439
Fe	8010.257	498.764	7214.455	9210.893
Zn	48.065	6.617	37.182	61.307
Ga	15.685	1.958	13.468	20.343
Rb	93.790	5.210	83.73	104.857
Sr	97.973	8.209	77.759	108.878
Y	17.346	1.082	16.011	19.986
Zr	72.200	6.923	64.715	93.445
Nb	6.520	2.318	2.647	10.955
Ba	1361.84	239.17	982.21	1649.60

Table 3. Continued.

Element[1]	Mean	1st Standard Deviation	Minimum	Maximum
Cow Creek Tributary (CCT) n=15[2]				
Ti	508.099	64.562	426.865	661.362
Mn	581.954	47.471	453.824	667.238
Fe	8041.896	181.144	7730.915	8424.475
Zn	44.682	6.193	37.083	61.964
Ga	15.534	1.300	13.424	18.283
Rb	92.068	4.862	79.983	99.022
Sr	99.992	3.647	88.19	104.654
Y	17.973	1.392	15.996	20.466
Zr	71.196	2.722	67.7	77.946
Nb	7.291	1.991	3.406	10.581
Ba	1658.53	67.96	1533.65	1735.68
Forest Camp Ridge (FCR) n=15[2]				
Ti	535.377	117.591	398.691	831.695
Mn	591.519	39.788	519.719	642.008
Fe	8006.444	590.673	7213.338	9311.156
Zn	44.088	2.061	40.388	46.694
Ga	16.361	1.697	13.269	18.765
Rb	93.947	4.059	88.884	100.004
Sr	85.650	5.008	76.447	90.069
Y	18.204	1.332	16.109	21.473
Zr	68.418	4.174	61.49	74.329
Nb	6.005	2.283	1.515	9.737
Ba	1600.03	68.35	1503.62	1693.06
Sugar Pine Ridge (SPR) n=15[2]				
Ti	503.601	89.766	390.359	659.79
Mn	605.337	64.975	507.29	745.796
Fe	8016.431	511.676	7266.17	8928.029
Zn	44.909	5.981	35.076	53.93
Ga	16.048	3.081	11.806	22.616
Rb	95.028	5.123	85.963	103.586
Sr	87.151	5.479	75.546	95.439
Y	17.853	1.267	16.062	20.707
Zr	68.651	3.851	61.609	74.856
Nb	6.846	1.783	3.766	9.833
Ba	1585.54	192.28	1247.19	1747.65

Table 3. Continued.

Element[1]	Mean	1st Standard Deviation	Minimum	Maximum
Philips Road (PHR) _n_=15[2]				
Ti	514.799	87.389	396.436	747.014
Mn	603.876	71.359	492.128	757.485
Fe	8068.148	596.582	7243.308	9256.168
Zn	42.189	4.869	35.812	48.59
Ga	16.166	2.101	13.49	19.965
Rb	94.996	6.792	78.007	104.501
Sr	91.803	11.282	73.562	110.255
Y	17.934	1.707	14.92	20.341
Zr	71.894	3.576	64.303	77.125
Nb	6.858	2.556	0.512	10.581
Ba	1632.32	97.91	1173.21	1672.02
Woodman Hill Ridge (WHR) _n_=15[2]				
Ti	462.834	59.353	362.75	569.824
Mn	586.529	49.634	496.311	666.494
Fe	7788.723	349.884	7004.509	8536.751
Zn	41.730	5.790	33.737	52.337
Ga	14.228	2.320	10.678	19.47
Rb	94.156	4.309	83.727	100.516
Sr	85.969	3.434	79.631	91.178
Y	17.855	1.280	16.496	20.821
Zr	70.551	4.197	65.033	77.399
Nb	7.189	2.375	1.987	10.614
Ba	1636.45	79.41	1521.17	1728.24
Backbone Ridge - Seaman Gulch 1 (BR1) _n_=21[2]				
Ti	519.988	115.034	348.593	880.259
Mn	597.714	71.676	485.188	738.803
Fe	7854.086	743.663	6788.019	10228.47
Zn	45.627	5.980	38.256	63.688
Ga	15.467	2.550	11.609	22.984
Rb	94.436	6.628	84.86	109.806
Sr	80.718	13.435	44.126	102.031
Y	16.581	1.342	14.167	19.7
Zr	67.911	4.592	58.997	76.648
Nb	6.96	1.740	3.317	10.351
Ba	1507.14	179.83	1173.21	1672.02

Table 3. Continued.

Element[1]	Mean	1st Standard Deviation	Minimum	Maximum
Backbone Ridge 2 - Section 26 (BR2) n=15[2]				
Ti	513.223	91.761	348.444	661.018
Mn	604.876	51.196	508.716	706.82
Fe	7914.555	459.143	6740.901	8632.924
Zn	44.524	4.729	38.956	51.205
Ga	16.773	1.844	13.98	20.211
Rb	96.161	5.370	86.831	104.033
Sr	84.310	12.496	42.738	97.407
Y	18.067	2.106	13.8	21.844
Zr	72.449	5.299	65.133	83.704
Nb	6.767	2.530	1.599	10.926
Ba	1559.87	71.24	1444.43	1624.36
Backbone Ridge 3 - Seaman Gulch 2 (BR3) n=15[2]				
Ti	483.214	73.411	378.259	618.052
Mn	592.709	48.117	533.701	696.34
Fe	7789.276	413.693	7175.562	8774.826
Zn	43.199	4.679	33.09	51.004
Ga	15.737	2.317	11.165	19.058
Rb	94.462	5.120	87.155	108.169
Sr	87.531	6.769	73.667	98.806
Y	18.137	1.507	15.688	20.974
Zr	71.275	5.363	65.595	83.222
Nb	7.003	2.047	3.713	10.451
Ba	1624.39	97.17	1562.02	1793.47
Backbone Ridge 4 - Quarry Workshop (BR4) n=15				
Ti	553.191	69.837	382.587	670.97
Mn	589.746	47.072	498.695	674.244
Fe	8088.206	477.719	7152.916	8793.566
Zn	46.220	6.546	36.807	63.458
Ga	15.908	1.543	13.212	18.39
Rb	92.837	6.527	82.884	102.963
Sr	89.864	9.266	72.802	109.106
Y	18.126	1.974	14.267	20.644
Zr	69.065	5.142	60.075	78.401
Nb	6.219	1.688	2.448	8.859
Ba	1513.52	91.65	1394.24	1666.89

[1] Ti=titanium, Mn=manganese, Fe=iron, Zn=zinc, Ga=gallium, Rb=rubidium, Sr=strontium, Y=yttrium, Zr=zirconium, Nb=niobium, Ba=barium. [2] Barium n=5.

Discussion of Geochemical Source Data

As noted by Hughes (1983:30), a critical prerequisite to reliable matches between artifacts and obsidian sources is the demonstration of restricted geochemical variability within a particular source. Previous x-ray fluorescence studies (Jack 1976; Hughes 1983) indicated that within-source trace element variability for the Tuscan source group was minor in comparison with other obsidian sources. However, because Tuscan obsidian occurs naturally in widely dispersed areas, the decision was made to reexamine the data to investigate whether geochemical variability might exist among the various collection loci.

Initially, each sampling locality was treated as a separate unit and both discriminant and descriptive analyses were performed on each of 15 separate groups since the data presented in Table 3 suggests that there is some chemical variability between sampling localities. The statistical package used for the analyses was SPSS Version 4.0 for an IBM 4570 VM/CMS computer. Descriptive analysis, which was conducted first, provided the basic univariate statistics for the variables Ti, Mn, Fe, Zn, Rb, Sr, Y, Zr, Nb, and Ba. Mean, median, mode, standard deviation, standard error, variance, kurtosis, standard error of kurtosis, skewness, standard error of skewness, range, minimum, maximum, and sum were determined for all the variables. In addition, the histogram frequencies were calculated.

While an examination of the central tendency and dispersion data in Table 3 indicates that certain element values (Ti, Mn, Fe, Zn, Rb, Sr, Y, Zr, Nb and Ba) vary across the localities examined, not all of these elemental values varied sufficiently between the source locales to allow them to serve as good discriminators. Therefore, only the nine best measured elements were employed as discriminating variables for the remainder of the analysis (see Hughes 1983 for further discussion of this point). These included Ti, Mn, Fe, Zn, Rb, Sr, Y, Sr, and Nb.

As noted by Hughes (1983:53), discriminant analysis, as it is applied to the chemical characterization of obsidians, accomplishes two basic objectives. First, it describes or identifies groups of objects on the basis of distinctive combinations of discriminating variables, and secondly, it predicts groups membership or classifies ungrouped cases into one or another of the groups in the sampling universe on the basis of mathematical equations derived from known groups (Hughes 1983:53).

The DISCRIMINANT command in the SPSS Advanced Statistics program performs linear discriminant analysis for two or more groups. The goal of this method of analysis was to classify the cases into one of several mutually exclusive groups, based on their values for a set of predictor variables. The DIRECT method was used for entering variables into the analysis phase. In other words, at each step, all variables passing the tolerance criteria were entered simultaneously into the discrimanant equation. The summary of results of this analysis included eigenvalues, standardized discriminant function coefficients, and within-groups correlations between the discriminant functions and the predictor variables.

Three separate discriminant analyses were executed on the entire set of specimens from the fifteen obsidian source locales. The first analysis, summarized in Table 4, employed untransformed trace element concentrations for the nine best measured elements with each source locale being considered as geochemically distinct. The results of this analysis indicated that difficulties arise in attempting to assign group membership if all 15 groups are considered to be separate and distinct sources. The percent of "grouped" cases correctly classified was weak (50.65%) when each locus was considered to be a separate source.

For the second analysis, each source locale was divided into 6 main source groups (e.g., Inks Creek [INK]; Paynes Creek [PYC]; Philips Road [PHR]; Paradise Ridge 1 [PR1]; Paradies Ridge 2 [PR2]; and remaining loci grouped as one) using the same combination of elements. The use of 6 main source groups produced a correct classification rate of only 69.7%.

In the third discriminant analysis, each sampling locale was placed into three prime source groups on the

Table 4. SPSS Discriminant Analysis Tuscan Obsidian Source Classification Matrix.

Source Name	Actual Group	No. of Cases	Predicted Group Membership							
			1	2	3	4	5	6	7	8
BR1	1	21	8	5	0	1	0	1	4	0
			38%	24%	0%	5%	0%	5%	19%	0%
BR2	2	15	4	4	0	2	0	4	0	0
			27%	27%	0%	13%	0%	27%	0%	0%
BR3	3	15	0	3	2	2	0	3	3	1
			0%	20%	13%	13%	0%	20%	20%	7%
BR4	4	15	2	0	0	3	1	3	2	1
			13%	0%	0%	20%	7%	20%	13%	7%
SPR	5	15	1	1	1	1	2	2	6	0
			7%	7%	7%	7%	13%	13%	40%	0%
FCR	6	15	1	1	0	3	2	6	1	0
			7%	7%	0%	20%	13%	40%	7%	0%
WHR	7	15	0	1	1	1	0	1	10	0
			0%	7%	7%	7%	0%	7%	67%	0%
CCT	8	15	0	0	0	0	0	0	0	10
			0%	0%	0%	0%	0%	0%	0%	67%
DCT	9	15	1	0	0	0	1	0	0	3
			7%	0%	0%	0%	7%	0%	0%	20%
OSC	10	15	0	0	0	0	0	0	0	3
			0%	0%	0%	0%	0%	0%	0%	20%
PR1	11	15	0	0	0	0	0	0	0	0
			0%	0%	0%	0%	0%	0%	0%	0%
PHR	12	15	1	3	0	2	0	0	3	3
			7%	20%	0%	13%	0%	0%	20%	20%
PYC	13	15	0	0	0	0	0	0	0	0
			0%	0%	0%	0%	0%	0%	0%	0%
PR2	14	15	0	0	0	0	0	0	0	0
			0%	0%	0%	0%	0%	0%	0%	0%
INK	15	15	0	0	0	0	0	0	0	0
			0%	0%	0%	0%	0%	0%	0%	0%

Table 4. Continued.

Source Name	Actual Group	No. of Cases	Predicted Group Membership						
			9	10	11	12	13	14	15
BR1	1	21	0 0%	1 5%	0 0%	1 5%	0 0%	0 0%	0 0%
BR2	2	15	0 0%	0 0%	0 0%	1 7%	0 0%	0 0%	0 0%
BR3	3	15	0 0%	1 7%	0 0%	0 0%	0 0%	0 0%	0 0%
BR4	4	15	2 13%	1 7%	0 0%	0 0%	0 0%	0 0%	0 0%
SPR	5	15	1 7%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
FCR	6	15	0 0%	1 7%	0 0%	0 0%	0 0%	0 0%	0 0%
WHR	7	15	0 0%	0 0%	0 0%	1 7%	0 0%	0 0%	0 0%
CCT	8	15	2 13%	3 20%	0 0%	0 0%	0 0%	0 0%	0 0%
DCT	9	15	7 47%	3 20%	0 0%	0 0%	0 0%	0 0%	0 0%
OSC	10	15	3 20%	9 60%	0 0%	0 0%	0 0%	0 0%	0 0%
PR1	11	15	0 0%	0 0%	14 93%	0 0%	0 0%	1 7%	0 0%
PHR	12	15	0 0%	1 7%	0 0%	2 13%	0 0%	0 0%	0 0%
PYC	13	15	0 0%	0 0%	0 0%	0 0%	15 100%	0 0%	0 0%
PR2	14	15	0 0%	0 0%	2 13%	0 0%	0 0%	13 87%	0 0%
INK	15	15	0 0%	0 0%	0 0%	0 0%	3 20%	0 0%	12 80%

basis of the geographic proximity among the various sampling locales and the central tendency data derived from the descriptive analysis. In other words, geographically proximate source locales which exhibited similar group means and ranges were arranged into one of the three prime source groups if their elemental means were within 2 standard deviations. Thus, Prime Group 1 included both the Paradise Ridge sources (PR1 and PR2), while Prime Group 3 included the Inks and Paynes Creek sources (INK and PYC). Prime Group 2 included those areas previously characterized by Richard Hughes as Tuscan obsidian, in addition to the remaining sample localities (BR1, BR2, BR3, BR4, SPR, FCR, CCT, DCT, OSC, PHR, WHR).

As shown in Table 5, the results were much stronger with the percent of "grouped" cases correctly classified equaling 100%. Although this high percentage of success was achieved by using eight elements as variables (Ti, Mn, Fe, Zn, Rb, Sr, Y, and Zr), the results were only slightly less robust (99.57% correctly classified "grouped" cases) with the use of a select group of variables (Rb, Sr, Y, Zr, and Nb).

To test the significance of these finds, a one-way analysis of variance (ANOVA) was performed on the nine best measured elements (Ti, Mn, Fe, Zn, Rb, Sr, Y, Zr, and Nb) from each sampling locus. Basically, analysis of variance is concerned with comparing two different estimates of

Table 5. SPSS Discriminant Analysis Tuscan Obsidian Source Classification Matrix of Prime Group Source Locales.

Source Name	Actual Group	No. of Cases	Predicted Group Membership		
			1	2	3
Prime Group 1	1	30	30 100%	0 0%	0 0%
Prime Group 2	2	171	0 0%	171 100%	0 0%
Prime Group 3	3	30	0 0%	0 0%	30 100%

variation which together can be used to calculate the variance of the assumed normally distributed parent population from which the samples have been drawn. As can be seen in Table 6, the results of the analysis of variance showed significant departure from randomness ($p < .05$) with the F value of all nine elements exceeding the critical value, thus indicating that the three prime group sampling localities contained obsidians of statistically significantly different geochemical types.

The results of these analyses can be seen in Figure 8, which plots the concentration of Zr against Mn. While significant contrasts can be seen with many of the other elements also (Sr vs. Zr; Sr vs. Rb; Sr vs. Mn; Zr vs. Rb), these two elements help draw the clearest contrasts between the three prime source groups. Each symbol represents one

Table 6. Results of Analysis of Variance by Element for Three Prime Groups. Critical Value for $F_{4,10}$ = 3.48 at .05 Significance Level.

Element	*F* value	Sig of *F*
Ti	3662.109	.000
Mn	1244.666	.000
Fe	4283.376	.000
Zn	883.232	.000
Rb	125.300	.000
Sr	5722.819	.000
Y	43.580	.000
Zr	1684.644	.000
Nb	7.193	.000

individual specimen which was sampled from the locus specified on Figure 8. The ellipses express the 95% confidence limits for Zr and Mn for each source (see Hughes 1988 for discussion of probability ellipses). It is clear from this figure that the Inks Creek and Paynes Creeks glasses contain higher concentrations of both Zr and Mn than the Paradise Ridge 1 and 2 source groups and the other prime source groups examined. Moreover, the Inks and Payne Creeks obsidian group is more variable in Zr and Mn composition.

Similar separations of these three prime source groups are illustrated when plots are made between the element concentrations of Zr against Rb (Figure 9), Sr against Rb (Figure 10), and Sr against Zr (Figure 11). The only significant exception to grouping the Tuscan obsidians into three prime sources arose with three anomalous

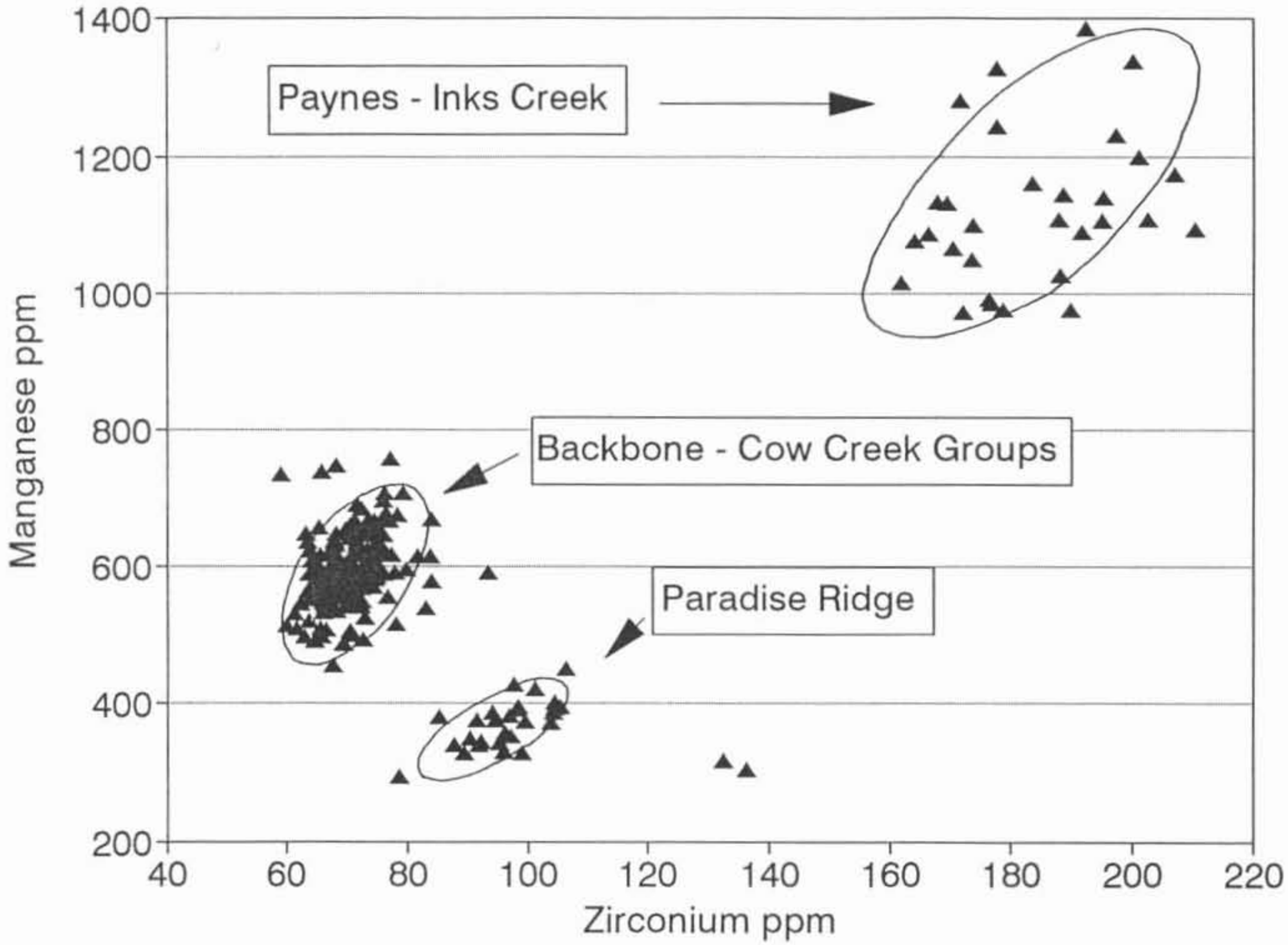

Figure 8. Zirconium (Zr) versus Manganese (Mn) Concentration Plot for Tuscan Obsidian Sources

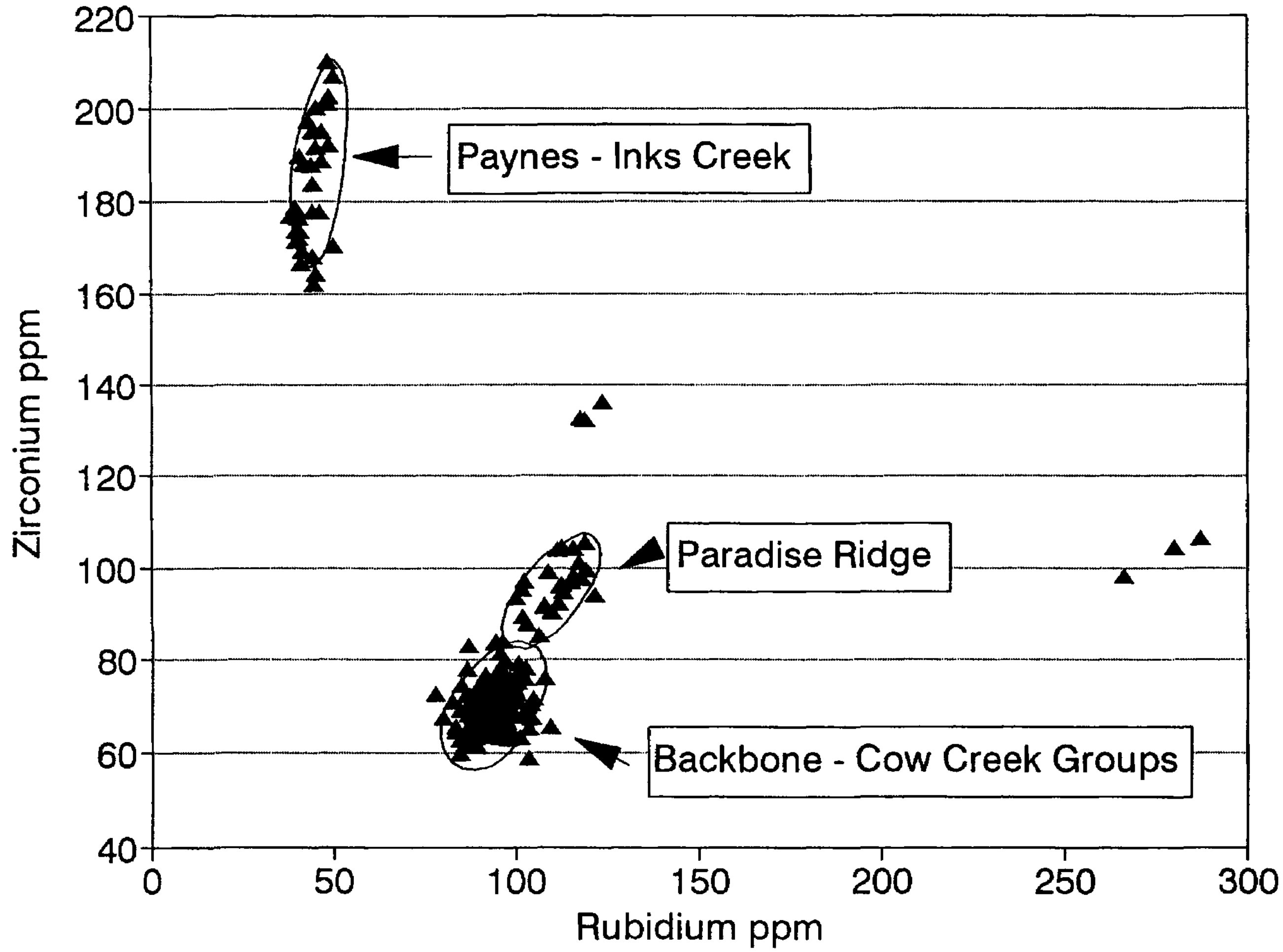

Figure 9. Rubidium (Rb) versus Zirconium (Zr) Concentration Plot for Tuscan Obsidian Sources.

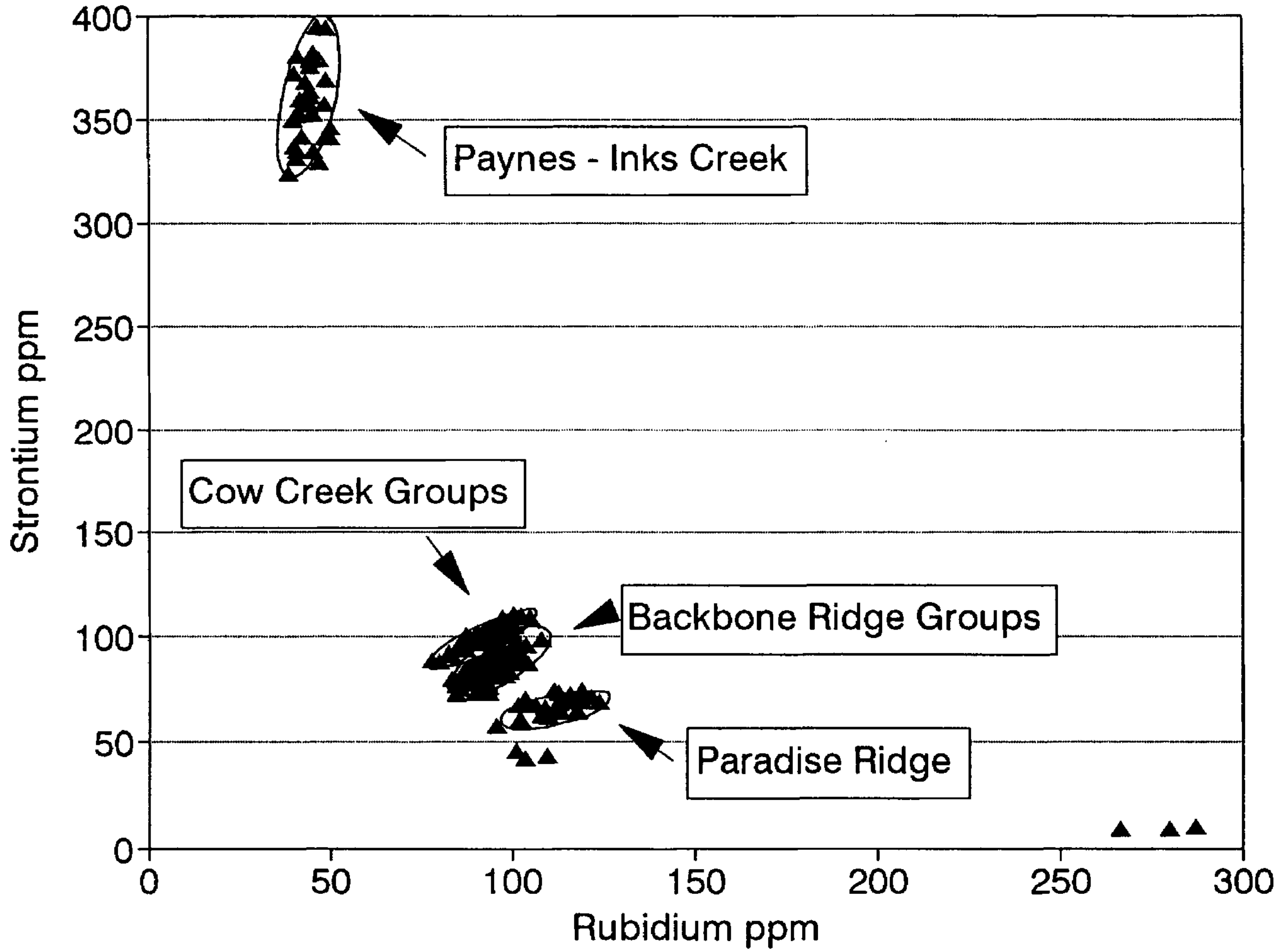

Figure 10. Rubidium (Rb) versus Strontium (Sr) Concentration Plot for Tuscan Obsidian Sources.

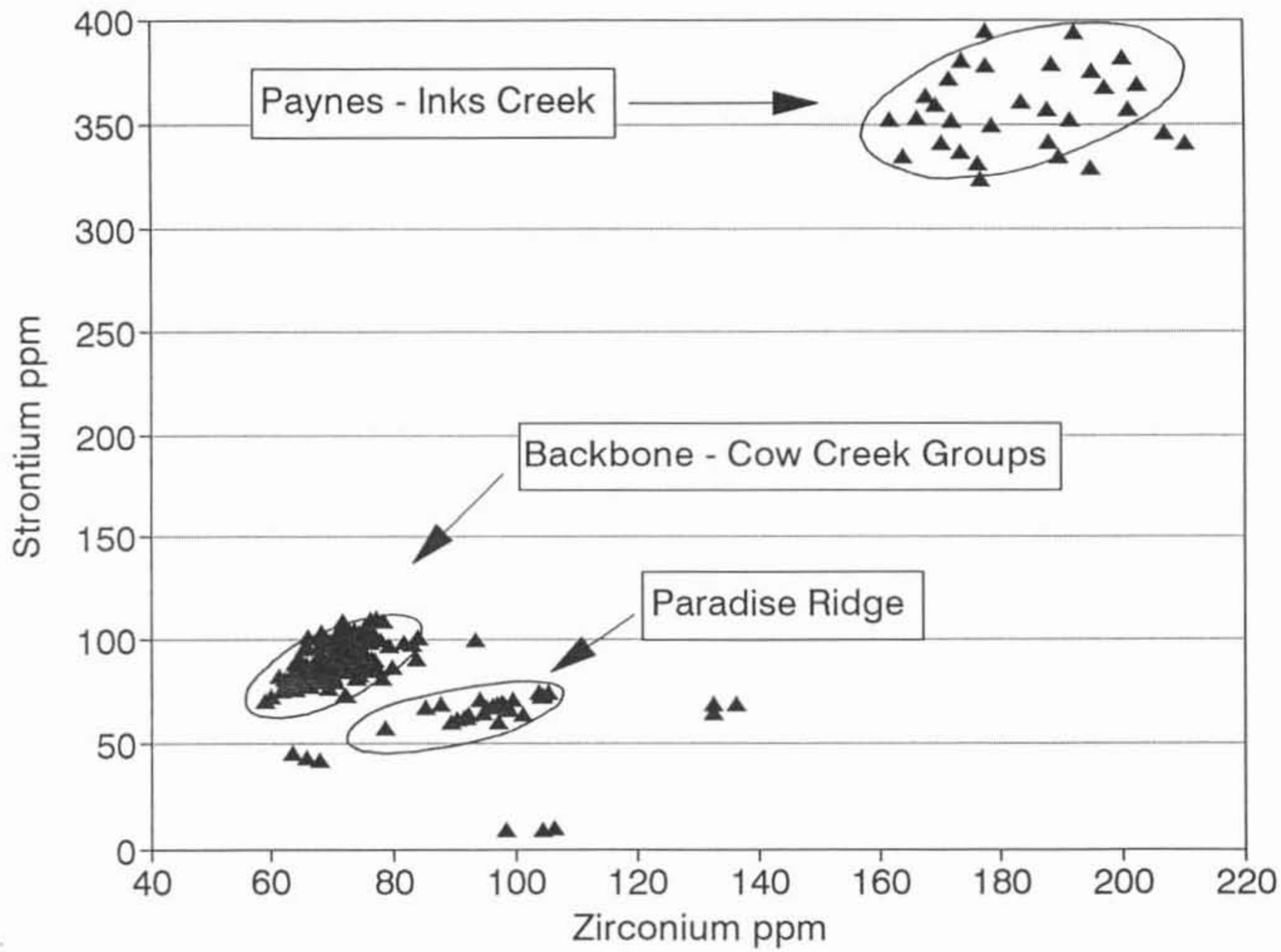

Figure 11. Zirconium (Zr) versus Strontium (Sr) Concentration Plot for Tuscan Obsidian Sources.

specimens from the Paradise Ridge 2 locale which were obtained from Al Farber. As seen in Figures 9 and 10, these three specimens exhibited Rb levels which are quite different from all other Tuscan obsidian source material examined (n=231).

