Chapter 16

Classification and Distribution of Debitage at the Keatley Creek Housepit Village

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Introduction

The general aim of this study is to examine some problems involving lithic source discrimination, especially of highly siliceous, chert-like rocks. In general, the accurate and reliable identification of different lithic sources can be important in demonstrating differential access to various lithic sources on the part of different bands or subgroups within communities, in demonstrating exchange relationships between prehistoric groups or subgroups, or in helping to date specific deposits such as storage pits if the relative importance of various lithic sources changes over time. Being able to accurately distinguish different lithic sources can, therefore, be an essential part of reconstructing past social and economic organization at sites such as Keatley Creek.

The specific goal of this chapter is to identify and discriminate the types of stone used for tools prehistorically at the Keatley Creek site. The method introduced in this analysis is a new approach to the problem. Many recent studies of archaeological lithics, especially cherts (e.g., Hoard et al. 1993), begin sourcing studies with sampling of known lithic source areas, incorporating quantitative analyses of trace element compositions. Statistical techniques such as discriminant analysis, are then utilized to define multi-dimensional fields characteristic of a particular source. Archaeological specimens of site lithics are subsequently analyzed and compared to the statistically defined fields and by statistical association, and are attributed to some source with some degree of confidence.

One problem with this approach is that no criteria are developed for classifying either the source areas or the site lithics. Instead, lithics and source materials are grouped by discriminant functions, which will change with the addition of any new source region in subsequent analyses. In fact, any new data will result in the permutation of previous discriminant functions to some degree.

Cherts, chalcedonies, and the like, which have proven difficult to source or characterize using standard trace element techniques (Leudtke 1978), require definition in another dimension besides chemistry for confident grouping, classification, and sourcing. Petrographic analysis of thin sections provides that dimension.

As an alternative approach, one can begin the analysis with site lithics, determine their petrographic and geochemical characteristics, and use this information to model possible geological sources. Using this approach, classes of material are defined by distinctions that reflect petrography, geochemistry, and source; not those that depend upon statistical algorithms and sampling. With such information in hand, field sourcing surveys become more focused, and the literature and previous research of others becomes more helpful.

I stress the use of both petrographic and geochemical characteristics, because petrography can distinguish important textural variation imperceptible by chemical analysis alone. But petrography, as the interpretation of optical phenomena, is ultimately subjective, and quantitative expressions of compositional characteristics aid in providing more objective criteria frequently required to ascertain petrogenetic similarities and differences.

The geochemical approach favored in this study also deviates from standard archaeometric practice. Whereas trace element analysis has been generally employed in attempts to discriminate chert types, I advocate instead, major and minor element analysis (i.e., Si, Al, Fe, Mg, Ca, Na, K, Ti, Mn, P). The reason for my preference is rooted in geochemical theory. Some differences in elemental composition are stochastic (e.g., variation in Fe concentration due to bacterial activity). Elements which reflect stochastic processes are useless in a lithic sourcing analysis because the observed values for those variables will be random and unpredictable. Many trace elements are concentrated by biogenic activity and diagenetic (post-depositional) changes by processes which are, for all practical purposes, stochastic.

In other cases, elemental compositions inhere from mineralogy (e.g., the *ratio* of Ca to P in apatite). In this case, the calcium and phosporus have a stoichiometric relationship, i.e., one dictated by elemental ratios in the chemical formula for apatite. Most rocks are composed chiefly of just a few major rock-forming minerals, which in turn are composed primarily of major elements. The weathering of rock to a sediment, due to sedimentary processes or diagenesis, is most expressively recorded by the major element flux. Elsewhere (Bakewell 1995), I have shown that cherts from different regions can be characterized by the patterning of major elements in the accessory sediments, which reflects differences in the mineralogy of those sediments. The important difference is that stoichiometric relationships are predictable.

The statistical procedures which I advocate to describe the geochemical characteristics of materials from different sources isolate stoichiometric relationships between elements. The methods are simple, bivariate, exploratory, rather than confirmatory, and measure correlation between elements. They reveal the patterned co-occurrence of elements reflective of the presence of specific minerals or combinations of minerals. Multivariate alternatives to this bivariate approach are normally weakened by correlated variables (see Tabachnick and Fidell 1989:92 for one discussion), but stoichiometric parameters in minerals ensure that high correlations will be present and meaningful in most geochemical data.

Multivariate analyses also require normal data distributions. But, because sedimentary regimes interface with highly stochastic processes (e.g., weather and biosphere), sedimentary rocks such as chert usually exhibit marked heterogeneity, characteristically skewed to low elemental concentrations, but punctuated with higher values, more typical of a Poisson distribution. As clastic components in a sediment vary, e.g., by locally induced contamination or dilution, then elemental concentrations will vary as well. The usual solution to these problems in trace element analysis is to minimize the range of values by data transforms to achieve normal distributions even though such transformations exaggerate expressions of central tendency. When pattern recognition, not quantification, is the goal, broad-ranging values are useful, underscoring relationships characteristic of a particular sedimentary source. Pattern recognition, both petrographic and geochemical, is the key to the discrimination and modeling of source types. Petrographic patterns are discernable whenever textural elements, microfossils, or mineral phases are repetitiously associated in a lithic fabric.

Table 1. Keatley Site and Source Volcanics, Major and Minor Elements (elements reported in Wt.%)

Element	CC-4	CC-7	CC-9	MC-1	MC-2	KB-1	KB-2	KB-3	KB-4
SiO_2	66.29	70.56	65.73	69.37	68.91	68.30	68. -	65.20	69.00
TiO_2	0.49	0.36	0.53	0.42	0.42	0.41	0.38	0.67	0.35
Al_2O_3	15.17	15.16	15.35	15.57	15.57	14.90	15.10	15.90	15.20
Fe_2O_3	3.86	2.64	4.02	2.63	2.63	3.45	2.73	4.08	2.67
MnO	0.03	0.05	0.06	0.04	0.04	0.07	0.06	0.06	0.06
MgO	1.09	1.08	2.01	1.10	1.10	1.79	1.20	1.96	1.14
CaO	3.21	2.42	3.54	2.88	2.87	3.55	2.88	4.06	2.91
Na_2O	3.88	4.18	3.28	4.61	4.55	3.73	4.36	4.58	4.25
K_2O	3.33	3.87	4.05	3.52	3.31	3.24	3.75	2.84	3.81
P_2O_5	0.21	0.14	0.25	0.10	0.10	0.15	0.13	0.28	0.13
LOI	1.09	0.36	0.93	0.38	0.38	0.46	0.50	0.35	0.45
Total	98.85	101.09	99.98	100.82	99.95	100.00	99.90	100.00	100.00

Notes: CC-4, 7, 9: Cache Creek cobbles; MC-1, 2: Medicine Creek pebbles; KB-1, 2, 3, 4: Keatley Creek debitage.

Table 2. Keatley Site and Source Volcanics Trace Elements (elements reported in ppm)

Element	CC-4	CC-7	CC-9	MC-1	KB-1	KB-2	KB-3	KB-4
Zr	189	197	172	158	176	203	191	197
Zn	60	54	67	61	65	63	74	67
Y	9	8	9	3	8	8	7	8
Cr	47	23	53	8	69	28	34	69
Nb	7	8	13	<1	4	8	6	6
V	80	48	91	51	67	48	82	67
Be	1.3	1.8	1.4	1.0	1.8	1.8	3.6	1.8
Ba	1,181	1,264	1,160	1,260	1,193	1,304	1,163	1,254
Ni	14	8	23	<1	23	8	15	23
Li	15	25	9	18	20	26	21	25
Sr	466	398	475	498	438	414	639	396
Cu	58	37	57	70	56	37	75	36
Sc	9	5	9	3	7	5	6	7

Notes: CC-4, 7, 9: Cache Creek cobbles; MC-1, 2: Medicine Creek pebbles; KB-1, 2, 3, 4: Keatley Creek debitage.

Table 3. Classifications for Keatley Site and Source Materials (elements recorded in Wt.%)

Sample	SiO_2	$Na_2O + K_2O$	Material Classification
Cache Creek (CC-4)	66.3	7.21	Trachydacite
Cache Creek (CC-7)	70.6	8.05	Rhyolite
Cache Creek (CC-9)	65.7	7.33	Trachydacite
Medicine Creek (MC-1)	69.4	8.13	Rhyolite
Medicine Creek (MC-2)	68.9	9.86	Trachydacite
Keatley Lithic (KB-1)	67.7	7.95	Trachydacite
Keatley Lithic (KB-2)	67.9	9.03	Trachydacite
Keatley Lithic (KB-3)	61.5	8.46	Trachydacite
Keatley Lithic (KB-4)	67.1	8.77	Trachydacite

Notes: CC-4, 7, 9: Cache Creek cobbles; MC-1, 2: Medicine Creek pebbles; KB-1, 2, 3, 4: Keatley Creek debitage.

Geochemical patterns are observed as *ratios* between constituent elements.

I will show that proceeding from site to source in the train of analysis may yield unexpected benefits, even if the source areas are not immediately located. After modeling lithic source types of debitage from the Keatley Creek housepit village, intrasite frequency distributions for these types will be plotted for three major housepit dwellings. Results of this analysis may aid in understanding the selective distribution and utilization of lithic resources in complex hunter-gatherer societies of the Canadian Plateau.

Background

The majority of the debitage studied from the Keatley Creek site comes from HP's 1, 5, and 7, located respectively near the western, southern, and eastern perimeters of the site at distances of 120–200 m from each other. Debitage at the site may be broadly divided into two categories: basaltic, and other. The basaltic component, described as "fine-grained basalts" comprises 70–90% of excavated lithic materials. The remaining "exotic cherts and chalcedonies" are of special interest, since preliminary investigations suggested a biased distribution of varieties of this material between major housepit sites in the village. The initial task was to segregate the non-basaltic component into types of stone reflecting potentially different sources. The initial sorting criteria had to be related to macroscopic traits discernible without the aid of sophisticated techniques since it would be impossible to apply detailed tests to all of the artifacts. The first step was to construct a preliminary classification from color and textural elements (e.g., grain size). Samples of these classes were then examined petrographically and geochemically. Where petrography and chemistry suggested common petrogenesis, preliminary classes were combined or split to form "types" of chert. Finally, the distribution of these refined and tested chert types was examined with regard to their occurrence in HP's 1, 5, and 7.

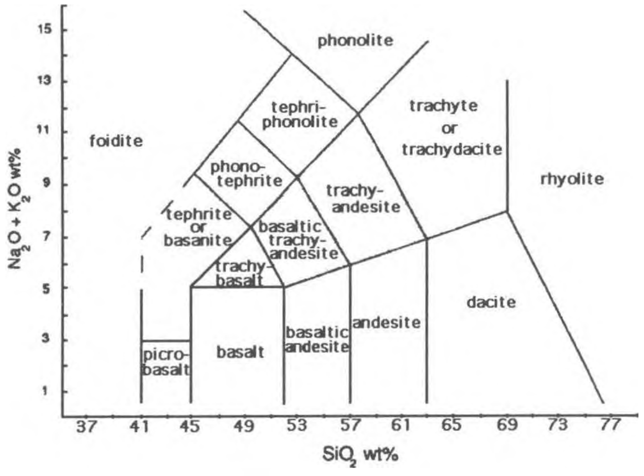


Figure 1. I.U.G.S. classification (after LeMaitre 1989).

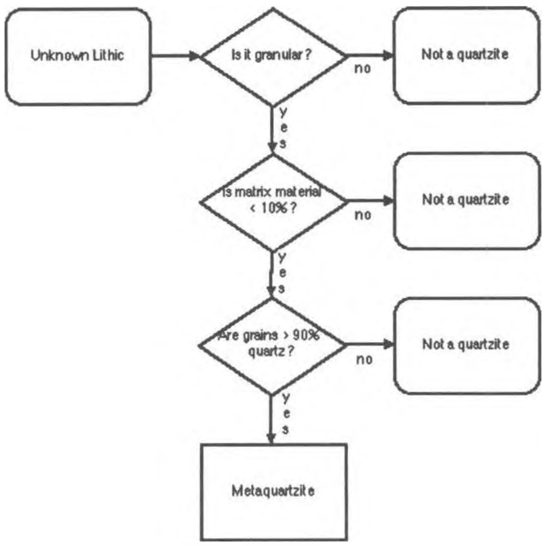


Figure 2. Quartzite type/variety criteria.

The Keatley Trachydacites

Before proceeding with an investigation of the non-basaltic debitage, the characteristics of the major, basaltic component will be briefly described. The traditional field practice of assigning fine-grained igneous rocks with a mafic (dark-gray to black) color index to the basalt category has resulted in the common description of dark, vitreous, igneous toolstone in Interior and Coastal British Columbia as basalt. However, where geochemical analyses have been performed on archaeological basalts in the Pacific Northwest (Bakewell 1991; Reid and Bakewell 1993; Bakewell and Irving 1993), no basalts have been identified. Classification of extrusive igneous rocks is based on geochemical criteria (Fig. 1), criteria which cannot be recognized in the field. The term "basaltic" is a perfectly acceptable descriptor if the definition is limited to mean "looks like basalt." However, until such time as geochemical and petrographic analyses become common practice, field classifications used to describe debitage materials in archaeological reports will remain *ad hoc* characterizations useful only in conveying a general image of the appearance of the stone.

The Keatley "basalts" are more accurately classified as trachytes, specifically trachydacites. The classification depends on total alkali vs. silica content, according to the fields illustrated in Figure 1. This really is an important distinction when questions of sourcing, intersite comparisons, or material science are considered. The archaeological sources of the Keatley trachytes are well known (Vol. I, Chap. 11). Large cobbles of the material

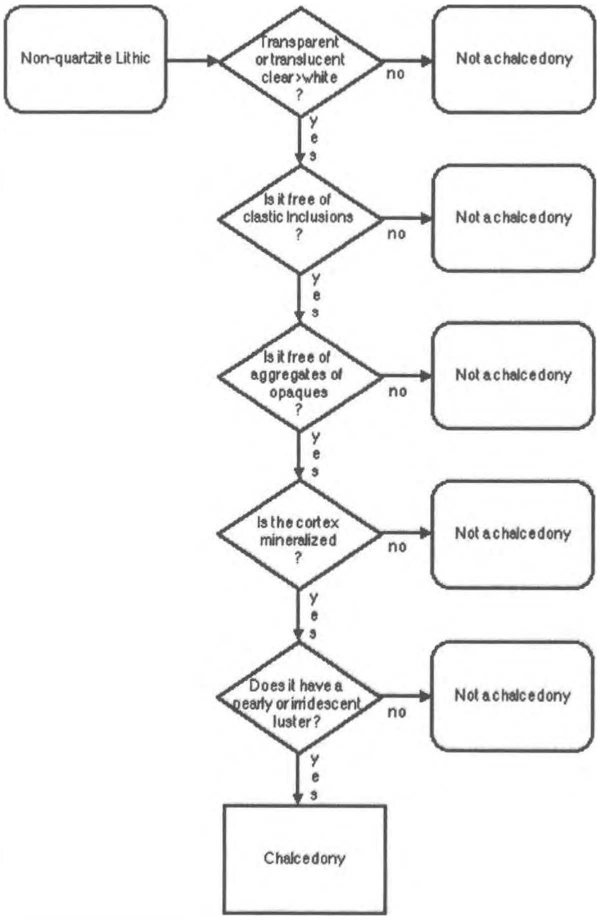


Figure 3. Chalcedony type/variety criteria.