A re-examination of these specimens suggests that they are not actually geologic specimens but are culturally modified flake fragments removed from cores. Visually, these specimens are also quite different in appearance, and a cursory examination of the extant literature of various obsidian sources for the region appears to match them closest with the trace element signature of Coso Volcanic obsidians. It is likely that these specimens are not associated with the Tuscan Formation geologically, but additional research should be conducted within the area in which the specimens at some future date.

Several other outliers (n=3) were noted with the Backbone Ridge source material. However, the low concentration levels of Sr in these specimens may be the result of contact with solids (wall-rock reaction) during eruption.

The essential information imparted in Figures 8 through 11 is that three different geochemical types of obsidian can be recognized on the basis of Zr vs. Mn contrasts. These distinctive groups of obsidian were named according to prominent geographic features, or proximity to them. The Paynes Creek geochemical type consists of obsidian collected from the Inks and Paynes Creek source locales, while the Paradise Ridge geochemical type consists of obsidian collected from the Paradise Ridge 1 and 2 source locales. The third geochemical type consists of the remaining source locales, namely the Backbone Ridge groups, Cow, Oat/Swede, and Dry Creeks, Forest Camp Ridge, Philips Road, Woodman Hill, and Sugar Pine Ridge.

Attempts to distinguish between the various sampling localities contained in Prime Group 2 (BR1, BR2, BR3, BR4, SPR, FCR, CCT, DCT, OSC, PHR, WHR) with discriminant analyses functions proved to be difficult despite apparent differences which were observed in the ratio of group means with the elements Rb and Sr. For the northernmost sources of the Tuscan obsidian sample localities near Backbone Ridge (BR1, BR2, BR3, BR4, SPR, PHR, FCR, WHR), the ratio of Rb to Sr consistently equalled 1.1 to 1.2, whereas the ratio of Rb to Sr in the Cow, Dry, and Oat/Swede Creeks obsidians consistently equalled .92 to .96. Moreover, as shown in Table 4, when each sample locale was identified as a separate and distinct geochemical source, only 2 specimens out of a total of 45 (4%) specimens analyzed in the Cow, Dry and Oat/Swede Creeks source locales were incorrectly classified as belonging to the Backbone Ridge groups. Though a slightly higher percentage of incorrectly classified specimens was noted within the Backbone Ridge groups (e.g., 13 out of 126 total, or 10% of the BBR groups were classified as belonging to the Cow, Dry and Oat/Swede Creek groups), the results of these data suggest that the Backbone Ridge and Cow Creek source groups are distinct. This bimodal distribution in the Sr and Rb ratio is illustrated in Figure 12 as two separate clusters contained within the larger ellipse which is classified as the Prime Group 2 sources (see Hughes 1988; and Shackley 1990 for a discussion of this process).

In order to determine whether the differences between the ratioed values were statistically significant, or merely random results produced by inherent instrument error, a Two-Tailed T-Test was performed on the Prime Group 2 sources for the elements Ti, Mn, Fe, Zn, Ga, Rb, Sr, Y, Zr, and Nb. Although there are other statistical procedures which compare group means, the T-Test was used since it calculated both the pooled- and separate variance estimates, along with the $\underline{F}$ value which tested the homogeneity of variance and its probability.

The results of the T-Test indicate that at the 95% confidence level the Backbone Ridge source groups ($\underline{n}$=126) can be distinguished from the Cow Creek source groups ($\underline{n}$=45) on the basis of the ratioed values of Sr ($\underline{t}$= 8.42 > $\underline{t}_{.05}$ = 1.96) and to a lesser degree Rb ($\underline{t}$= 2.00 > $\underline{t}_{.05}$ = 1.96). As noted above, there were two specimens in the Cow Creek source groups that had very high levels of Rb which placed

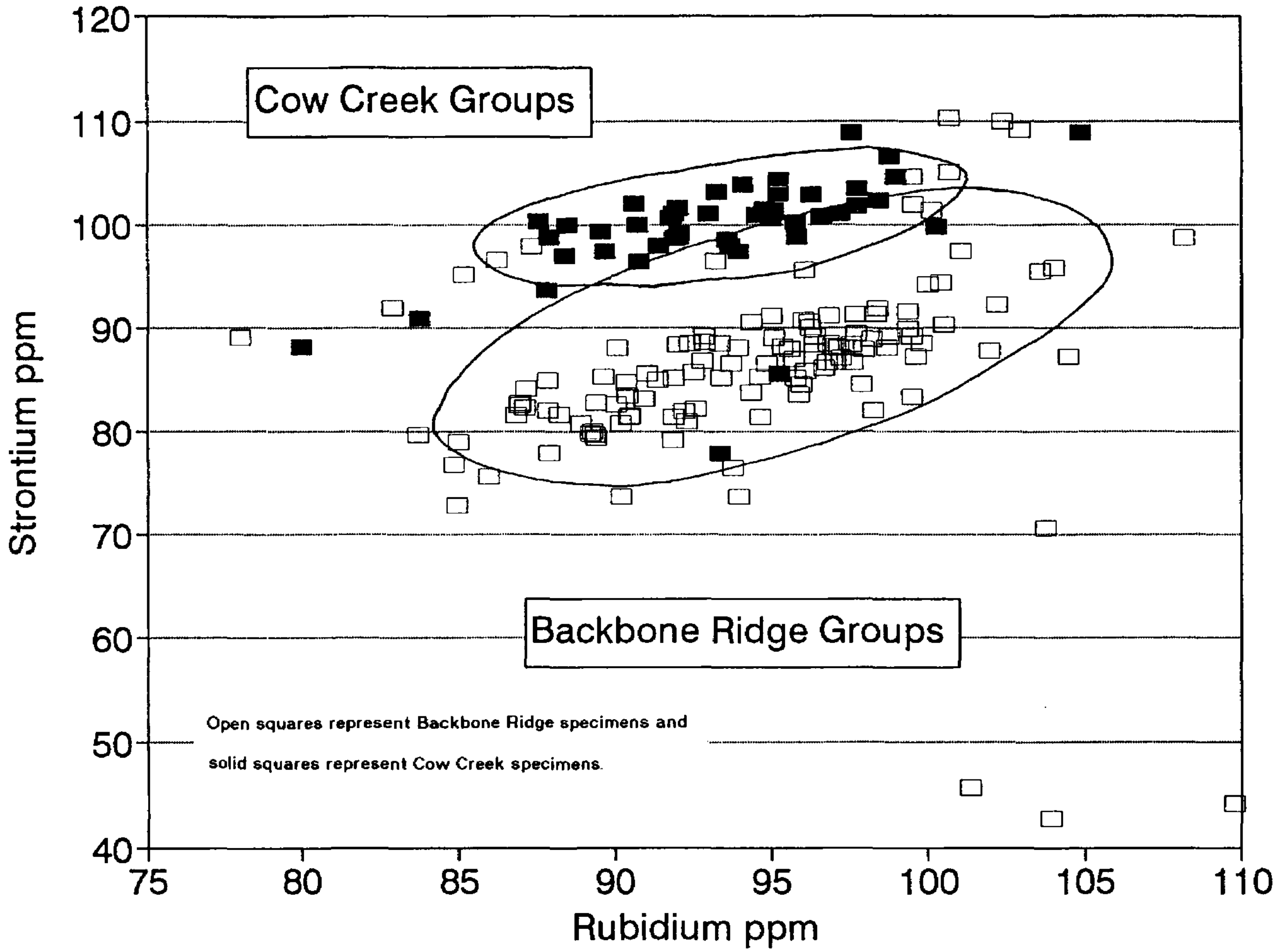

Figure 12. Rubidium (Rb) versus Strontium (Sr) Concentration Plot for the Backbone Ridge and Cow Creek Tuscan Obsidian Sources.

them in the Backbone Ridge source groups during discriminant analysis. However, if these specimens are removed from the groups, there are significant differences in the Rb values as well for the Cow Creek source groups.

The above data appears to suggest that while it is possible to have some overlap between these source subgroups at the extreme high and low ranges of the elemental values for Rb and Sr, statistically significant differences are present between these groups. Rather than occurring as random events, the differences observed in the ratios between Sr and Rb for the Cow Creek and Backbone Ridge glass appear to form a pattern, especially in regards to the Sr ppm values. Whether or not these distinctions carry archaeological significance in terms of obsidian procurement patterns will be discussed in Chapter IV.

Knapping Qualities of Tuscan Obsidian

Unfortunately, early explorers who traveled through California generally restricted their observations of native groups to village life and took little notice of lithic procurement and production practices. Although the ethnographic record does provide limited data on the use and production of stone tools, relatively little has been recorded about the various physical qualities by which a native knapper ranked the different lithic raw material types.

Ethnographic accounts gathered by DuBois (1935:25) indicate that the Wintu made expeditions to Glass Mountain to the north to collect obsidian. Heizer and Treganza (1972:305) also noted that somewhere on Glass Mountain was a large obsidian quarry from which the Atsugewi, Achomawi, Yana and McCloud River Wintu secured implement material. However, obsidian source data compiled over the last several years for the Redding Wintu and Yana territories suggests that a much larger percentage of the obsidian used actually came from the local Tuscan sources. This fact has resulted in a quandary for some researchers since it has been assumed that the Tuscan obsidian is inferior in quality to the Medicine Lake region glasses (e.g., Chase-Dunn 1992). Reasons given for the supposedly superior nature of the Grasshopper Flat obsidians in the Medicine Lake Highlands have ranged from "better quality", "bigger pieces", "easier to collect", "less wastage", "shorter hunt time", "less cortex to remove", and the fact that the Grasshopper Flat source, being higher in elevation, was not in any one group's habitation area (e.g., Sundahl, cf. Chase-Dunn 1992:150).

The fact that some lithic resources are much better suited to knapping than others is not being disputed. However, given the preponderance of Tuscan obsidian glass over the Medicine Lake Highlands obsidian in many archaeological site assemblages, the supposedly inferior quality of Tuscan obsidians bears further investigation.

In order to evaluate the supposedly inferior nature of Tuscan glass, the following subjective appraisal of the knapping qualities of the different Tuscan obsidians was compiled with the assistance of experienced knapper, Russell Bevill. With regard to physical properties which would promote predictable flaking results, six different attributes were assessed for samples from each of the sample localities. These include sharpness of flakes, amount of inclusions, luster, hardness, brittleness and ability to pressure flake.

Bifaces and/or tools were manufactured from each source material using direct freehand percussion tech-niques and, in some cases, bipolar reduction. Tools used included a deer antler tine, small sandstone cobble hammer-abrader, and a granite hammerstone. An evaluation of the various attributes listed above was noted for each source area after knapping through the use of a ordinal scale with 5 indicating the sharpest, hardest, most brittle and best pressure flaking properties, and 1 indicating the dullest, softest, non-brittle and worst pressure flaking conditions. The results of this analysis can be found in Table 7. Although the presence of internal flaws and/or inclusions did limit the ability to control the removal of certain flakes, overall, variations in luster did not substantially alter the flaking results.

As shown in Table 7 the results of this analysis suggest that while all the obsidian sources examined here can be used to produce bifacial tools and other artifacts, some of the glasses are much better suited to knapping than

Table 7. Knapping and Use Qualities of Tuscan Obsidian.

Source Group	S[1]	H[2]	B[3]	PF[4]	I[5]	L[6]
BR1	5	1	3	5	0	Eart[7]
BR2	3	5	2	5	0	Eart
BR3	5	3	4	4	1	Vitr[8]
BR4	4	4	3	5	3+	Eart
FCR	5	4	5	4	0	Vitr
PHR	5	5	4	3	3+	Eart
OSC	5	4	4	5	0	Grea[9]
CCT	4	3	4	5	0	Eart
DCT	4	4	4	4	0	Eart
SPR	5	4	3	5	5+	Grea
WHR	5	4	3	5	0	Eart
PYC	3	2	5	5	9+	Grea
INK	2	2	5	5	9+	Grea
PR1	5	4	3	5	0	Vitr

[1] Sharpness, [2] Hardness, [3] Brittleness, [4] Pressure Flaking Ability, [5] Amount of Inclusions, [6] Luster, [7] Earthy, [8] Vitreous, [9] Greasy.

others. Oat/Swede Creek Dry Creek, Cow Creek Tributary, Woodman Hill, Forest Camp, Sugar Pine Ridge, Philips Road, Paradise Ridge 1, as well as the Backbone Ridge source localities (BR1 - BR4) are all excellent raw materials. According to Bevill (personal communication 1993), the quality of material from these source locales is similar and compares very favorably to glass obtained from the Medicine Lake Highlands. Pressure flakes remove easily and predictably from all of these materials and the flakes, once removed, are generally very sharp. As a combined group, these sources are easy to control during direct freehand percussion or bipolar reduction with hardness and brittleness being assessed as 4 and 3 - 4 respectively on the ordinal scale.

Moreover, although the majority of the cobbles used for this analysis measured only 4 to 8 cm in diameter, it was found that in most cases several formed tools and numerous usable flake tools could be produced from one small nodule. Bifaces measuring 6.5 cm in length were easily produced from cobbles obtained at the Backbone Ridge locales, suggesting that at most of the source locales mentioned above, the size of the nodule would not have been a major limiting factor in terms of lithic reduction techniques regardless of the need to produce dart or arrow points.

The results also indicate that some of the source groups, such as Inks and Paynes Creek are not as predictable during reduction. The materials from these sources are vitrophyric, very brittle and frequently 'crumble' during bipolar and/or freehand percussion reduction and essentially destroy or waste the core. Flakes produced from this material are also generally duller than the other Tuscan glasses. Despite these apparent drawbacks, once a suitable nodule is reduced, the softness of the glass allows for ease in pressure flaking, which most likely accounts for its occurrence in local site assemblages. Nevertheless, it seems likely that the Inks and Paynes Creek sources would have gained a reputation for being inferior raw materials relative to the other Tuscan glasses.

Summary and Conclusions

Geochemical data obtained as a result of the EDXRF analyses suggest that there are at least three major and one minor geochemically distinct artifact-quality glass sources which can be identified within the Tuscan Formation. The major geochemical source groups include the Paynes - Inks Creeks source locales (PYC/INK), the Paradise Ridge 1 - 2 source locales (PR1/2), and the Backbone Ridge - Cow Creek source locales (BR1, BR2, BR3, BR4, SPR, FCR, PHR, WHR, CCT, DCT, OSC). Each of these glass localities consists of a spatially distinct source which exhibit geochemical modalities along two or more trace elements. Moreover, the results of these analyses indicate that at the 95% confidence level the Backbone Ridge source groups can be distinguished from the Cow Creek source groups on the basis of the ratioed values of Sr and to a lesser extent Rb.

In terms of knappability, obsidians from the Paynes and Inks Creek groups, and to a lesser extent, perhaps the Paradise Ridge obsidians, are visually distinct. However, attempts to visually source the remaining Tuscan obsidians are met with difficulties. The Paynes and Inks Creek materials as a group are distinctive, being vitrophyric and non-vitreous. As a result of this vitrophyric nature, the glass from these sources is unpredictable during knapping and is of poor quality. However, the remaining sources are very similar megascopically, and the degree of variability within each source is great with highly vitreous material occurring within the same locale along with dull, matte-like material. Obsidians from these other locales vary knapping quality from good to very good.

As noted previously, "accessibility" of stone at a source refers to three characteristics: its overall abundance, its density or concentration within the source area, and its ease of extraction. Although the density of raw material is less at some of the source areas than others, overall, the Tuscan obsidians are moderately abundant, and in most cases average at least 60 specimens per $2m^2$. Raw material is most abundant at the northern source areas (SPR and FCR) with more than 300 nodules occurring within an one square meter area. Although density is apparently low at the various localities along Backbone Ridge Road, it is likely that the low densities observed at these locales are due to prehistoric quarrying activities and modern/recent disturbances as a result of road grading, construction activities and recreational vehicle use.

In sum, while it was not possible to identify every potential Tuscan obsidian source locality in the study area, and while there is variability in its distribution, there is sufficient information to indicate clearly that sources of artifact-quality glass in the region are widely distributed and abundant. At all the source areas examined, stone occurs mainly on the surface, thus providing easy access. However, some of the largest boulders of obsidian were found within the newly graded portions of Backbone Ridge Road suggesting that the presence of subsurface deposits of obsidian can not be summarily dismissed. Quite clearly, Tuscan obsidian was easy to extract and readily accessible to aboriginal groups traveling or living within the study area. Thus, "quarrying" Tuscan obsidian refers primarily to picking it up off the ground.

While most of the source locales showed signs of prehistoric use in the form of reduced nodules and flakes, none of the Tuscan glass localities examined exhibited evidence of habitation at the source. Therefore, if any of the Tuscan sources were physically "controlled", the evidence is not extant. However, based on the spatial distribution of Tuscan obsidian across the landscape it is likely that some of the obsidian source locales were situated well within the tribal boundaries of specific aboriginal groups, such as the Yana.

The results of this analysis suggest that while all the sources explored here can yield obsidian usable in producing bifacial tools and other artifacts, some of the glasses are much better suited to knapping than others. Nevertheless, as a combined group, these obsidians are easy to control during direct freehand percussion or bipolar reduction. The Backbone Ridge and Cow Creek source localities contain some of the largest nodules observed during the course of this study and constitute excellent raw materials. Pressure flakes remove easily and predictably from all of these materials, and the flakes, once removed, are generally very sharp. On the other hand, the results also indicate that the Inks and Paynes Creek glass is not as predictable during lithic reduction. The materials from these sources are vitrophyric, very brittle and frequently 'crumble' during bipolar and/or freehand percussion reduction and essentially destroy or waste the core. However, despite these apparent drawbacks, once a suitable nodule is reduced, the softness of the glass allows for ease in pressure flaking, which is most likely one reason for its occurrence in local site assemblages.

Data obtained as a result of this study suggest that the previously held notions that Tuscan obsidian was limited in its abundance, distribution and quality are inaccurate. For the most part Tuscan obsidian can be viewed as a desirable raw material which would have been easily accessible to prehistoric peoples. If this statement is true, then clearly, some factor besides the supposedly "inferior" nature of Tuscan obsidians accounts for its limited use during certain temporal periods.

In summary, it has been possible to show that the Tuscan Formation contains at least three major and one minor geochemically distinct artifact-quality glass sources. However, it remains to be seen whether or not these distinctions carry any archaeological significance. The following chapter will examine the various issues pertaining to the archaeological distribution of Tuscan obsidian and discuss in greater depth the archaeological implications of these geochemical distinctions.

CHAPTER VI

ARCHAEOLOGICAL DISTRIBUTION OF TUSCAN OBSIDIAN

Introduction

It has been argued by various researchers that it is one thing to determine the geographic source area for a commodity such as obsidian, but quite another matter to infer the social mechanisms responsible for the occurrence of that material at an archaeological site (Hughes and Bennyhoff 1986:238; Ward 1977). In the present context, while it has been possible to show that the Tuscan Formation contains at least three distinct geochemical source groups of artifact-quality obsidian, it remains to be seen whether or not these distinctions carry any archaeological significance. Hence, an understanding of the technology and function of artifacts made of Tuscan obsidian and their specific source provenience in the context of hunter-gatherer archaeological assemblages constitutes the focus of this chapter.

A review of the theoretical perspective which guided this phase of the study is first presented in order to explicate the relationship between lithic assemblages and various settlement/subsistence systems. Subsequently, through an analysis of site-specific data of Tuscan obsidian artifacts and their provenience an attempt will be made to reconstruct the mobility and procurement ranges used by these early hunter-gatherers in the study area. In this reconstruction, the distribution of source areas in space, the accessibility of the stone at the source and the knapping and use qualities of Tuscan glass are considered to be important in determining prehistoric raw material selection practices.

Lithic Resource Procurement, Lithic Technology and Mobility Strategies

The term, "mobility strategies", may be defined as the annual pattern of movement over the landscape pursued by hunter-gatherers, while "seasonal rounds" refers to the annual sequence in which particular resources and locations are used by a group of hunter-gatherers (Kelly 1983, 1985). Mobility strategies are important therefore in understanding how resources are procured (Shackley 1990:19).

Mobility strategy studies may be viewed as just one facet of a growing body of middle-range theory that deals specifically with forager subsistence economics (Shackley 1985:2). The value of hunter-gatherer mobility strategy theory is that it seeks to explain the variability within the archaeological record rather than simply creating another set of generalizations about hunter-gatherer behavior (Thomas 1983:11).

Following concepts introduced by Binford (1980) regarding residential and logistical mobility strategies, lithic technology and procurement in hunter-gatherer contexts can be viewed as a reflection of mobility and settlement choices made by the prehistoric people (Kelly 1985). To briefly summarize Binford's (1980) model, logistical mobility refers to the movement of organized task groups from a residential location to procure and/or process a variety of specific resources. A logistical strategy implies storage of processed resources and generally increased time spent at a particular residential base. The groups which practice this form of mobility are often referred to as "collectors".

In contrast, "foragers" are highly mobile groups who make relatively frequent residential moves in order to "map onto" a region's resource locations and relocate the group closer to the desired item. Because of the frequent residential moves associated with this type of strategy, foragers do not generally store foods. Instead, they procure and process the resources for immediate or nearly immediate consumption (Kelly 1985).

As Kelly (1992:45) has recently pointed out, it is clear that Binford did not intend for the concepts of foragers and collectors to become types.

> Instead, he used them as conceptual tools that helped him to think about the organization of camp movements relative to foraging activities and thus to understand the role mobility plays in creating archaeological sites. (Kelly 1992:45)

Therefore, the forager-collector dichotomy is best conceived as a malleable continuum which functions as an adaptive response to changing environmental and/or social conditions (Shackley 1990:21).

Since Binford's initial concepts were introduced, there have been a number of archaeological studies which have attempted to reconstruct prehistoric mobility by examining the organization of stone tool technologies (Binford 1979; Kelly 1985; Shackley 1985, 1990). While it is true that there are a number of factors which affect tool production, use, and discard, one of the most important factors is undoubtedly the type and distribution of lithic raw materials (Kelly 1985).

Recurring observations based upon archaeological and ethnographic data suggest that frequent residential moves and/or the consequent increase in time spent at residential bases results in a high incidence of recycling and reuse of tools manufactured from the better quality raw materials (Binford 1979; Kelly 1983). If high quality raw material is unavailable within the foraging radius of the group or the length of time spent at the residential base is prolonged, the use of bipolar reduction techniques may become necessary, along with the reuse or scavenging of previously worked materials and incorporation of local, but potentially inferior material into the assemblage (Binford 1979).

According to mobility theory, during logistical forays, or when the time spent at a residential base is brief, the lithic assemblage pattern is different. Due to the limited time spent at the specific locality, there would be little inclination for recycling and reuse of tools (Shackley 1985). Instead, the lithic materials noted in these types of assemblages would reflect the kinds of activities associated with the maintenance of formed tools such as projectile points (e.g., numerous small retouch flakes) and show little evidence of use of inferior local materials. High percentages of tools made from non-local or high-grade exotic materials would also be evident in the personal gear. In other words, bifacial tools or cores made from non-local, high-grade lithic raw materials are generally associated with frequent and/or lengthy residential movements, while expedient flake tools from local, and perhaps, inferior raw materials, coupled with the use of bipolar reduction are generally associated with infrequent residential moves (Kelly 1992:55).

As pointed out by Kelly (1992:55) reconstructing mobility strategies from prehistoric technology is hampered by several difficulties. First, there are no simple relationships between mobility and tool manufacture and other variables such as tool function, raw material type, and distribution intervene. Also, the reconstruction of different tool manufacturing methods from debitage is loaded with interpretive difficulties. Lastly, stone tools are not routinely used to a significant extent by living foragers, making it difficult to ethnographically test ideas relating stone tools to mobility (Kelly 1992:56).

Although patterns of obsidian dispersion can be accounted for, in part, by prehistoric exchange systems operating within fairly elaborate socio-ceremonial systems, ethnographic data and archaeological work conducted by Binford (1979) and others (Kelly 1983, 1985; Meltzer 1984; and Shackley 1985, 1986, 1990) suggests that among many hunter-gatherer populations the majority of lithic raw materials enters the system embedded within the subsistence procurement schedule. While it is true that at the present time, interpretations of stone tool assemblages along dimensions of mobility are largely subjective, characterizing the lithic raw materials within an archaeological assemblage and determining their source may be a potential indicator of at least a portion of the territory or procurement range exploited through the annual cycle or seasonal rounds (Shackley 1985). Viewed in this manner, obsidian source profiles often relate more directly to aspects of residential mobility and group provisioning strategies than to specialized collection forays or formalized socio-ceremonial exchange relationships (Basgall 1989).

With these perspectives in mind, this study seeks to contribute to a better understanding of northeastern California prehistory by examining the relationship between the nature and distribution of lithic sources in a region. With a focus on Tuscan obsidian, insights into how prehistoric people procured and exploited raw materials can be achieved when the archaeological objectives which guided this research are used to account for the variability viewed in the archaeological record. Thus, regional studies of raw material location, accessibility, and quality have the potential to expand our understanding of the articulation between lithic procurement and other aspects of hunter-gatherer adaptations.

Spatial and Temporal Overview

An examination of the geochemical trace element data resulting from numerous archaeological investigations conducted within the study area indicates that the spatial and temporal distribution of Tuscan obsidian encompasses an extended period of time over a broad-ranging area (Table 8). Artifacts made from Tuscan obsidians are found in archaeological site assemblages as far north as Goose Lake in Modoc County and as far south as Mendocino Pass and Black Butte Lake in Mendocino and Glenn counties (Figure 13). Tuscan obsidian artifacts are also encountered as far west as Pilot Ridge in the South Fork Mountain Range in Humboldt

Table 8. Archaeological Site Distribution Data for Tuscan Obsidian Artifacts.

Site Trinomial	Reference	Date of Component	Site Type[1]	Obsidian Sources[2]
CA-SHA-47 na[3]	1992 Vaughan, T.	A.D. 700 A.D. 1850	OCC	94% T 5% GF 1% UNK
CA-SHA-192 (n=54)[4]	1984 Baker, S.	3000 B.C. A.D. 1600+	OCC	59.3% T 35.3% GF 1.8% BM 3.7% UNK
CA-SHA-195 (n=26)	1990 Baker, S.	6640 B.P. 5900 B.P.	OCC	30% T 50% GF 20% UNK
CA-SHA-222 (n=10)	1982 Sundahl, E.	Shasta Complex	OCC	100% T
CA-SHA-228 (n=15)	1981b Clewett, S. Sundahl, E.	No dates	OCC	53.4% T 26.6% GF 20% UNK
CA-SHA-229 (n=2)	"	No dates	TC	100% T
CA-SHA-230 (n=8)	"	1000 B.P.	OCC	50% T 50% GF
CA-SHA-231 (n=23)	"	No dates	OCC	69.7% T 13% GF 17.3% UNK
CA-SHA-236 na	1992 Vaughan, T.	A.D. 700 A.D. 1850	OCC	94% T 5% GF 1% UNK
CA-SHA-266 (n=20)	1981a Clewett, S. Sundahl, E.	Shasta Complex	OCC	90% T 5% MLH 5% UNK
CA-SHA-266 (n=20)	1982 Sundahl, E.	Shasta Complex	OCC	90% T 5% GF 5% UNK

Table 8. Continued.

Site Trinomial	Reference	Date of Component	Site Type[1]	Obsidian Sources[2]
CA-SHA-290 (n=136)	1988 Dondero, S. Johnson, J.J.	No dates	OCC	78.7% T 15.4% GF 1.4% MGM 3.0% NO 0.1% BM
CA-SHA-291 (n=19)	"	"	OCC	78.9% T 15.8% GF 5.3% MGM
CA-SHA-294 (n=79)	"	"	OCC	53.2% T 45.6% GF 1.3% BX
CA-SHA-350 na	1987 Kelly, M. Nilsson, E. Cleland, J.	No dates	OCC	20% T 60% GF 20% SW
CA-SHA-385 na	"	"	OCC	14% T 14% MGM 71% BM
CA-SHA-395 na	"	"	OCC	50% T 50% GF
CA-SHA-396 na	"	"	OCC	16% T 59% GF 18% BM 4.5% UNK 2% NO
CA-SHA-397 na	"	"	EO	100% T
CA-SHA-400 na	"	"	OCC	50% T 50% GF
CA-SHA-475 (n=140)	1983 Clewett, S. Sundahl, E.	5600 B.C. 2000 B.C. A.D. 500	TC OCC TC	96% T 1% BLMT 1% BM 2% UNK

Table 8. Continued.

Site Trinomial	Reference	Date of Component	Site Type[1]	Obsidian Sources[2]
CA-SHA-476 (n=396)	1989 Basgall, M. Hildebrandt, W.	4650 B.P. 1050 B.P.+	OCC	7% T 90.5% GF 1.5% BM <1% MGM <1% UNK <1% SM
CA-SHA-479 (n=99)	1990 Baker, S.	6640 B.P. 895 B.P.	OCC	56% T 44% GF
CA-SHA-499 (n=20)	1990 Sundahl, E.	No dates	OCC	30% T 60% GF 10% UNK
CA-SHA-511 (n=41)	1984 Raven, C. *et al.*	A.D. 500+	OCC	7.3% T 92.7% GF
CA-SHA-594 (n=22)	1992 Hull, K. *et al.*	3300 BP 100 BP	OCC	5% T 63% GF 16% BM 5% MGM 5% SH 5% SW
CA-SHA-864 (n=12)	1984b Sundahl, E.	2000 B.C. A.D. 1800	TC	16.6% T 58.3% GF 16.6% BM 8.3% UNK
CA-SHA-987 (n=22)	1986 Sundahl, E.	5000 B.P. 1500 B.P.+	OCC	81.8% T 27.3% GF
CA-SHA-992 (n=21) combined[5]	1982 Clewett, S. Sundahl, E.	1300 B.C. A.D. 1800	OCC	95% T 5% GF
CA-SHA-994	"	"	LS	95% T 5% GF
CA-SHA-995	"	"	LS	95% T 5% GF

Table 8. Continued.

Site Trinomial	Reference	Date of Component	Site Type[1]	Obsidian Sources[2]
CA-SHA-1144 (n=1)	1988 Dondero, S. Johnson, J.J.	No dates	TC	100% T
CA-SHA-1158 (n=1)	"	"	TC	100% T
CA-SHA-1169 (n=271)	1989 Basgall, M. Hildebrandt, W.	5200 B.P. 950 B.P.+	OCC	16.6% T 80% GF 1.1% RRG <1% EML <1% HF <1% SH <1% SM
CA-SHA-1175 (n=117)	"	4300 B.P. 1450 B.P.+	OCC	9% T 90% GF <1% BX <1% UNK
CA-SHA-1176 (n=122)	"	3000 B.P. 900 B.P.	OCC	14% T 81% GF 1.6% BM 2.5% RRG <.1% CB <.1% UNK
CA-SHA-1183 (n=16)	1984 Raven, C. et al.	No dates	LS	6.3% T 93.7% GF
CA-SHA-1464 na	1987 Kelly, M. Nilsson, E. Cleland, J.	No dates	EO	20% T 54% GF 17% BM 2.4% BS 2.4% BLMT 2.4% SW 2.4% UNK

Table 8. Continued.

Site Trinomial	Reference	Date of Component	Site Type[1]	Obsidian Sources[2]
CA-SHA-1465 na	1987 Kelly, M. Continued.	No dates	OCC	6.6% T 76.6% GF 3.3% SW 3.3% EML 3.3% FM
CA-SHA-1471 na	"	"	OCC	100% T
CA-SHA-1474 na	"	"	OCC	18% T 54.5% GF 18% BM 9% UNK
CA-SHA-1481 (n=10)	1984 Farber, A. Neuensch- wander, N.	A.D. 500+ A.D. 1600	OCC	10% T 90% GF
CA-SHA-1483 (n=10)	1985 Sundahl, E.	500 B.P.	TC	80% T 20% GF
CA-SHA-1484 (n=8)	"	No dates	LS	63% T 37% GF
CA-SHA-1485 (n=5)	"	No dates	TC	80% T 20% UNK
CA-SHA-1544 (n=11)	1986 Tyree, K.	2000 B.P.+	OCC	73% T 27% GF
CA-SHA-1684 (n=31)	1987 Shackley, S.	No dates	OCC	10% T 77% GF 10% EML 3% RRG
CA-SHA-1720 (n=86) combined	1991 Hull, K. Nilsson, E. Kelly, M.	500 B.C. A.D. 1845	OCC	81% T 10% GF 9% UNK

Table 8. Continued.

Site Trinomial	Reference	Date of Component	Site Type[1]	Obsidian Sources[2]
CA-SHA-1723	1991 Hull, K. Continued.	1500 B.C. A.D. 1845	OCC	81% T 10% GF 9% UNK
CA-SHA-1724	"	No dates	LS	"
CA-SHA-1752	"	A.D. 1500 A.D. 1845	TC	"
CA-SHA-1841 (n=24)	1992 personal communication Skinner, C.	No dates	OCC	83.3% T 12.5% GF 4.7% KM
CA-SHA-1842 (n=62)	"	No dates	OCC	72.5% T 27.4% GF
CA-SHA-1843/H (n=21)	"	No dates	LS	71.4% T 23.8% GF 4.8% EML
CA-SHA-1891 (n=16)	"	No dates	OCC	87.5% T 12.5% GF
CA-SHA-1943 (n=8)	1992 Hull, K. et al.	5000 BP 100 BP	LS	37.5% T 62.5% GF
CA-SHA-1947/H (n=11)	"	3300 BP 100 BP	OCC	14% T 57% GF 29% BM
CA-TEH-10 (n=90)	1990 Johnson, J.	A.D. 1750 A.D. 1850	CE	58.8% T 22.2% GF 10% BX 6.6% MGM 1.1% NV 1.1% UNK
CA-TEH-387 (n=1)	1988 Dondero, S. Johnson, J.J.	No dates	LS	100% T

Table 8. Continued.

Site Trinomial	Reference	Date of Component	Site Type[1]	Obsidian Sources[2]
CA-TEH-748 (n=6)	1988 Dondero, S. Continued.	No dates	OCC	50% T 33.3% GF 16.6% UNK
CA-TEH-810 (n=27)	1991 Sundahl, E.	No date	OCC	63% T 22% GF 11.1% MGM 3.7 % UNK
CA-TEH-962 (n=30)	1982 Farber, A.	Shasta Complex	OCC	3.3% T 70% GF 10% BX 3.3% NGM 6.7% YJ
CA-TEH-1196 (n=14)	1988 Dondero, S. Continued.	No dates	LS	50% T 35.7% GF 7.1% MGM 7.1% NO
CA-TEH-1211 (n=4)	"	"	LS	50% T 50% GF
CA-TEH-1232 (n=5)	"	"	LS	60% T 40% GF
CA-TEH-1264 (n=1)	"	"	LS	100% T
CA-TEH-1432 (n=6)	1987 Ritter, E.	3000 B.P. A.D. 1800+	RS	50% T 33% KM 17% UNK
CA-TEH-1468 (n=3)	1987	No dates	LS	100% T
CA-TEH-1490 (n=10)	1988 Hamusek, B.	A.D. 1 A.D. 1300+	TC	60% T 10% GF 10% BM 20% KM
CA-TEH-1523 (n=29)	1991 Sundahl, E.	700 BP	OCC	76% T 24% GF

Table 8. Continued.

Site Trinomial	Reference	Date of Component	Site Type[1]	Obsidian Sources[2]
CA-GLE-105 (n=20)	1990 Bayham, F. Johnson, K.	3750 B.P A.D. 1850+	OCC TC	50% T 5% GF 35% BX 5% NV 5% BH
CA-SIS-584 (n=1)	1984 Krieger, J. Goheen, A.	No dates	LS	TP
05-09-53-262B Modoc Co. (n=1)	1987 Gates, G.	No dates	LS	TP
CA-MEN-1071 (n=3)	1980 Farber, A.	1000 B.C. A.D. 500	TC	33% T 35% MLH 35% BX
CA-HUM-546/H (n=60)	1983a Hildebrandt, W. Hayes, J.	2500 B.C. A.D. 500	LS	1.6% T 68.3% GF 8.3% EML 15% MLH 1.6% NV 1.6% CH 1.6% SH 1.6% HC
CA-HUM-558 (n=50)	"	"	LS	4% T 64% GF 12% EML 10% MLH 10% UNK
CA-HUM-588 (n=46)	"	"	LS	6.5% T 39% GF 34.7% MLH 15% EML 2.1% BM 2.1% SM

Table 8. Continued.

Site Trinomial	Reference	Date of Component	Site Type[1]	Obsidian Sources[2]
CA-HUM-595 (n=21)	1983a Hildebrandt, W. Continued.	2500 B.C. A.D. 500	LS	4.8% T 33.3% GF 38% MLH 9.5% BX 4.8% HC 4.8% SLSY
CA-TRI-177 (n=31)	1988 Sundahl, E.	A.D. 1850+	EO	39% T 61% GF
CA-TRI-205 (n=81)	1982 Jensen, P. Farber, A.	3000 B.C. A.D. 1850+	OCC	11% T 62% GF 22.2% YJ 2.5% BX 2.5% UNK
CA-TRI-240 (n=55)	1983b Hildebrandt, W. Hayes, J.	No dates	TC	2% T 87% GF 4% BM 2% SH 2% SM 4% UNK
CA-TRI-243 (n=11)	1983 Vaughan, T.	No dates	LS	9% T 72.7% GF 18.1% BX
CA-TRI-262 (n=26)	1983b Hildebrandt, W. Hayes, J.	No dates	TC	7.5% T 81% GF 4% SH 4% UNK
CA-TRI-862 (n=3)	1984 Vaughan, T.	A.D.1860 A.D.1930	EO	33% T 66% GF
CA-TRI-1008 (n=47)	1988 Sundahl, E.	No dates	TC	4% T 96% GF
CA-TRI-1019 (n=15)	1990 Nilsson, E.	pre A.D. 1270 A.D. 1670	TC	40% T 60% GF

Table 8. Continued.

Site Trinomial	Reference	Date of Component	Site Type[1]	Obsidian Sources[2]
CA-TRI-1123 (n=15)	1987 Sundahl, E.	A.D. 900 A.D.1850	TC	20% T 74% GF 6% SLSY
CA-TRI-1196 (n=3)	1992 personal communication Sundahl, E.	No dates	LS	33% T 66% UNK
CA-BUT-5 (n=7)	1987 Shackley, S.	No dates	OCC	14% T 14% NV 28% SH 28% BM/SH 14% BM
CA-BUT-288 (n=20)	1987 Zancanella, J.	4500 B.C. A.D. 1600	OCC	80% T 15% BX 5% GF
CA-BUT-290 (n=20)	"	2300 B.C. A.D. 1300	OCC	60% T 20% GF 10% BX 5% YJ 5% UNK
CA-BUT-294 (n=21)	"	1000 B.C. A.D.1500	OCC	38% T 9.5% GF 29% BX 19% NGM 4.5% FM
CA-BUT-518 (n=4)	1980 Offerman, J.	A.D. 900 A.D.1850	TC	25% T 75% MLH
CA-BUT-1073 (n=55)	1991 Baker, S.	A.D. 600 A.D.1850+	LS	13% T 21.8% GF 5.5% EML 14.5% BM 1.8% SH 7.2% SW 9.1% BS 4% KM 21.8% BX 1.8% NV

Table 8. Continued.

Site Trinomial	Reference	Date of Component	Site Type[1]	Obsidian Sources[2]
CA-PLU-115 (n=54)	1983 Crew, H. Peak, A.	No dates	OCC	17% T 15% GF 13% VYA 2% MONO 3.7% WR 7% MGM 3.7% MH 2% CS 9% BH 11% UNK 7% BX
CA-LAS-973 (n=38)	1989 Manuel, D.	2000 B.C. A.D.1850	OCC	5% T 29% GF 5% EML 37% BM 3% KM 8% SW

Site Type[1]: OCC=Occupation, TC=Temporary Camp, LS=Lithic Scatter, EO=Ethnographic village, RS=Rockshelter, C=Cemetery.

Obsidian Sources[2]: BLMT=Blue Mountain, BS=Blue Spring, BH=Bodie Hills, BX=Borax Lake, BS=Bordwell Spring, BM=Buck Mountain, CH=Callahan, CS=Coso, CB=Cougar Butte, EML=East Medicine Lake, FM=Fox Mountain, GF=Grasshopper Flat/Lost Iron Wells/Red Switchback, HF=Harris Flat, HC=Home Camp, KM=Kelly Mountain, MLH=Medicine Lake Highlands, MGM=Modoc Glass Mountain, MONO=Mono, MH=Mount Hicks, NGM=Napa Glass Mountain, NV=Napa Valley, NO=Not Obsidian,RRG=Railroad Grade, SM=Spodue Mountain, SW=South Warners, SH=Sugar Hill, SLSY=Sylvan Marsh/Silver Lake, T=Tuscan, TP=Tuscan Present, UNK=Unknown, VYA=Vya, WR=Warners, YJ=Yellowjacket/Stoney Rhyolite Core.

na[3]: No specific site data for geochemical results which are presented in report.
(n=)[4]: Number of artifacts subjected to EDXRF.
combined[5]: Geochemical data from all sites in report combined for analysis.

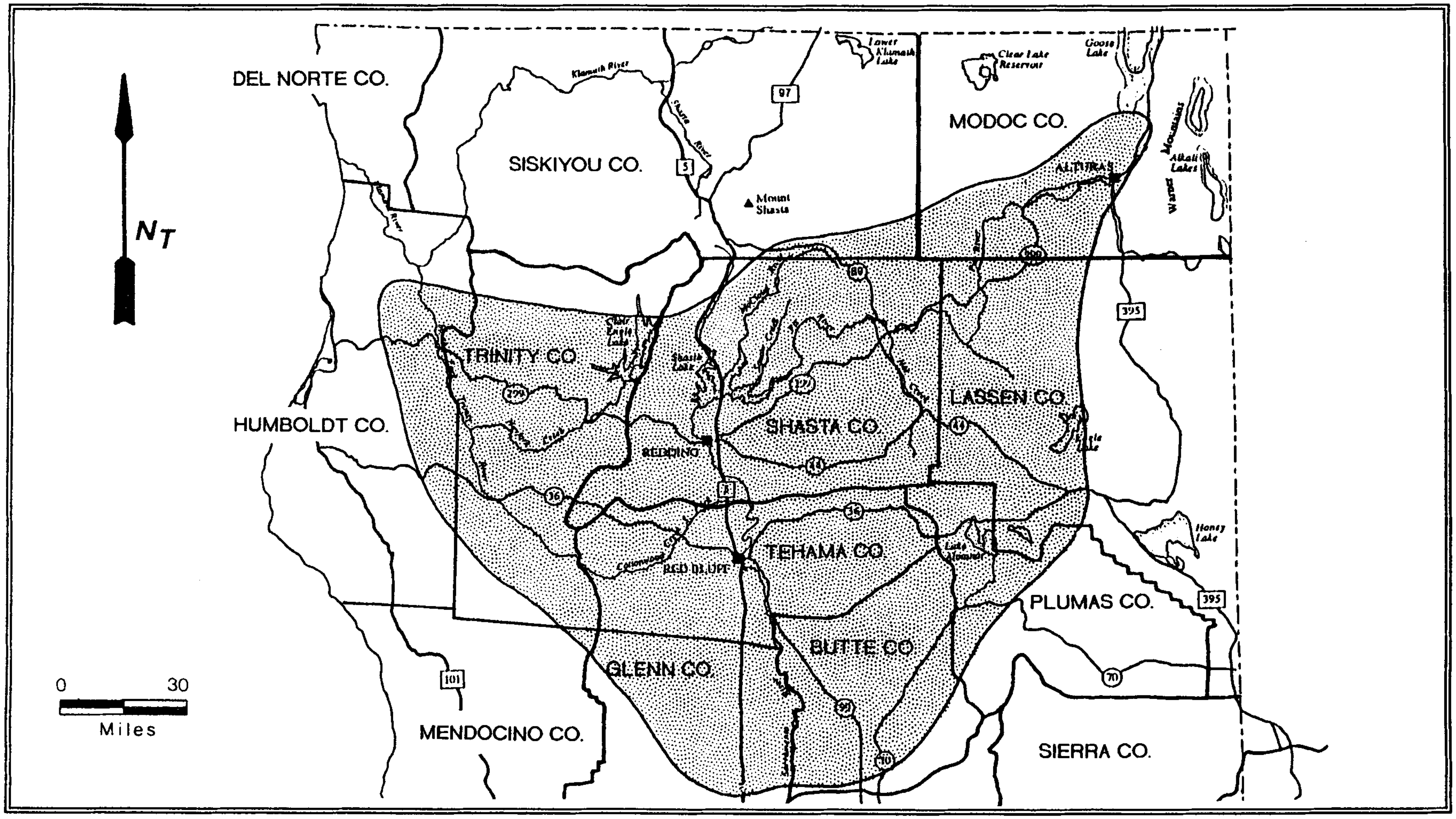

Figure 13. Spatial Distribution of Tuscan Obsidian Artifacts.

County, and as far east as Honey Lake in Lassen County and Bucks Lake in Plumas County.

Tuscan obsidian was found to occur in virtually all known types of prehistoric sites and in all flaked tool categories. The various site types in which Tuscan obsidian is present include rockshelters, isolated finds, simple lithic scatters, temporary or seasonal campsites, major prehistoric/ethnographic villages, and cemeteries. Additionally, the artifact categories for which Tuscan obsidian is noted include projectile points, bifaces, unifaces, cores, scrapers, drills, knives, edge-modified or utilized flaked tools, as well as debitage.

Not unexpectedly, the greatest percentages of Tuscan obsidian use are found in sites situated near the source deposits and areas south. Archaeological sites from Shasta, Tehama, Glenn and Butte Counties account for the greatest use of Tuscan obsidian. Approximately 35% to 50% of the sourced items from archaeological assemblages in these counties are comprised of Tuscan obsidians (Figure 14). However, the further east, west, or north one travels from the core geological source area, the use of Tuscan obsidian declines, and greater percentages of other obsidians begin to appear in the archaeological record. For instance, in Siskiyou and Modoc Counties the percentage of Tuscan obsidian drastically declines with Tuscan obsidian artifacts

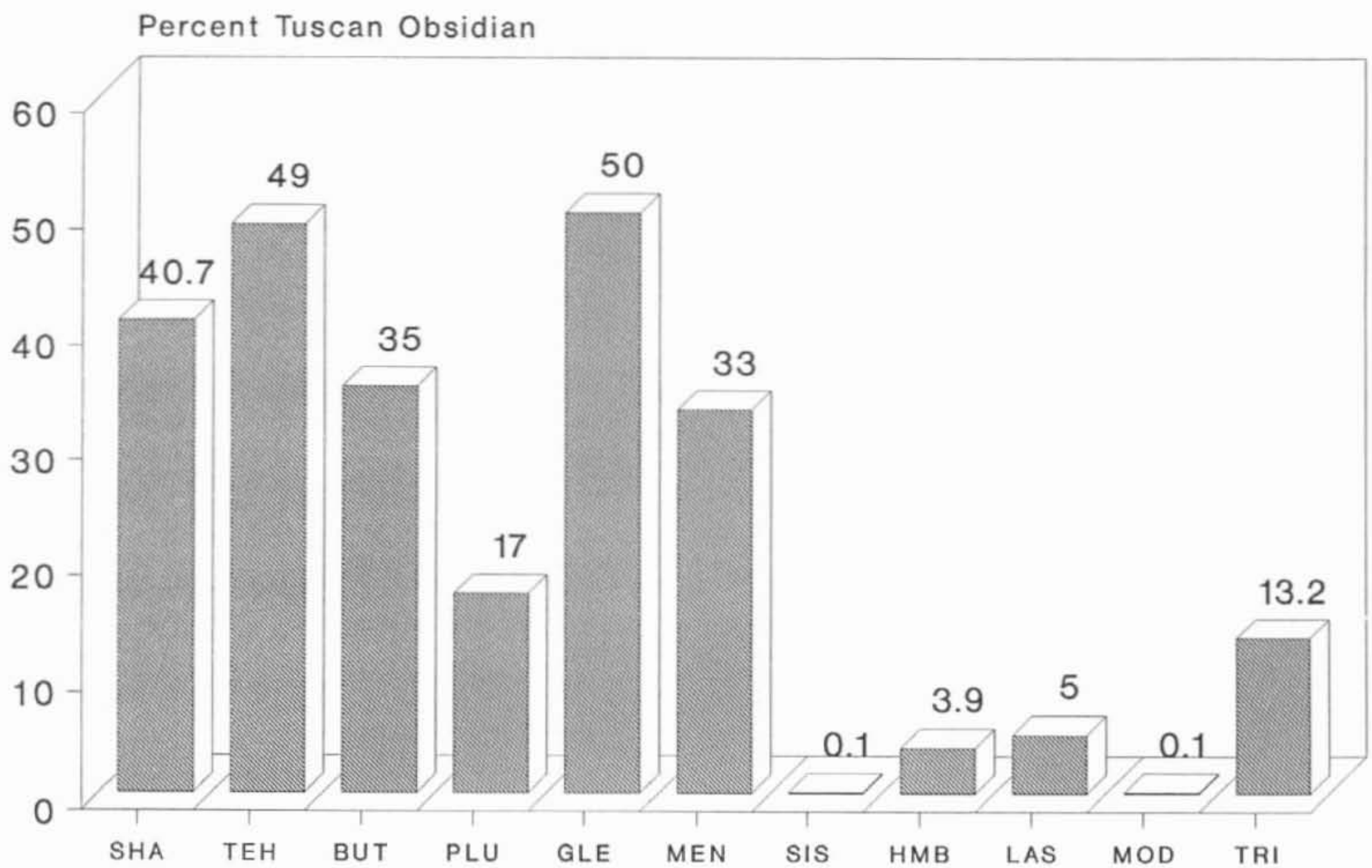

Figure 14. Distribution of Tuscan Obsidian in Northern California by County.

only making an occasional appearance in local site assemblages.

Temporally, Tuscan obsidian is well represented from the earliest time periods onward throughout the study area. However, archaeological investigations conducted at specific sites in the region do suggest that diachronic variability in Tuscan obsidian use is present. Site specific discussions regarding these diachronic patterns have been presented in Chapter III and need not be repeated. However, based on an examination of the site data presented in Table 8, some additional general observations are advanced.

The use of Tuscan obsidian in lands traditionally claimed by the Achumawi appears to have occurred in all prehistoric and ethnographic time periods. Kelly, Nilsson and Cleland (1987) noted in the Lake Britton region that Tuscan obsidian was encountered in almost all of the sites which they investigated. While Kelly, Nilsson and Cleland (1987) did not advance an explanation for their observations they noted that the percentage of Tuscan obsidian varied greatly between the different tool categories. Whereas Tuscan obsidian accounted for approximately 18% of projectile points analyzed from the various sites, it accounted for only 4% of the obsidian debitage from these same sites. Moreover, there appeared to be a trend away from the use of Grasshopper Flat/Lost Iron Wells/Red Switchback obsidians in the late periods, with an increase in Tuscan obsidians along with obsidians from Buck Mountain (Kelly et al. 1987).

Further to the east and north, on the Modoc Plateau in Lassen and Modoc counties (Figures 13 and 14), Tuscan obsidian was found in only minor amounts in a few sites as curated tools. A similar pattern appears to exist for sites located in Humboldt County. While Tuscan obsidian was found in this region in some very early contexts beginning around 2500 B.C., it was only present in minor amounts. Although the data presented in Table 8 is far from conclusive, the use of Tuscan obsidian was only noted in one archaeological site context in Siskiyou County. However, the proximity to other reliable obsidian sources throughout this portion of the state most likely played a major role in the limited use of Tuscan obsidian by the aboriginal inhabitants of this region.

In Butte County, Tuscan obsidian dominated the archaeological assemblages during the earliest time periods. According to Zancanella (1987), beginning around 4500 B.C., (inferred from point typology) Tuscan obsidian accounted for nearly 80% of the sourced specimens found at CA-BUT-288 and continued to be the dominant obsidian source present. However, Zancanella (1987) stated that the percentage of Tuscan obsidian appears to decline in nearby sites such as CA-BUT-294 sometime beginning around 1000 B.C.

Unfortunately, interpretations regarding the spatial and temporal distribution of Tuscan obsidian artifacts are inherently limited by a number of factors. In some northern California counties the small number of excavated archaeological sites makes it difficult to discuss regional obsidian procurement patterns beyond the tentative inferences which have been presented here. Furthermore, at the current time there exists no general consensus among area researchers on the sampling methods to be used to select the artifacts for obsidian characterization analysis. Therefore, until the methods of sample selection and the number of artifacts which are subjected to obsidian characterization analysis undergo modifications, the interpretations regarding Tuscan obsidian procurement patterns on a regional level which have been presented above should be considered provisional.

Site Specific Analyses

Theoretical Expectations

To what extent the geochemical differences observed in the various artifact-quality Tuscan glass sources are related to prehistoric behavioral changes and decisions will be the focus of the final component of this study. In pursuing this objective, the general expectations derived from theoretical considerations will be outlined. Next, previous research in the Squaw Creek drainage will be reviewed. Following this the raw material selection observable in the archaeology of this area will be considered. Following this, there will be a parallel treatment in the Paynes Creek area. The succeeding and final sections of this chapter will then present an explanation of the temporal distribution of Tuscan obsidian in the Squaw Creek and Paynes Creek areas utilizing the concepts of mobility and resource procurement strategies.

To briefly review, geochemical data obtained as a result of the EDXRF analyses suggest that there are at least three major and one minor geochemically distinct artifact-quality glass sources which can be identified within the Tuscan Formation. These artifact-quality glass sources are all located approximately 20 miles apart and include, from north to south, the Backbone Ridge source locales, the Cow Creek source locales, the Paynes - Ink Creek source locales and the Paradise Ridge source locales (Figure 15).

Except for the Paynes - Ink Creeks source locales, there are no significant differences in the quality of the obsidian from these sources which would have been visible to the aboriginal inhabitants. Therefore, if spatial or temporal differences are evident in the frequencies with which the remaining source materials occur within the archaeological record on a regional scale, then the explanation for use of that specific glass source must lie in such factors as proximity and/or access rather than

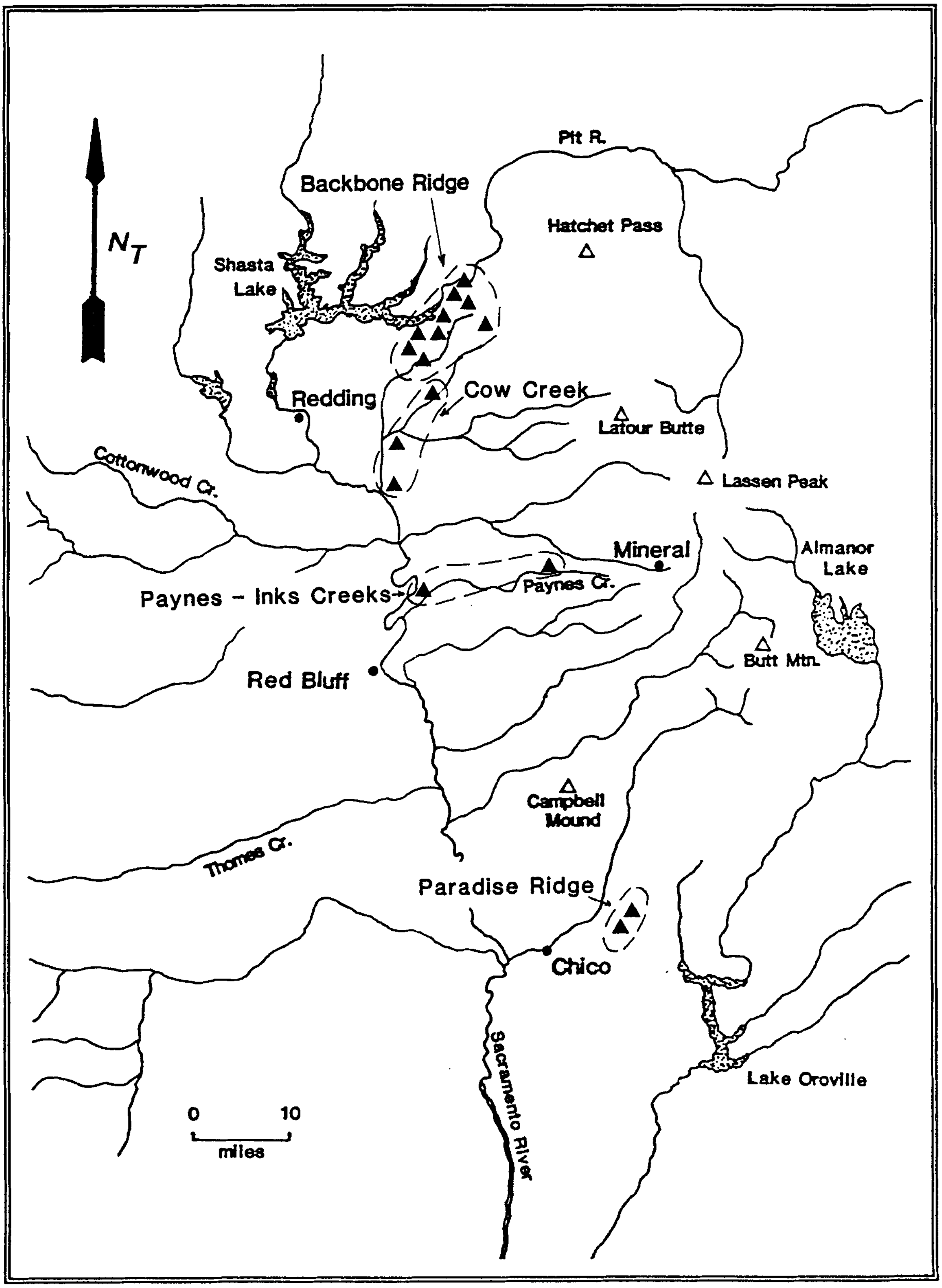

Figure 15. Tuscan Artifact-Quality Glass Sources.

deliberate selection on the part of prehistoric peoples for its flaking or aesthetic qualities.

It has been proposed that during the earliest periods of occupation hunter-gatherers inhabiting the study area practiced a foraging type mobility strategy which involved extensive procurement ranges (Sundahl 1992). It is true that distinguishing between various obsidian sources in which the effective distance is only 20 to 30 miles apart may not result in significant behavioral differences for groups practicing such a wide-ranging mobility strategy. However, during the late prehistoric period when most territories in the study area were approximately 40 miles in diameter, there is good reason to suspect that procuring obsidians from source locales located only 20 miles apart such as the Backbone Ridge and Cow Creek source locales, would have significant behavioral differences in terms of mobility and/or procurement ranges, territorial boundaries, social boundary defense, and inter-group social interaction.

More specifically, the research expectations in this portion of the study were conceived as follows. In the northern portions of the study area (e.g., Squaw Creek drainage) it was expected that during the earliest periods of occupation the large procurement ranges of these early inhabitants would be reflected by a greater diversity in the various obsidian sources. While it was anticipated that the majority of the obsidian lithic material in the site assemblages would be comprised of the various Medicine Lake Highland and Tuscan source groups, it was expected that differences in the various percentages of these source groups would be reflected in the various flaked stone tool types. For instance, since the Backbone Ridge and Cow Creek source groups were readily available and in close proximity to the Squaw Creek drainage, it was expected that obsidians from both of these geochemical source groups would be present in all flaked tool categories to some degree.