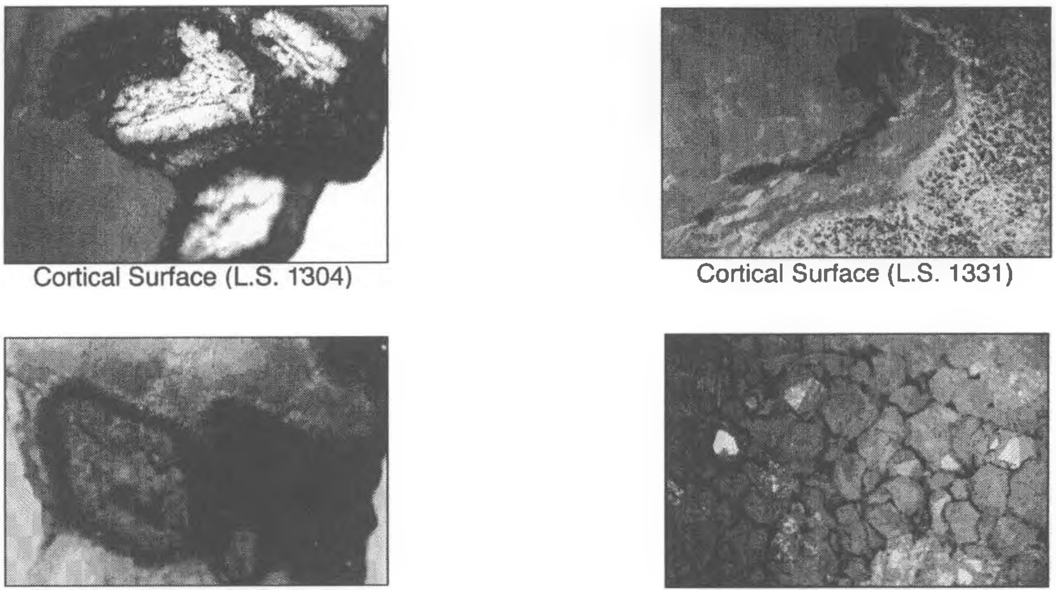
may be obtained at Cache Creek, about 35 air km from the Keatley Creek site. Smaller patinated pebbles, of the same sort of material, occur in the Medicine Creek highlands in Hat Creek Valley, about 20 air km from the site. This material is commonly referred to in the archaeological literature as "Cache Creek Basalt" and was considered to originate in geological sources of Kamloops Group or Chilcotin Group basalts (Richards 1988:14) whence it became incorporated into glacial deposits whose erosion created the concentrations of cobbles that formed prehistoric sources. In fact, the geochemistry of Cache Creek, Medicine Creek, and Keatley site lithics (Tables 1 and 2) does not remotely resemble anything in the Kamloops Group (Ewing 1981) or the Chilcotin Group (Bevier 1982). Richards' source attributions suggest that this "Cache Creek Basalt" originates in a diffuse geological source that covers an area in excess of 10,000 km^2 (Richards 1988:12, Fig. 2), when actually, the probable geological source is the nearby Trachyte Hills, a far smaller area through which Medicine Creek flows, included in the boundaries of Richards' map, but excluded as a possible source region because it does not constitute part of the Kamloops or Chilcotin Groups. I highlight Richards' study to emphasize the point that geochemical analyses are crucial in classifying fine-grained igneous rocks (e.g., Table 3). Material classification was important in Richards' study *Microwear Patterns on Experimental Basalt Tools*, with an entire chapter devoted to the "Geology and Petrography of Cache Creek Basalt," yet the materials were inaccurately described. Extensive petrographic analyses of thin sections were reported, including photomicrographs ostensibly showing olivine. While I have not had the opportunity to examine those thin sections, or sections of "basalt" reported in other studies of area toolstone (e.g., Magne 1979), thin sections of cobbles from the same sources (e.g., CC-4, 7, 9 of this report) show no olivine. In fact, it would be most unusual to find olivine in a rock with nearly 70% SiO_2. I suspect that the thin section analysis was biased by the investigator's assumption that the sample was basalt, an *a priori* conclusion induced by field characterizations. Other textural features observed in the current study, flow-banding and rounded, resorbed plagioclase crystals, were not reported by Magne or Richards. Petrographic features of lithics from the Keatley Creek assemblage match those of samples from Cache Creek and Medicine Creek sources. The materials are highly vitrophyric, with very few phenocrysts (usually total less than 5%), and are dominated by plagioclase with traces of pyroxenes and occasional quartz. In all, ten thin sections were examined from ten cobbles of dark gray-black material from Cache Creek. In addition, four thin sections were made of material from four Medicine Creek pebbles, and thin sections were made from four lithics from the Keatley Creek assemblage. Petrographic examinations of the thin sections were used to select the most optically diverse specimens from the source area materials for chemical analyses (i.e., CC-4, 7, 9 and MC-1,2). All four specimens from the archaeological assemblage were analyzed. Most geochemical analyses were completed for major and minor elements (Table 1) and trace elements (Table 2) using inductively-coupled plasma spectrometry (ICP) (Thompson and Walsh 1983).

Table 4. Keatley Creek Amygdaloidal Trachydacite Major and Minor Elements (Wt.%)

Element	Sample Number AB-1
SiO_2	67.4*
TiO_2	0.27
Al_2O_3	14.1
Fe_2O_3	3.00
MnO	0.04
MgO	1.51
CaO	2.97
Na_2O	4.69
K_2O	3.34*
P_2O_5	0.11
LOI	nd
Total	(97.43)

Table 5. Keatley Creek Amygdaloidal Trachydacite Trace Elements (ppm)

Element	Sample Number AB-1
Zr	145
Zn	62
Y	7.3
Cr	40
Nb	n.d.
V	67
Be	4.1
Ba	1130
Ni	27
Li	36
Sr	397
Cu	67
Sc	5.8
As	<3
Mo	2
Ag	<.1
Cd	<1
Sn	<10
Sb	<5
Sb	<5
Pb	<2
Bi	5



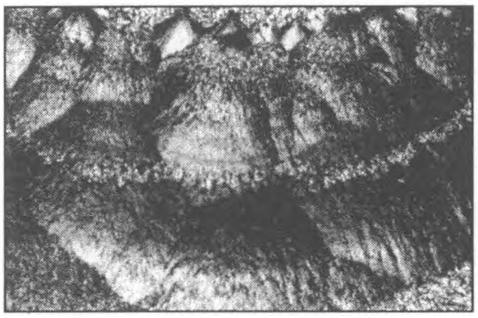
Cortical Surface (L.S. 1304)

Cortical Surface (L.S. 1331)

Cortical Surface (L.S. 1020)

Cortical Surface (L.S. 1286)

Cortical Features of Keatley Chalcedony (Width of field: 10 mm.)



Chalcedonic Texture 1B2(D) Crossed Nichols (Width of Field: 3 mm)

Figure 4. Cortical/textural features of Keatley chalcedony (width of field 10 mm).

Where major elements were determined by ICP analysis, Lithium Metaborate fusions were performed (source samples). XRF analyses generated the major element data for site lithics. Table 3 lists the International Union of Geophysical Sciences classification for the samples. Most are trachydacites, but slight differences require classification of one sample as rhyolite and another as dacite, since compositions straddle the trachyte, rhyolite and dacite fields (Fig. 1). The important point is that this material is quite distinctive. Because of the high total alkali content, if this toolstone occurs as a component in assemblages from other Plateau sites, it would be fairly easy to identify. Minor variations in alkali and silica suggest that two or more outcrops contribute cobbles to the fluvial sources. Although coarse-grained cobbles are present in the fluvial sources, selection for fine-grained, vitrophyric material is obvious in the assemblage. The trachydacites are generally easy to distinguish from the "exotic cherts and chalcedonies" although examination of the latter materials disclosed that a small quantity of amygdaloidal trachydacite was considered a variety of "exotic chert" by Gargett in a previous study (Hayden and Gargett 1989). This is easy to excuse, since the amygdules (vesicles filled with secondary minerals) are rare, and give the trachytes in which they occur a distinctively different appearance. Geochemical analysis (Tables 4 and 5) discloses the conformity of this amygdaloidal variety with previously described trachydacites. Note that characterization of fine-grained igneous rocks requires different methods than those advocated for modeling cherts in this study.

Keatley Cherts and Chalcedonies

The other major division in chipped stone debitage at the Keatley Creek site, referred to as "exotic cherts and chalcedonies" in previous studies (Hayden and Gargett 1989), while comprising the minor component, embraces a bewildering array of colors and textures. Using color and texture as discriminants, Gargett visually divided the materials in this component into more than 32 varieties. Since some of the materials which Gargett identified were recombined for curation it was not possible to systematically examine each of his proposed varieties. In addition, new materials were excavated subsequent to Gargett's study.

Classification by color and texture is very subjective and extremely susceptible to interpretive differences. For these reasons, early in this study it was decided that the best results could be obtained by a completely independent evaluation of the variability in the assemblage. Classes described by Gargett and divisions suggested by UBC geologist Ted Danner, who also examined specimens from the collection, will not be discussed in this study. More than 2,000 pieces of debitage are included in this analysis. Colors and textures are frequently gradational, and a wide array of thermal alterations and hydration effects exists in the materials, further confounding attempts to establish classes based solely upon visual criteria. The goal is to create classes of material robustly defined by petrographic and geochemical criteria, yet useful in identifying large numbers of artifacts because they are linked to combinations of color and texture observable without instruments more sophisticated than a binocular microscope. Creating such classes entailed prelim-

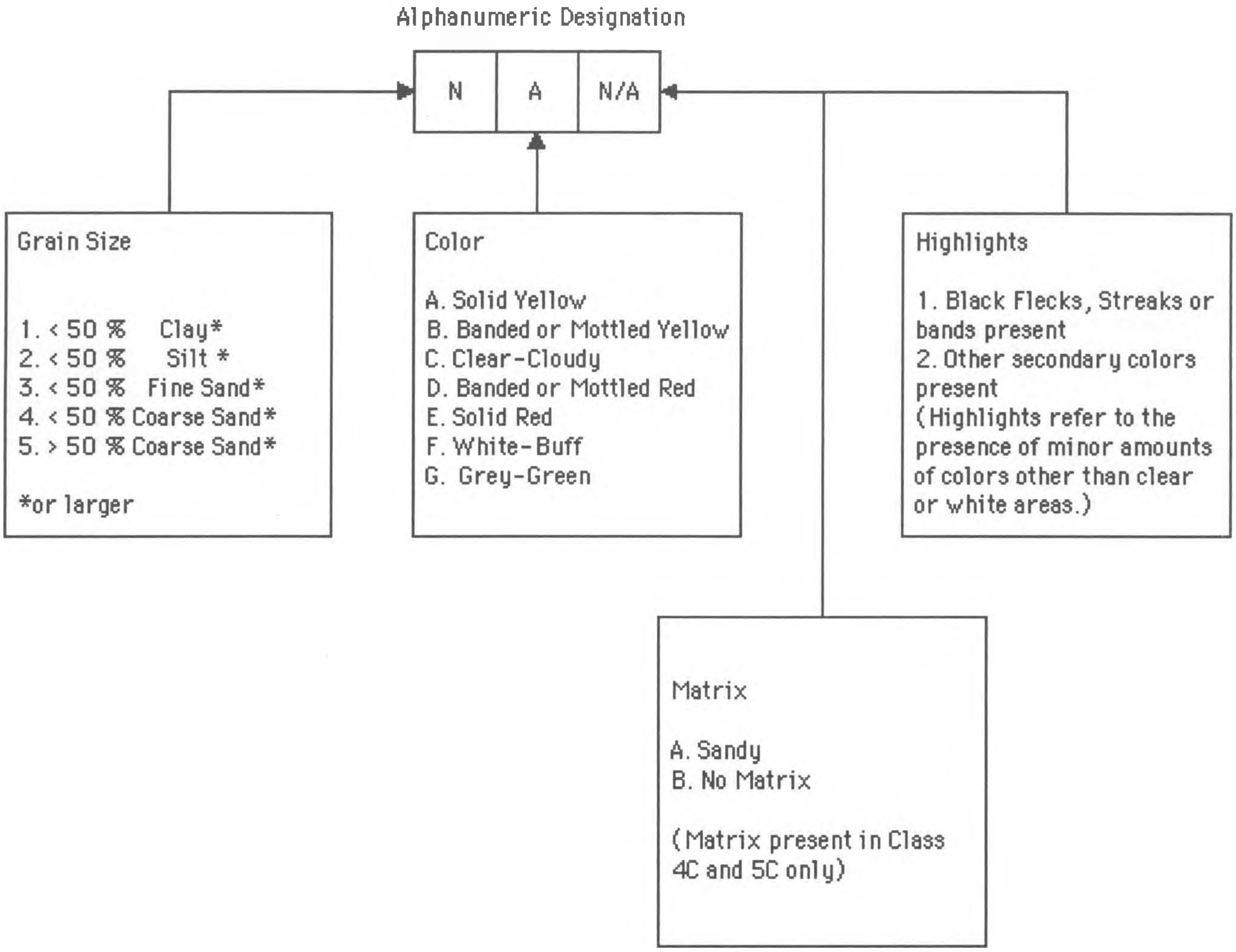
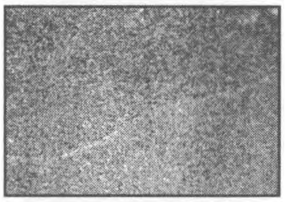


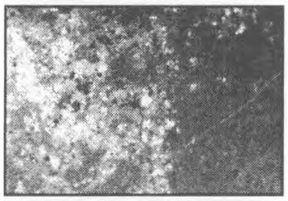
Figure 5. Keatley chert preliminary class criteria

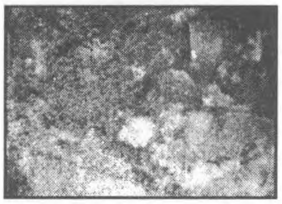
Table 6. Classification by Color and Grain Size

	Grain Size				
	1	2	3	4	5
	<50% Clay	<50% Silt	<50% Fine Sand	<50%	>50%
Color	or larger	or larger	Element	Sample Number AB-1	
	or larger	Coarse Sand	Coarse Sand		
Yellow	1A	2A	3A	4A	5A
Banded (Yellow and Black)	1B1	2B1	3B1	4B1	
Banded (Yellow and Other)	1B2				
White-Buff	1C		3C	4CA (Sandy) 4CB (Plain)	5CA (Sandy) 5CB (Plain)
Banded (Red and Black)	1D1	2D1	3D1	4D1	
Banded (Red and Other)	1D2				
Red	1E	2E	3E	4E	5E
Clear-Cloudy	1F				
Gray-Green	1G	2G	3G		


Grain Size 1
1A(B)


Grain Size 2
2E(B)


Grain Size 3
3A(B)


Grain Size 4
4A(C)

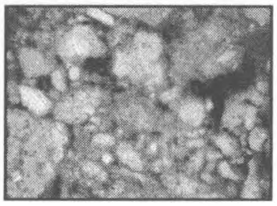
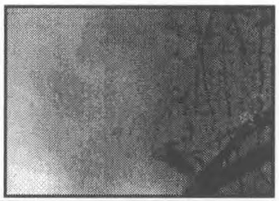
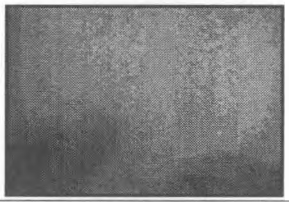
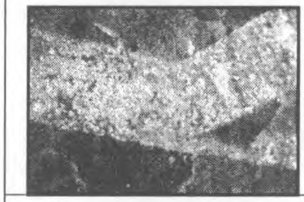
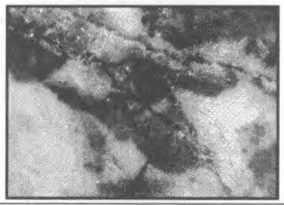

Grain Size 5
5CB(E)

Figure 6. Grain size distribution in the Keatley chert (width of field 6 mm, polished surfaces in reflected light).