Even with the larger procurement ranges which have been hypothesized for the early inhabitants, the ease of access and relative proximity to source locales, led to the expectation that there would be a greater use of obsidians from the Backbone Ridge and Cow Creek source groups relative to the Paynes and Paradise Ridge source groups in the Squaw Creek drainage for all time periods. However, due to the hypothesized large procurement ranges, it was anticipated that the differences in the percentages between the Backbone Ridge and Cow Creek source groups would be minimal during the earliest periods. This relatively equal apportionment of the two closest Tuscan sources within the tool assemblage would have continued until the relatively recent prehistoric times when, it has been hypothesized, the Wintu began encroaching upon previously held Yana territory. It was anticipated that as a result of this encroachment that sites associated with Wintu occupation in the Squaw Creek drainage would perhaps exhibit a decrease reliance on the Tuscan obsidians and an concomitant increase in glass from the Medicine Lake Highlands since traditional claims by Yana indicated that most of the Tuscan obsidian source locales were situated within their territory. If artifact-quality glass from the Tuscan source groups were present, it was anticipated that there would be a greater reliance on the Backbone Ridge source locales since some of the collection localities appear to be located within or along the hypothesized border between the Wintu and Yana groups.

It was also anticipated that certain differences would emerge in the obsidian procurement patterns between the upper and lower portions of the drainage. Due to the relative proximity and distance between the various sites and source locales, it was expected that there would be a greater use of the Tuscan obsidians in the lower portions of the drainage throughout all time periods involved, while the sites within the upper portions of the drainage would exhibit a greater dependency upon obsidians from the Medicine Lake Highland sources.

Obsidian procurement patterns in the southern portion of the study area were expected to follow similar patterns in terms of proximity and/or access to source locales especially during the later prehistoric time periods. For sites in the Inks and Paynes creeks drainage area, it was expected that there would be a greater reliance on the local glass sources for expediently made flaked tools in all time periods; however, the use of the Paynes Creek source materials would increase in the later time periods. This increase in the use of Paynes Creek source materials during the late prehistoric period would be accompanied by an increase in the relative abundance of the Cow Creek source materials as well, owing to an increasingly circumscribed procurement range.

It was also anticipated that although the presence of glass from the Medicine Lake Highland sources would be present throughout all prehistoric periods, the percentage of material from this source would decline during the later time periods with a concomitant increase in the use of the various Tuscan source groups. Likewise, while it is anticipated that artifact-quality glass from the Backbone Ridge source locales will be present in the flaked stone assemblage at the Paynes Creek sites, it is expected that the overall percentage of material from this source will decrease over time with a decrease in mobility compared with the earliest time periods.

In the following sections, these expectations regarding Tuscan obsidian use within the Squaw Creek and Paynes Creek drainages (representing the more northerly and more southerly archaeological areas respectively) will be examined in the light of the new geochemical source data generated by the present study. The raw data used in this analysis are presented in Appendix C and will be referred to in summary fashion here.

Archaeological Investigations in the Squaw Creek Drainage

The Squaw Creek drainage, which has been the focus of intensive archaeological investigations since the 1970s, consists of a 25 mile-long tributary to the Pit River in north-central Shasta County. By far the greatest contribution to archaeological research within the drainage has been made by S. Edward Clewett, and his field classes at Shasta College. Clewett, and his assistant E. Sundahl, spent one or more weeks each year for a total of 14 years investigating six prehistoric sites (Sundahl 1992:i).

Excavations by Shasta College field program began at CA-SHA-475, commonly known as the Squaw Creek site, in 1971. Most of the work in the drainage during the 1970s through 1980s concentrated on excavating this deeply stratified midden site resulting in the recovery of more than 100,000 artifacts, including nearly 830 classifiable projectile points (Henn and Sundahl 1988). Investigations at this site proved to be highly significant enabling the cultural history in the area to be extended some 7500 to 8000 years into the past and resulting in a refinement of the region's chronological sequences (Sundahl 1992).

Although Shasta College field classes conducted excavations at several other sites in the drainage and the areas surrounding Shasta Lake, a relatively small percentage of the entire Squaw Creek drainage has actually been surveyed for cultural resources (Sundahl 1992:13). Because of the steep terrain found generally throughout the drainage, the limited surveys which have been performed primarily focused on the terraces of the creek and adjacent ridge tops (Sundahl 1992:13). Thus, Sundahl (1992:20) feels that the 37 recorded prehistoric sites plotted within the Squaw Creek drainage are probably only a small sample of the actual number of loci of prehistoric human activity, and that the sample may not be representative of the extent of prehistoric use since the reconnaissances largely avoided areas away from the creek (Figure 16).

Most of the recorded sites in the drainage have been interpreted as occupational areas varying from small lithic scatters to large, and in some instances, extensive, multi-loci sites. The depths of the cultural deposits also vary from nil to more than 3 meters at CA-SHA-475 (Sundahl 1992:129). The information level available for each site varies widely. Eight of the sites in the drainage have been excavated or tested to some extent, and surface collections have been made from an additional 16 sites (Sundahl 1992).

While Sundahl's overview was in preparation, funding was made available by the Shasta-Trinity National Forest to perform additional obsidian studies on the Squaw Creek drainage material. Although the main objective for this work was to explore the variability in obsidian procurement

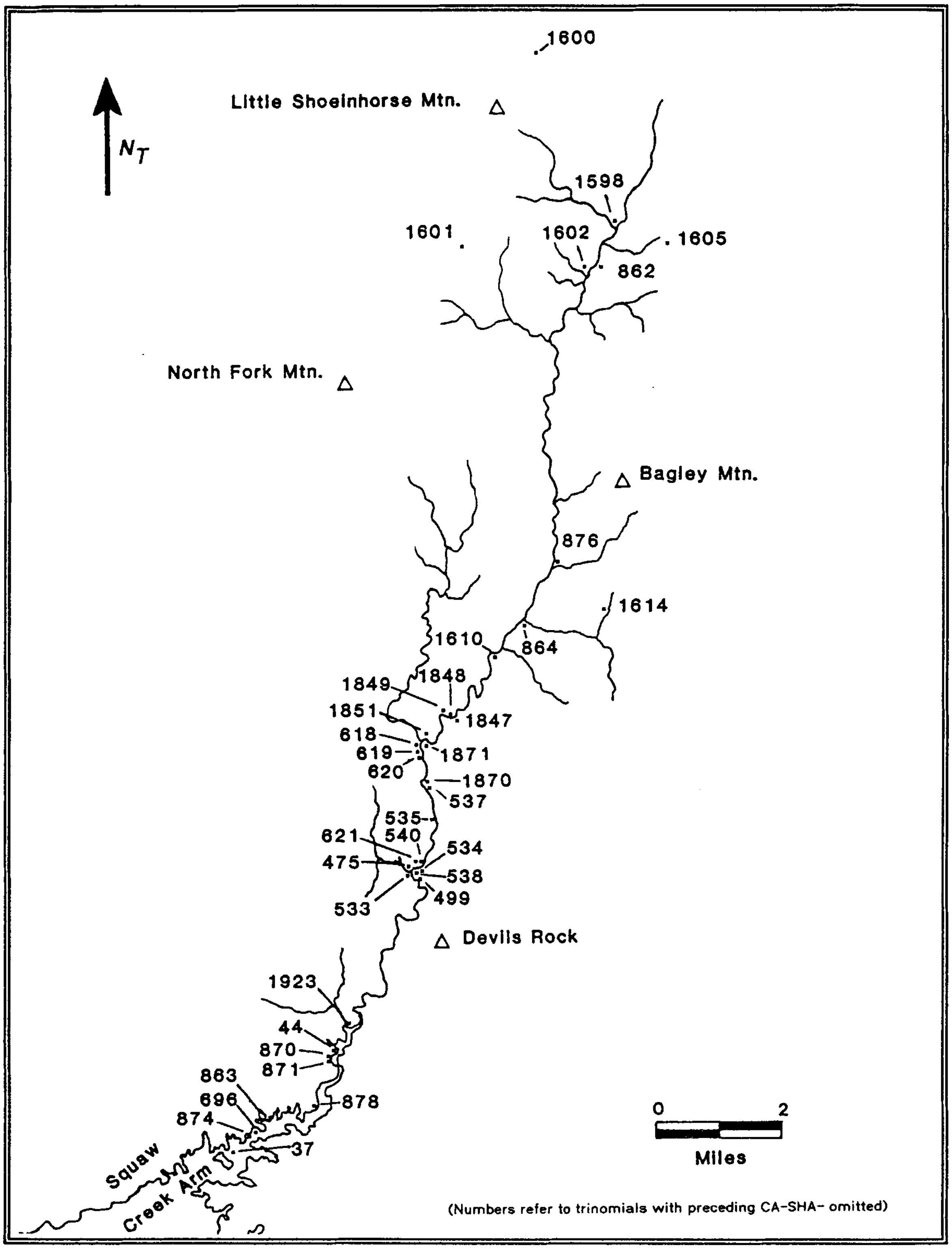

Figure 16. Archaeological Sites within the Squaw Creek Drainage.

within the Squaw Creek drainage in a geographic/temporal framework, Sundahl's immediate objectives focused on increasing the data base toward that end (1992:125). In order to accomplish these objectives, a total of 165 obsidian specimens from 14 prehistoric sites were submitted to the present author for EDXRF chemical characterization analysis, the results of which can be found in Appendix C.

Previous investigations suggest that approximately 98% of all obsidian recovered in the Squaw Creek drainage can be assigned to two geochemical sources, the Grasshopper Flat/ Lost Iron Wells/Red Switchback (GF/LIW/RS) geochemical source situated within the Medicine Lake Highlands, and the undifferentiated Tuscan source south of the Pit River (Sundahl 1992:125). Past obsidian characterization studies performed at CA-SHA-475 have indicated that the obsidian procurement pattern was not static and changed over time from an early dependence on GF/LIW/RS obsidian, to a dramatic increase in the use of Tuscan obsidian during the middle periods of occupation. During the most recent occupational phases at the Squaw Creek site, the use of GF/LIW/RS obsidian once again increased. However, Tuscan obsidians continued to represent a major source (Sundahl 1984).

Table 9 presents the results of the obsidian characterization analysis performed on the 165 specimens from the Squaw Creek sites in conjunction with this study.

The sites are arranged in geographical order from south to north beginning with those found within the lower drainage. The data are presented in summary fashion here in Table 9; a detailed discussion of each site and its characteristics may be found in Sundahl's recent overview of the Squaw Creek drainage (1992).

Table 9. EDXRF Source Data for the Squaw Creek Sites.

Site Trinomial[1]	Age of Component	Site Type[2]	Obsidian Sources[3]
Lower Drainage			
CA-SHA-696 (n=6)	Possible Squaw Creek Phase -5000 BP to 3000 BP Howell Phase -300 BP to 150 BP	OCC	33.5% GF 33.5% BBCC 16.5% BBR 16.5% CCT
CA-SHA-878 (n=37)	Chirpchatter Phase -8000 BP to 5000 BP Squaw Creek Phase -5000 BP to 3000 BP Monday Flat Phase -3000 BP to 1700 BP Wheeler Ranch to Howell Phase -1700 BP to 150 BP	OCC	46% GF 21.5% BBR 21.5% BBCC 11% CCT
CA-SHA-44 (n=35)	Chirpchatter Phase -8000 BP to 5000 BP Monday Flat Phase -3000 BP to 1700 BP Wheeler Ranch Phase -1700 BP to 300 BP Howell Phase -300 BP to 150 BP	OCC	60% GF 18% BBR 18% BBCC 4% CCT
CA-SHA-1923 (n=9)	Possible Monday Flat -3000 BP to 1700 BP Possible Wheeler Ranch -1700 BP to 300 BP Howell Phase -300 BP to 150 BP	OCC	56% BBR 33% CCT 11% BBCC

Table 9. Continued.

Site Trinomial[1]	Age of Component	Site Type[2]	Obsidian Sources[3]
Middle Drainage			
CA-SHA-534 (n=3)	Squaw Creek Phase -5000 BP to 3000 BP Monday Flat Phase -3000 BP to 1700 BP Wheeler Ranch Phase -1700 BP to 300 BP	OCC	66.6% GF 33.4% CCT
CA-SHA-539 (n=3)	Squaw Creek Phase -5000 BP to 3000 BP Monday Flat Phase -3000 BP to 1700 BP	TC	66.6% BBCC 33.4% LDG
CA-SHA-1871 (n=2)	Squaw Creek Phase -5000 BP to 3000 BP	TC	50% BBCC 50% CCT
CA-SHA-620 (n=1)	Chirpchatter Phase -8000 BP to 5000 BP	LS	100% GF
CA-SHA-864 (n=8)	Possible Squaw Creek -5000 BP to 3000 BP Monday Flat Phase -3000 BP to 1700 BP Wheeler Ranch Phase	OCC	50% GF 12.5% YJ 12.5% UNK 25% CCT
CA-SHA-876 (n=4)	Squaw Creek Phase -5000 BP to 3000 BP Monday Flat Phase -3000 BP to 1700 BP Wheeler Ranch Phase -1700 BP to 300 BP	TC	50% GF 25% CCT 25% BBCC
Upper Drainage			
CA-SHA-1602 (n=2)	Wheeler Ranch Phase -1700 BP to 300 BP	TC	100% GF
CA-SHA-1605 (n=10)	Wheeler Ranch Phase -1700 BP to 300 BP	TC	90% GF 10% NQ

Table 9. Continued.

Site Trinomial[1]	Age of Component	Site Type[2]	Obsidian Sources[3]
Upper Drainage			
CA-SHA-1601 (n=32)	Wheeler Ranch Phase -1700 BP to 300 BP	TC	78% GF 3% YJ 6.1% BM 3% NQ 3.3% BBR 3.3% CCT 3.3% BBCC
CA-SHA-1598 (n=12)	Wheeler Ranch Phase -1700 BP to 300 BP	LS	66.6% GF 8.3% YJ 8.3% LDG 16.6% UNK

Site Trinomial[1] n = number of items subjected to obsidian characterization analysis.

Site Type[2]: OCC - occupation site, TC - temporary camp, LS - lithic scatter.

Obsidian Sources[3]: BBR=Backbone Ridge Tuscan, BM=Buck Mountain, BBCC= Backbone Ridge/Cow Creek Tuscan, CCT=Cow Creek Tuscan, GF=Grasshopper Flat/Lost Iron Wells/ Red Switchback, LDG=Lodgepole, NQ=Nelson Quarry, UNK=Unknown, YJ=Yellowjacket.

Squaw Creek Prehistoric Raw Material Selection: New Data and Inferences

As discussed in Chapter V, the data obtained in the present study suggested that Backbone Ridge and Cow Creek source groups exhibit statistically significant differences among the elements Sr, and to a lesser degree Rb, with the Cow Creek groups possessing higher levels of Sr. While it is possible to have some overlap between these source subgroups at the extreme low ranges of the elemental value for Sr, the data indicate that separations between these two source subgroups can be made at the 95% confidence level.

Since these results were preliminary and, unlike the other Tuscan geochemical source groups which were quite distinct in their trace element signatures (e.g., Paynes - Inks and Paradise Ridge), there was some degree of overlap between these two source subgroups it was decided that the source assignments of artifacts within the Backbone Ridge and Cow Creek geochemical source groups would be separated into three subcategories on the basis of the Rb and Sr levels. Thus, specimens would be assigned to the Backbone Ridge geochemical group if they exhibited low values of Sr (e.g., below 90 ppm), especially in comparison with higher levels of Rb, and the Cow Creek geochemical group identification would be assigned to a specimen if it exhibited extremely high levels of Sr (e.g., over 96 ppm) in relation to lower values of Rb. If the levels of Sr and Rb were within the range of overlap seen for the Backbone Ridge/Cow Creek geochemical subgroups (e.g, at 2 standard errors), specimens would not be assigned beyond the level of Backbone/Cow Creek geochemical source groups. The results of this re-analysis can be seen in Table 9.

As noted by Sundahl (1992:127), the obsidian samples from the lower portion of the drainage are fairly well divided between the GF/LIW/RS geochemical source (46%; n=40) and the Tuscan sources (54%; n=44). Unfortunately data which would correlate the artifact source assignment by specific temporal periods were not available at the time this study was undertaken except for some very general and gross categories. However, it appears that the sites which were examined in this portion of the drainage range in age from 8000 years BP to 150 years BP, with all four of the sites possessing a late component (300 BP to 150 BP). Although Tuscan obsidians accounted for nearly 54% of the samples analyzed (Figure 17), of that 54%, 22% could be further divided into the Backbone Ridge subgroup, 12% could be separated into the Cow Creek subgroup, and 20% could not be separated beyond the Backbone Ridge/Cow Creek geochemical source group level. As seen in Figure 17 artifact-quality glass from the other Tuscan source locales were absent in these site assemblages.

In contrast to the obsidian procurement patterns seen in the lower drainage sites, obsidian artifacts recovered from sites in the upper drainage are predominantly comprised of GF/LIW/RS obsidian (78.6%), with small amounts of Tuscan glass (5.3%). The remaining 16.1% of the obsidian analyzed derived from other sources in the Medicine Lake Highlands and the Buck Mountain region of the Warner Mountains (Figure 18). While the overall percentage of Tuscan obsidians was low within these upper drainage sites

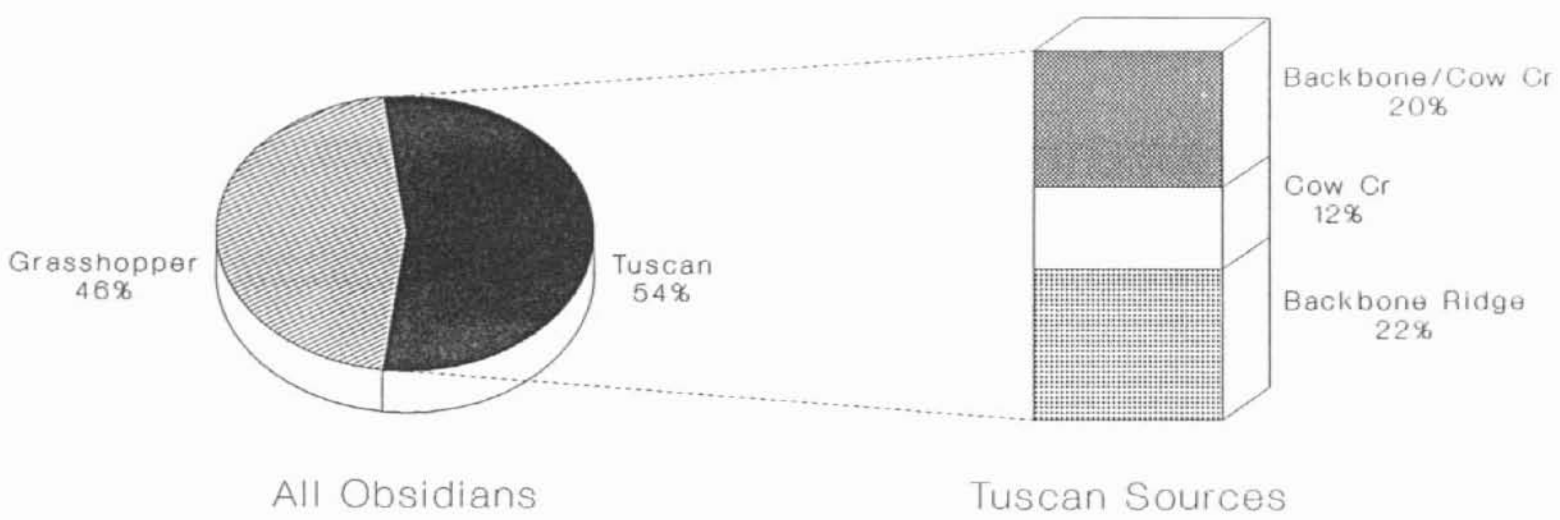

Figure 17. Obsidian Procurement in the Lower Squaw Creek Drainage.

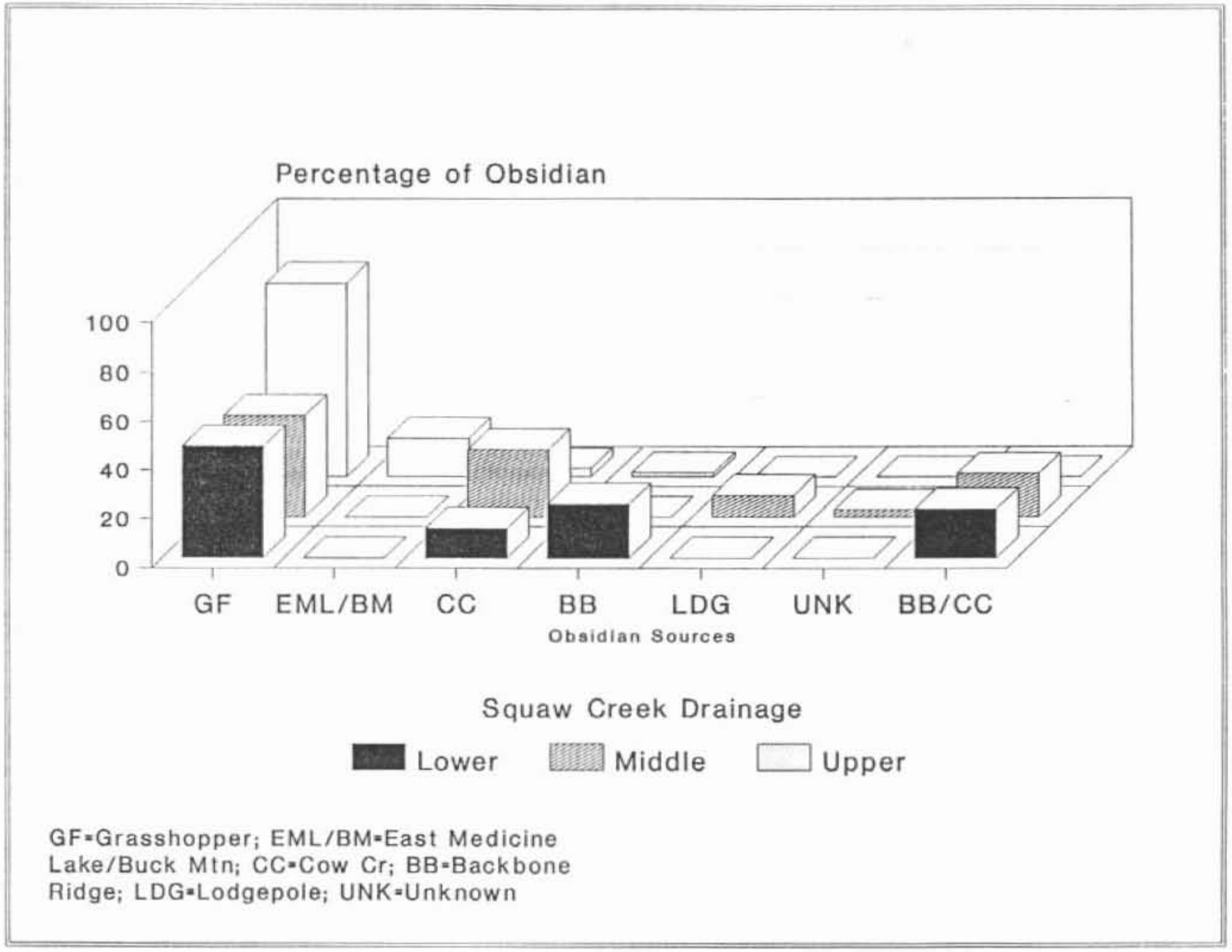

Figure 18. Obsidian Procurement in the Upper, Middle, and Lower Squaw Creek Drainage.

as expected, it was surprising to find that 3.6% of the total found could be assigned to the Cow Creek subgroup while the Backbone Ridge subgroup, which is closer, accounted for only 1.7% of the obsidian. Perhaps, with a larger sample size the differences between these two source subgroups would reverse. It should also be noted that the sites examined in this portion of the drainage could all be assigned to the Wheeler Ranch Phase, which is dated between 1700 BP to 300 BP.

The data obtained from the sites located in the middle portion of the drainage presented perhaps the most interesting patterns in regards to obsidian procurement (Figure 18). As observed in the lower portion of the drainage, obsidian from the GF/LIW/RS comprised a large majority of the specimens analyzed accounting for nearly 42% of the total. Of the remaining 58% of the specimens examined, 9% were assigned to the Lodgepole obsidian source in the Warner Mountain Range, 3% were unknown, and the remaining 46% were assigned to various Tuscan obsidian sources. Of the 46% that were identified as Tuscan obsidian, 28% could be assigned to the Cow Creek subsource and 18% could not be assigned beyond the Backbone Ridge/Cow Creek geochemical source group level. There were no clearly defined Backbone Ridge, Paynes - Inks Creek, or Paradise Ridge obsidian samples found in this portion of the Squaw Creek drainage system. The sites tested in this portion of the drainage range in age from 8000 BP to 300 BP, with the majority of them falling between the 5000 BP to 300 BP temporal periods.

Archaeological Investigations in the Paynes Creek Drainage

Over the last several years, the Bureau of Land Management, Ukiah District, has acquired a tract of land along the east bank of the Sacramento River near the town of Bend in northern Tehama County, California. Known as the Payne's Creek Recreational Area, this tract has received a great deal of interest from BLM from the standpoint of protection and management issues which surround the many natural and cultural resources located throughout the region (Sundahl 1993). In order to evaluate and provide protection for the cultural resources situated within the Payne's Creek Recreational Area, BLM entered into a Cooperative Agreement with the Shasta-Tehama-Trinity Joint Community College District in order to conduct field investigations at three prehistoric sites, CA-TEH-810, CA-TEH-1523, and CA-TEH-1526 (Figure 19).

Both CA-TEH-810 and CA-TEH-1523 are open midden sites located close to the eastern bank of the Sacramento River, while CA-TEH-1526 is a small rockshelter site located approximately one-half mile southeast of CA-TEH-810 along an intermittent drainage. Two of the sites, CA-TEH-810 and CA-TEH-1523, were excavated during the 1990 field season (Sundahl 1991), and again during the following year.

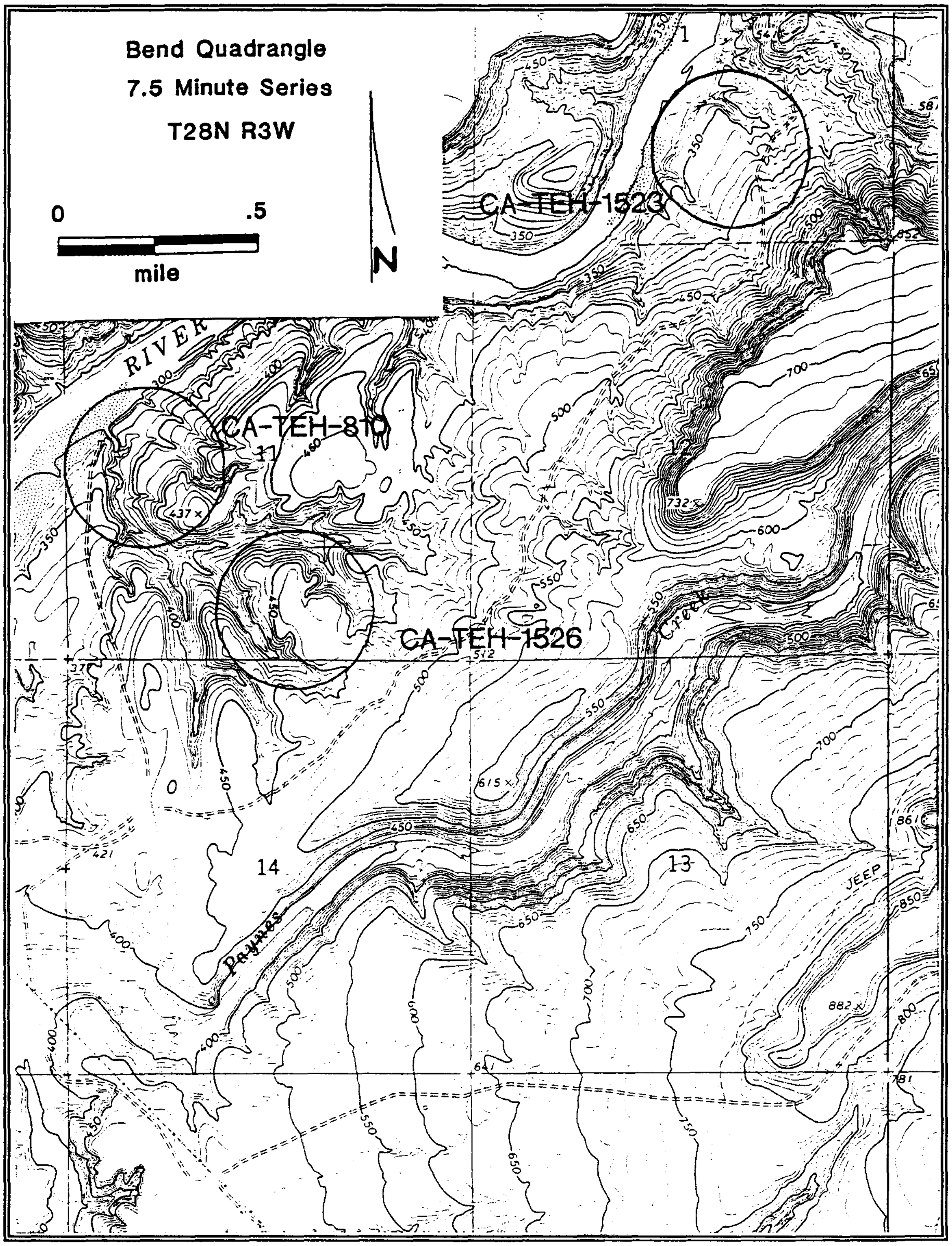

Figure 19. Archaeological Sites within the Paynes Creek Drainage.

Excavations at CA-TEH-1526 were undertaken by the Shasta College Field Class during the 1991 field season under the direction of S.E. Clewett and Elaine Sundahl. Additional excavations were conducted at all three sites in 1992.

Table 10 presents the results of the obsidian characterization analyses performed on the 68 specimens from the Bend sites in conjunction with this study. The data are presented in summary fashion here in Table 10; a detailed discussion of each site and its characteristics may be found in Sundahl's report "Archaeological Excavations in the Bend Area, Tehama County, California" (1993).

Paynes Creek Prehistoric Raw Material Selection: New Data and Inferences

As pointed out by Sundahl (1993:156), determining the source of an obsidian artifact should yield clues to the directions of travel and/or trade on the part of the inhabitants. The data presented in Table 10 indicate that Tuscan obsidians predominated in all temporal components of the Bend site assemblages, while the GF/LIW/RS source was the second most commonly represented geochemical source group. Glass Mountain obsidian made up only a small percentage of the obsidian at one site where it was found. It should also be noted that three of the specimens which were originally characterized as "unknowns" by Richard Hughes in 1990 for CA-TEH-810 and CA-TEH-1523 can now be

Table 10. EDXRF Source Data for the Paynes Creek Sites.

Site Trinomial[1]	Age of Component	Site Type[2]	Obsidian Sources[3]
CA-TEH-810 (n=27)	2500 BP to historic contact	OCC	22% GF 11% GM 4% UNK 26% BBR 18.5% CCT 18.5% BBCC PYC P
CA-TEH-1523 (n=29)	2500 BP to A.D. 1840	OCC	24% GF 24% BBR 17% CCT 35% BBCC PYC P
CA-TEH-1526 (n=12)	600 BP	RS	16.7% GF 16.7% BBR 33.3% CCT 33.3% BBCC

Site Trinomial[1] n = number of items subjected to obsidian characterization analysis.

Site Type[2] OCC - occupation site; RS - rockshelter.

Obsidian Sources[3]: BBR=Backbone Ridge Tuscan, BBCC= Backbone Ridge/Cow Creek Tuscan, CCT=Cow Creek Tuscan, GM= Modoc Glass Mountain, GF=Grasshopper Flat/Lost Iron Wells/ Red Switchback, PYC P= Paynes/Inks Creek obsidian present, UNK=Unknown.

assigned to the Paynes/Inks Creek source group on the basis of the analysis undertaken for this study.

Based on an analysis of obsidian hydration rim readings provided by L. Swillinger, it appears that obsidian from the GF/LIW/RS source makes up a slightly larger percentage relative to Tuscan obsidian in the earlier time periods, namely the Bend I and II levels. The three specimens of Glass Mountain obsidian are assigned to the Bend III levels of CA-TEH-810 (Sundahl 1993:156). Sundahl (1993) tentatively dated Bend I between 2500 B.P. to 1500 B.P., while Bend II is dated from 1500 B.P. to 700 B.P. Bend III, beginning around 700 B.P., appears to represent a narrow span of time and blends into the historic contact period or Bend IV.

Since GF/LIW/RS and other exotic-appearing obsidians tend to be selected over Tuscan obsidian for analyses, the percentages for the obsidian sources are inherently biased (Sundahl 1993:156). Nonetheless, certain inferences can be drawn from the limited data at hand.

Lithic procurement patterns at the Bend sites suggest an emphasis on obtaining obsidian from glass sources to the north, namely Backbone Ridge and Cow Creek Tuscan subsources and GF/LIW/RS (Figure 20). Although data estimating the relative abundance of the Paynes/Inks Creek obsidian is not currently available, artifacts deriving from this geochemical group were found in the site assemblages of CA-TEH-810 and CA-TEH-1523 and have been visually identified in the artifact assemblage from CA-TEH-1526. This suggests that the procurement and use of locally obtainable obsidian also occurred. Despite its proximity to the sites, the

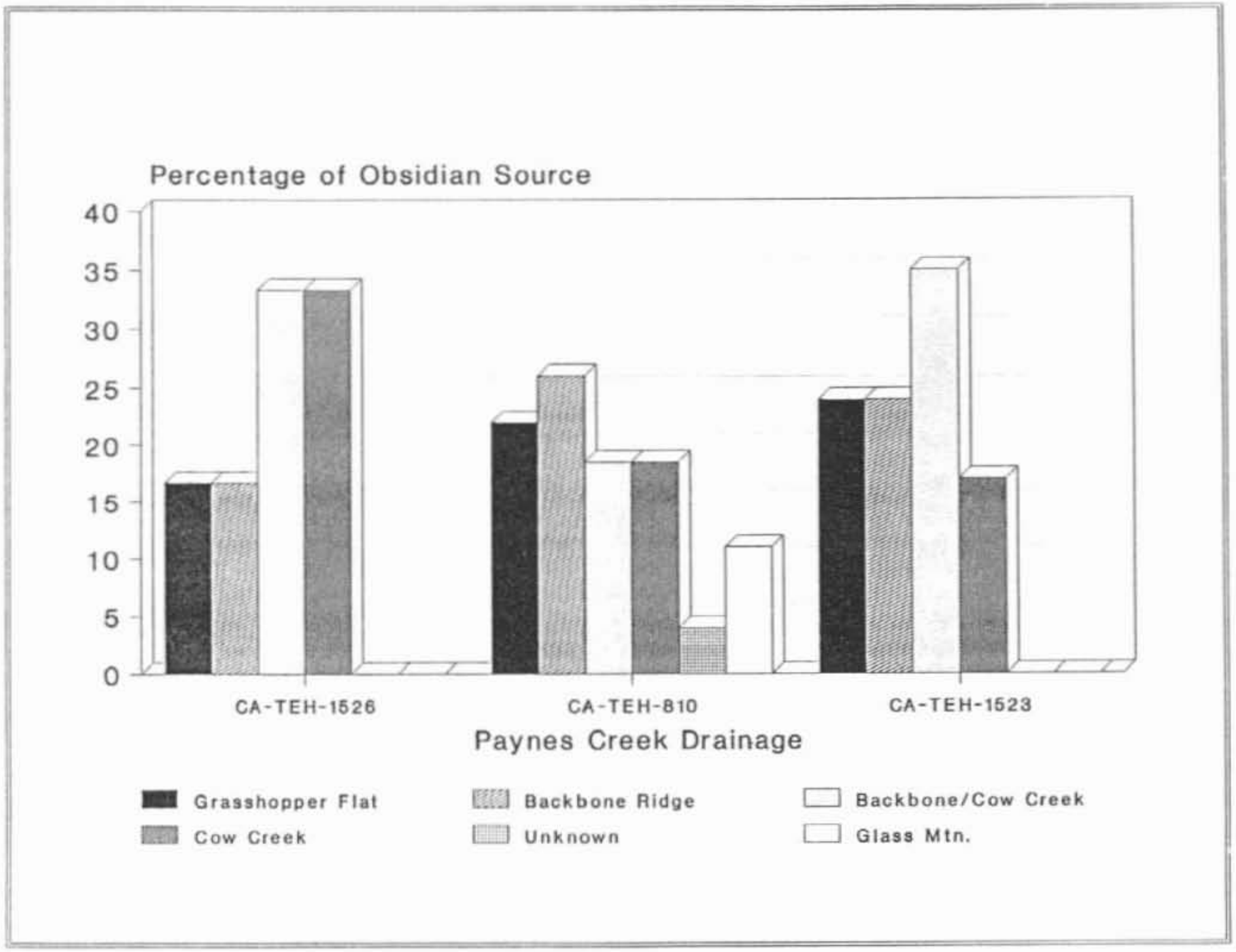

Figure 20. Obsidian Procurement within the Paynes Creek Drainage.

Kelly Mountain geochemical source group situated approximately 50 miles to the east did not provide obsidian from these sites, or did the more distant sources to the south, east or west (Sundahl 1993:156).

As expected, the obsidian characterization data suggests that for the latest occupational phase, an emphasis was placed on obtaining obsidian from the nearest Tuscan outcrops in the Cow Creek subgroup localities (Figure 20). Tuscan obsidian from the Cow Creek subgroup comprised approximately 33% of the total obsidian assemblage at CA-TEH-1526, while the Backbone Ridge obsidians accounted for only 16.7% of the total amount. The remaining 33.3% of Tuscan obsidian could not be separated beyond the level of Backbone Ridge/Cow Creek geochemical sources.

The data also indicate that similar patterns of obsidian procurement were operating at CA-TEH-810 and CA-TEH-1523, both open midden sites which were inhabited during the Bend I, II, and III phases, or between 2500 BP to A.D. 1840 or historic contact. Data obtained from these sites suggest that obsidian was procured from the Backbone Ridge subsource groups in moderate amounts as well as the Cow Creek subsource groups (Figure 20). Obsidian from the Backbone Ridge subsource accounted for approximately 26% of the total amount of Tuscan obsidians at CA-TEH-810, while approximately 18.5% was comprised of the Cow Creek subsource. The remaining amounts (18.5%) were comprised of obsidian which could not be further separated beyond the Backbone Ridge or Cow Creek geochemical source group level. A similar pattern was observed at CA-TEH-1523, with Backbone Ridge obsidians accounting for nearly 24% of the total, while Cow Creek obsidians accounted for approximately 17% of the total. The remaining 35% of the Tuscan obsidian at this site could not be separated beyond the Backbone Ridge/Cow Creek source level.

While the data gathered as a result of this analysis did not allow for fine-grained temporal distinctions to be made in terms of obsidian procurement patterns for each individual site, the majority of the findings are, however, consistent with expectations which were generated at the start of this investigation. As anticipated, the data gathered for the Squaw and Paynes Creek drainages indicated that there was a greater diversity in the various obsidian sources associated with the earliest time periods. This expectation is consistent with the fact that during the earliest periods of occupation hunter-gatherer groups throughout the area appear to have practiced a foraging mobility strategy which involved large procurement ranges.

Even with the larger procurement ranges which have been hypothesized for the early inhabitants, it was expected that there would be a greater use of obsidians from the Backbone Ridge and Cow Creek source groups relative to Paynes and Paradise Ridge source groups, especially in the

Squaw Creek drainage area. While it was anticipated that the differences in the percentages between the Backbone Ridge and Cow Creek source groups would be minimal during the earliest periods at the sites investigated, it was hypothesized that this relatively equal apportionment of these two sources would have continued until the late prehistoric period when differences in obsidian procurement patterns would begin to emerge. As can be seen in Figure 18, the data gathered as a result of this analysis are consistent with both of these expectations.

Mobility Strategies and Resource Procurement

The previous sections have described the archaeological distribution of Tuscan obsidians in two areas of northeastern California through successive periods of time. The final task is to place the data within a theoretical framework which will explain the observed patterns of Tuscan obsidians procurement and distribution.

Explaining the Temporal Distribution of Tuscan Obsidian in the Squaw Creek Drainage

Archaeological data obtained from the Squaw Creek drainage coupled with ethnographic and linguistic data indicate an utilization over an extended period of time beginning around 8000 years ago. Sundahl (1992:139) views this cultural continuity as that of a single group or closely related groups. Given the long term use of the

Squaw Creek drainage and apparent continuity of cultural traditions, she hypothesized that these peoples were the direct ancestors of the Hokan-speaking Shasta or Achumawi (Sundahl 1992).

Data obtained from the obsidian characterization analyses component of this study indicate that during the earliest time periods in the Squaw Creek drainage, raw material procurement patterns in the northern portion of the study area focused on obsidian from the GF/LIW/RS geochemical source in the Medicine Lake Highlands. While obsidian from two of the Tuscan geochemical source groups were present in the site assemblages of this temporal span, it was never of overwhelming proportions. Both the Backbone Ridge and Cow Creek source subgroups are represented in the Tuscan obsidian assemblage in varying amounts suggesting that raw material procurement ranges were large and extended over a broad region during this time period. The data obtained from the obsidian characterization analyses phase of this study are consistent with expectations which were generated at the start of this investigation.

It has been suggested by Sundahl (1992:138) that the drainage was occupied by small groups of people living in family groups who relied heavily on the hunting of large game and made direct forays to the north to obtain the majority of their obsidian from the Medicine Lake Highland sources. However, data obtained from the obsidian characterization analyses component of this study indicates that while there was a greater use of Medicine Lake Highland obsidians in sites situated within the upper portion of the Squaw Creek drainage as evidenced by the greater frequency with which this material occurs in the obsidian assemblages, in the middle and, especially lower, portions of the drainage artifact-quality glass from the Tuscan sources were present in greater frequencies (Figure 21).

While it is true that the inhabitants during these earliest time periods may have made direct forays to the north to obtain some of their obsidian from the Medicine Lake Highland sources, it is more likely that at least some or all of the groups living in the Squaw Creek drainage passed down into the northern Sacramento Valley during their annual subsistence rounds where they procured obsidians from the Cow Creek area while pursuing other resources.

The succeeding temporal period, identified as the Squaw Creek Phase, is dated between 5000 and 3000 years B.P.. Sundahl (1992) sees this phase as representing a continuity of occupation in the Squaw Creek drainage by the Hokan-speaking peoples. Although there is a greater reliance on the processing of vegetal resources during this period of time, the emphasis on hunting appears to have continued. The Squaw Creek drainage witnessed an increase in the number of sites dating to this time period which

GF-Grasshopper; EML/BM-East Medicine Lake/Buck Mtn; CC-Cow Cr; BB-Backbone Ridge; BB/CC-Backbone Ridge/Cow Creek

Figure 21. Obsidian Procurement in the Upper and Lower Squaw Creek Drainage.

suggests that population densities had began to increase (Sundahl 1992:140).

Sundahl (1992:40) suggests that the shift from a primary dependency on GF/LIW/RS obsidian to a predominant use of Tuscan obsidian during this period of time reflects a shift in procurement strategies to the south rather than to the north. Data obtained in this study supports Sundahl basic hypothesis of a southerly shift in mobility strategies during this period of time. Although the data is limited, approximately 28% of the total obsidian assemblage analyzed from sites located in the middle portion of the drainage were comprised of obsidians from the Cow Creek geochemical source group and another 18% were of the Backbone Ridge/Cow Creek source group.

Sundahl (1992:140) notes that possible explanations for this shift in procurement ranges might include environmental changes which made the foothills more attractive than the highlands, changes in political-ethnolinguistic boundaries which made the highlands inaccessible, or changes in subsistence/settlement patterns from a widely ranging transhumant pattern to a more intensive, localized strategy. Although the Squaw Creek archaeological data suggests that occupation was becoming intensified during this period of time, the data from the present study would argue for a continuation of the foraging mobility pattern with the only difference being that the direction and location of the procurement range itself shifted to the south.

This foraging mobility pattern appears to have continued into the subsequent phase known as the Monday Flat Phase. Monday Flat Phase sites are dated between 3000 B.P. and 1700 B.P. and appear to represent base camps in which a variety of different tasks were performed (Sundahl 1992). Notched-pebble net weight found in the artifact assemblages of this phase suggest a somewhat greater use of riverine resources than was observed earlier (Sundahl 1992). On the other hand, the present study indicates that the patterns of obsidian procurement remained relatively stable during this time period except for a slight increase in obsidians from northern sources again.

It is noteworthy that by the time of the Wheeler Ranch Phase, dated between 1700 B.P. and 300 B.P., it appears that a change in the obsidian procurement patterns was again taking place. In the upper portion of the drainage, the data obtained from this study suggest that obsidian was procured primarily from the north, with an emphasis on the GF/LIW/RS geochemical source group. Approximately 79% of all obsidian from this time period derived from the GF/LIW/RS geochemical source group. Minor amounts of obsidian from Buck Mountain, Nelson Quarry, and the Lodgepole sources, all located within the Warner Mountain Range of northeastern California are present, as well as minor amounts of Yellowjacket obsidian from the Medicine Lake Highlands. At only one site in the upper part of the drainage was obsidian from any of the Tuscan geochemical source groups present. The obsidian artifacts which were assigned to the Backbone Ridge (n=1) and Cow Creek geochemical source subgroups (n=2) at this site only accounted for 10% of the total obsidian assemblage which was analyzed. The overwhelming predominance of obsidian from the northern sources and near exclusion of Tuscan obsidians suggest that perhaps some type of change in political-ethnolinguistic boundaries was taking place between the upper and mid to lower portions of the drainage. This data is consistent with Sundahl's hypothesis of Wintu intrusion in the Squaw Creek drainage during the late prehistoric periods (Sundahl 1992). However, whether the small bands living in this part of the drainage retreated from areas they once inhabited as a result of the Wintu intrusion can not be conclusively demonstrated with the limited data at hand.

Sundahl notes (1992:136) that the distinction between the Wheeler Ranch and the succeeding Howell Phase is largely subjective at this point in time and is based in large measure on ethnographic reconstructions provided in her overview (1992:136). However, Sundahl (1992:136) suggest that the Howell Phase dates within the past 300 to 400 years and reflects a new subsistence pattern involving large Wintu populations that had established permanent villages near the mouth of Squaw Creek. A greater emphasis on fishing and acorn gathering versus hunting and the collection of other plant foods is also thought to have occurred at these sites.

While the present study can add very little to the hypothesized subsistence model presented by Sundahl, it can, address questions of possible Wintu population movements into the Squaw Creek drainage in a tentative fashion. As noted in the beginning of this section it was anticipated that sites associated with Wintu occupation in the Squaw Creek drainage would exhibit a decrease reliance on the Tuscan obsidians and an concomitant increase in glass from the Medicine Lake Highlands. If artifact-quality glass from the Tuscan source groups were present, it was anticipated that there would be a greater reliance on the Backbone Ridge source locales since some of the collection localities appear to be situated within or along the hypothesized border between the Wintu and Yana groups.

It was also anticipated that certain differences would emerge in the obsidian procurement patterns between the upper and lower portions of the drainage, perhaps as a result of changes in the tribal boundaries. Due to the relative proximity and distance between the various sites and source locales it was expected that there would be a greater use of the Tuscan obsidians in the lower portions of the drainage throughout all time periods involved, while the sites within the upper portions of the drainage would exhibit a greater dependency upon obsidians from the Medicine Lake Highland sources.

The obsidian geochemical source data generated by the present study suggests that perhaps such a change was occurring in the Squaw Creek drainage during the late prehistoric period (Figure 21). In contrast to the obsidian procurement patterns witnessed at the sites in the upper portion of the drainage, it appears that in the lower portion of the drainage, the sites which were primarily occupied during the Howell Phase (the latest prehistoric period) relied heavily on obsidians from the Tuscan source groups. While the data are limited, obsidian characterization analyses indicate that CA-SHA-696 and CA-SHA-1923 both contain overwhelming to total dependence upon obsidians from the Tuscan sources. Moreover, even though Cow Creek obsidians are present in both site assemblages, in at least one case (CA-SHA-1923), the percentage of Backbone Ridge obsidians (56%) accounts for the majority of the specimens analyzed.

In brief, whether or not the Squaw Creek drainage witnessed a population replacement by encroaching Wintu groups cannot be conclusively demonstrated with the limited data at hand. However, obsidian procurement patterns illustrated at the Howell and, in some instances, at the Wheeler Ranch Phase sites in the Squaw Creek drainage appears to suggest that by the later prehistoric periods a shift in mobility and settlement strategies was also taking place in the northern portion of the study area. This shift saw the change in mobility strategies from one which relied on foraging to one dependent on a collector strategy, which may be associated with Sundahl's hypothesized Wintu intrusion. In any case, the decrease in residential mobility and/or regional interaction is illustrated by the shift in obsidian procurement ranges for these later occupations in the Squaw Creek drainage.

As was observed in the southern portion of the study area, it appears that as the northern Sacramento Valley and surrounding areas became more heavily populated during the Late Prehistoric Period freedom to easily move from one area to another may have become restricted as conflicts arose over competition for available land and resources, thus necessitating the use of more locally available toolstone. Hence, for those groups which had been pushed into the upper areas of the Squaw Creek drainage that had been uninhabited prior to this time there was the necessity to procure obsidians from previously unexploited sources. Moreover, the change in mobility strategies witnessed in the lower Squaw Creek drainage resulted in an obsidian procurement pattern which had become more circumscribed, focusing on the local and easily accessible Backbone Ridge sources.

Explaining the Temporal Distribution of Tuscan Obsidian in the Paynes Creek Drainage

An examination of source data from the Paynes Creek drainage sites in the Bend area of Tehama County suggests that during the earlier time periods obsidian procurement ranges were quite extensive and included the foothill regions near the Cow Creek tributaries and the Pit River area to the north. This inference is consistent with Sundahl's earlier conclusions (1993). As noted by Sundahl (1993:156-157), data obtained from the Bend area sites:

> ... fit an hypothesis of being a seasonal expression of a transhumant people who came to the river to exploit the riverine habitat, hunting rabbits, fishing and collecting mussel shells among other activities, and then during other seasons moved to the foothill areas where they made obsidian artifacts, hunted large mammals, and collected pinenuts, acorns, and manzanita berries.

The greater percentage of distant obsidian sources present in the earlier time periods in the Bend area seem to reflect these large procurement ranges. It was during these earliest periods, when the population densities were presumably at their lowest and food storage strategies were lacking that a high residential mobility pattern would be expected. The greater percentage of the Backbone Ridge obsidians seen during the Bend I and Bend II components at sites CA-TEH-810 and CA-TEH-1523 appears to argue for just such a mobility pattern - one that focused on resource utilization over a widely ranging area along the east side of the Sacramento River.

However, beginning around 700 B.P., it appears that there was a growing dependency on the seasonal use of riverine resources with procurement ranges becoming more circumscribed (Sundahl 1993). Present findings indicate that during this period of time there appears to have been a decrease in the use of the more distant obsidian sources with obsidians from the Cow Creek Tuscan subgroup comprising a major proportion of the obsidian assemblage recovered from CA-TEH-1526 along with the appearance of Paynes/Inks Creek obsidian. Although artifacts within the earliest components were few in number, an analysis of the debitage recovered from the Bend sites indicates that a subtle increase in emphasis on task-specific activities occurred in Bend III times, suggesting a change in the mobility strategy to one that was more logistically organized (Sundahl 1993:152). This technological observation lends additional support to the expected obsidian procurement pattern.

This shift in obsidian procurement patterns and reduction in size of procurement range is consistent with findings obtained from archaeological data which suggest that as the northern Sacramento Valley and surrounding areas became more heavily populated during the late prehistoric period by indigenous peoples and immigrants such as the Wintu, freedom to easily move from one area to another may have become restricted as conflicts over available land and resources necessitated the use of more locally available toolstone.

In summary, this study contributes to the performance of archaeological research throughout much of the northern California region because of the data it yields on new obsidian source locales and geochemical differences found in artifact-quality obsidians found within the Tuscan Formation. This study has illustrated that there no significant differences in the quality of the obsidian from the Backbone Ridge and Cow Creek subsources which would have been visible to the aboriginal inhabitants. Therefore, the spatial and temporal differences which are beginning to emerge as a result of this study suggest that explanations for use of one specific glass source over another must lie in such factors as proximity and/or access rather than deliberate selection on the part of prehistoric peoples for its flaking or aesthetic qualities.

It is true that distinguishing between various obsidian sources in which the effective distance is only 20 to 30 miles apart may not result in significant behavioral differences for groups practicing a foraging type mobility strategy such as that witnessed during the earliest time periods in the study area. However, during the late prehistoric period when tribal boundaries were well-established and the territories were restricted in size, there is good reason to suspect that procuring obsidians from source locales located only 20 miles apart, such as the Backbone Ridge and Cow Creek source locales, would have significant behavioral differences in terms of mobility and/or procurement ranges, territorial boundaries, social boundary defense, and inter-group social interaction. Therefore, in all likelihood, subjecting the Tuscan obsidians to this level of source assignment would make a difference in the reconstruction of late prehistoric lifeways.

CHAPTER VII

CONCLUSIONS

Introduction

Over the last several years, the approach taken by many researchers has been to utilize the data obtained from obsidian characterization analysis in order to test various models of obsidian procurement patterns, population dispersal, lithic raw material use, and cultural change, all of which relate in some fashion to the collective concept of "mobility strategies". However, although it is true that data obtained from obsidian characterization analyses can be useful in the investigation of such issues as prehistoric exchange networks, mobility strategies and hunter-gatherer procurement patterns, it is first necessary that artifact-quality obsidian be traceable to specific quarries or, as is the case with Tuscan obsidian, "lithic collection localities".

With these perspectives in mind, the present study has as its principal objective the gathering of relevant data regarding the archaeological, geological, geographical, petrological and geochemical variability of artifact-quality glass derived from the Tuscan obsidian source located in northern California. The second component of this research focused on three main aspects of lithic raw material variation in an attempt to determine and provide an explanation for the temporal and spatial distribution of artifacts manufactured from Tuscan obsidian and to see whether or not the geochemical distinctions noted as a result of this study carry any archaeological significance.

Final Conclusions

Early research of the Tuscan Formation artifact-quality glass sources conducted by Jack (1976) and Hughes and Hampel (Hughes 1983) provided archaeologists with a rough idea of the distinctiveness of this source when compared with known sources, but these studies failed to recognize the internal variability which needs to be known in order to fully appreciate the attributes of this lithic source which are likely to have been important to prehistoric stoneworkers.

Eight previously unidentified artifact-quality glass sources were found within the Tuscan Formation as a result of this study. These sources were found to be relatively well dispersed over the landscape, making them available to early hunter-gatherers in diverse environments. Moreover, geochemical data obtained in this study indicates that there are at least three major and one minor type of geochemically distinct artifact-quality glass sources which can be identified within the Tuscan Formation. The major types include the Paynes - Inks Creeks source located in northeastern Tehama County, the Paradise Ridge 1 - 2 source located in northern Butte County, and the Backbone Ridge - Cow Creek sources located in the foothills and mountains east of Redding, in Shasta County, California. Each of these glass localities consists of spatially distinct sources which exhibit geochemical modalities along two or more trace elements. Moreover, the results of these analyses indicate that with 95% confidence, the Backbone Ridge - Cow Creek geochemical source group can be further divided into the Backbone Ridge subsource and the Cow Creek subsource based on the trace elements Sr, and to a lesser degree, Rb.

While it was not possible to examine every potential Tuscan obsidian source locality within the study area, sufficient information is available to clearly indicate that artifact-quality glass sources in the region are widely distributed and relatively abundant. At all the source areas examined, artifact-quality stone occurs mainly on the surface and is easily accessible. Since "quarrying" Tuscan obsidian refers primarily to picking it up off the ground, the term "collection localities" should be used when discussing Tuscan obsidian lithic production systems as it is more reflective of the manner in which the aboriginal stoneworkers procured this material.

Quite clearly, Tuscan obsidian was easy to extract and was readily accessible to aboriginal groups traveling or living within the study area. Moreover, raw materials from these source locales would have been available to even the earliest peoples in the area since the geological age of this formation is associated with the Pliocene.

The most obvious and archaeologically significant result of this study is the demonstration that there are several different geochemical varieties of artifact-quality glass present within the Tuscan Formation, and further, that at least three of those varieties were used during prehistoric times. To judge from the results of the current study, obsidian from the Backbone Ridge and Cow Creek source locales were the two most heavily exploited of the three varieties used prehistorically. There is no conclusive evidence as yet to indicate that the Paradise Ridge geochemical type was utilized during prehistoric times.

Except for the Paynes - Ink Creeks source locales, there are no significant differences in the quality of the obsidian from the remaining sources which would have been visible to the aboriginal inhabitants. Therefore, if spatial or temporal differences show up in the frequencies with which the remaining source materials occur within the archaeological record on a regional scale, then the explanation for use of that specific glass source must lie in such factors as proximity and/or access rather than deliberate selection on the part of prehistoric peoples for its flaking or aesthetic qualities.

Based on the spatial distribution of Tuscan obsidian across the landscape it is likely that some of the obsidian source localities exploited during the late prehistoric times were situated within the territory of specific tribal groups, such as the Yana. However, while most of the locales showed signs of prehistoric use in the form of reduced nodules and flakes, none of the Tuscan glass localities examined exhibited evidence of habitation or prolonged occupation. Therefore, if any of the Tuscan sources were physically "controlled" the evidence is not extant.

The results of this analysis also suggest that while all the obsidian sources examined possess obsidian suitable for the production of bifacial tools and other artifacts, glasses from some locales are much better suited to knapping than others. As a combined group, however, obsidian from all of these sources are easy to control during direct freehand percussion or bipolar reduction. The Backbone Ridge and Cow Creek source localities contain some of the largest nodules observed during the course of this study and are particularly well suited for flaking purposes. Pressure flakes remove easily and predictably from all of these materials, and the flakes, once removed, are generally very sharp. To the contrary, the results also indicate that the Inks and Paynes Creek glass is not as predictable during lithic reduction. The materials from these sources are vitrophyric, very brittle and frequently 'crumble' during bipolar and/or freehand percussion reduction and essentially destroy or waste the core. However, despite these apparent drawbacks, once a suitable nodule is reduced, the relative softness of the glass allows for ease in pressure flaking, which is most likely one reason for its occurrence in site assemblages from the southern portion of the study area.

Data obtained as a result of this study suggest that the previously held notions of Tuscan obsidian as a lithic resource which was limited in its abundance, distribution and quality are inaccurate. For the most part Tuscan obsidian can be viewed as a desirable raw material that was easily accessible to prehistoric peoples. If this statement is true, then clearly, some other factor besides the supposedly "inferior" nature of Tuscan obsidians accounts for its limited use during certain temporal periods. It is proposed here that changes in mobility strategies related to subsistence activities provide an alternative explanation for this circumstance.

While the distance from a geological source to a site where that obsidian source is represented in the assemblage cannot always be taken as a direct measure of the distance a population traveled, it can be taken as a direct indication of the distance that the raw material was transported. Based on an examination of the geochemical source data from sites located within the northern and southern portions of the study area, it appears that during the earliest periods of time much of the obsidian raw material represented in archaeological site assemblages is non-local, coming from distances as great as 100 kilometers away. These data suggest that regardless of the actual tactic employed for the procurement of these raw materials, the overall patterns of obsidian raw material use by the inhabitants of the Paynes and Squaw Creek drainages imply that these people were extremely mobile. However, beginning around 700 B.P. in the southern portion of the study area and perhaps as early as 1700 B.P. in the northern portion, the obsidian procurement patterns appear to have changed suggesting that the procurement ranges of these peoples were becoming more circumscribed.

An examination of site-specific geochemical source data from the Paynes Creek drainage in the southern portion of the study area, suggests that during the earliest time periods prehistoric mobility ranges were quite extensive and included the foothill regions near the Cow Creek tributaries in addition to the Medicine Lake Highlands and Pit River region further north. An analysis of the obsidian geochemical data obtained from the Squaw Creek drainage in the northernmost portion of the study area suggests that a similar pattern was occurring in regards to the obsidian procurement patterns from sites in the region.

Like the Paynes Creek peoples, the Squaw Creek inhabitants appeared to have been very mobile during these early years and to possess extensive procurement ranges. Furthermore, while the data are limited it appears that obsidians from the Cow Creek subsource showed up in archaeological record of the Squaw Creek sites in greater frequency during the earlier time periods while obsidians from the Backbone Ridge subsource were present in the archaeological record of the Paynes Creek sites in greater frequency during the earliest time periods. The fact that both groups exploited the same obsidian sources during these earliest time periods suggest, perhaps, that an overlap of procurement ranges or territorial boundaries was occurring and/or that these groups were of the same ethnolinquistic affiliation.

An analysis of site-specific obsidian data from the sites investigated within the study area suggest that for the most part, this foraging based mobility pattern appears to have continued during the subsequent temporal phases. However, obsidian procurement patterns inferable for the Squaw Creek drainage between 1700 B.P. to 300 B.P., and perhaps as early as 700 B.P. in the Paynes Creek region, lend support to the view that by the later prehistoric periods mobility and settlement strategies were changing in both the northern and southern portions of the study area with procurement ranges becoming more circumscribed.

The results of this analysis lend support to the view that as the northern Sacramento Valley and surrounding areas became more heavily populated during the late prehistoric period, the mobility of the aboriginal inhabitants became more restricted. Local population increases of indigenous peoples as well as displacement of indigenous groups of immigrants such as the Wintu restricted the freedom to easily move from one area to another. This increase in population most likely resulted in competition and conflicts for available land and resources, thus possibly necessitating the use of more locally available toolstone for the inhabitants.