Mixed Textures and
Fracture Shadowing
1B1(C) Polished surface
in reflected light.
Width of field 6 mm.


Oxide Staining
1B2(G) Polished surface
in reflected light.
Width of field 6 mm.


Fracture Filling
1D1(D) Polished surface
in reflected light.
Width of field 4 mm.


Marbling
1D2(C) Polished surface
in reflected light.
Width of field 6 mm.

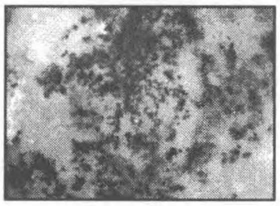

Dendritic Oxides
2B1(E) Polished surface
in reflected light.
Width of field 4 mm.

Figure 7. Banding and highlighting in the Keatley chert.

inary definition by color and texture, subsequent sampling of preliminary groups for petrographic and geochemical characteristics, association of observed petrographic and geochemical attributes with corresponding suites of color and texture, and finally, a redefinition of types in terms of aggregates of color and texture associated with petrographic and geochemical criteria.

Sorting the Stone

In this section, the methods, criteria and problems associated with preliminary definition by color and texture are discussed. Visual criteria such as these are the least reliable discriminants in most cases, but for some classes of material, color and texture may be sufficiently diagnostic. The attribute combinations used to construct the preliminary classes are strictly defined, since the final types depend upon visual criteria for identification.

The first division extracts quartzites from the assemblage. The criteria used to define quartzites may be organized and illustrated by means of a decision tree (Fig. 2). The first requirement to be satisfied is the presence of a granular texture, an observation which can generally be confirmed by tactile as well as visual means. This criterion excludes all microcrystalline and cryptocrystalline materials. The second condition assumes the presence of less than 10% matrix material (clay, silt, etc.). This requirement excludes wacke sandstones from the type. The third condition assures that the grains are greater than 90% quartz, excluding other arkoses and arenites from the type. Quartz grains are typically clear and unweathered, the color in quartzites resulting largely from characteristics of the cement joining the grains and minor interstitial components. The final criterion, flattened or recrystallized grains, is not applied in this analysis since the distinction it makes is irrelevant to the primary research objective (differentiation of chert types). In addition, recrystallization is difficult to recognize without thin section analysis. It is, however, included to illustrate an important point. The term "quartzite" represents another of those field generalizations which can encompass two very different rocks, metamorphic varieties (metaquartzites) and sedimentary varieties (quartzarenites or orthoquartzites). Both varieties of material exist in the Keatley assemblage. No attempt will be made to isolate or analyze the distributional characteristics of these varieties and all quartzites will be considered as one type.

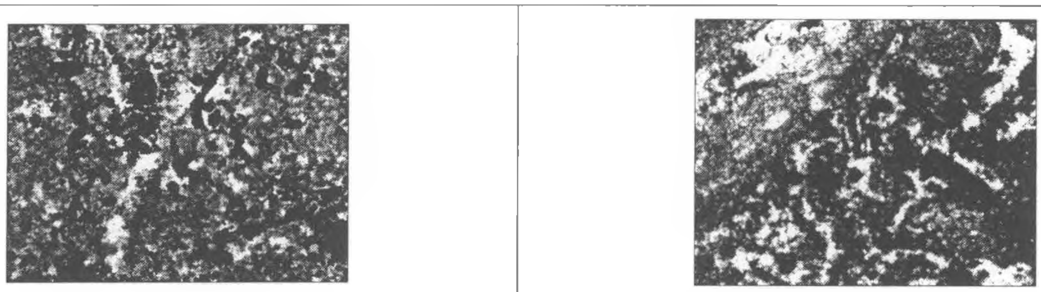
Table 7. Occurrences of Relict Carbonate Textures in Reddish and Yellowish Varieties of the Keatley Chert

		Relict Carbonate Textural Features					
Class	**n**	**Algal**	**Pelloidal**	**Fossil**	**Dolomitic**	**Dissolved**	**Other**
1A	6	2	3	2	1		
1E	3	3	2	2			
2A	4	2		2	1		
2E	5	1	2	3			
3A	9	2	6				3
3E	4	1	1	2	1		1
4A	2	2	2				
4E	3	3		1			
1B1	3	2	1	1			1
1D1	3	1	1	3			
1B2	7	1		1			5
1D2	4	1	3	1	1		
2B1	3	2	2	1		1	
2D1	2	1	1	1		1	
3B1	4	1	1	3			
3D1	1	1	1				
4B1	1			1			
4D1	4	2	2	3		3	
Total	68	28	28	27	4	5	10

Other: 3A: Samples E and H are argillites; Sample I is an altered tuff 3E:
Sample B is a volcanoclastic chert 1B1:
Sample B is an altered tuff 1B2:
Samples A, B, F, G are altered tuff; Sample D is a chalcedony

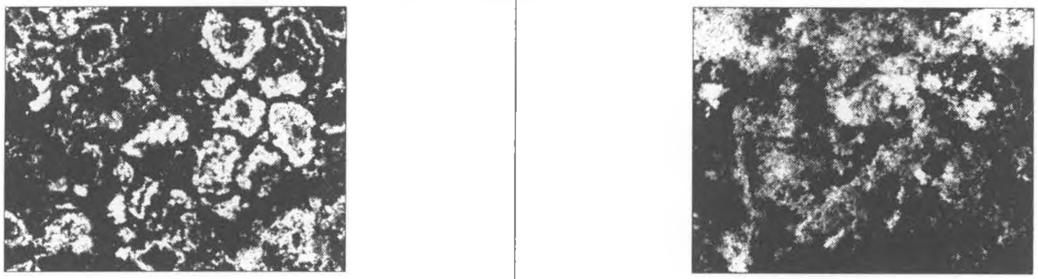
The second division isolates a chalcedony type from remaining debitage. The decision tree in Figure 3 illustrates the application of criteria to debitage after quartzite identification. First, transparent or translucent, clear to white debitage is selected for inspection. No chalcedonies of other colors exist in the Keatley assemblage in any significant quantity. Unusual and rare specimens of materials are excluded from this analysis. The second and third criteria, absence of clastic and globular inclusions (globules are crystalline aggregates of opaques which appear as dark, rounded specks or spots), separate chalcedony from cryptocrystalline materials of similar appearance. The fourth criterion refers to characteristics of the cortical surface, where such a surface is present. The chalcedonic material appears to have formed in a manner which resulted in heavily mineralized cortical surfaces (Fig. 4). Mineralization of these cortical surfaces may be very fine-grained (e.g., Fig. 4, L.S.1331, right side of image), and in such cases is of a brownish hue. Other crystals are pinkish (Fig. 4, L.S. 1020), white (Fig. 4, L.S. 1304) or clear (Fig. 4, L.S. 1286). The fifth criterion refers to a characteristic luster or sheen present in the material. Finally, although the attribute is not widely represented in Keatley chalcedonies, some laminar varieties (flowstone) are present. Distributional summaries treat both nodular and laminar varieties as one type.

Only about 13% of the "chert" debitage could be relegated to quartzite or chalcedony types by application of these criteria. Sorting the remaining 87% presented one of the most difficult and challenging aspects of the study. No natural characteristics existed which allowed for clear distinction of material types in the remainder of the sample, because the attributes (e.g., color and grain size) were continuously variable and seemed randomly associated. The remaining debitage was therefore sorted by color and textural character-



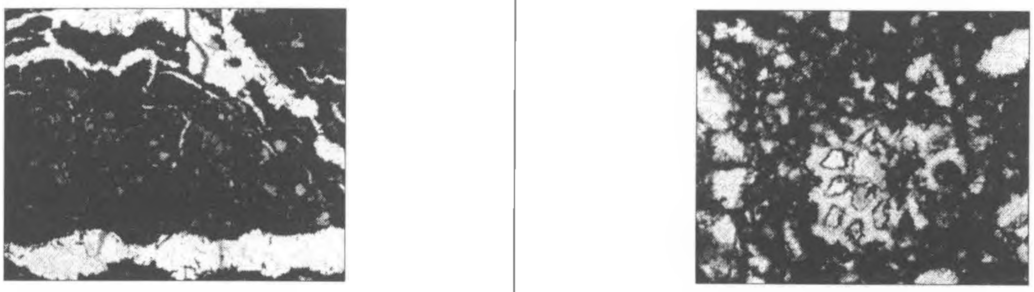
3A(A) Pelloidal texture, dense organics. Width of field 3 mm.

2E(A) Vuggy pelloidal texture. Width of field 3 mm



4A(A) Algal texture. Width of field 3 mm.

3B1(B) Fossiliferous (Bryazoan) Width of field 3 mm.



2E(C) Fossiliferous, Dolomitic Width of field 3 mm.

3B1(B) Fossiliferous (Bryazoan) Width of field 3 mm.

Figure 8. Relic carbonate texture in the Keatley jasperoid.

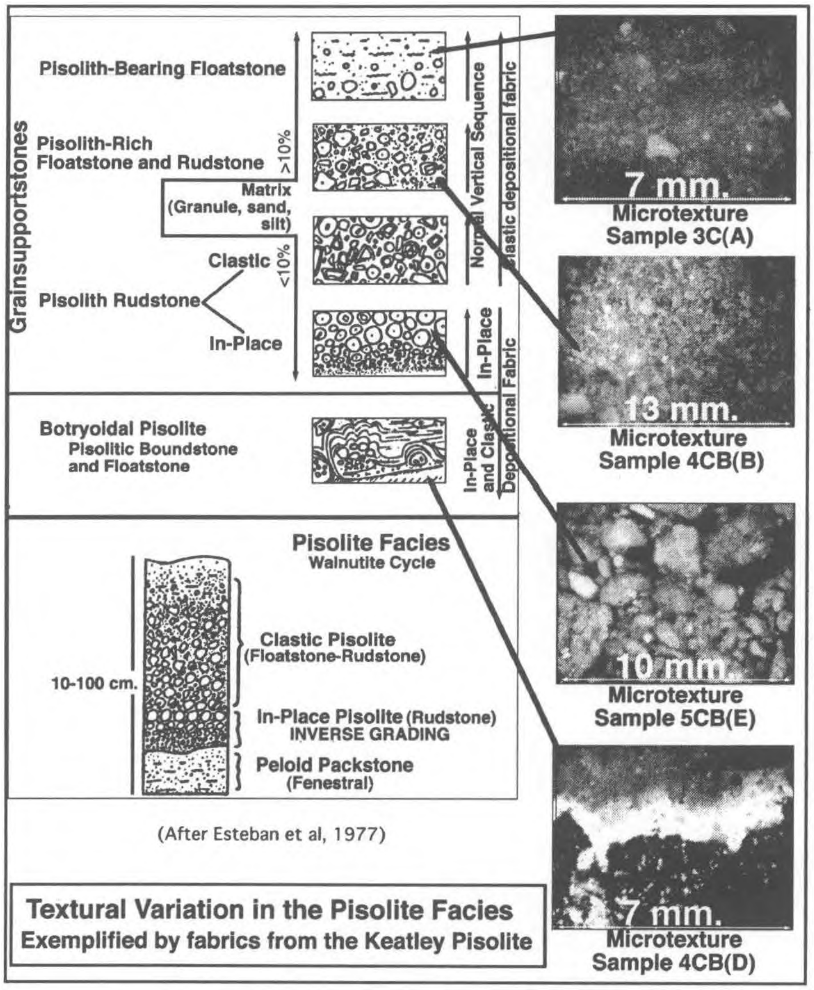
Table 8. Petrographic Features of Keatley Pisolite Facies (c.f. Figure 12)

Sample	Pisolitic Floatstone	Floatstone Rudstone	Rudstone	Botryoidal	Opalized	Hydrated
3C(A)	x				x	
3C(B)				x	x	
4CA(A)		x			x	x
4CA(B)		x			x	
4CA(C)		x			x	
4CA(D)		x			x	
4CA(F)			x		x	
4CB(A)		x			x	
4CB(B)		x			x	
4CB(C)	x					
4CB(D)	x					
5CA(A)			x		x	
5CA(B)	x					x
5CA(C)				x	x	
5CB(A)		x			x	
5CB(C)	x					
5CB(E)			x		x	
5CB(F)			x			
5CB(G)			x			
5CB(H)		x			x	
5CB(I)	x					
5E(A)			x			
5E(B)		x				
5E(C)				x	x	
5E(D)			x			
5E(E)			x			
5E(F)		x				x
5E(G)	x					
Totals (28)	7	10	8	3	15	3

Table 9. Petrographic Varieties in the Gray Chert

Sample	Argillite	Schist	Altered Tuff	Jasperoid	Chert	Marl
1G(A)				x		
1G(B)				x		
1G(C)			x			
1G(D)						x
1G(E)			x			
2G(A)				x		
2G(B)				x		
2G(C)					x	
2G(D)			x			
2G(E)			x			
2G(F)		x				
2G(G)			x			
3G(A)	x					
3G(B)	x					
3G(C)			x			
Totals (15)	2	1	6	4	1	1

istics into a number of groups corresponding to arbitrary distinctions depicted in Figure 5. The classes received alphanumeric designations. The first discriminant is grain size. Grain size refers to the dominant particle size, where 1 = dominantly cryptocrystalline (less than 50% clay-sized or larger particles), 2 = microcrystalline (greater than or equal to 50% clay-sized, 3 = silty, 4 = fine sand, and 5 = coarse sand (Fig. 6). The second discriminant is color and patterning. Patterning is described as solid or banded/mottled. Banding and mottling was found to arise from a variety of causes (Fig. 7) resulting in mixed textures where grain size varieties are abruptly conjoined by tectonic or diagenetic processes or secondary mineralization. Highlighting, a third discriminant, usually resulted from oxide staining and secondary mineralization. The net result of the application of the visual criteria described in Figure 5 was the segregation of a number of varieties (Table 6). Residual debitage which could not be described by the criteria outlined in Figure 5 (there were very few pieces) were considered "exotics" and will be described at a later time. Careful inspection of Table 6 will show that some patterning exists. Solid reddish and yellowish materials all exhibit gradation in grain-size and are paralleled by reddish and yellowish banded or mottled varieties. Gray-Green materials do not have banded or mottled counterparts. Clear-Cloudy and White-Buff color varieties do not exhibit an unbroken gradational grain-size change, but occur in sandy textures only after a gap at grain-size 2. This patterning is symptomatic of similarities and differences observable at the level of thin section or geochemical analysis.