Regional Implications, Study Evaluation, and Directions for Future Research

Obviously there are many questions left unanswered in the present study as well in any research involving lithic raw material procurement and mobility strategies. In particular, we have not yet succeeded in determining how a group obtained obsidian from a specific source. However, by identifying and locating the source of all of the obsidian and other lithic specimens represented in an assemblage or set of assemblages, we can begin to outline a geographic range for raw material procurement and use regardless of how that material was obtained. It is only when this initial step is completed that we can begin to truly address the problem of tactics, whether the raw material was obtained directly or indirectly.

As noted by Hughes (1988:263),

> The fact that minor and trace element composition variations can exist between sources of obsidian within the same volcanic field argues that archaeological dating of artifacts cannot proceed without specific obsidian source attributions, because of potential differences in source-specific obsidian hydration rates...geochemical proximity cannot be used as a proxy for obsidian characterization.

On the basis of data obtained as a result of this study, it is clear from the observed variability in the minor and trace element composition of artifact-quality glasses found within the Tuscan Formation that the term "Tuscan obsidian" can no longer be used to specify a homogeneous geochemical entity. Since there are at least three distinct geochemical varieties of artifact-quality glass within the geographical limits of the Tuscan Formation, archaeological use of the term should be restricted to the geographic reference of the region following the convention established by Hughes for the Coso volcanic field (1988).

On a more general note, many of the specific variables considered here in assessing Tuscan obsidian raw material variables such as size of nodule, hardness, brittleness and luster, may not be relevant for all lithic studies. However, many of the general issues in this study should be relevant for the investigation of other lithic production systems. Detailed knowledge of raw material locations from a regional perspective, the accessibility of raw material at the source locality, and the knapping quality of the specific lithic resource all have the potential to expand our understanding of the interaction between lithic procurement strategies and other aspects of prehistoric human behavior.

It should also be noted that changes in mobility strategies are never an all-or-nothing phenomenon. Rarely do we deal with a change from a completely mobile way of life to full sedentism when dealing with aboriginal populations. Rather, the changes in mobility strategies and procurement ranges should be viewed as gradual adjustments and fluctuations in mobility patterns as a result of changing cultural and environmental conditions. Examination of other lithic assemblages with a focus on obsidian characterization analysis from a larger sample of prehistoric sites of all temporal periods represented within the region is needed to more fully address the issue of mobility and procurement ranges.

Moreover, the limited amount of obsidian characterization and hydration data available at this time precludes examinations of temporal differences in procurement strategies for the specific varieties of Tuscan obsidian. Therefore, it would be fruitful if future research could focus on determining the specific location from which the Tuscan obsidian originated from and when obsidian from the different geochemical sources appeared in the archaeological record.

Major and minor element composition data for artifact-quality glass from each of the Tuscan geochemically distinct source types should be conducted in order to determine if there is any interfield hydration rate variability present in the different varieties. Moreover, while this study has been able to discern subtle differences in the trace element composition between the Backbone Ridge and Cow Creek subgroups, additional research is needed to help refine the issues surrounding this observation.

This study contributes to the conduct of archaeological research of much of the northern California region because of data it yields on new obsidian source locales and geochemical differences within the Tuscan Formation for the various artifact-quality glass sources. The patterns of obsidian procurement which emerged from this study could be used in regional level synthesis when examining lithic production systems.

Finally, it should be noted that in discussions of prehistoric lithic procurement strategies and patterns, it is important to consider the "lithic landscape" as well as raw material variations. The data obtained as a result of this study suggest that if factors such as raw material location, accessibility, distribution, and quality are taken into consideration, then, from an aboriginal perspective, obsidian obtained from the Tuscan source may be viewed as a desirable resource.

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APPENDIX A

MEGASCOPIC DESCRIPTIVE ATTRIBUTES FOR OBSIDIAN ARTIFACTS

A. **Color: Hand Specimen**
- Not Applicable

B. **Color: Texture (CT)**
0 Not Applicable
1 Banded, Distinct
2 Banded, Indistinct
3 Mottled
4 Veined
5 Uniform
6 Other

C. **Light Transmittance (LT)**
0 Not Applicable
1 Opaque
2 Translucent
3 Transparent

D. **Surface Luster (SL)**
0 Not Applicable
1 Adamantine
2 Chatoyant
3 Earthy
4 Greasy
5 Metallic
6 Resinous
7 Submetallic
8 Vitreous

E. **Surface Texture (ST)**
0 Not Applicable
1 Smooth
2 Flawed
3 Matte
4 Grainy
5 Hackly
6 Other

F. **Inclusions (I)**
0 Not Applicable
1 None
2 Accidental
3 Bubbles
4 Microphenocrysts
5 Megascopic Phenocrysts
6 Spherulites
7 Other

G. **Cortex (C)**
0 Not Applicable

1 Cortex Present, Smooth
2 Cortex Present, Crenulated

H. **Shape: Roundness (SR)**
0 Not Applicable
1 Well-rounded
2 Rounded
3 Sub-rounded
4 Sub-angular
5 Angular
6 Not determinable

I. **Shape: Sphericity (SS)**
0 Not Applicable
1 Discoidal
2 Sub-discoidal
3 Spherical
4 Sub-prismoidal
5 Prismoidal
6 Not determinable

Specimen	Hand Specimen Color	CT	LT	SL	ST	I	C	SR	SS	Wt. gms	Length cms	Width cms	Thickness cms
PR2-1	N2.5/0 5YR 4/4	1	0	2	4	4	2	4	3	16.4	3.7	2.4	1.9
PR2-2	N2.5/0 5YR 4/4	1	2	2	4	4	1	5	4	17.4	5.5	3.0	1.3
PR2-3	N2.5/0 5YR 4/4	2	2	2	4	4	0	5	5	8.0	5.7	2.0	0.8
PR2-4	N2.5/0 5YR 4/4	1	2	2	4	4	1	5	5	9.2	4.4	3.3	0.7
PR2-5	N1/0 5YR 4/8	1	2	1	4	4	1	4	4	13.6	3.6	2.8	1.5
PR2-6	N1/0	5	2	2	4	4	1	4	4	11.8	4.3	2.1	1.2
PR2-7	N2.5/0 5YR 4/6	1	2	7	4	4	1	0	0	1.9	2.8	3.1	0.4
PR2-8	N1/0 2.5YR 4/6	1	2	2	4	4	1	4	0	5.2	3.3	2.4	0.8
PR2-9	N2.5/0	5	1	3	4	4	1	0	0	3.7	2.3	1.9	1.7
PR2-10	N1/0	5	1	3	4	4	1	0	0	2.8	2.8	1.9	0.7
PR2-11	N1/0	5	2	7	4	4	0	0	0	2.1	2.9	1.4	0.7
PR2-12	N1/0	5	3	7	1	6	0	0	0	3.4	3.0	1.5	1.0
PR2-13	N2.5/0	4	2	7	1	5	0	0	0	2.4	2.1	1.9	0.8
PR2-14	N2.5/0 2.5YR 4/6	1	2	2	4	4	1	0	0	3.3	2.1	1.5	1.2
PR2-15	N1/0	5	3	7	1	1	0	0	0	1.5	1.7	1.5	0.8
PR1-1	N2.5/0 2.5YR 4/6	3	3	2	4	4	1	5	5	19.2	4.8	1.8	1.8
PR1-2	N3/0 2.5YR 3/6	3	2	7	4	4	1	5	5	18.7	4.2	2.1	1.6
PR1-3	N2.5/0 2.5YR 3/4	3	2	3	3	4	1	5	5	4.8	3.7	1.3	0.9
PR1-4	N2.5/0 2.5YR 3/6	3	2	3	4	4	1	5	5	1.1	2.4	1.0	0.5
PR1-5	N2.5/0	3	1	2	3	4	0	5	5	0.9	3.2	0.6	0.6
PR1-6	N2.5/0	3	1	3	1	1	0	5	5	1.0	1.5	1.2	1.1
PR1-7	N2.5/0	3	2	3	3	4	0	5	5	1.3	2.9	0.9	0.9

Specimen	Hand Specimen Color	CT	LT	SL	ST	I	C	SR	SS	Wt. gms	Length cms	Width cms	Thickness cms
PR1-8	N2.5/0	3	3	7	3	1	0	5	5	0.6	2.5	0.6	0.7
PR1-9	N2.5/0	4	2	3	3	4	0	5	5	0.7	2.9	0.6	0.4
PR1-10	N2.5/0 2.5YR 4/6	4	2	7	4	4	0	5	5	0.9	3.3	0.9	0.4
PR1-11	N2.5/0 2.5YR 4/6	3	2	3	4	4	0	5	5	0.5	2.0	1.0	0.5
PR1-12	N2.5/0 2.5YR 3/6	3	3	7	1	1	1	5	5	0.2	1.0	1.2	0.4
PR1-13	N2.5/0 2.5YR 4/6	3	2	2	1	4	0	5	5	0.1	1.1	0.6	0.5
PR1-14	N2.5/0	5	3	7	1	1	0	5	5	0.2	1.9	0.9	0.4
PR1-15	N2.5/0	5	3	3	4	4	0	5	5	0.2	2.3	0.7	0.3
INK-1	N1/0	5	1	3	2	5	1	3	3	9.3	2.8	2.3	1.7
INK-2	N1/0	5	1	3	2	5	1	3	3	3.2	2.0	2.0	1.0
INK-3	N1/0	5	1	4	5	5	1	4	4	69.3	6.0	4.0	3.8
INK-4	N1/0	5	1	4	5	5	1	3	3	11.2	3.0	2.3	1.8
INK-5	N1/0	5	1	6	2	5	1	2	2	22.5	3.2	2.9	2.2
INK-6	N1/0	5	1	3	5	5	1	3	3	30.1	4.2	3.4	2.6
INK-7	N1/0	5	1	3	4	5	1	2	2	14.1	2.7	2.5	2.1
INK-8	N1/0	5	1	4	5	5	1	3	3	19.0	3.2	2.8	2.5
INK-9	N1/0	5	1	4	4	5	1	4	4	12.8	3.1	2.3	2.0
INK-10	N1/0	5	1	4	5	5	1	2	2	5.3	2.0	2.0	1.5
INK-11	N1/0	5	1	3	4	5	1	4	4	8.5	2.5	1.7	1.8
INK-12	N1/0	5	1	6	5	5	1	2	2	11.0	2.7	2.5	1.9
INK-13	N1/0	5	1	6	4	5	1	1	1	13.4	3.3	2.3	1.8
INK-14	N1/0	5	1	6	5	5	1	3	3	8.1	2.4	1.9	1.6

Specimen	Hand Specimen Color	CT	LT	SL	ST	I	C	SR	SS	Wt. gms	Length cms	Width cms	Thickness cms
INK-15	N1/0	5	1	6	5	5	1	3	3	10.1	2.8	1.9	1.6
PYC-1	N2/0	5	1	3	5	5	1	4	3	44.7	4.0	3.7	3.0
PYC-2	N2/0	5	1	3	5	5	1	3	3	12.6	2.7	2.9	2.0
PYC-3	N2/0	5	1	3	5	5	1	3	2	12.8	2.8	2.4	2.1
PYC-4	N2/0	5	1	3	5	5	1	4	3	22.0	3.1	2.7	2.2
PYC-5	N2/0	5	1	3	5	5	1	4	4	13.7	2.9	2.2	1.8
PYC-6	N2/0	5	1	4	5	5	1	4	3	27.7	3.0	3.2	2.4
PYC-7	N2/0	5	1	4	5	5	1	4	3	35.2	0.0	0.0	0.0
PYC-8	N2/0	5	1	4	5	5	1	3	4	18.1	3.9	2.0	1.9
PYC-9	N2/0	5	1	4	5	5	1	4	4	9.2	2.7	2.2	2.0
PYC-10	N2/0	5	1	4	5	5	1	4	4	16.3	2.9	2.7	2.1
PYC-11	N2/0	5	1	3	5	5	1	4	3	57.7	4.1	4.0	3.2
PYC-12	N2/0	5	1	3	5	5	1	2	3	179.5	0.0	0.0	0.0
PYC-13	N2/0	5	1	4	5	5	1	0	0	278.5	0.0	0.0	0.0
PYC-14	N2/0	5	1	4	5	5	1	0	0	2.6	2.2	1.9	0.8
PYC-15	N2/0	5	1	3	5	5	1	5	4	23.7	4.5	2.8	1.9
PHR-1	N2/0 10R 3/6	3	2	7	1	4	1	0	0	3.0	2.3	2.3	0.9
PHR-2	N3/0	5	1	4	2	5	2	1	3	6.7	2.3	2.1	1.3
PHR-3	N2/0	2	2	7	2	5	1	2	4	5.3	3.0	2.7	0.9
PHR-4	N4/0	5	1	3	3	4	1	0	0	1.9	2.7	1.9	0.5
PHR-5	N3/0	5	1	4	2	3	1	2	3	7.1	3.0	2.5	1.2
PHR-6	N4/0	1	1	3	3	5	1	4	5	10.0	3.5	2.2	1.1

Specimen	Hand Specimen Color	CT	LT	SL	ST	I	C	SR	SS	Wt. gms	Length cms	Width cms	Thickness cms
PHR-7	N3/0	2	2	7	1	1	1	3	4	12.7	3.3	2.6	1.7
PHR-8	N3/0	5	1	7	2	5	1	3	3	9.4	2.4	2.3	1.4
PHR-9	N2/0	4	2	7	1	4	1	4	4	25.3	4.1	3.0	2.5
PHR-10	N3/0	1	2	4	1	4	1	2	2	33.8	4.3	3.3	2.5
PHR-11	N3/0	5	2	4	2	4	1	5	5	49.1	5.8	5.6	1.2
PHR-12	N2/0	1	3	7	1	4	2	4	2	94.1	5.7	5.2	3.4
PHR-13	N2/0 10R 3/6	3	2	7	1	1	1	3	2	108.0	6.0	4.4	3.8
PHR-14	N3/0	5	1	3	3	1	1	4	1	221.6	8.3	7.9	2.6
PHR-15	N2/0	1	2	7	2	1	1	4	3	105.8	5.8	5.8	4.3
BR1-1	N2/0	2	1	7	2	4	2	4	2	30.0	3.8	3.6	2.0
BR1-2	N4/0	5	1	3	3	1	1	0	0	6.8	2.9	2.2	1.0
BR1-3	N2/0 10R 3/6	3	1	4	4	1	1	3	3	6.1	2.5	2.3	1.2
BR1-4	N2/0 10R 3/6	3	2	7	1	1	1	2	4	13.4	3.0	2.4	1.9
BR1-5	N3/0	5	1	3	4	5	2	2	2	16.3	2.7	2.7	2.0
BR1-6	CLEAR	3	3	7	1	5	2	1	3	4.4	2.0	1.7	1.3
BR1-7	N2/0	1	2	4	1	4	1	2	1	59.7	3.8	3.0	3.1
BR1-8	N2/0 10R 3/6	2	2	7	1	4	1	2	2	123.6	6.2	4.9	3.6
BR1-9	N3/0	5	3	7	1	5	1	2	2	27.3	4.7	3.3	3.0
BR1-10	N2/0 10R 3/6	1	1	7	1	4	1	1	3	13.2	2.8	2.2	1.9
BR1-11	N3/0 10R 3/6	3	1	3	3	4	1	1	2	10.0	2.8	2.0	1.6
BR1-12	N4/0	5	1	4	3	4	1	2	2	30.1	3.9	3.0	2.6
BR1-13	N2/0 10R 3/6	3	3	7	1	4	1	2	2	9.5	2.9	2.3	1.3

Specimen	Hand Specimen Color	CT	LT	SL	ST	I	C	SR	SS	Wt. gms	Length cms	Width cms	Thickness cms
BR1-14	N2/0 10R 3/6	4	3	4	4	4	2	2	2	115.2	5.7	5.3	3.6
BR1-15	N2/0 10R 3/6	3	3	7	1	4	1	2	3	149.6	6.9	5.0	4.5
BR2-1	N3/0	2	2	4	1	5	1	2	3	13.2	2.7	2.5	2.0
BR2-2	N5/0	1	1	3	3	1	1	2	2	10.0	3.0	2.8	1.3
BR2-3	N2.5/0	2	2	4	1	1	1	2	2	12.5	2.6	2.5	1.7
BR2-4	N3/0	1	1	3	3	4	1	4	2	10.0	2.6	2.7	1.7
BR2-5	N2.5/0	4	1	3	4	4	2	2	3	28.8	3.8	3.0	2.6
BR2-6	N2.5/0	1	1	4	3	1	1	4	3	19.2	3.3	2.7	2.2
BR2-7	N2/0	1	1	7	1	1	1	2	4	13.3	3.0	2.6	2.1
BR2-8	N3/0	5	1	4	3	1	1	2	2	19.9	2.9	2.7	2.4
BR2-9	N2.5/0	1	2	7	1	5	2	2	3	9.8	2.8	2.1	1.8
BR2-10	N5/0	1	1	3	3	4	1	4	2	11.2	2.8	2.5	1.6
BR2-11	N4/0	1	2	4	1	4	1	2	2	20.0	3.5	3.1	1.6
BR2-12	N2/0	3	2	7	1	1	1	4	4	22.8	3.3	2.7	1.9
BR2-13	N6/0	3	1	3	3	4	1	2	3	5.2	2.1	2.0	1.5
BR2-14	N3/0	1	1	4	2	4	1	3	2	21.1	3.2	3.0	2.5
BR2-15	N3/0	5	1	4	2	5	1	3	3	11.5	2.4	2.4	1.9
BR3-1	N2/0	5	3	7	1	4	1	4	2	12.8	3.1	2.5	1.9
BR3-2	N2/0 10R 3/4	4	3	7	1	4	1	1	3	153.4	6.1	5.8	4.3
BR3-3	N2/0 10R 3/4	4	1	3	3	4	1	2	3	127.9	5.6	5.5	3.9
BR3-4	N2/0	1	2	6	1	4	1	2	2	29.6	3.5	3.8	2.4
BR3-5	N2/0	1	2	7	1	4	1	2	2	9.4	2.8	2.5	1.4

Specimen	Hand Specimen Color	CT	LT	SL	ST	I	C	SR	SS	Wt. gms	Length cms	Width cms	Thickness cms
BR3-6	N2/0	4	2	7	1	4	1	2	3	15.2	3.4	2.5	1.9
BR3-7	N2.5/0	5	1	4	4	1	1	4	3	11.0	2.8	2.1	1.8
BR3-8	N3/0	5	1	4	3	1	1	2	2	6.5	2.0	2.2	1.8
BR3-9	N2/0	4	1	4	4	1	1	2	2	9.6	2.5	2.3	1.5
BR3-10	N2.5/0	5	2	4	4	4	1	1	2	15.3	3.3	2.7	1.7
BR3-11	N3/0	5	1	3	3	4	1	1	3	14.4	2.8	2.2	2.0
BR3-12	N3/0	5	1	2	5	5	1	4	5	13.8	4.0	2.5	1.3
BR3-13	N2/0	1	2	7	1	4	1	3	5	26.0	4.4	3.0	2.3
BR3-14	N3/0	1	2	7	1	4	1	4	4	60.1	5.7	3.3	3.0
BR3-15	N3/0	5	2	3	3	4	1	1	2	167.7	6.8	6.8	2.7
BR4-1	N3/0	4	1	3	4	5	1	2	2	14.2	3.5	2.9	1.5
BR4-2	N5/0	5	1	3	3	4	1	0	0	2.5	2.1	2.0	0.7
BR4-3	N3/0	5	1	4	1	1	1	2	2	8.4	2.6	2.2	1.4
BR4-4	N2/0	1	2	7	1	5	1	3	3	19.7	3.2	2.5	2.2
BR4-5	N2/0 10R 3/6	4	1	7	1	4	1	3	2	9.3	2.9	2.1	1.7
BR4-6	N3/0	1	1	4	4	4	1	2	3	14.6	2.5	2.6	2.3
BR4-7	N2.5/0	2	2	7	1	5	1	4	2	10.0	2.7	2.5	1.9
BR4-8	N2/0	1	1	7	1	1	1	3	4	10.1	3.0	1.9	1.9
BR4-9	N2/0	1	2	7	1	4	1	4	2	12.4	3.4	3.1	1.4
BR4-10	N2/0	1	2	7	1	4	1	4	2	30.1	4.0	3.7	2.0
BR4-11	N3/0	1	2	4	1	1	1	3	3	28.9	3.3	3.3	3.0
BR4-12	N3/0	2	2	4	1	4	1	1	2	193.7	7.4	5.3	4.4

Specimen	Hand Specimen Color	CT	LT	SL	ST	I	C	SR	SS	Wt. gms	Length cms	Width cms	Thickness cms
BR4-13	N2/0	1	2	7	1	4	1	1	2	88.5	6.2	4.1	3.4
BR4-14	N2/0 10R 3/6	4	2	7	1	4	1	4	2	77.2	5.8	4.3	3.0
BR4-15	N2/0	2	2	3	2	5	1	2	3	168.3	7.0	5.9	4.8
FCR-1	N3/0	2	2	7	1	4	1	4	2	99.2	5.8	5.4	2.8
FCR-2	N2.5/0	2	2	7	1	4	1	4	2	7.8	2.4	2.4	1.8
FCR-3	N4/0	4	2	4	3	4	1	4	2	8.5	2.5	2.8	2.1
FCR-4	N3/0	5	2	4	1	4	1	4	2	11.2	3.2	2.5	1.6
FCR-5	N2.5/0	1	2	7	1	4	1	2	4	8.6	2.8	1.8	1.6
FCR-6	N3/0	2	2	3	3	4	1	4	4	12.4	3.4	2.3	1.8
FCR-7	N3/0	1	2	4	1	4	1	4	2	10.0	3.0	2.7	1.5
FCR-8	N4/0	2	2	4	1	4	1	4	3	10.0	2.5	2.3	2.0
FCR-9	N3/0	5	1	3	2	5	1	5	2	10.0	2.5	2.1	2.1
FCR-10	N2.5/0	5	1	4	3	1	1	3	3	9.4	2.7	1.9	1.9
FCR-11	N3/0	5	1	3	3	4	1	2	3	6.0	2.3	1.9	1.2
FCR-12	N3/0	1	3	7	1	4	1	2	3	8.1	2.4	2.2	2.0
FCR-13	N2/0	4	3	7	1	4	1	4	3	20.0	3.6	2.8	2.6
FCR-14	N5/0	1	2	7	1	5	1	4	4	23.0	4.0	2.7	2.5
FCR-15	N3/0	4	3	7	1	5	1	2	2	21.1	3.6	2.6	2.0
SPR-1	N3/0	4	2	7	1	4	1	2	3	5.5	2.2	2.1	1.1
SPR-2	N2/0	4	3	7	1	5	1	2	4	9.0	2.8	2.3	1.3
SPR-3	N2/0	1	3	7	1	4	1	2	3	13.2	2.9	2.8	1.8
SPR-4	N2/0	1	2	7	1	4	1	3	3	19.0	3.2	3.0	2.4

Specimen	Hand Specimen Color	CT	LT	SL	ST	I	C	SR	SS	Wt. gms	Length cms	Width cms	Thickness cms
SPR-5	N4/0	5	2	4	2	5	1	5	3	3.0	1.8	1.6	0.9
SPR-6	N2/0	5	3	7	1	4	1	4	3	16.8	3.1	2.6	1.5
SPR-7	N4/0	2	2	3	3	5	1	4	2	33.6	4.2	3.9	1.9
SPR-8	N3/0	5	1	4	1	4	1	3	2	35.0	4.3	3.5	2.3
SPR-9	N4/0	2	2	7	1	4	1	4	3	67.0	4.3	3.9	3.3
SPR-10	N4/0	4	2	3	3	4	1	3	2	10.0	3.0	2.4	1.5
SPR-11	N2.5/0	4	2	7	1	4	1	2	2	8.2	2.3	2.3	1.9
SPR-12	N3/0	4	2	7	1	4	1	3	2	20.1	3.0	2.7	2.7
SPR-13	N2/0	1	2	7	1	4	1	4	3	20.1	3.0	3.0	2.7
SPR-14	N2/0	1	2	7	2	3	1	2	2	18.2	2.8	2.9	2.3
SPR-15	N4/0	3	7	1	4	1	4	3	3	15.1	2.9	2.4	2.1
WHR-1	N3/0	5	2	3	3	4	2	2	5	9.3	3.6	2.0	1.2
WHR-2	N2/0	1	2	7	1	4	1	4	3	10.1	2.8	2.8	2.1
WHR-3	N3/0	5	2	4	3	4	1	2	2	14.4	2.8	2.6	1.6
WHR-4	N2.5/0	1	2	7	1	1	1	3	4	13.0	3.6	1.9	1.9
WHR-5	N2/0	1	2	7	1	1	1	4	3	15.0	2.8	2.7	1.8
WHR-6	N4/0	5	1	3	3	4	1	3	2	14.2	2.9	2.6	2.1
WHR-7	N3/0	1	1	3	3	1	1	2	2	12.3	3.0	2.4	1.8
WHR-8	N3/0	4	1	4	4	4	1	2	2	6.8	2.3	2.1	1.4
WHR-9	N3/0	4	1	4	4	4	1	3	2	15.5	3.4	3.0	2.1
WHR-10	N2/0	4	3	7	1	4	1	2	2	10.0	2.8	1.9	1.4
WHR-11	N3/0	4	2	7	2	4	1	1	2	8.6	2.9	1.9	1.5

Specimen	Hand Specimen Color	CT	LT	SL	ST	I	C	SR	SS	Wt. gms	Length cms	Width cms	Thickness cms
WHR-12	N3/0	2	2	4	2	5	1	2	2	9.6	2.8	2.4	1.6
WHR-13	N2/0 10R 3/6	1	1	6	4	1	1	3	2	9.4	2.8	2.4	2.3
WHR-14	N2.5/0	5	2	4	4	4	2	2	4	8.8	3.1	1.8	1.4
WHR-15	N4/0	5	1	3	3	1	1	2	3	8.7	2.6	2.2	1.6
OSC-1	N2/0	5	2	3	3	4	2	2	2	28.2	3.4	3.1	2.2
OSC-2	N4/0	5	1	3	3	4	2	4	4	14.8	3.6	2.2	1.9
OSC-3	N3/0	5	2	3	3	4	2	2	2	13.0	2.5	2.5	1.9
OSC-4	N3/0	5	2	3	3	1	2	2	2	27.5	3.3	3.0	2.6
OSC-5	N3/0	5	2	3	3	4	2	2	2	76.4	5.2	3.8	3.5
OSC-6	N3/0	5	2	4	3	4	2	2	2	59.6	4.4	3.5	3.8
OSC-7	N4/0	5	1	3	3	4	2	2	2	26.3	3.7	2.9	2.5
OSC-8	N4/0	5	1	3	3	4	2	3	3	38.2	3.6	3.3	3.0
OSC-9	N3/0	4	2	3	3	4	2	3	3	35.2	4.1	3.6	2.1
OSC-10	N4/0	1	1	4	3	4	2	2	2	27.2	3.4	3.1	2.4
OSC-11	N3/0	5	1	4	3	1	2	3	3	56.8	5.1	3.8	2.8
OSC-12	N5/0	1	2	6	1	1	2	2	2	47.5	4.1	3.7	2.5
OSC-13	N5/0	5	1	3	3	4	2	4	4	39.4	5.0	3.0	2.7
OSC-14	N2/0	4	2	4	3	4	2	3	3	10.0	2.7	2.2	1.4
OSC-15	N2/0	4	1	6	3	4	2	3	3	78.4	4.1	3.2	3.4
DCT-1	N2/0	4	2	7	1	4	1	4	4	12.9	3.2	2.2	1.7
DCT-2	N5/0	4	2	6	1	4	1	2	2	4.2	1.7	1.5	1.4
DCT-3	N3/0	5	2	4	3	1	2	2	2	13.1	2.6	2.5	1.6

Specimen	Hand Specimen Color	CT	LT	SL	ST	I	C	SR	SS	Wt. gms	Length cms	Width cms	Thickness cms
DCT-4	N3/0	5	1	3	3	1	1	3	3	6.8	1.9	1.9	1.4
DCT-5	N3/0	5	1	6	2	3	1	3	3	13.0	2.9	2.3	2.0
DCT-6	N2/0	4	2	7	1	1	1	3	3	6.3	2.4	1.7	1.4
DCT-7	N3/0	4	2	7	1	4	1	4	4	17.3	3.4	2.4	2.0
DCT-8	N5/0	4	2	7	1	4	1	3	3	18.7	2.9	2.8	2.4
DCT-9	N4/0	5	1	3	3	1	1	4	4	6.5	2.7	1.8	1.4
DCT-10	N3/0	5	1	3	3	1	1	3	3	10.0	2.8	1.7	1.6
DCT-11	N2/0	4	2	3	3	4	2	3	3	25.0	3.6	2.4	2.3
DCT-12	N3/0	1	1	3	3	1	2	2	2	33.5	4.6	3.4	2.0
DCT-13	N2/0	4	2	7	1	4	1	1	1	13.3	3.0	2.9	1.5
DCT-14	N6/0	4	2	3	3	4	1	2	4	24.0	4.5	2.4	2.1
DCT-15	N3/0	4	2	4	3	4	1	2	4	10.0	3.0	2.2	1.5
CCT-1	N3/0	5	1	3	1	1	1	2	4	15.3	3.7	2.3	1.9
CCT-2	N2/0	2	2	4	1	1	1	2	4	14.9	3.5	2.0	1.8
CCT-3	N2/0	1	2	7	1	1	1	1	2	69.3	4.9	4.2	3.0
CCT-4	N4/0	1	2	4	1	4	1	2	2	40.1	4.7	3.3	2.2
CCT-5	N3/0	2	1	4	1	1	1	2	3	21.2	3.2	3.0	2.3
CCT-6	N3/0	2	1	6	1	1	1	2	2	48.2	4.8	4.0	2.1
CCT-7	N2.5/0	4	2	4	1	4	1	0	0	1.8	1.9	2.1	0.5
CCT-8	N2.5/0	5	1	4	1	4	1	2	4	34.5	4.5	3.3	2.1
CCT-9	N2/0	4	3	4	1	4	1	2	3	97.3	4.9	4.9	3.9
CCT-10	N2.5/0	1	2	7	1	4	1	1	2	27.8	3.7	3.4	2.1

Specimen	Hand Specimen Color	CT	LT	SL	ST	I	C	SR	SS	Wt. gms	Length cms	Width cms	Thickness cms
CCT-11	N3/0	2	2	4	1	4	2	4	2	108.5	6.1	5.0	3.3
CCT-12	N5/0	5	1	4	3	4	1	2	3	12.2	2.9	2.5	1.9
CCT-13	N2.5/0	4	2	4	4	4	1	1	2	170.1	5.6	6.4	4.4
CCT-14	N2/0	4	2	7	1	4	1	1	2	25.2	3.1	3.0	2.3
CCT-15	N3/0	4	2	4	3	4	1	0	0	0.9	2.7	1.0	0.3