(After Esteban et al, 1977)

Figure 9. Pisolitic textures in the Keatley chert.

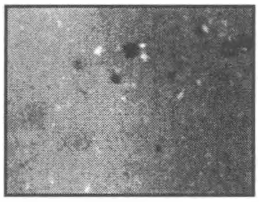
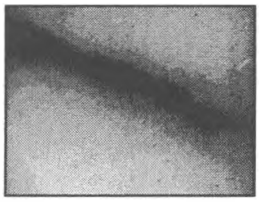
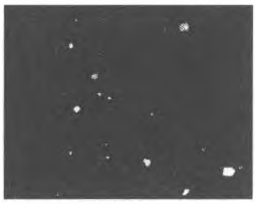
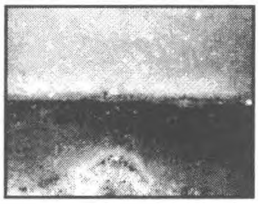
 **1F(A) Aggregates of opaques in the Keatley Tuff** **(Width of field 3 mm)**	 **1C(B) Collapse structure in the Keatley Tuff** **(Width of field 3 mm)**
 **1F(B) Clastic inclusions in the Keatley Tuff** **(Enhanced Contrast) (Width of Field 3 mm)**	 **1F(C) Layering in the Keatley Tuff** **(Width of Field 7 mm)**

Figure 10. Petrographic characteristics of the Keatley tuff.

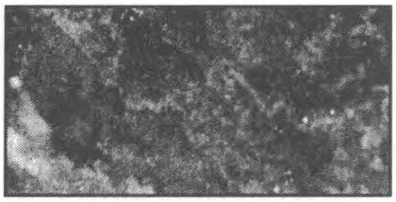
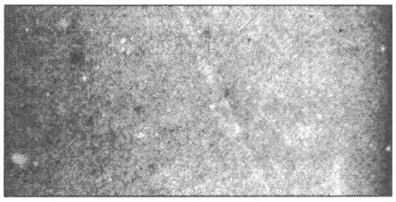
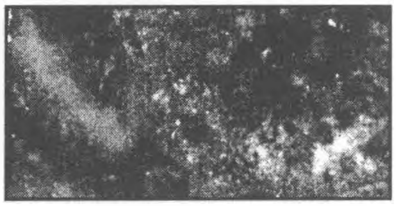
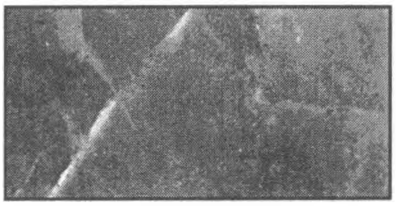
 2G(A) Jasperoid Reflected Light (Width of Field 7 mm)	 2G(F) Schist Reflected Light (Width of Field 10 mm)
 2G(C) Radiolarian Chert Reflected Light (Width of Field 7 mm)	 2G(D) Altered Crystal Vitric Tuff Reflected Light (Width of Field 7 mm)
 1G(B) Jasperoid (Enhanced) Reflected Light (Width of Field 7 mm)	 1G(A) Jasperoid Reflected Light (Width of Field 7 mm)

Figure 11. Petrographic textures in the Keatley gray chert.

Table 10. Distribution of Types by Housepit: Raw Counts

HP	Jasperoid	Pisolite	Tuff	Chalcedony	Quartzite	Totals
1	61	325	74	6	7	473
5	115	82	28	93	13	331
7	561	155	218	37	85	1056
All	737	562	320	136	105	1860

Table 11. Distribution of Types in Housepit 1: Raw Counts

Unit	J	P	T	C	Q	Totals
Roof	10	28	6	1	2	47
Rim	40	247	41	5	0	333
Floor	9	12	5	0	1	27
All*	59	287	52	6	3	407
Rim Sq. XF	17	168	16	2	0	203
Sq. XF Lvl. 1	9	37	6	1	0	53
Sq. XF Lvl. 2	3	29	1	0	0	33
Sq. XF Lvl. 3	5	102	9	1	0	117

Level 1= Excavation Levels 1-3 J=Jasperoid P=Pisolite T=Tuff; Level 2= Excavation Levels 4-6 C=Chalcedony Q=Quartzite; Level 3= Excavation Levels 7-9; * Excludes "surface" and "other" strata

Table 12. Distribution of Types in Housepit 5: Raw Counts

Unit	J	P	T	C	Q	Totals
Roof	30	16	1	6	7	60
Rim	69	45	13	70	1	198
Floor	3	2	0	2	2	9
All*	102	63	14	78	10	267
Rim Sq. XF	19	2	1	1	0	23
Rim Sq. E	11	7	2	25	0	45
Rim Sq. F	38	36	10	44	1	129
Sq. F Lvl. 1	15	11	2	9	0	37
Sq. F Lvl. 2	18	15	2	8	0	43
Sq. F Lvl. 3	5	10	6	27	1	49

Level 1= Strata VIIIA and VIIIB J=Jasperoid P=Pisolite T=Tuff; Level 2= Strata VIIID,E,F,I,G C=Chalcedony Q=Quartzite; Level 3= Stratum VIIIH; * Excludes "surface" and "other" strata

Petrographic Analyses of the Keatley Chert

Having separated the "cherts" by the criteria specified in the preceding section, samples were taken from each group for petrographic and geochemical analysis. The sampling process was not random. The first objective in the petrographic analysis was to describe features of the chert best observable in thin section. For that reason, samples representative of the most divergent hues and textures found within each group were selected for analysis. This explains why, in some varieties (e.g., 1C and 1F), very few specimens were selected for petrographic and geochemical analyses (everything looked the same), while in others with very few members (e.g., 1G, 2G, 3G) many samples were taken (everything looked different). It was hoped that this sampling strategy would produce the most diverse set of petrographic and geochemical characteristics.

Sedimentary rocks are extremely scale sensitive. At the outcrop scale, one may find a fairly complete suite of petrographic features. As the metric scale of analysis decreases, variability in petrographic (and geochemical) characteristics between samples increases. The debitage flakes analyzed from the Keatley Creek site usually consisted of less than a cubic centimeter of material. When a geologist examines thin sections of samples from an outcrop, he compiles a list of attributes that characterize the material. In examining a collection of flakes from cultural contexts, the assumption of a single origin for all items cannot be reasonably made.

Table 13. Distribution of Types In Housepit 7: Raw Counts

Unit	J	P	T	C	Q	Totals
Roof	20	6	2	1	3	32
Rim	487	116	82	33	70	788
Floor	1	1	1	0	1	4
All*	508	123	85	34	74	824
Rim Sq. AA	239	61	48	27	13	388
Sq. AA Lvl 1	32	4	5	9	4	54
Sq. AA Lvl 2	110	49	31	10	8	208
Sq. AA Lvl 3	97	8	12	8	1	126
Rim Sq. XD	14	0	0	0	0	14
Rim Sq. D	59	6	7	1	5	78
Rim Sq. K	89	22	10	2	27	150
Rim Sq. L	28	4	5	1	1	39
Rim Sq. M	30	17	6	2	13	68
Rim Sq. N	14	5	5	0	11	35
Rim Sq. O	14	1	1	0	0	16
DKL Trench 1	26	5	0	1	4	36
DKL Trench 2	148	26	21	3	29	227
DKL T2 Lvl 1	91	16	12	3	13	135
DKL T2 Lvl 2	57	10	9	0	16	92
MNO Trench 2	41	9	8	1	16	75
MNO T2 Lvl 1	10	6	3	1	14	34
MNO T2 Lvl 2	17	2	4	0	2	25
MNO T2 Lvl 3	14	1	1	0	0	16

Level 1= Strata XIIIA and XIIIB; J=Jasperoid P=Pisolite T=Tuff Level 2= Strata XIIIC and XIII; C=Chalcedony Q=Quartzite
Level 3= Stratum XIIIF; * Excludes "surface" and "other" strata

In debitage analyses, sets of petrographic attributes must be enumerated by thin section and similar sets combined only when theory allows such combinations. The products of this process are synthetic descriptions, aggregates of textural and mineralogical attributes found in several samples that might be considered characteristic of a "type" of rock, one of hypothetically common origin and formation. Where geochemical analyses allow, such attribute combinations are used to reorganize varieties formed in the initial sorting process into the types analyzed for distributional characteristics later in the study.

The first set of features defines the petrographic attribute called in this study "Relict Carbonate Texture" (Fig. 8). Use of the word "relict," in this case, signifies a siliceous replacement of the original minerals. In the process of silicification, much of the fine detail originally present in the carbonate rock has been lost. In many cases, the best evidence of carbonate texture is presented only by "ghosts" (morphological outlines) of carbonate species in a dissolution texture. However, in some thin sections, remarkably well preserved forms of calcareous algae, bryozoans, echinoderm fragments, crinoid stem, and brachiopod spines are present, frequently with pelloidal masses. These fossils and textures can easily be attributed to a shallow carbonate environment conducive to the deposition of a biopelmicrite (limestone) or biopelsparite (coarse limestone). Siliceous replacement of rhombahedral authigenic carbonates (e.g., dolomite) occurs in many thin sections. Thin sections with relict carbonate texture also exhibit a finely dispersed suspension of phosphatic or organic particles which results in a murky appearance in plane polarized view. Relict carbonate texture dominates the reddish and yellowish lithics, both banded and solid (Table 7). On the basis of this petrographic evidence, the bulk of the reddish and yellowish debitage can be classified as "jasperoid," a dense, chert-like siliceous rock in which cryptocrystalline quartz has replaced the carbonate minerals.

The second major textural suite is actually a special case of relict carbonate texture, "Relict Pisolitic Texture." This texture results from the inclusion and aggregation of pisolites, rounded to sub-rounded, usually coated grains, in a carbonate matrix of varying concentration (Fig. 9). As in the previous case, much of the structure in the pisolites has been lost, although frequently, the coating of grains characteristic of pisolites may still be seen. This material contains a lot of opaline silica. The pisolites themselves are usually opaline. Matrix material is usually replaced by cryptocrystalline quartz, but occasionally by chalcedony. The glassy nature of the material makes it extremely susceptible to hydration (e.g., Fig. 4, cortical surface). The pisolitic texture is reasonably easy to discern (except in some occurrences of pisolitic floatstone and botryoidal pisolite) and has been commonly referred to as "Speckled Chert" by those

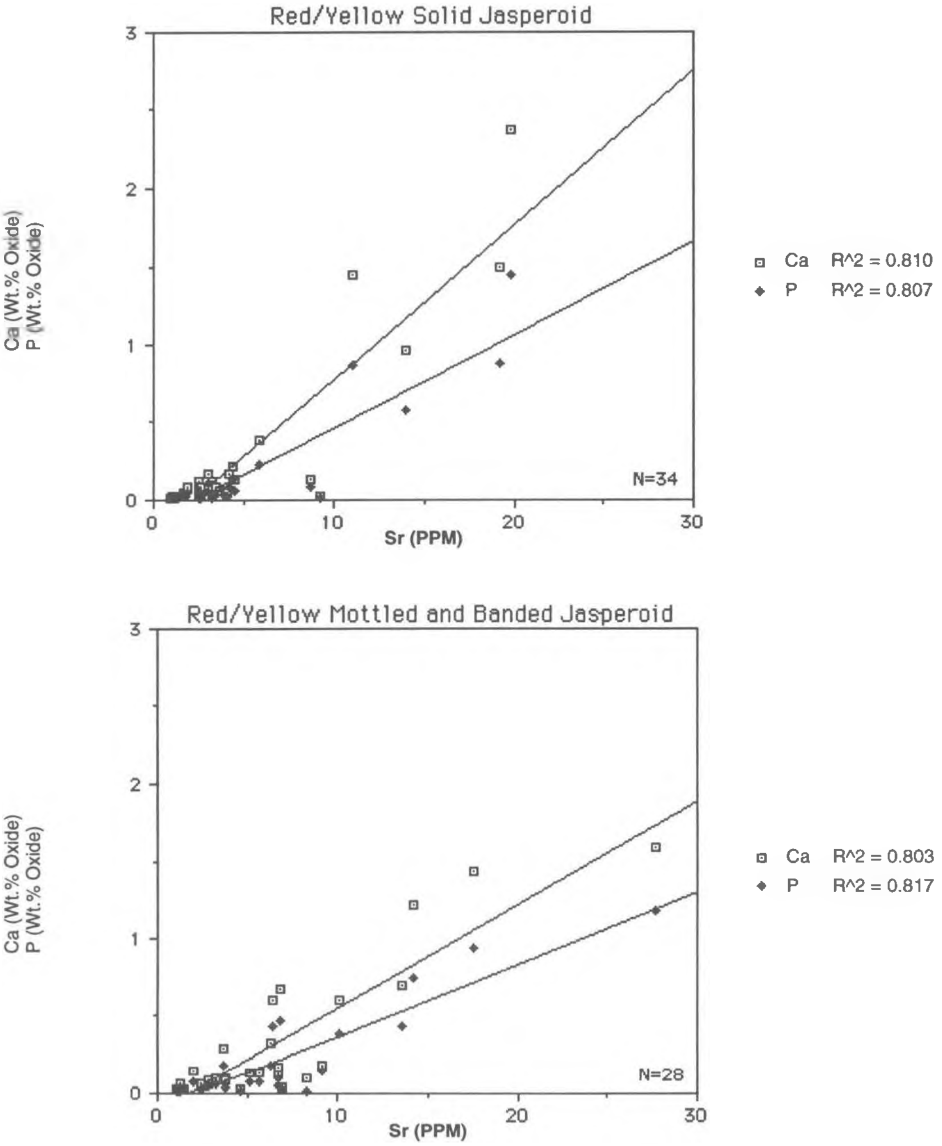


Figure 12. Ca and P vs. Sr in the Keatley jasperoid.

familiar with the Keatley Creek materials. Samples from provisional classes 3C, 4CA, 4CB, 5CA, 5CB, and 5E consist nearly entirely of pisolite (Table 8).

The third suite of petrographic features describes the "Keatley Tuff," an altered vitric tuff. Materials of this type are usually considered pyroclastic igneous rocks. At Keatley Creek, clear-cloudy varieties (1F) of this material look similar to the chalcedony. One obvious petrographic difference is that no chalcedonic quartz was observed in any of the thin sections of vitric tuff examined, although it would not be unusual to find some chalcedonic quartz in an altered vitric tuff. The majority of the rock consists of cryptocrystalline quartz and zeolite minerals, products of the alteration of volcanic glass. Occasional ghosts of crystal shards are present, where phenocrysts have been replaced by quartz, but outlines of the original euhedral mineral (a feldspar or amphibole) may be discerned. A suite of textural features (globular inclusions, collapse structures, angular clastic inclusions, and layering) may be observed in this material (Fig. 10). Provisional classes 1B2, 1C, and 1F appear to consist almost entirely of altered tuff.

The only remaining varieties not yet characterized by some set of common petrographic features are the gray-green lithics of provisional classes 1G, 2G, and 3G.

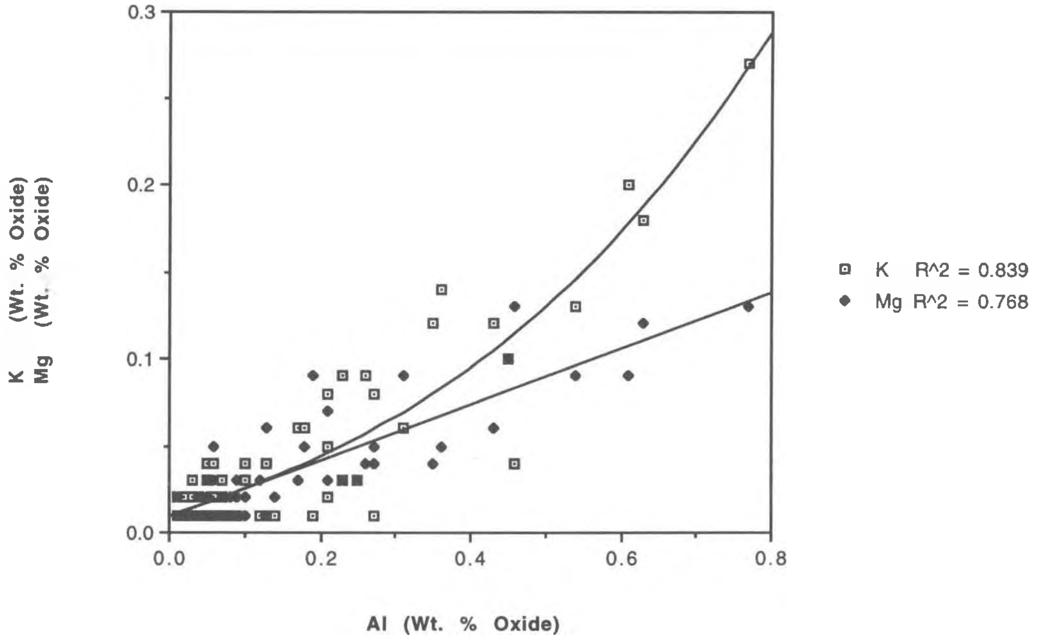


Figure 13. K and Mg vs. Al in the Keatley jasperoid.

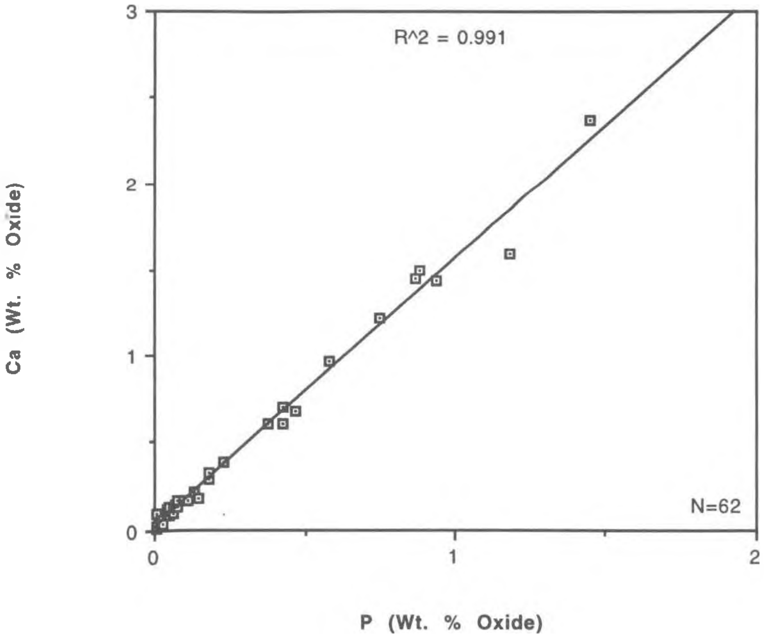


Figure 14. Ca vs. P in the Keatley jasperoid.

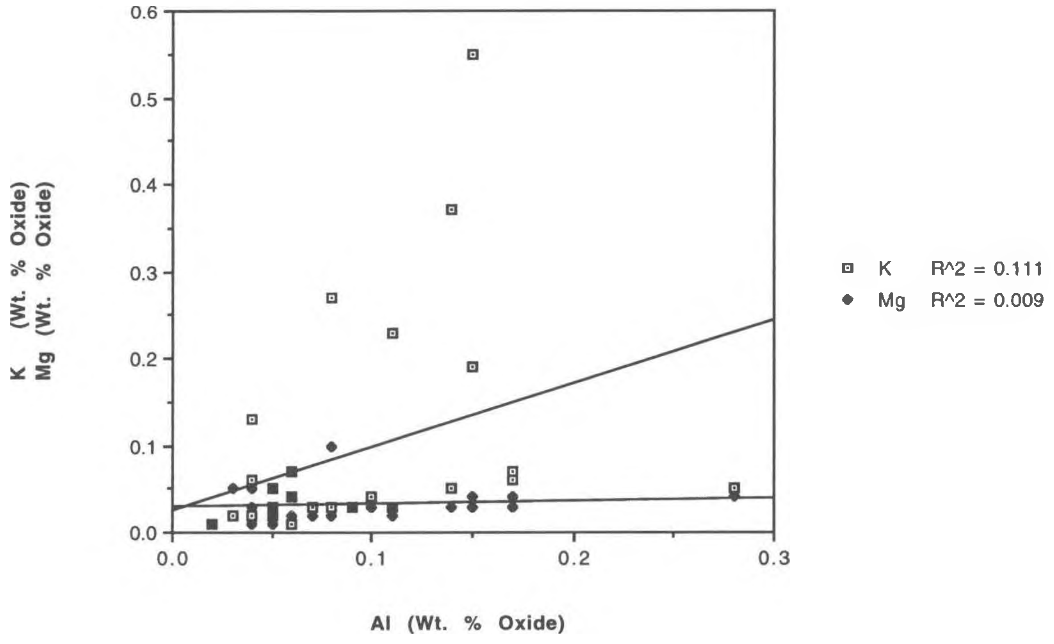


Figure 15. K and Mg vs. Al in the Keatley pisolite.

The diversity present in this group does not allow for the formation of any common set of petrographic characteristics. Many different kinds of material are present within these provisional classes (Table 9, Fig. 11). The most abundant variety is a tuffaceous material which shares geochemical and petrographic characteristics with the Keatley Tuff, allowing for the expansion of that type to include gray, as well as clear-cloudy and white-buff members. The gray-green materials also include some jasperoid (silicified limestone) which can be included as a minor constituent of the Jasperoid type. Other gray materials include distinctively rare (in this assemblage) varieties such as argillite, marl (a mixed siliciclastic and carbonate rock), a silicified schist and a radiolarian chert.

Geochemical Patterns in the Keatley Chert

By this time, it may have become apparent that, aside from two isolated occurrences (one piece of volcanoclastic chert in variety 3E and one piece of radiolarian chert in the gray materials), there are no true cherts in the Keatley Creek assemblage. Petrographic evidence indicates a preponderance of silicified carbonates (jasperoid and pisolite), a chalcedony, altered vitric tuff, and quartzite. Petrographic criteria alone could be used to construct class definitions at this point, but the petrographic observations made in this study are subjective. Interpretations of thin section texture and mineralogy can be disputed (just as I have questioned Richard's report of olivine in Cache Creek "basalts"). Therefore, petrographic class distinctions made in this study are contrasted with geochemical evidence. Geochemical patterns in the Keatley Creek "cherts" are examined to determine whether petrographic patterns and chemical anaylses can be harmoniously integrated as type criteria. The proposed groupings are then evaluated using discriminant analysis techniques based on geochemical data.

Only those samples for which thin sections existed were quantitatively analyzed. This procedure provides an opportunity to directly compare analytical results with petrographic observations. Geochemical analyses were all performed by ICP analysis. The analyses were originally conceived as trace element studies, since that seemed to present (from reviews of the available literature) the most promise of success. Therefore, metaborate fusions were not performed as part of the

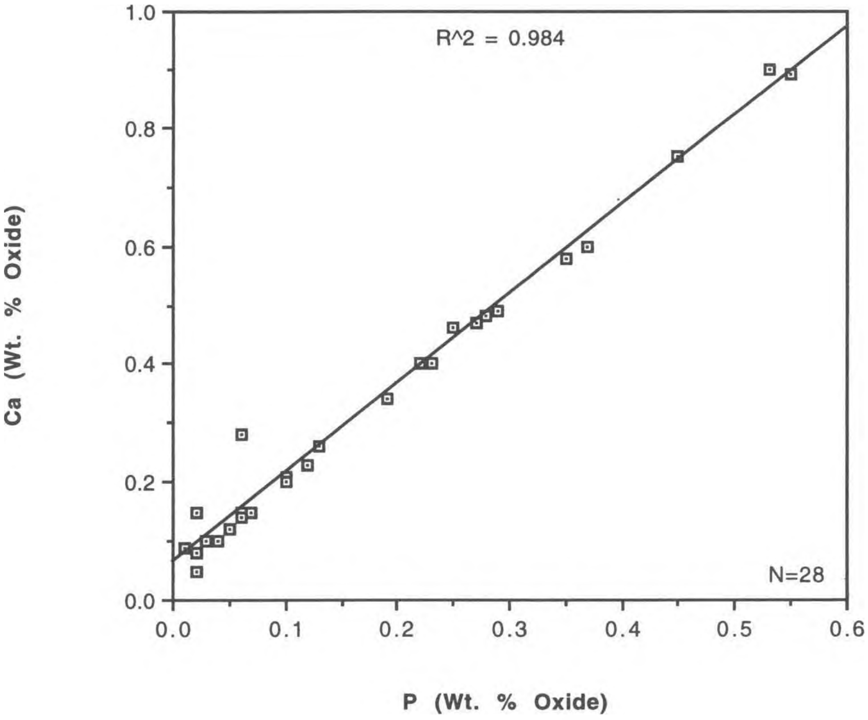


Figure 16. Ca vs. P in the Keatley pisolite.

process. As a result, there may have been some undissolved materials, and the concentrations of major elements may be slightly higher than reported. Nevertheless, the data seem to provide strong discriminatory patterning for each of the proposed types.

In the petrographic analyses, textural observations resulted in an interpretation that all of the reddish and yellowish materials, both solid and banded or mottled, were essentially similar, i.e., jasperoid, and potentially attributable to the same kind of source. If this was true, then some patterning should exist in the geochemistry to support merging the two varieties. There is such evidence, and one example is the patterning of Ca and P with Sr (Fig. 12). Correlation levels are equivalent, the range of compositional values is similar, and the patterns are strongly similar. Strong correlation of K and Mg with Al also exists in both banded and solid materials, as is shown in a combined plot (Fig. 13). A near perfect correlation between Ca and P is also evident (Fig. 14), but this is not unique to the jasperoid material. The Keatley Pisolite, described next, was also originaly a carbonate sediment, and shares some characteristics with the Keatley Jasperoid.

The Keatley pisolite is, as I mentioned in the section on petrography, fairly easy to distinguish macroscopically, because of the speckled appearance of the material. Both the pisolite and the jasperoid are both replacement textures of carbonate sediment. It is interesting to note, however, that the association of K and Mg with Al, clearly does not occur in the pisolite (Fig. 15 vs. Fig. 13). This and other geochemical distinctions support petrographic evidence for separating this material from the jasperoid. A very different physical environment is required for the formation of a pisolite, and it is likely to represent a different toolstone source. What they do share is the very high correlation between Ca and P (Fig. 16), a relationship which probably results from apatite which was not dissolved during diagenesis when the carbonate minerals were replaced by silica. Apatite is *seventeen orders of magnitude* less soluble than calcite in aqueous solution at 25°C. Solubility differences in minerals (e.g., the phosphates hypothesized in this case and the sulphates in the next example) may result in residual minerals that resist diagenetic changes, providing stoichiometric variables for type discrimination.