APPENDIX B

SAMPLE	TI ppm	Mn ppm	Fe ppm	Zn ppm	Ga ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm
PR1-1	626.77	390.81	7842.34	33.11	15.46	115.86	68.86	18.25	98.32	9.91
PR1-2	697.67	348.53	7348.92	44.52	13.53	110.11	62.38	14.77	90.33	11.02
PR1-3	814.58	426.57	8690.28	32.31	13.30	118.36	70.00	15.48	97.76	10.48
PR1-4	688.63	356.55	8063.62	53.62	11.23	112.81	68.40	17.29	96.39	9.28
PR1-5	915.37	385.76	8651.47	42.84	19.39	121.77	71.56	15.79	94.10	6.93
PR1-6	588.92	352.21	7744.05	39.40	15.25	102.45	60.51	17.76	97.30	8.67
PR1-7	719.56	294.34	7001.92	50.18	14.67	95.70	57.58	16.55	78.51	7.87
PR1-8	813.52	339.65	8245.07	53.48	13.15	107.96	62.94	15.20	91.89	7.24
PR1-9	764.61	376.45	8026.51	27.78	13.94	113.32	64.77	13.92	94.68	12.65
PR1-10	1101.93	419.34	10032.40	38.14	12.65	117.39	64.33	21.43	101.23	10.89
PR1-11	666.12	339.25	7975.24	53.18	9.28	103.36	68.88	13.94	87.89	8.96
PR1-12	682.73	374.80	7817.00	60.78	14.17	108.04	62.83	20.12	91.64	10.86
PR1-13	835.37	379.00	8658.61	83.60	11.69	106.31	67.68	15.74	85.23	8.71
PR1-14	746.77	344.16	8352.93	60.46	9.95	112.03	64.33	17.30	92.41	7.78
PR1-15	617.95	326.80	7388.84	69.43	11.93	102.10	60.68	9.96	89.56	15.55
PHR-1	444.38	492.13	7243.31	47.37	13.85	78.01	89.11	14.92	72.65	0.51
PHR-2	403.96	540.60	7272.86	37.24	13.49	90.16	73.56	17.78	72.36	8.79
PHR-3	747.01	591.48	8423.57	35.93	14.36	93.71	86.50	19.38	71.15	6.75
PHR-4	442.84	555.31	7465.51	41.38	17.09	90.03	82.54	17.51	70.09	6.26
PYC-2	6928.27	1027.11	48428.51	89.13	21.28	42.28	342.14	40.16	188.14	4.78
PYC-3	6918.35	1090.11	51712.46	96.85	19.73	45.61	352.93	44.46	191.77	3.09
PYC-4	7256.64	1107.57	52669.63	116.26	18.79	44.36	357.25	37.59	188.05	5.03
PYC-5	7807.25	1144.69	54865.13	109.44	19.98	47.17	379.54	39.69	188.80	3.96
PYC-6	7579.19	1173.47	50960.36	105.97	16.63	50.37	346.58	40.71	207.09	4.07
PYC-7	6349.30	985.02	46020.15	108.63	13.15	38.61	324.03	33.84	176.98	9.31
PYC-8	6535.16	975.30	47171.63	104.74	19.49	41.33	335.14	41.54	189.85	0.70
PYC-9	8384.68	1230.58	56089.74	108.43	19.72	43.59	367.82	40.32	197.50	4.18

SAMPLE	TI ppm	Mn ppm	Fe ppm	Zn ppm	Ga ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm
PYC-10	7132.25	976.41	49475.29	107.31	18.92	40.13	350.17	36.20	178.78	5.49
PYC-11	7755.65	1140.13	56561.83	103.29	21.36	44.61	375.76	39.44	195.29	4.98
PYC-12	8974.75	1337.25	61298.92	111.50	18.00	45.42	381.93	39.48	200.28	3.96
PYC-13	7017.56	1049.20	50516.34	116.19	16.09	40.27	337.27	34.71	173.61	4.83
PYC-14	6749.31	1106.26	48009.73	109.51	18.31	47.18	329.48	36.91	195.17	2.46
PYC-15	7555.31	1161.64	54148.61	90.01	17.74	44.87	360.92	38.37	183.84	5.31
BR1-1	501.34	646.39	7948.53	41.13	13.99	98.28	81.98	16.93	63.36	3.32
BR1-2	880.26	590.61	10228.47	40.40	14.47	86.96	82.77	16.66	70.14	8.30
BR1-3	671.93	485.19	8006.73	44.72	13.94	84.86	76.64	16.64	69.32	6.42
BR1-4	527.13	558.35	7479.75	38.26	11.81	87.83	85.05	16.61	66.19	4.84
BR1-5	398.14	733.78	7061.99	39.99	14.58	103.79	70.51	18.63	59.00	8.79
PHR-5	511.20	554.60	7857.05	35.81	19.18	91.89	85.09	17.40	76.81	8.54
PHR-6	576.41	757.50	9256.17	45.36	16.81	100.69	110.26	19.68	77.13	10.58
PHR-7	396.44	576.75	7863.66	41.31	13.83	104.50	87.18	16.44	67.73	3.39
PHR-8	536.27	539.54	7671.67	49.50	14.43	90.17	80.84	17.78	69.62	7.67
PHR-9	561.35	707.12	8622.91	39.51	15.92	102.41	110.01	20.32	76.14	6.49
PHR-10	519.80	592.54	7874.50	35.87	16.45	91.91	98.71	20.34	70.71	6.81
PHR-11	504.21	608.14	8002.29	47.60	19.09	99.49	83.29	16.30	64.30	6.70
PHR-12	439.32	650.80	8755.72	48.59	14.43	100.70	104.99	16.90	72.59	5.99
PHR-13	549.20	669.04	8571.42	38.99	19.97	99.52	104.63	20.25	73.75	5.37
PHR-14	519.26	566.47	7596.57	44.07	16.40	93.37	88.49	16.12	68.58	9.03
PHR-15	570.34	656.13	8545.01	44.31	17.20	98.39	91.85	17.91	74.80	10.00
PYC-1	7783.79	1198.93	53605.34	100.00	18.45	48.77	357.85	38.29	201.20	1.91
BR1-6	490.81	634.94	6788.02	40.98	15.39	101.35	45.67	17.53	63.59	7.40
BR1-7	611.08	665.53	8684.91	47.50	22.98	99.54	102.03	17.20	74.65	7.41
BR1-8	437.70	613.05	7855.85	39.13	16.88	97.56	88.35	18.44	68.54	8.12
BR1-9	552.18	648.72	8475.66	45.69	18.94	99.81	88.44	15.61	73.92	8.27

SAMPLE	TI ppm	Mn ppm	Fe ppm	Zn ppm	Ga ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm
BR1-10	481.75	495.10	7037.90	41.06	11.61	84.99	78.99	15.29	62.98	8.46
BR1-11	348.59	550.67	7542.48	50.28	14.20	86.93	82.64	14.57	63.91	7.18
BR1-12	569.12	654.61	8092.87	43.29	18.39	97.70	89.44	17.52	69.84	6.87
BR1-13	549.82	622.72	7916.59	47.45	14.53	96.85	88.45	15.47	63.96	5.16
BR1-14	552.29	623.80	8252.21	51.56	15.29	96.00	90.68	15.66	73.46	5.52
BR1-15	368.80	503.48	6895.78	46.24	15.35	89.22	79.77	16.50	70.49	5.46
BR2-1	543.51	569.87	7724.66	51.21	18.37	90.11	88.10	17.81	69.00	9.19
BR2-2	508.69	602.16	8061.29	39.55	18.03	96.39	89.16	17.00	67.46	9.34
BR2-3	445.92	614.41	8076.97	43.08	16.45	94.34	90.59	17.99	83.70	6.93
BR2-4	632.83	563.69	8019.28	39.53	13.98	93.40	85.12	18.43	69.53	4.55
BR2-5	574.77	659.64	8341.65	43.08	20.21	104.03	95.85	17.40	70.51	1.60
BR2-6	580.58	619.94	8292.25	47.33	16.80	101.97	87.78	19.52	76.16	3.40
BR2-7	488.86	608.55	8085.80	39.08	16.10	97.90	84.59	15.71	73.71	9.64
BR2-8	465.67	617.65	7918.44	40.43	16.04	97.08	86.72	13.80	72.93	6.76
BR2-9	348.44	515.72	7347.71	47.59	18.38	86.83	81.61	20.32	78.16	6.67
BR2-10	428.19	508.72	7420.95	47.26	14.77	89.40	79.37	18.31	65.74	7.82
BR2-11	567.45	604.19	7948.26	50.04	15.56	96.70	86.08	20.24	65.13	7.12
BR2-12	661.02	706.82	8632.92	51.18	18.98	101.08	97.41	17.88	79.42	4.06
BR2-13	468.65	599.81	8010.29	49.12	14.83	90.50	81.45	15.23	73.97	10.93
BR2-14	603.38	645.99	8096.95	40.46	18.26	98.74	88.10	21.84	73.24	6.91
BR2-15	380.38	635.99	6740.90	38.96	14.84	103.94	42.74	19.50	68.08	6.59
BR3-1	469.02	644.06	8010.53	47.41	19.06	97.17	88.04	15.75	71.09	3.96
BR3-2	550.91	537.14	7676.69	33.09	13.12	87.34	98.06	17.06	83.22	8.84
BR3-3	439.14	616.83	7785.79	40.86	14.05	96.79	86.70	20.07	65.60	7.14
BR3-4	603.20	696.34	8774.83	51.00	18.26	108.17	98.81	17.94	76.11	6.92
BR3-5	489.65	553.63	7455.63	44.47	13.16	91.39	85.00	15.69	70.68	8.73
BR3-6	378.26	623.82	8021.53	43.04	18.09	97.65	91.26	18.34	75.10	7.58

SAMPLE	TI ppm	Mn ppm	Fe ppm	Zn ppm	Ga ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm
BR3-7	432.25	595.64	7985.66	44.01	16.76	97.61	86.65	19.30	79.70	3.71
BR3-8	397.60	585.36	7453.35	39.74	13.95	90.48	81.35	18.78	65.66	4.03
BR3-9	530.11	547.33	7507.20	44.27	15.06	91.81	79.04	17.94	66.09	7.74
BR3-10	459.94	602.58	7892.85	45.70	15.29	95.37	88.16	20.97	69.07	6.43
BR3-11	392.90	533.70	7329.17	40.13	15.89	87.16	84.15	16.56	68.23	10.45
BR3-12	482.76	550.93	7175.56	43.96	11.17	93.96	73.67	18.61	72.08	6.93
BR3-13	460.15	579.89	7612.27	36.12	17.60	92.03	88.34	17.46	65.85	5.07
BR3-14	618.05	659.34	8369.26	49.11	18.23	96.05	95.67	19.59	72.95	9.13
BR3-15	544.29	564.04	7788.84	45.07	16.38	93.96	88.08	18.01	67.70	8.40
BR4-1	560.81	652.66	8516.34	49.40	16.87	100.44	94.35	20.64	75.17	6.23
BR4-2	602.44	620.39	8136.85	42.78	14.25	95.77	85.13	14.27	71.72	6.76
BR4-3	524.36	584.94	8726.94	39.94	16.16	88.19	81.58	19.19	65.52	7.04
BR4-4	571.89	580.05	8265.63	40.24	14.22	87.10	82.26	15.93	64.97	6.17
BR4-5	382.59	572.74	7581.37	36.81	13.21	86.24	96.57	17.87	72.47	5.30
BR4-6	526.58	562.40	7702.33	49.50	14.62	95.87	83.63	17.16	63.53	8.86
BR4-7	525.04	588.28	7845.09	42.68	18.09	94.65	81.39	17.48	63.80	7.08
BR4-8	645.68	498.70	7437.98	63.46	16.34	82.88	92.03	16.78	71.17	4.72
BR4-9	670.97	674.24	8793.57	48.36	18.39	102.96	109.11	20.39	78.40	4.48
BR4-10	602.83	579.60	8193.08	47.03	15.54	85.18	95.26	18.91	74.63	6.82
BR4-11	604.30	615.15	8225.93	51.44	16.34	97.97	87.90	19.10	66.84	8.32
BR4-12	555.12	603.44	7887.66	39.44	14.07	96.98	88.16	18.73	70.09	6.63
BR4-13	490.95	635.54	8366.08	46.16	16.45	100.15	101.36	20.56	71.71	7.94
BR4-14	513.26	565.12	8491.32	45.95	17.35	93.23	96.43	15.18	65.88	2.45
BR4-15	521.04	512.95	7152.92	50.13	16.74	84.95	72.80	19.71	60.08	4.50
WHR-1	567.65	666.49	8536.75	44.85	11.93	100.52	90.35	18.46	76.96	10.04
WHR-2	463.53	568.40	7558.74	37.41	12.89	89.61	85.25	17.75	72.13	5.49
WHR-3	487.56	606.77	7930.07	40.46	15.88	99.51	89.22	16.52	68.93	7.33

SAMPLE	TI ppm	Mn ppm	Fe ppm	Zn ppm	Ga ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm
WHR-4	511.21	596.80	7914.45	41.44	13.32	92.89	88.64	16.96	67.37	8.65
WHR-5	424.80	543.82	7427.25	38.22	12.33	90.43	83.47	17.00	66.84	8.19
WHR-6	389.85	496.31	7004.51	38.92	11.94	83.73	79.63	18.77	65.84	10.61
WHR-7	362.75	599.49	7913.36	41.67	19.47	98.77	89.21	18.64	65.03	5.61
WHR-8	414.52	536.82	7818.82	51.44	13.01	92.29	80.94	17.61	66.97	1.99
WHR-9	452.65	601.10	7677.75	41.75	15.14	95.75	86.96	16.50	70.73	7.28
WHR-10	496.22	676.16	8108.94	33.74	15.91	96.83	91.18	19.23	76.61	9.65
WHR-11	461.40	561.88	7756.98	52.34	10.68	92.55	82.22	17.41	69.64	6.28
WHR-12	448.16	618.47	7780.00	35.25	13.97	95.95	84.52	16.50	73.74	6.68
WHR-13	408.64	616.05	7835.94	41.53	14.94	96.09	85.88	19.10	77.40	3.56
WHR-14	569.82	585.31	8088.06	50.56	17.39	92.82	86.81	16.57	67.23	7.49
WHR-15	483.74	524.06	7479.25	36.38	14.62	94.62	85.26	20.82	72.86	8.98
CCT-1	520.57	583.48	8055.63	42.04	15.02	92.05	99.18	19.44	72.28	10.16
CCT-2	634.88	586.92	8221.76	61.96	16.51	93.67	98.08	16.50	69.00	3.41
CCT-3	465.38	565.04	8060.06	43.20	18.28	91.78	100.72	17.10	68.01	8.20
CCT-4	464.19	590.67	8103.56	38.39	16.61	98.44	102.32	20.27	74.73	5.10
CCT-5	426.87	591.04	8041.14	41.78	15.90	95.78	100.24	20.47	77.95	7.62
CCT-6	528.33	616.62	7945.52	44.08	13.42	90.62	102.08	17.34	70.90	6.69
CCT-7	466.23	548.45	7830.76	46.31	14.29	87.59	100.37	17.45	70.42	5.42
CCT-8	476.33	667.24	8424.48	42.03	17.33	99.02	104.65	18.46	71.23	7.57
CCT-9	525.08	569.66	8122.57	42.21	15.10	92.99	101.08	16.45	72.03	7.74
CCT-10	661.36	580.64	7953.93	48.91	14.34	89.54	99.42	17.52	69.65	9.67
CCT-11	479.79	582.58	7770.48	49.71	15.86	87.89	98.87	16.76	69.74	8.62
CCT-12	491.19	453.82	7730.92	49.67	14.69	79.98	88.19	16.00	67.70	10.58
CCT-13	452.02	592.34	8014.25	37.08	14.28	92.01	101.65	18.62	72.34	6.74
CCT-14	530.57	645.80	8157.37	44.42	15.30	97.77	101.88	18.13	73.22	5.78
CCT-15	498.69	555.03	8196.03	38.43	16.08	91.89	101.16	19.11	68.75	6.08

SAMPLE	TI ppm	Mn ppm	Fe ppm	Zn ppm	Ga ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm
FCR-1	551.64	618.52	8059.76	44.76	17.12	99.37	89.92	21.47	71.51	5.65
FCR-2	485.59	576.77	7917.35	45.37	15.37	89.28	79.89	18.43	68.32	6.25
FCR-3	672.99	637.08	9311.16	46.09	14.91	91.06	85.51	17.19	75.14	3.63
FCR-4	471.05	600.50	8073.48	45.72	18.28	95.61	87.96	17.00	69.89	4.33
FCR-5	470.84	606.50	7830.17	46.12	15.89	97.08	88.24	17.00	70.52	7.41
FCR-6	651.68	519.72	7741.31	43.79	18.77	89.36	79.66	18.38	63.67	4.87
FCR-7	498.01	631.26	8299.87	45.01	18.14	100.00	94.23	17.31	71.81	9.74
FCR-8	541.30	563.84	7213.34	45.21	16.66	93.78	76.45	16.11	63.93	7.52
FCR-9	644.52	642.01	7997.26	46.69	17.01	96.20	90.57	19.33	70.62	8.14
FCR-10	398.69	529.35	7314.97	43.11	13.55	89.38	82.72	18.04	61.49	9.45
FCR-11	443.12	545.26	7574.28	44.14	13.27	88.88	80.75	17.36	62.22	3.17
FCR-12	499.86	570.00	7660.74	40.41	17.66	90.94	83.09	18.79	74.33	1.52
FCR-13	831.70	583.95	9245.41	40.39	17.88	92.37	88.45	18.09	67.35	5.82
FCR-14	423.41	615.40	7831.54	41.10	15.15	96.26	90.07	19.67	67.58	6.22
FCR-15	446.26	632.63	8026.04	43.41	15.75	99.63	87.26	18.89	67.91	6.39
BR1-6B	398.77	738.80	7688.62	63.69	17.05	109.81	44.13	19.70	65.78	10.35
BR1-16	559.37	553.05	7631.42	43.83	13.96	91.86	81.34	14.17	64.08	5.63
BR1-17	467.41	537.62	7510.34	50.32	14.98	90.90	83.18	15.95	66.72	4.36
BR1-18	556.66	545.21	7620.20	46.94	16.84	90.35	84.72	17.13	72.02	7.88
BR1-19	487.45	616.02	8363.26	53.49	16.60	96.37	88.37	16.41	76.65	8.30
BR1-20	509.17	534.37	7854.23	42.24	13.06	92.22	81.95	15.59	67.56	8.13
SPR-1	659.79	648.39	8508.31	53.61	16.29	102.23	92.22	16.71	68.17	6.25
SPR-2	397.82	541.12	7466.12	40.09	11.81	87.87	77.82	16.77	66.27	7.80
SPR-3	429.94	507.29	7399.05	35.08	15.61	87.82	82.04	19.28	66.63	8.55
SPR-4	549.53	682.79	8212.02	43.48	19.86	98.38	91.34	17.89	72.51	3.77
SPR-5	422.17	507.61	7266.17	46.87	13.68	85.96	75.55	16.49	61.61	7.03
SPR-6	517.81	588.26	7911.91	53.79	18.67	95.09	89.04	18.04	65.27	6.71

SAMPLE	TI ppm	Mn ppm	Fe ppm	Zn ppm	Ga ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm
SPR-7	390.36	571.57	7656.29	41.27	13.21	94.36	83.71	16.66	64.25	9.83
SPR-8	479.09	600.57	8147.25	42.12	14.70	97.26	87.03	18.28	70.73	4.29
SPR-9	549.44	616.32	8149.35	49.02	15.00	98.24	88.94	16.06	68.23	8.22
SPR-10	645.57	656.50	8813.14	53.93	20.72	103.59	95.44	17.89	65.47	5.20
SPR-11	480.11	583.24	7965.76	47.07	13.56	92.55	85.75	17.89	74.86	7.48
SPR-12	549.91	656.82	8505.19	42.18	16.12	95.01	91.13	19.11	70.68	8.83
SPR-13	410.08	597.43	7664.60	43.04	14.00	94.87	86.54	17.15	73.07	6.91
SPR-14	453.71	576.34	7653.29	35.77	14.87	92.82	89.13	18.87	73.70	7.44
SPR-15	618.70	745.80	8928.03	46.31	22.62	99.38	91.59	20.71	68.32	4.39
INK-1	10845.71	1326.96	73264.53	118.51	23.98	46.70	394.39	35.10	177.90	4.29
INK-2	8520.67	1077.35	56213.53	111.79	16.02	45.38	335.43	35.14	164.17	3.97
INK-3	9416.81	1099.38	63502.48	98.10	21.45	41.16	380.67	36.50	173.75	4.75
INK-4	8481.92	971.35	56242.77	97.56	13.13	40.80	351.81	35.69	172.09	6.81
INK-5	6858.33	1093.07	47083.48	102.29	18.44	48.51	341.45	42.17	210.52	1.44
INK-6	8698.66	1087.76	61939.86	106.51	18.50	41.71	353.31	36.86	166.53	6.64
INK-7	8928.90	1281.31	63809.51	103.40	25.24	40.47	372.53	40.35	171.63	9.96
INK-8	11213.16	1385.12	73296.37	116.82	24.46	48.89	394.25	33.79	192.46	5.01
INK-9	9512.27	1133.39	66425.67	114.34	16.67	44.73	364.18	36.92	167.92	2.91
INK-10	8812.58	1016.80	58927.88	127.97	20.27	44.93	352.47	38.15	161.93	8.51
INK-11	9040.60	1130.62	62039.25	112.41	19.10	41.82	359.69	33.85	169.47	7.85
INK-12	7174.37	990.66	50336.74	95.54	16.42	40.82	331.66	36.57	176.48	8.27
INK-13	8061.49	1107.93	55437.06	109.52	21.96	49.13	369.54	40.90	202.71	8.24
INK-14	9623.31	1242.87	63902.80	127.84	20.06	44.51	378.41	36.17	177.89	7.10
INK-15	9550.32	1067.23	62489.68	121.31	20.61	50.14	341.06	33.26	170.53	1.38
DCT-1	645.89	609.99	8168.12	50.40	15.07	94.98	100.65	17.34	73.50	6.75
DCT-2	659.78	532.03	8040.21	61.31	13.47	97.20	101.17	16.07	66.16	10.96
DCT-3	388.53	619.70	8177.61	44.69	14.01	94.07	103.93	16.52	71.76	10.06

SAMPLE	TI ppm	Mn ppm	Fe ppm	Zn ppm	Ga ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm
DCT-4	418.49	548.98	7554.05	47.89	15.61	87.79	93.69	16.96	72.49	4.00
DCT-5	619.24	644.52	8587.87	48.71	13.52	97.58	108.88	17.49	76.12	6.83
DCT-6	541.41	578.69	7796.02	44.40	16.60	95.26	85.56	17.83	65.59	8.18
DCT-7	428.11	568.82	7812.23	43.43	14.08	91.41	98.08	18.66	71.21	7.02
DCT-8	430.45	557.04	7214.46	46.79	16.31	93.37	77.76	16.01	65.43	7.12
DCT-9	617.76	563.10	7822.04	54.15	17.35	88.47	99.93	19.99	71.32	7.16
DCT-10	384.31	489.14	7222.83	37.33	13.85	83.73	91.01	16.65	64.72	5.77
DCT-11	762.66	689.44	9210.89	56.07	20.34	104.86	108.83	17.77	71.80	5.79
DCT-12	550.69	600.91	8072.02	47.57	15.48	90.72	99.93	17.26	75.18	3.48
DCT-13	427.40	590.45	8165.29	46.25	14.61	92.03	98.88	16.77	69.92	4.16
DCT-14	476.88	618.70	8124.24	54.81	18.37	95.09	101.47	18.50	74.37	7.88
DCT-15	451.19	591.45	8185.97	37.18	16.61	100.29	99.83	16.41	93.45	2.65
OSC-1	509.28	629.71	8272.32	53.12	19.31	93.25	103.24	17.82	68.30	9.93
OSC-2	526.54	553.84	7814.03	37.82	14.81	93.92	97.45	16.42	70.30	6.28
OSC-3	483.27	554.56	7549.11	38.60	15.49	90.79	96.52	16.73	70.98	3.44
OSC-4	613.94	668.91	8295.41	50.07	16.30	95.23	104.34	19.10	76.16	6.53
OSC-5	318.27	668.10	8636.21	53.80	19.91	96.60	100.79	15.92	84.04	8.50
OSC-6	420.85	553.43	7683.60	43.10	17.34	88.38	97.01	15.61	67.90	7.34
OSC-7	463.08	591.83	8024.97	51.63	16.14	93.60	98.58	15.18	69.37	7.40
OSC-8	472.79	578.36	7990.83	54.23	14.51	94.79	101.54	16.65	84.00	9.72
OSC-9	566.18	589.37	8091.21	43.82	17.34	95.21	103.12	15.79	76.13	3.10
OSC-10	557.28	606.17	7983.72	41.86	17.76	96.30	103.00	15.77	74.49	4.55
OSC-11	466.65	569.96	7764.34	39.77	16.80	89.68	97.51	17.98	70.61	6.08
OSC-12	551.71	613.68	8227.79	40.53	17.66	95.85	98.86	15.60	81.60	5.50
OSC-13	473.22	657.82	8541.05	44.24	17.05	97.75	103.49	18.08	74.36	7.06
OSC-14	553.95	574.62	7920.89	42.10	11.20	94.55	100.92	17.49	72.31	10.76
OSC-15	561.16	591.33	8280.49	49.85	16.17	98.78	106.67	17.29	75.91	4.56

SAMPLE	TI ppm	Mn ppm	Fe ppm	Zn ppm	Ga ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm
PR2-1	725.05	401.04	7909.79	31.44	13.59	112.87	73.47	19.26	104.51	11.03
PR2-2	779.66	393.76	8119.22	31.32	18.02	119.03	74.48	20.06	105.55	12.69
PR2-3	786.42	372.64	7929.34	33.84	19.53	119.51	71.55	18.02	99.67	12.03
PR2-4	661.32	371.86	7711.28	26.50	13.39	111.76	74.47	18.30	103.92	14.60
PR2-5	750.79	326.66	7642.04	29.90	16.05	109.43	66.26	17.36	99.21	11.60
PR2-6	1074.26	316.06	9242.35	25.34	12.40	117.76	65.10	19.19	132.60	10.59
PR2-7	829.51	386.32	8187.17	33.04	17.10	116.10	72.32	17.35	104.34	10.29
PR2-8	821.28	381.29	7709.07	35.36	18.55	115.15	68.99	19.25	96.96	11.46
PR2-9	428.78	448.44	10729.23	52.44	21.03	287.32	10.23	61.76	106.38	34.12
PR2-10	377.32	392.33	8845.14	44.33	20.60	280.14	9.31	63.16	104.50	29.59
PR2-11	287.54	394.40	8276.89	49.05	21.13	266.33	9.33	56.29	98.41	33.11
PR2-12	1120.47	317.03	9311.28	27.04	15.13	119.06	69.13	19.47	132.46	9.81
PR2-13	713.35	330.13	7616.16	38.58	15.06	112.43	68.06	16.78	96.01	10.97
PR2-14	706.19	341.43	7842.35	37.95	12.23	101.74	67.76	19.12	95.40	12.94
PR2-15	1020.46	303.38	9086.47	38.03	14.66	123.96	68.99	18.58	136.24	10.61

SAMPLE LABEL	BA PPM	LA PPM	CE PPM	PR PPM	ND PPM	SM PPM
BR1-15	1477.63	18.69	34.79		38.24	
BR2-5	1619.37	37.82	38.55		28.40	6.48
BR2-9	1509.15	23.72	33.79		28.70	
BR2-10	1444.43	32.80	41.25		24.46	6.60
BR2-12	1624.36	24.28	39.66		20.24	7.62
BR2-15	1602.04	20.12	28.58		26.84	7.35
BR3-2	1793.47	33.31	55.28	2.53	38.58	7.49
BR3-4	1702.29	32.85	38.81		39.69	
BR3-9	1702.44	24.33	37.38		24.73	
BR3-12	1684.31	18.04	40.14		34.70	
BR3-14	1562.02	26.85	32.92		28.03	
BR4-1	1666.90	26.67	36.11		33.55	6.69
BR4-5	1498.54	22.55	37.39		17.23	7.78
BR4-7	1394.24	20.53	29.08	1.87	13.24	6.95
BR4-9	1547.76	31.17	37.86		46.32	
BR4-15	1460.19	13.10	23.06	8.75	15.26	6.22
WHR-1	1609.73	26.54	45.62	10.45	11.14	6.75
WHR-4	1716.99	21.53	41.25		25.93	6.19
WHR-6	1615.13	24.51	40.39	5.68	37.86	6.43
NBS-278	1061.81	40.98	73.96	21.42	29.43	8.10
WHR-10	1728.24	31.31	39.96		37.68	6.85
WHR-11	1512.17	24.62	35.53	4.42	40.54	

SAMPLE LABEL	BA PPM	LA PPM	CE PPM	PR PPM	ND PPM	SM PPM
CCT-3	1691.96	25.54	41.96		33.85	6.48
CCT-5	1678.52	28.32	47.72		52.52	6.44
CCT-8	1652.81	30.09	41.29		36.11	
CCT-12	1735.68	23.18	42.99	8.04	40.71	8.35
CCT-15	1533.65	21.66	28.75		45.76	6.31
FCR-2	1539.58	21.97	39.95		13.45	
FCR-6	1651.35	18.25	46.65		33.59	
FCR-7	1693.06	23.87	44.02		37.22	7.09
FCR-8	1508.62	12.25	35.69		12.01	6.30
FCR-9	1607.57	33.03	37.33		32.42	7.54
SPR-4	1747.65	26.76	35.72		32.20	7.14
SPR-5	1494.67	31.38	35.70		39.09	6.29
SPR-8	1728.16	26.32	31.32		37.72	6.73
SPR-10	1247.19	27.86	20.32	11.24	11.21	
SPR-14	1710.03	28.06	37.69		31.88	6.38
INK-2	606.18	35.84	34.23	4.42	9.12	7.26
INK-8	751.40	28.00	59.55	2.10	26.68	7.58
NBS-278	1034.55	43.00	67.45	8.86	38.48	7.98
INK-10	422.39	15.33	23.60	13.22	11.07	7.93
INK-12	792.70	37.90	50.11		35.12	8.06
INK-15	465.87	17.46	24.71	2.14	6.05	7.01
DCT-5	1649.60	28.24	41.95	6.98	27.06	7.16

SAMPLE LABEL	BA PPM	LA PPM	CE PPM	PR PPM	ND PPM	SM PPM
DCT-8	1586.15	22.85	29.34	7.16	30.64	7.26
DCT-9	1297.16	36.29	20.74	1.77	24.10	7.22
DCT-11	982.21	12.29	23.39	1.48	16.20	8.11
DCT-14	1294.08	14.50	37.14	12.00	17.07	7.15
OSC-1	1163.84	16.03	31.32		22.30	
OSC-3	1617.89	23.97	36.42		32.68	
OSC-4	1679.09	21.22	48.91		40.29	
OSC-10	1624.27	15.68	43.41		31.71	6.26
OSC-15	1142.94	24.49	21.30	4.57	23.96	6.34
PR2-1	959.16	43.71	66.21		23.25	
NBS-278	1067.34	48.40	72.95	22.74	33.34	