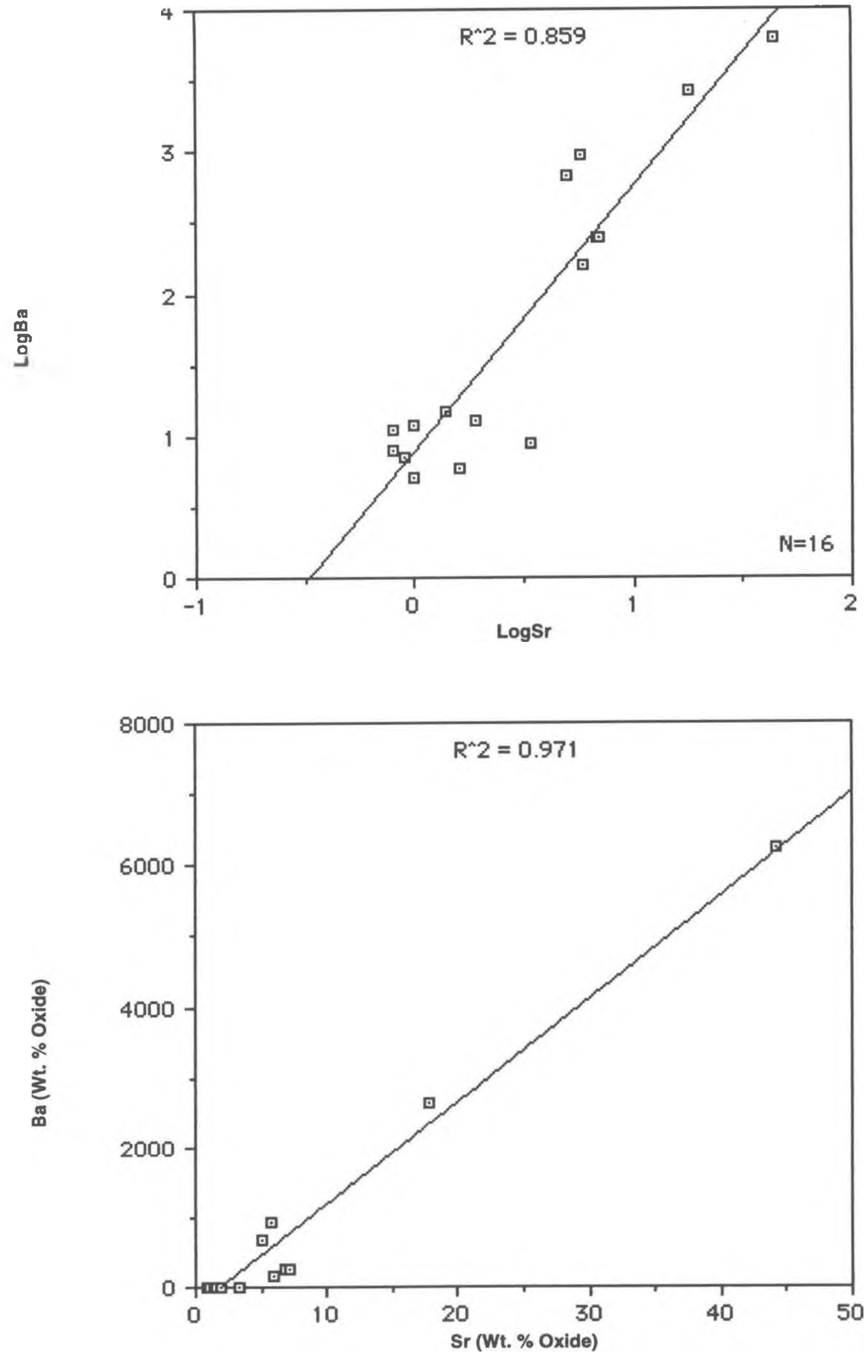
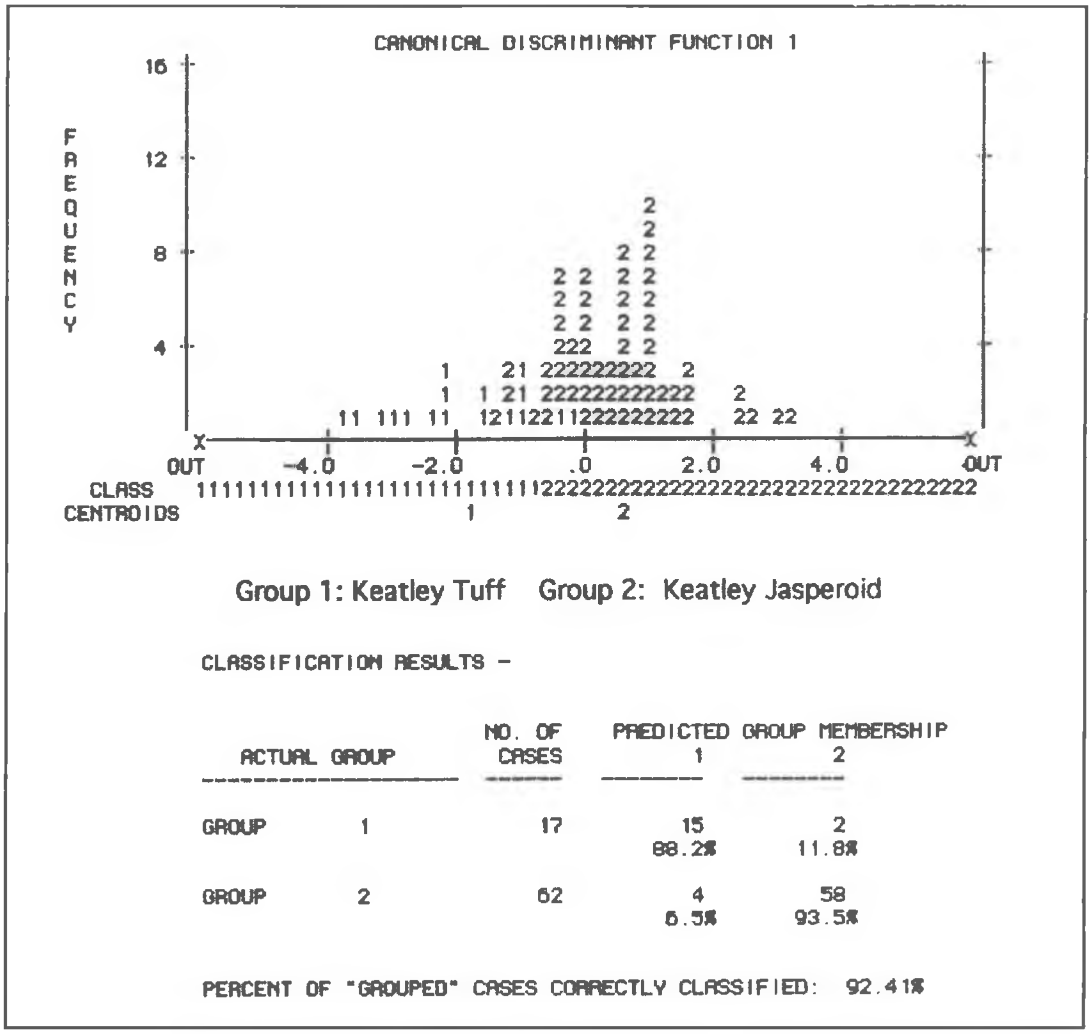


Figure 17. Ba vs. Sr in the Keatley tuff.

Besides quartzite and chalcedony, which were not modeled geochemically, the only remaining "type" is the altered vitric tuff. The sole reliable signature I could find for this material is a fairly strong correlation between Ba and Sr. The correlation apparently exists over a tremendous range of Barium/Strontium values. Indeed, since some might claim the correlation exists due to the extreme and median values, I plotted the logarithmic transforms as well, and the relationship seems to hold (Fig. 17).



Group 1: Keatley Tuff   Group 2: Keatley Jasperoid

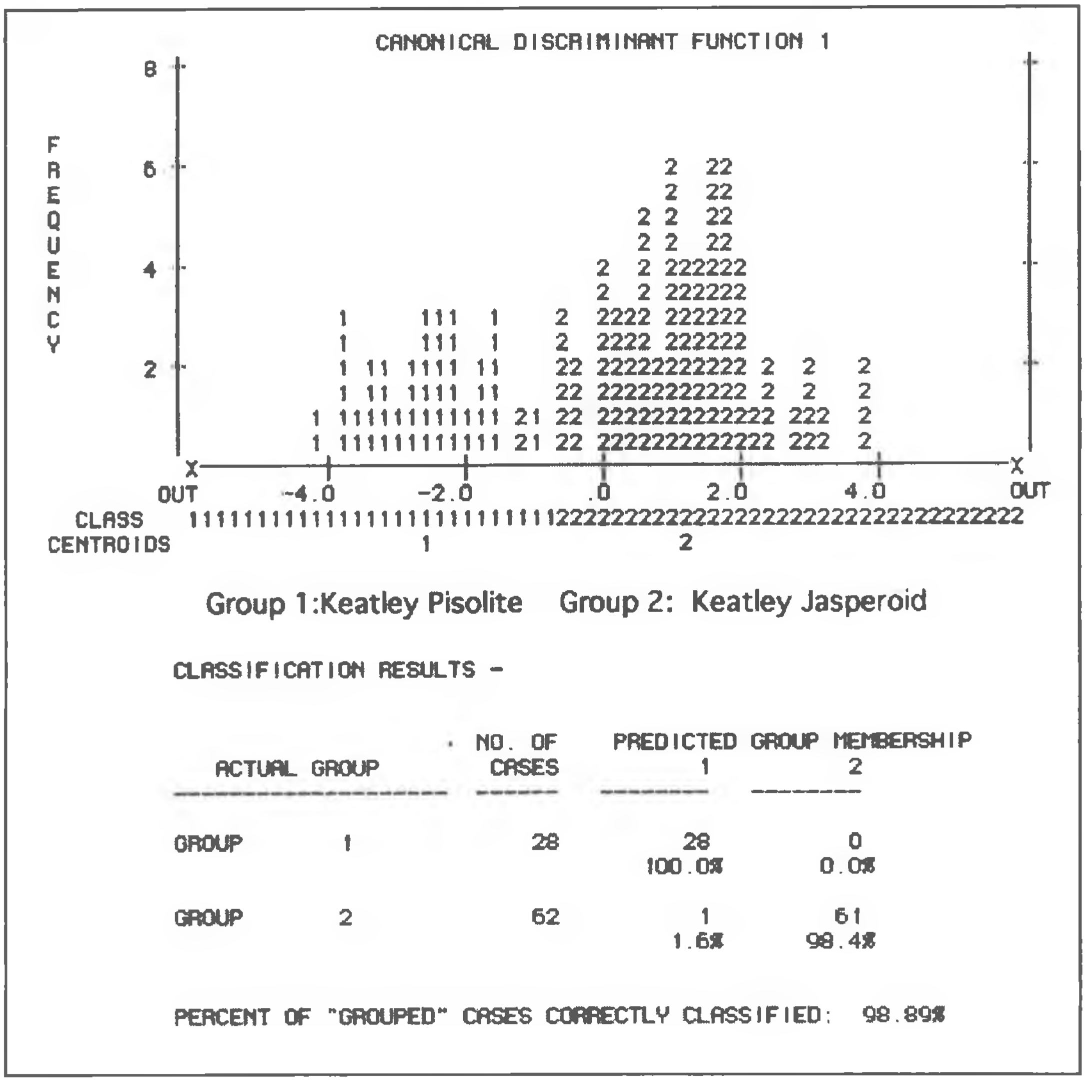
```
CLASSIFICATION RESULTS -

                           NO. OF      PREDICTED GROUP MEMBERSHIP
  ACTUAL GROUP             CASES           1              2
----------------------    ------      ---------      ---------

GROUP          1             17            15              2
                                        88.2%          11.8%

GROUP          2             62             4             58
                                         6.5%          93.5%

PERCENT OF "GROUPED" CASES CORRECTLY CLASSIFIED:  92.41%
```

Figure 18. Tuff vs. jasperoid discriminant analysis.

Barium/Strontium patterning in this material emphasizes the interpretive problems inherent in sampling Poisson distributions. Few cases will be found where the rock will be so rich in barite/celestite ($BaSO_4$/$SrSO_4$) as to yield compositions reflective of the higher values. Data transforms are appropriate devices for exploring relationships in such circumstances. In any event, the tuff simply does not have any of the geochemical characteristics of the two previously described materials.

Finally, I present the results of the discriminant analysis which was run using geochemical values (with log transforms to satisfy normality requirements) for the major and minor elements (*all* of them, rather than a selected few). The goal is to test whether materials classified as the Keatley Tuff, Keatley Jasperoid, and Keatley Pisolite can be distinguished using summary values for the major and minor element data, as well as ratio analysis.

In the first analysis, which compares the tuff to the jasperoid (Fig. 18), the discriminant function predicted group memberships in 92.4% of the cases, with 88.2% of the tuff and 93.5% of the jasperoid "correctly" classified. In the second analysis, pisolite was compared to jasperoid (Fig. 19), and 98.9% of the group members were correctly predicted, with 100% of the pisolite and 98.4% of the jasperoid cases correctly classified. The third analysis combines all three types (Fig. 20) and



```
                         CANONICAL DISCRIMINANT FUNCTION 1
         8 +                                                             +
           |                                                             |
           |                                                             |
F          |                                                             |
R        6 +                                   2  22                     +
E          |                                   2  22                     |
Q          |                                 2 2  22                     |
U          |                                 2 2  22                     |
E        4 +                              2  2 222222                    +
N          |                              2  2 222222                    |
C          |           1     111  1    2  2222 222222                    |
Y          |           1     111  1    2  2222 222222                    |
         2 +           1 11 1111 11    22 22222222222 2  2   2           +
           |           1 11 1111 11    22 22222222222 2  2   2           |
           |         1 111111111111 21 22 2222222222222 222  2           |
           |         1 111111111111 21 22 2222222222222 222  2           |
            X--------+---------+---------+---------+---------+---------X
          OUT      -4.0      -2.0        .0       2.0       4.0       OUT
  CLASS     111111111111111111111111111222222222222222222222222222222222222
CENTROIDS                    1                  2
```

Group 1:Keatley Pisolite   Group 2: Keatley Jasperoid

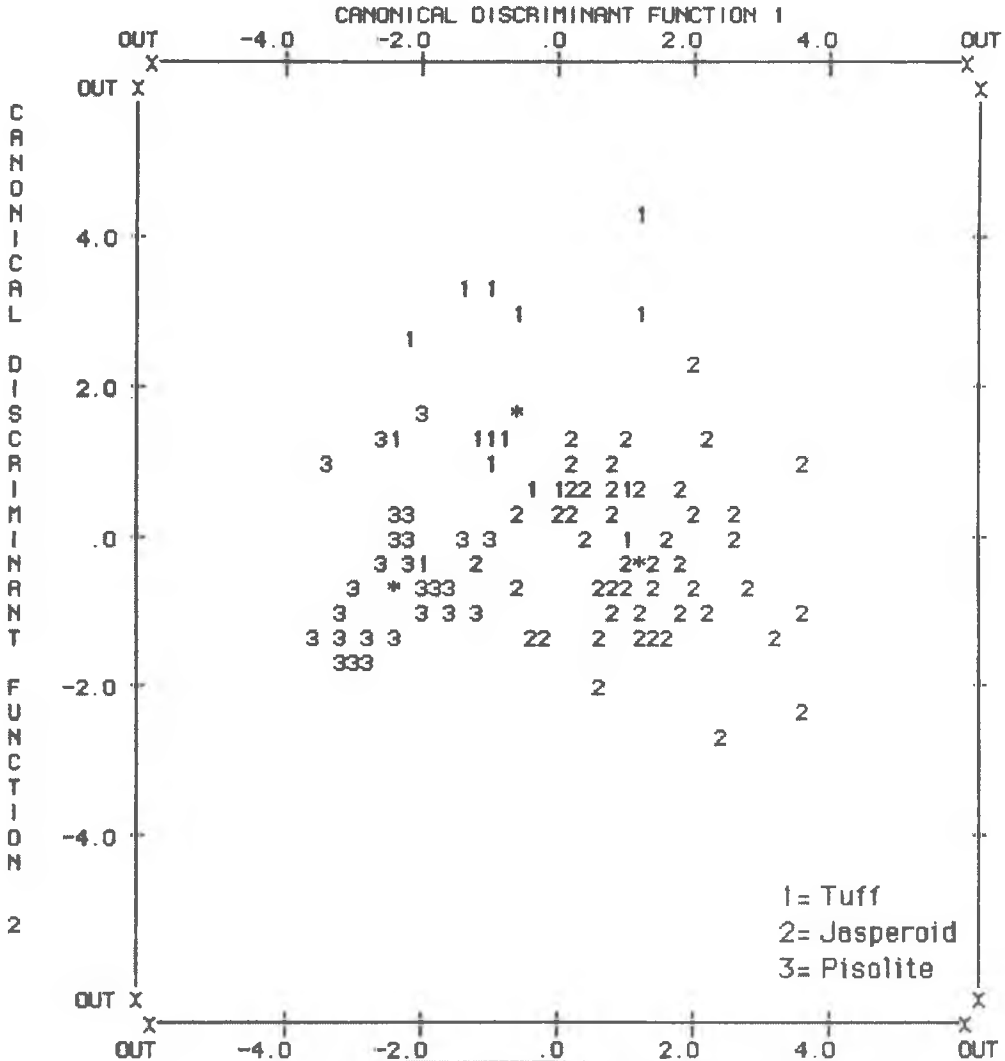
```
CLASSIFICATION RESULTS -

                            NO. OF      PREDICTED GROUP MEMBERSHIP
      ACTUAL GROUP          CASES           1           2
   --------------------     ------      --------    --------

   GROUP        1             28           28           0
                                        100.0%        0.0%

   GROUP        2             62            1          61
                                          1.6%       98.4%

   PERCENT OF "GROUPED" CASES CORRECTLY CLASSIFIED:  98.89%
```

Figure 19. Pisolite vs. jasperoid discriminant analysis.

generates two discriminant functions to predict group membership. In the combined analysis, although exactly the same data and methods were used, overall predictability drops to 90.6% (lower than in either of the two paired cases), with predicability of tuff membership dropping from 88.2% to 81.2%.

This demonstrates one of the problems inherent in discriminant analyses. The results change with the addition of new data. Nevertheless, the technique is useful, and points out some interesting facts. The pisolitic material is easiest to identify in the field, even without the use of thin section analysis, and it can be seen in the plot (Fig. 20), that these cases cluster very closely about the group centroid, indicating that the major element chemistry is a reliable predictor of membership. At the other extreme, cases that represent altered tuff are diffusely spread in the plot, have the lowest degree of predictability, and are correspondingly difficult to distinguish in the field, petrographically, and geochemically.

The results of these discriminant analyses may be viewed as statistical confirmation of the proposed types by some, but all the statistics really say is that major element concentrations vary systematically in the selected groups to some degree. The petrographic features and geochemical patterns apparent in the materials are much more indicative of the physical and chemical environment (i.e., the sources), and it is these attributes that demand consideration when modeling and seeking prospective sources and material types.



```
                         CLASSIFICATION RESULTS
                         NO. OF    PREDICTED GROUP MEMBERSHIP
 ACTUAL GROUP            CASES          1          2          3
 --------------------    ------    --------   --------   --------
 GROUP       1             16          13          2          1
                                     81.2%      12.5%       6.2%

 GROUP       2             62           4         56          2
                                      6.5%      90.3%       3.2%

 GROUP       3             28           1          0         27
                                      3.6%       0.0%      96.4%

   PERCENT OF "GROUPED" CASES CORRECTLY CLASSIFIED:   90.57%
                       106 CASES WERE PROCESSED
```

Figure 20. Pisolite, jasperoid, and tuff discriminant analysis.

One objective of this research was to show that petrographic and geochemical analyses could generate criteria useful for characterizing lithics from archaeological sites and modeling sources, and that major element chemistry could be used to do it. I have shown elsewhere (Bakewell 1995) that major element chemistry varies significantly and in patterned ways in cherts. I have shown in this section that site lithics may also be characterized by petrography and geochemistry of major elements.

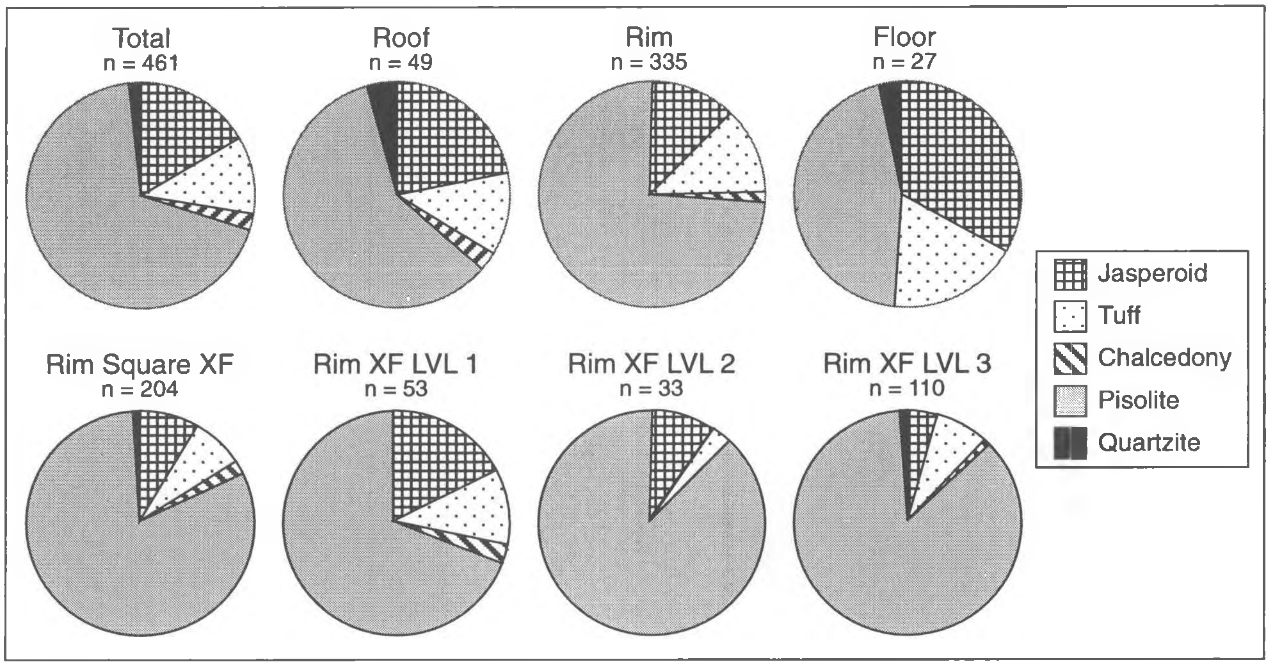


Figure 21. Material distribution in HP 1 by type and level of strata.

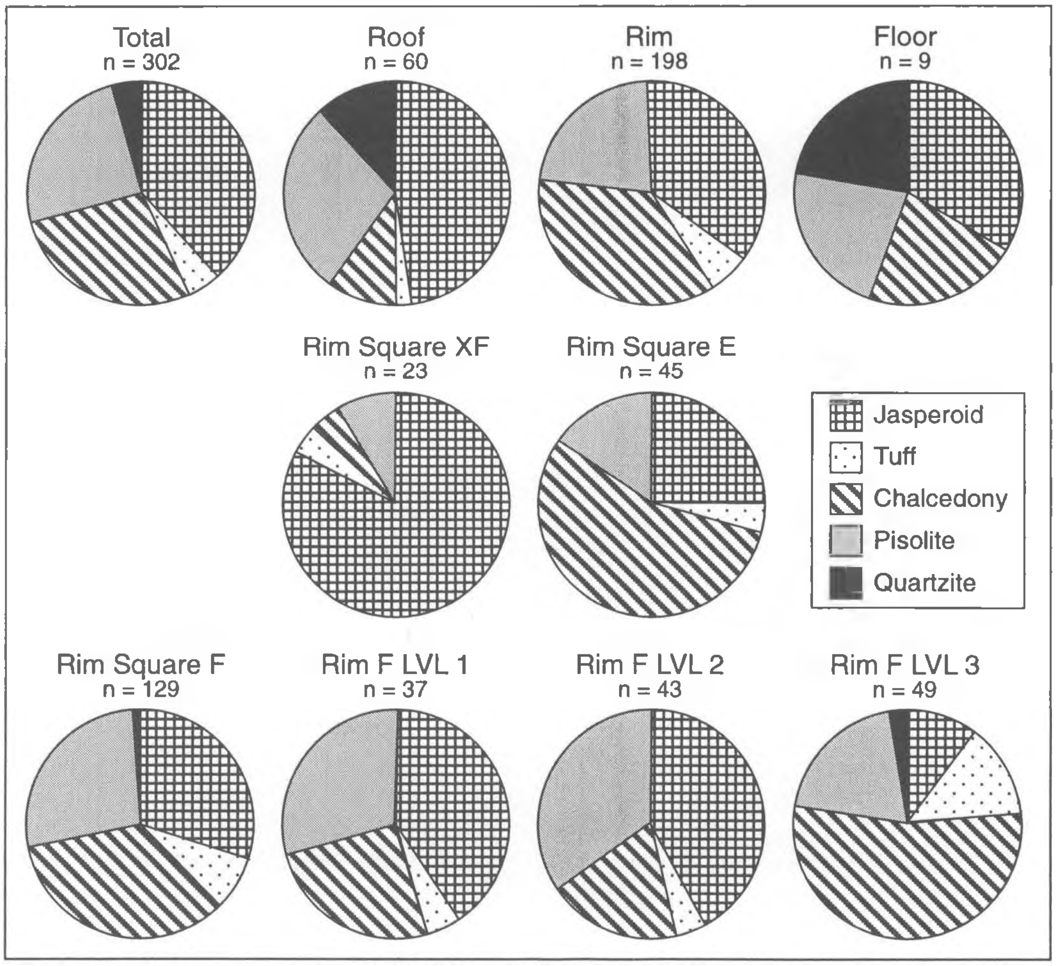


Figure 22. Material distribution in HP 5 by type and level of strata.

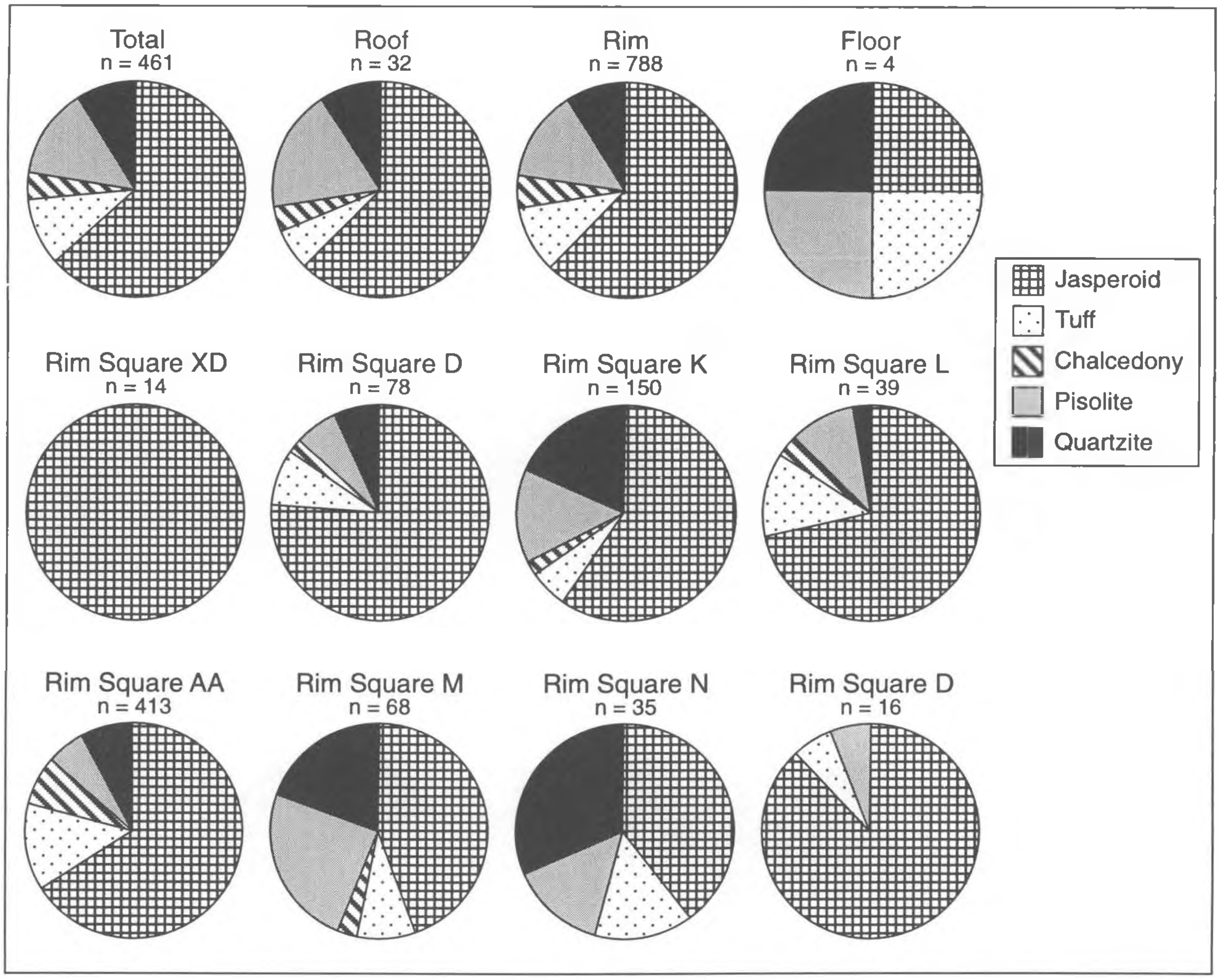


Figure 23. Material distribution in HP 7 by type and Excavation Square.