APPENDIX C

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B. Hamusek

SPECIMEN NUMBER	Rb ppm	S.D.	Sr ppm	S.D.	Y ppm	S.D.	Zr ppm	S.D.	Nb ppm	S.D.	OBSIDIAN SOURCE
73-60	86	5	83	3	14	2	62	4	7	3	Tuscan
73-73A	103	5	90	3	12	2	65	4	12	3	Tuscan
73-73B	74	5	91	3	12	2	59	4	3	3	Tuscan
73-78A	90	-	103	-	13	-	89	-	11	-	Unknown
73-78B	99	5	108	3	15	2	72	4	0	3	Tuscan
73-94A	84	5	98	3	13	2	63	4	10	3	Tuscan
73-94B	81	5	86	3	11	2	55	4	2	3	Tuscan
73-101A	77	5	84	3	14	2	53	4	9	3	Tuscan
73-101B	75	5	85	3	9	2	51	4	4	3	Tuscan
73-112A	106	5	111	3	15	2	74	4	10	3	Tuscan
73-118	139	6	73	4	27	3	187	7	11	3	GF/LIW/RS
73-119	145	6	77	4	29	3	180	7	13	3	GF/LIW/RS
71-87	85	5	83	3	15	2	71	4	4	3	Tuscan
71-144	141	6	76	4	25	3	185	7	9	3	GF/LIW/RS
71-172	128	6	68	4	24	3	174	7	12	3	GF/LIW/RS
71-189	92	5	98	3	13	2	72	4	6	3	Tuscan
71-401A	117	-	67	-	20	-	159	-	9	-	Unknown
71-409A	164	7	120	5	23	3	226	7	0	4	Glass Mtn
71-409B	140	6	76	4	29	3	189	7	13	3	GF/LIW/RS

S.D. = Standard Deviation Value at 1 sigma level

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SPECIMEN NUMBER	Rb ppm	S.D.	Sr ppm	S.D.	Y ppm	S.D.	Zr ppm	S.D.	Nb ppm	S.D.	OBSIDIAN SOURCE
71-409C	95	5	87	3	11	2	65	4	9	3	Tuscan
71-415A	158	7	118	5	23	3	207	7	6	4	Glass Mtn
71-423	87	5	95	3	17	2	67	4	7	3	Tuscan
71-424A	94	5	92	3	13	2	75	4	13	3	Tuscan
71-424B	80	5	79	3	16	2	52	4	5	3	Tuscan
71-430A	70	5	72	3	11	2	58	4	9	3	Tuscan
71-436A	85	5	95	3	19	2	71	4	8	3	Tuscan
71-443	87	5	82	3	13	2	63	4	7	3	Tuscan
71-444A	149	7	112	5	22	3	222	7	8	4	Glass Mtn
71-450	94	5	81	3	20	2	63	4	8	3	Tuscan
71-451A	82	5	96	3	15	2	66	4	8	3	Tuscan
71-451B	129	6	75	4	27	3	165	7	8	3	GF/LIW/RS
71-457A	88	5	103	3	20	2	70	4	7	3	Tuscan
71-457B	74	5	87	3	12	2	61	4	7	3	Tuscan
71-463A	133	6	73	4	27	3	176	7	5	3	GF/LIW/RS
71-463B	85	5	99	3	16	2	69	4	4	3	Tuscan
71-476	85	5	81	3	15	2	61	4	7	3	Tuscan
71-477A	141	6	75	4	26	3	182	7	12	3	GF/LIW/RS
71-483	86	5	97	3	16	2	70	4	5	3	Tuscan

S.D. = Standard Deviation Value at 1 sigma level

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SPECIMEN NUMBER	Rb ppm	S.D.	Sr ppm	S.D.	Y ppm	S.D.	Zr ppm	S.D.	Nb ppm	S.D.	OBSIDIAN SOURCE
71-484A	81	5	90	3	19	2	65	4	7	3	Tuscan
72-7	82	5	93	3	14	2	64	4	4	3	Tuscan
72-8A	89	5	86	3	13	2	69	4	3	3	Tuscan
72-8B	93	5	95	3	19	2	67	4	7	3	Tuscan
72-23	86	5	101	3	17	2	72	4	8	3	Tuscan
72-32A	75	5	80	3	10	2	57	4	5	3	Tuscan
72-32B	78	5	92	3	14	2	56	4	0	3	Tuscan
72-47	86	5	92	3	17	2	69	4	7	3	Tuscan
72-57	82	5	93	3	14	2	57	4	10	3	Tuscan
72-59A	97	5	108	3	14	2	65	4	10	3	Tuscan
72-64A	130	6	68	4	18	3	166	7	0	3	GF/LIW/RS
72-72	81	5	92	3	13	2	69	4	6	3	Tuscan
72-74A	125	6	73	4	23	3	163	7	12	3	GF/LIW/RS
72-82A	99	5	110	3	12	2	69	4	2	3	Tuscan
72-102A	146	6	77	4	28	3	203	7	8	3	GF/LIW/RS
72-102B	92	5	75	3	21	2	54	4	8	3	Tuscan
72-102C	93	5	93	3	14	2	57	4	0	3	Tuscan
72-111	130	6	69	4	25	3	178	7	8	3	GF/LIW/RS
72-120A	91	5	82	3	16	2	67	4	7	3	Tuscan

S.D. = Standard Deviation Value at 1 sigma level

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SPECIMEN NUMBER	Rb ppm	S.D.	Sr ppm	S.D.	Y ppm	S.D.	Zr ppm	S.D.	Nb ppm	S.D.	OBSIDIAN SOURCE
72-129A	95	5	83	3	18	2	68	4	8	3	Tuscan
72-148A	145	6	83	4	25	3	183	7	8	3	GF/LIW/RS
72-148B	101	5	97	3	18	2	75	4	0	3	Tuscan
72-158	87	5	83	3	18	2	62	4	5	3	Tuscan
72-159A	134	6	68	4	26	3	176	7	7	3	GF/LIW/RS
72-167A	87	5	69	3	26	2	61	4	13	3	Tuscan
72-174A	128	6	74	4	27	3	179	7	13	3	GF/LIW/RS
72-174B	88	5	102	3	15	2	64	4	11	3	Tuscan
72-193A	95	5	108	3	18	2	69	4	8	3	Tuscan
72-193B	87	5	83	3	18	2	62	4	6	3	Tuscan
72-218	84	5	91	3	11	2	68	4	8	3	Tuscan

S.D. = Standard Deviation Value at 1 sigma level

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B. Hamusek

SPECIMEN NUMBER	Rb ppm	S.D	Sr ppm	S.D	Y ppm	S.D	Zr ppm	S.D	Nb ppm	S.D.	OBSIDIAN SOURCE
258-253-9	87	5	10	3	18	2	67	4	9	3	Tuscan
258-253-16A	132	6	7	4	26	3	175	7	14	3	GF/LIW/RS
258-253-16B	100	3	8	6	16	3	97	4	11	1	Buck Mountain
258-253-16C	83	5	8	3	17	2	60	4	5	3	Tuscan
258-253-17	134	6	7	4	24	3	176	7	9	3	GF/LIW/RS
258-253-19A	151	6	7	4	26	3	195	7	9	3	GF/LIW/RS
258-253-19B	154	6	8	4	27	3	207	7	11	3	GF/LIW/RS
258-253-19C	147	6	8	4	26	3	200	7	13	3	GF/LIW/RS
258-253-31	138	6	7	4	28	3	195	7	8	3	GF/LIW/RS
258-253-38	85	5	9	3	15	2	73	4	7	3	Tuscan
258-225-1	112	6	6	3	18	4	88	6	9	6	Nelson Quarry
258-225-4A	141	6	7	4	27	3	180	7	14	3	GF/LIW/RS
258-225-4C	140	6	7	4	22	3	180	7	13	3	GF/LIW/RS
258-225-4B	142	6	7	4	28	3	187	7	9	3	GF/LIW/RS
46-4	85	5	9	3	16	2	71	4	7	3	Tuscan
46-131	87	5	8	3	17	2	61	4	5	3	Tuscan
46-251	149	6	7	4	29	3	190	7	8	3	GF/LIW/RS
46-252	134	6	7	4	28	3	188	7	15	3	GF/LIW/RS

S.D. = Standard Deviation Value at 1 sigma level

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B. Hamusek

SPECIMEN NUMBER	Rb ppm	S.D	Sr ppm	S.D	Y ppm	S.D	Zr ppm	S.D	Nb ppm	S.D.	OBSIDIAN SOURCE
46-577	87	5	8	3	21	2	55	4	2	3	Tuscan
258-111-9	135	6	7	4	28	3	204	7	10	3	GF/LIW/RS
72-239	135	6	7	4	28	3	188	7	11	3	GF/LIW/RS
72-350	89	5	8	3	16	2	65	4	8	3	Tuscan
23-535	142	6	7	4	27	3	175	7	13	3	GF/LIW/RS
23-5471	133	6	7	4	28	3	185	7	14	3	GF/LIW/RS
23-1977	136	6	7	4	28	3	180	7	9	3	GF/LIW/RS
23-712	94	5	8	3	15	2	70	4	8	3	Tuscan
23-518	146	6	7	4	26	3	183	7	10	3	GF/LIW/RS
258-225-7	142	6	7	4	27	3	183	7	9	3	GF/LIW/RS
258-41-1	143	6	7	4	26	3	189	7	13	3	GF/LIW/RS
258-41-36	84	5	9	3	17	2	66	4	9	3	Tuscan
258-41-73	137	6	7	4	28	3	192	7	10	3	GF/LIW/RS
258-201-14	93	5	9	3	19	2	65	4	9	3	Tuscan
258-201-15	92	5	10	3	14	2	62	4	8	3	Tuscan
258-111-14F	94	5	10	3	18	2	71	4	9	3	Tuscan
258-111-14I	86	5	8	3	16	2	69	4	8	3	Tuscan
258-111-15H	134	6	7	4	28	3	183	7	14	3	GF/LIW/RS

S.D. = Standard Deviation Value at 1 sigma level

September 10, 1992
B. Hamusek

SPECIMEN NUMBER	Rb ppm	S.D	Sr ppm	S.D	Y ppm	S.D	Zr ppm	S.D	Nb ppm	S.D.	OBSIDIAN SOURCE
258-111-14H	138	6	7	4	26	3	182	7	13	3	GF/LIW/RS
258-111-15F	135	6	7	4	26	3	186	7	9	3	GF/LIW/RS
258-111-14J	142	6	7	4	28	3	180	7	10	3	GF/LIW/RS
258-111-14K	84	5	8	3	15	2	60	4	6	3	Tuscan
258-111-15G	138	6	7	4	27	3	185	7	10	3	GF/LIW/RS
258-111-15E	93	5	8	3	17	2	73	4	15	3	Tuscan
258-111-14E	142	6	7	4	27	3	177	7	12	3	GF/LIW/RS
258-111-15C	138	6	7	4	31	3	183	7	13	3	GF/LIW/RS
258-111-15I	138	6	7	4	29	3	182	7	11	3	GF/LIW/RS
258-111-15D	145	6	7	4	27	3	190	7	7	3	GF/LIW/RS
258-111-14G	132	6	7	4	28	3	179	7	15	3	GF/LIW/RS
258-147-1	85	5	9	3	13	2	65	4	9	3	Tuscan
258-147-4	83	5	9	3	14	2	73	4	7	3	Tuscan
258-46-2	86	5	9	3	17	2	64	4	6	3	Tuscan
258-46-4	86	5	9	3	19	2	75	4	8	3	Tuscan
258-46-7	104	6	7	5	18	1	91	3	10	2	Lodgepole
258-280-1	89	5	9	3	14	2	75	4	9	3	Tuscan
258-280-2	81	5	9	3	15	2	66	4	8	3	Tuscan

S.D. = Standard Deviation Value at 1 sigma level

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B. Hamusek

SPECIMEN NUMBER	Rb ppm	S.D	Sr ppm	S.D	Y ppm	S.D	Zr ppm	S.D	Nb ppm	S.D.	OBSIDIAN SOURCE
258-138-4	82	5	9	3	16	2	82	4	7	3	Tuscan
258-138-5	132	6	7	4	27	3	184	7	9	3	GF/LIW/RS
258-199-1	138	6	7	4	26	3	187	7	10	3	GF/LIW/RS
258-317-1	83	5	9	3	15	2	67	4	11	3	Tuscan
258-317-2A	86	5	9	3	19	2	72	4	8	3	Tuscan
258-317-2B	93	5	8	3	17	2	67	4	8	3	Tuscan
258-317-2C	91	5	8	3	16	2	59	4	9	3	Tuscan
258-317-2D	91	5	8	3	15	2	77	4	13	3	Tuscan
258-317-2E	96	5	9	3	11	2	73	4	10	3	Tuscan
258-317-2F	95	5	10	3	18	2	67	4	11	3	Tuscan
258-317-2G	89	5	8	3	14	2	61	4	5	3	Tuscan
258-317-2H	93	5	9	3	19	2	69	4	0	3	Tuscan
258-253-10	140	6	7	4	28	3	185	7	14	3	GF/LIW/RS
258-253-13	126	6	6	4	24	3	173	7	10	3	GF/LIW/RS
258-253-14	133	6	7	4	27	3	184	7	6	3	GF/LIW/RS
258-253-15	135	6	7	4	25	3	183	7	10	3	GF/LIW/RS
258-253-21	143	6	7	4	27	3	188	7	12	3	GF/LIW/RS
258-253-39	140	6	7	4	26	3	202	7	8	3	GF/LIW/RS

S.D. = Standard Deviation Value at 1 sigma level

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B. Hamusek

SPECIMEN NUMBER	Rb ppm	S.D	Sr ppm	S.D	Y ppm	S.D	Zr ppm	S.D	Nb ppm	S.D.	OBSIDIAN SOURCE
258-253-40	116	6	6	3	18	4	97	6	18	6	Nelson Quarry
258-138-2	84	5	9	3	19	2	64	4	3	3	Tuscan
258-138-3	86	5	9	3	14	2	63	4	9	3	Tuscan
258-138-7	141	6	6	4	25	3	178	7	15	3	GF/LIW/RS
258-138-6	93	5	9	3	15	2	64	4	9	3	Tuscan
258-106	86	5	9	3	14	2	72	4	12	3	Tuscan
258-106-2	74	5	8	3	15	2	67	4	8	3	Tuscan
258-106-3A	130	6	7	4	27	3	181	7	11	3	GF/LIW/RS
258-106-3B	133	6	7	4	24	3	181	7	16	3	GF/LIW/RS
258-106-3C	129	6	7	4	29	3	175	7	8	3	GF/LIW/RS
258-106-3D	136	6	7	4	28	3	180	7	14	3	GF/LIW/RS
258-106-3E	138	6	7	4	25	3	183	7	13	3	GF/LIW/RS
258-106-3F	145	6	8	4	29	3	187	7	16	3	GF/LIW/RS

S.D. = Standard Deviation Value at 1 sigma level

November 30, 1992
B. Hamusek

SPECIMEN NUMBER	Zn ppm	Ga ppm	Pb ppm	Th ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	OBSIDIAN SOURCE
258-111-1	51.7	14.3	20.6	n.d.	85.4	94.2	17.3	71.1	4.8	TUSCAN
S.D. +/-	5	2.5	5.1		2.7	4.0	2.6	6.9	6.6	
258-111-11	57.3	15.8	20.9	17.1	94.6	99.1	15.2	67.6	0.7	TUSCAN
S.D. +/-	4.7	2.4	5.0	7.4	2.4	3.9	2.5	6.8	6.4	
258-111-14L	42.1	11.5	26.7	21.6	131.7	70.5	27.2	184.0	7.4	GF/LIW/RS
S.D. +/-	4.6	2.3	5.0	7.1	2.5	3.8	2.3	6.8	6.5	
258-111-14M	45.5	14.9	19.3	15.1	90.8	85.3	17.1	72.2	8.9	TUSCAN
S.D. +/-	4.5	2.3	4.9	7.3	2.3	3.8	2.3	6.7	6.4	
258-111-14N	45.8	15.6	19.3	12.5	85.6	94.3	17.2	66.3	3.5	TUSCAN
S.D.+/-	4.5	2.2	4.9	7.7	2.3	3.8	2.2	6.7	6.4	
258-111-14P	51.2	14.0	17.6	7.7	85.5	93.5	17.4	66.6	5.5	TUSCAN
S.D. +/-	4.6	2.3	5.0	7.4	2.3	3.8	2.3	6.8	6.5	
258-111-14Q	54.7	14.5	16.7	12.4	83.5	94.5	17.3	73.9	6.7	TUSCAN
S.D.+/-	4.7	2.3	5.0	8.3	2.4	3.8	2.4	6.8	6.5	

S.D. = Standard Deviation Value at 1 sigma level

November 30, 1992
B. Hamusek

SPECIMEN NUMBER	Zn ppm	Ga ppm	Pb ppm	Th ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	OBSIDIAN SOURCE
258-111-14R	56.2	17.7	20.7	14.0	91.8	83.6	14.4	65.3	8.1	TUSCAN
S.D.+/-	4.	2.4	5.0	7.8	2.4	3.8	2.4	6.8	6.5	
258-111-15K	35.3	12.4	24.8	22.1	138.0	73.7	27.3	187.6	10.6	GF/LIW/RS
S.D.+/-	4.5	2.2	5.0	6.9	2.4	3.8	2.2	6.8	6.4	
258-111-15L	53.0	13.5	19.0	16.5	86.4	94.3	19.8	72.6	4.6	TUSCAN
S.D.+/-	4.5	2.2	4.9	7.1	2.3	3.8	2.2	6.7	6.4	
258-111-15M	55.9	15.1	18.7	n.d.	91.9	98.9	18.2	73.2	6.1	TUSCAN
S.D.+/-	4.6	2.3	5.0		2.3	3.8	2.3	6.8	6.5	
258-111-15N	44.5	14.0	29.8	23.8	145.5	77.7	30.0	185.1	8.9	GF/LIW/RS
S.D.+/-	4.7	2.4	5.0	7.1	2.6	3.8	2.4	6.8	6.5	
258-147-2	44.1	15.7	27.7	18.8	133.4	71.0	29.2	179.3	5.8	GF/LIW/RS
S.D.+/-	4.6	2.3	5.0	7.2	2.5	3.8	2.3	6.8	6.5	
258-147-3	56.7	13.4	30.0	23.1	130.2	73.8	24.4	178.3	9.6	GF/LIW/RS
S.D.+/-	5.6	3.0	5.3	7.6	2.8	3.9	2.6	7.0	6.6	

S.D. = Standard Deviation Value at 1 sigma level

November 30, 1992
B. Hamusek

SPECIMEN NUMBER	Zn ppm	Ga ppm	Pb ppm	Th ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	OBSIDIAN SOURCE
258-255-5C	75.9	13.7	30.0	19.4	141.3	72.7	28.4	183.9	13.5	GF/LIW/RS
S.D.+/-	5.5	3.0	5.4	8.2	2.9	4.0	2.8	7.0	6.7	
258-255-6A	65.0	15.0	34.8	26.4	137.0	72.7	25.2	169.5	11.8	UNKNOWN
S.D.+/-	5.2	2.8	5.2	7.6	2.8	4.0	2.7	7.0	6.6	
258-255-7A	54.6	11.4	27.9	19.6	147.4	78.4	25.1	189.0	6.4	GF/LIW/RS
S.D.+/-	4.7	2.4	5.1	7.4	2.6	3.8	2.4	6.9	6.5	
258-253-1	32.8	12.1	30.6	23.1	147.1	77.4	28.9	196.7	11.0	GF/LIW/RS
S.D.+/-	4.6	2.4	5.0	7.1	2.5	3.8	2.4	6.8	6.5	
258-253-2A	29.7	11.2	27.3	17.8	143.4	75.3	27.4	189.8	6.3	GF/LIW/RS
S.D.+/-	4.5	2.3	5.0	7.2	2.4	3.8	2.3	6.8	6.4	
258-253-2B	61.0	16.2	26.4	16.5	148.7	75.7	26.8	193.2	15.7	GF/LIW/RS
S.D.+/-	4.9	2.5	5.1	7.9	2.7	3.9	2.5	6.9	6.5	
258-253-11	43.0	14.9	24.7	17.9	134.8	72.7	27.9	178.3	10.7	GF/LIW/RS
S.D.+/-	4.7	2.4	5.0	7.4	2.5	3.8	2.4	6.8	6.5	

S.D. = Standard Deviation Value at 1 sigma level

November 30, 1992
B. Hamusek

SPECIMEN NUMBER	Zn ppm	Ga ppm	Pb ppm	Th ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	OBSIDIAN SOURCE
258-253-16D	61.9	13.9	25.5	18.2	147.6	74.4	31.4	190.2	10.4	GF/LIW/RS
S.D.+/-	4.8	2.4	5.1	7.6	2.6	3.9	2.5	6.9	6.5	
258-253-16E	58.4	16.9	32.0	15.2	154.3	80.4	28.7	188.3	6.7	GF/LIW/RS
S.D.+/-	4.8	2.5	5.1	8.1	2.7	3.9	2.5	6.9	6.5	
258-253-18	44.2	12.4	23.8	19.7	140.1	74.3	25.6	184.8	9.8	GF/LIW/RS
S.D.+/-	4.5	2.2	5.0	7.0	2.4	3.8	2.3	6.8	6.4	
258-253-24A	70.3	16.5	35.5	26.0	167.2	89.7	24.5	204.3	9.9	YELLOWJACKET
S.D.+/-	5.0	2.7	5.2	7.5	2.9	4.0	2.7	7.0	6.6	
258-253-24B	51.9	11.0	27.7	21.2	138.3	74.6	26.2	183.3	10.9	GF/LIW/RS
S.D.+/-	4.8	2.4	5.0	7.3	2.6	3.9	2.5	6.9	6.5	
258-253-24C	54.7	14.1	29.5	29.5	139.7	73.3	32.2	185.1	11.4	GF/LIW/RS
S.D.+/-	4.9	2.5	5.1	7.4	2.7	3.9	2.5	6.9	6.6	
258-253-25A	40.3	19.1	28.8	24.8	157.6	79.2	29.0	199.5	11.8	GF/LIW/RS
S.D.+/-	4.6	2.3	5.0	7.0	2.5	3.8	2.3	6.8	6.5	

S.D. = Standard Deviation Value at 1 sigma level

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B. Hamusek

SPECIMEN NUMBER	Zn ppm	Ga ppm	Pb ppm	Th ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	OBSIDIAN SOURCE
258-253-32A	41.5	13.2	34.9	22.5	150.1	74.6	29.7	187.7	9.9	GF/LIW/RS
S.D.+/-	4.7	2.4	5.0	7.2	2.6	3.8	2.4	6.8	6.5	
258-253-33A	50.7	12.6	31.5	22.4	149.2	78.5	29.7	187.6	9.3	GF/LIW/RS
S.D.+/-	4.7	2.4	5.	7.3	2.6	3.9	2.4	6.9	6.5	
258-253-33B	58.5	15.6	30.5	23.0	146.5	69.9	28.2	187.2	6.7	GF/LIW/RS
S.D.+/-	4.8	2.5	5.0	7.4	2.7	3.9	2.5	6.9	6.5	
258-253-41	35.0	17.3	22.8	12.5	113.5	73.0	19.7	99.3	11.7	BUCK MOUNTAIN
S.D.+/-	4.5	2.3	4.9	7.9	2.4	3.8	2.3	6.7	6.5	
258-106-3K	46.4	13.8	19.2	12.9	86.6	97.6	17.0	63.9	3.6	TUSCAN
S.D.+/-	4.7	2.4	5.0	8.0	2.3	+ 3.8	2.3	6.8	6.4	
258-106-3L	60.3	14.6	24.8	13.9	88.3	81.8	15.8	69.7	5.1	TUSCAN
S.D.+/-	4.9	2.5	5.1	8.3	2.5	3.9	2.5	6.8	6.5	
258-106-3M	46.8	11.5	20.3	12.6	89.6	95.6	18.2	79.3	5.8	TUSCAN
S.D.+/-	4.5	2.2	4.9	7.7	2.3	3.8	2.2	6.7	6.4	

S.D. = Standard Deviation Value at 1 sigma level

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B. Hamusek

SPECIMEN NUMBER	Zn ppm	Ga ppm	Pb ppm	Th ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	OBSIDIAN SOURCE
258-106-3N	44.3	12.4	25.6	16.7	144.0	76.9	27.1	183.4	8.0	GF/LIW/RS
S.D.+/-	4.6	2.3	5.0	7.4	2.5	3.8	2.4	6.8	6.5	
258-106-3P	59.4	11.1	19.0	11.4	83.4	93.3	18.0	68.4	6.0	TUSCAN
S.D.+/-	4.6	2.3	5.0	8.7	2.4	3.8	2.3	6.8	6.5	
258-106-3Q	45.8	13.9	19.8	16.7	92.8	90.0	16.8	75.1	4.1	TUSCAN
S.D.+/-	4.6	2.	5.0	7.2	2.3	3.8	2.3	6.8	6.5	
258-106-3R	50.4	14.8	23.5	20.4	87.5	83.9	15.0	67.4	11.1	TUSCAN
S.D.+/-	4.7	2.3	5.0	7.2	2.4	3.8	2.4	6.8	6.5	
258-106-3S	56.6	16.5	20.8	14.6	86.0	98.3	14.6	67.3	5.9	TUSCAN
S.D.+/-	4.7	2.4	5.0	7.8	2.5	3.9	2.5	6.8	6.5	
258-106-3T	56.3	13.8	27.0	23.6	147.9	69.9	25.5	181.6	10.9	GF/LIW/RS
S.D.+/-	4.9	2.6	5.1	7.4	2.8	3.8	2.6	6.9	6.6	
258-106-5H	42.6	15.7	17.5	14.6	87.3	78.5	15.7	65.4	7.2	TUSCAN
S.D.+/-	4.5	2.2	4.9	7.3	2.3	3.8	2.3	6.7	6.4	

S.D. = Standard Deviation Value at 1 sigma level

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B. Hamusek

SPECIMEN NUMBER	Zn ppm	Ga ppm	Pb ppm	Th ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	OBSIDIAN SOURCE
258-106-5I	44.6	18.5	33.7	28.4	155.6	80.2	27.9	200.8	9.0	GF/LIW/RS
S.D.+/-	4.7	2.4	5.0	7.0	2.5	3.8	2.4	6.8	6.5	
258-106-5J	64.1	19.9	21.7	10.3	98.7	85.0	15.1	84.6	3.3	UNKNOWN-TUSCAN?
S.D.+/-	5.0	2.5	5.0	11.4	2.5	3.9	2.6	6.9	6.5	
258-106-7A	56.4	13.3	25.7	16.7	138.7	75.9	26.0	179.4	11.2	GF/LIW/RS
S.D.+/-	4.8	2.4	5.1	7.7	2.6	3.9	2.5	6.9	6.5	
258-106-7B	65.3	14.0	19.0	11.7	92.8	86.4	20.7	61.4	9.8	TUSCAN
S.D.+/-	4.8	2.4	5.0	9.0	2.4	3.9	2.4	6.8	6.5	
258-106-7C	49.9	15.4	29.8	16.9	129.9	70.2	23.7	177.5	5.3	GF/LIW/RS
S.D.+/-	5.0	2.6	5.1	8.2	2.8	3.9	2.7	7.0	6.6	
258-252-1	48.8	14.2	25.2	13.3	141.2	78.6	25.7	183.1	7.1	GF/LIW/RS
S.D.+/-	4.8	2.4	5.1	8.5	2.6	3.9	2.5	6.9	6.5	
258-252-2	30.9	13.1	24.3	21.6	144.0	76.0	29.2	183.4	11.3	GF/LIW/RS
S.D.+/-	4.5	2.3	5.0	7.0	2.4	3.8	2.3	6.8	6.5	

S.D. = Standard Deviation Value at 1 sigma level

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B. Hamusek

SPECIMEN NUMBER	Zn ppm	Ga ppm	Pb ppm	Th ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	OBSIDIAN SOURCE
258-225-4D	37.8	16.3	28.8	26.9	152.6	81.7	27.0	193.6	16.0	GF/LIW/RS
S.D.+/-	4.6	2.3	5.0	6.9	2.5	3.8	2.3	6.8	6.5	
258-225-4E	44.6	17.3	26.6	21.7	144.5	72.9	26.2	190.0	6.6	GF/LIW/RS
S.D.+/-	4.6	2.4	5.0	7.1	2.5	3.8	2.4	6.8	6.5	
258-225-4G	41.1	13.7	26.3	22.1	150.1	79.4	26.4	186.6	9.6	GF/LIW/RS
S.D.+/-	4.5	2.3	5.0	7.0	2.5	3.8	2.3	6.8	6.5	
258-225-4H	68.2	18.5	31.2	17.3	160.3	83.1	25.5	205.0	11.5	GF/LIW/RS
S.D.+/-	5.1	2.6	5.2	8.1	2.9	4.0	2.7	7.0	6.6	
258-225-4F	48.2	11.6	27.6	21.9	134.0	72.8	24.9	187.4	12.2	GF/LIW/RS
S.D.+/-	4.7	2.4	5.0	7.2	2.5	3.8	2.4	6.8	6.5	
258-201-16A	32.1	14.5	28.0	24.7	153.6	80.8	29.3	196.8	11.0	GF/LIW/RS
S.D.+/-	4.5	2.3	5.0	7.0	2.5	3.8	2.3	6.8	6.5	
258-201-16B	48.4	12.5	31.9	25.1	161.3	91.3	33.1	227.3	8.3	YELLOWJACKET
S.D.+/-	4.7	2.4	5.0	7.2	2.6	3.8	2.4	6.9	6.5	

S.D. = Standard Deviation Value at 1 sigma level

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B. Hamusek

SPECIMEN NUMBER	Zn ppm	Ga ppm	Pb ppm	Th ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	OBSIDIAN SOURCE
258-201-16C	52.9	15.0	25.3	13.2	104.4	80.4	16.8	99.8	11.7	UNKNOWN-TUSCAN?
S.D.+/-	4.8	2.5	5.0	8.4	2.5	3.9	2.5	6.8	6.5	
258-201-37A	42.7	15.5	25.7	24.9	140.2	74.6	29.3	187.1	9.5	GF/LIW/RS
S.D.+/-	4.4	2.2	4.9	6.8	2.4	3.8	2.2	6.8	6.4	
258-201-37B	43.4	15.9	30.4	22.0	151.0	77.0	26.3	189.0	11.1	GF/LIW/RS
S.D.+/-	4.6	2.3	5.0	7.1	2.5	3.8	2.3	6.8	6.5	
258-201-37C	48.2	20.2	30.3	21.8	141.0	77.8	30.9	188.4	5.8	GF/LIW/RS
S.D.+/-	4.7	2.4	5.0	7.2	2.6	3.8	2.4	6.8	6.5	

S.D. = Standard Deviation Value at 1 sigma level