The results of analyses of Keatley Creek debitage suggest that there are five major types of material present in the site debitage besides trachydacite: jasperoid, pisolite, tuff, chalcedony, and quartzite. Sourcing studies over the last five years at Keatley Creek have located several areas that may be sources for the jasperoid. The material seems to be associated with unconsolidated ignimbrite deposits in several upland localities of the region and is known alternatively as Glen Fraser, Hat Creek, Maiden Creek, and Medicine Creek Chert (Vol. I, Chap. 11). These are surficial, not bedrock sources. Bedrock sources may also have been located (Rusty Creek and Fountain Valley Cherts), but these lack the luster and secondary mineralization resulting from inclusion in the ignimbrite. Petrographic and geochemical analyses have not yet been completed for the proposed bedrock sources, so it is impossible to say with certainty whether they are related to ignimbrite deposits, or whether they may have been directly exploited in prehistory. In five years of searching, no actual source has been located for either the pisolite or the vitric tuff, although high concentrations of pisolitic debitage have been found during surveys of Fountain Valley (Vol. I, Chap. 11). We know from cortical characteristics that the quartzite debitage is reduced from water-worn cobbles. We also know from the delicate cortical features preserved on the chalcedony that this material must be quarried from an *in situ* source. One suggested source for the chalcedony is Blue Ridge Ranch, but these materials have not been analyzed as yet either. Beyond these observations, we know nothing of the exact "chert" sources. What, then, has this analysis produced? Certainly, if this analysis had been available *before* the field surveys, then the search would have been more directed, and the results easier to evaluate. This analysis has established an entirely new approach to the sourcing of chert-like materials. But beyond the obvious, the analysis has been worth the effort if for no more than one fact: each housepit at the Keatley Creek site is itself a lithic source.

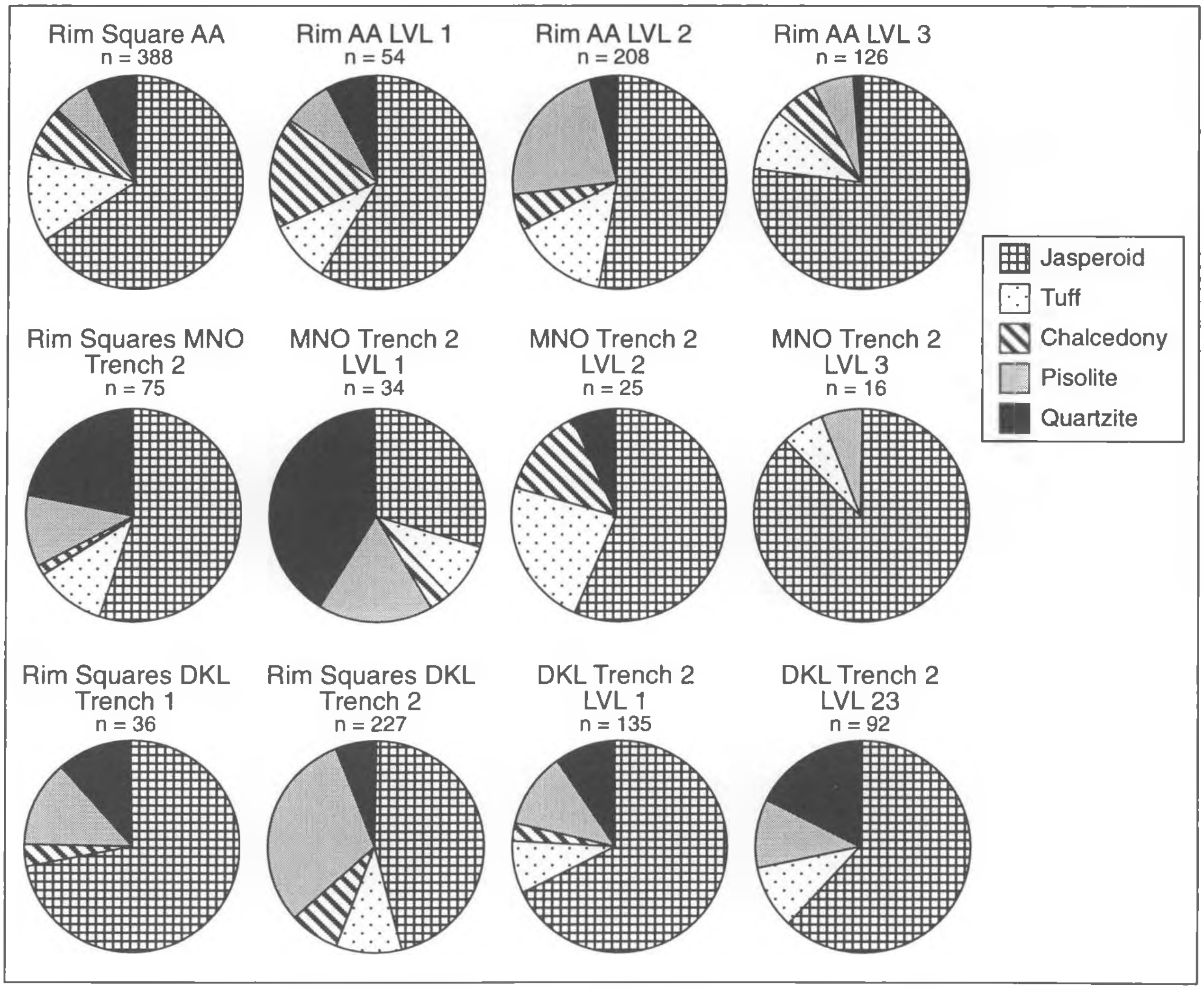


Figure 24. Material distribution in HP 7 by excavation square and sublevels.

Classification of chert-like debitage from HP's 1, 5, and 7 according to the five types of material defined in this study and analysis of distributional trends has disclosed some very interesting patterns.

Distribution of the Keatley Chert

Housepit formation at Keatley Creek represents episodic cultural sedimentation. This sedimentation results in accumulation of stratified deposits, especially in rim strata, debris which rings the housepit from successive roof-building episodes (Vol. I, Chap. 11). The distribution of the five classes of siliceous debitage identified in this study was analyzed by frequency of occurrence in the strata of HP's 1, 5, and 7, including rim, floor, and roof strata (Tables 10–13, Figs. 21–25). Based on the lithic source types defined in this study, it is clear that there were major differences in the use of specific stone types between residents of different housepits (Table 10, Fig. 25). Housepit 1 shows a distribution strongly skewed towards pisolite, which accounts for nearly 70% of the chert-like debitage. Jasperoid and tuff are approximately equal in HP 1, with about 15% of the debitage in either category. Chalcedony and quartzite are present in HP 1 only in trace amounts.

In HP 7, a markedly different pattern exists: more than half the debitage flakes were jasperoid, while pisolite and tuff occurred with frequencies in the 15–20% range.

Chalcedony, a minor constituent of the debitage materials in HP's 1 and 7, with frequencies of less than 5%, is a major material in the debitage of HP 5, occurring with frequencies roughly equivalent to

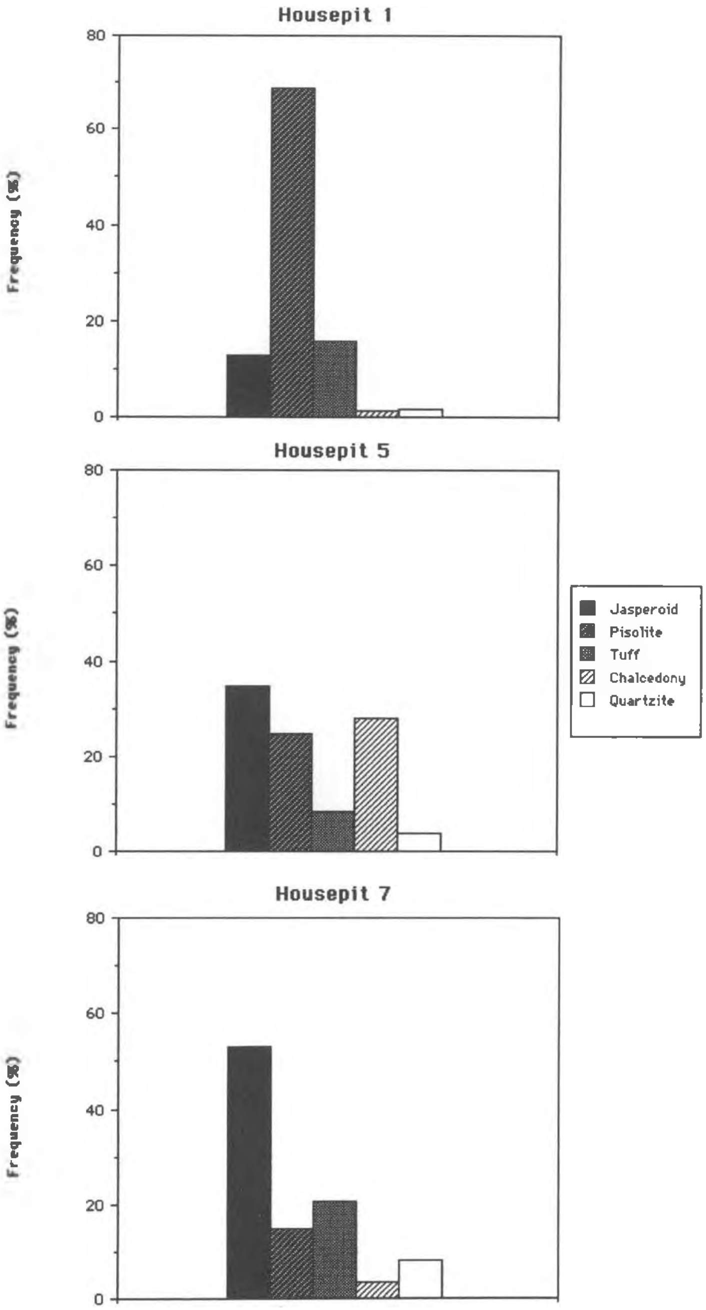
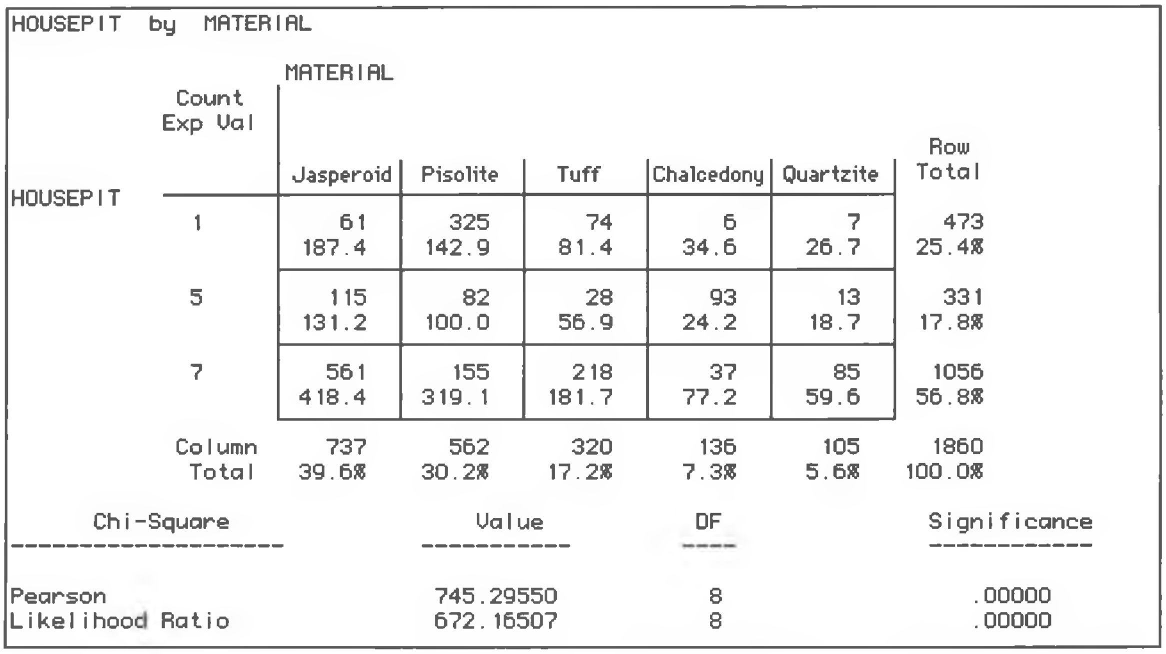


Figure 25. Material distribution by housepit.

pisolite and tuff. Considering that this chalcedony is of gemstone quality, and does not exist naturally in quantities anywhere near that of massively deposited carbonates, like the pisolite and jasperoid, this is truly remarkable. These distributional characteristics do not change substantially in any stratigraphic unit of the housepits in question where large enough samples exist for comparison (Figs. 21–24). The distributions result from the classification of *all* the excavated cherty debitage. Table 10 lists the raw counts by housepit for all 1860 pieces of debitage constituting the five types. Chi-square analysis of the distribution of the five types of material, considered together (Fig. 26), or separately (Fig. 27), suggests that the patterns are not random, but that some culturally selective factor is responsible for the distribution of this material. (Editor's note: In 1999, Bill Prentiss undertook additional excavations in the northwest rim of HP 7. Resutls of his debitage analysis fully corroborate the pattern documented in this chapter.)



```
HOUSEPIT  by  MATERIAL

                    MATERIAL
          Count  |
          Exp Val|
                 |                                                     Row
                 | Jasperoid| Pisolite |  Tuff    |Chalcedony| Quartzite|  Total
HOUSEPIT  -------+----------+----------+----------+----------+----------+
             1   |     61   |    325   |     74   |      6   |      7   |   473
                 |  187.4   |  142.9   |   81.4   |   34.6   |   26.7   |  25.4%
                 +----------+----------+----------+----------+----------+
             5   |    115   |     82   |     28   |     93   |     13   |   331
                 |  131.2   |  100.0   |   56.9   |   24.2   |   18.7   |  17.8%
                 +----------+----------+----------+----------+----------+
             7   |    561   |    155   |    218   |     37   |     85   |  1056
                 |  418.4   |  319.1   |  181.7   |   77.2   |   59.6   |  56.8%
                 +----------+----------+----------+----------+----------+
          Column      737        562        320        136        105      1860
           Total    39.6%      30.2%      17.2%       7.3%       5.6%    100.0%

        Chi-Square                   Value             DF              Significance
--------------------           -----------           ----              ------------

Pearson                          745.29550              8                    .00000
Likelihood Ratio                 672.16507              8                    .00000
```

Figure 26. Crosstabs analysis of material distribution.

Discussion

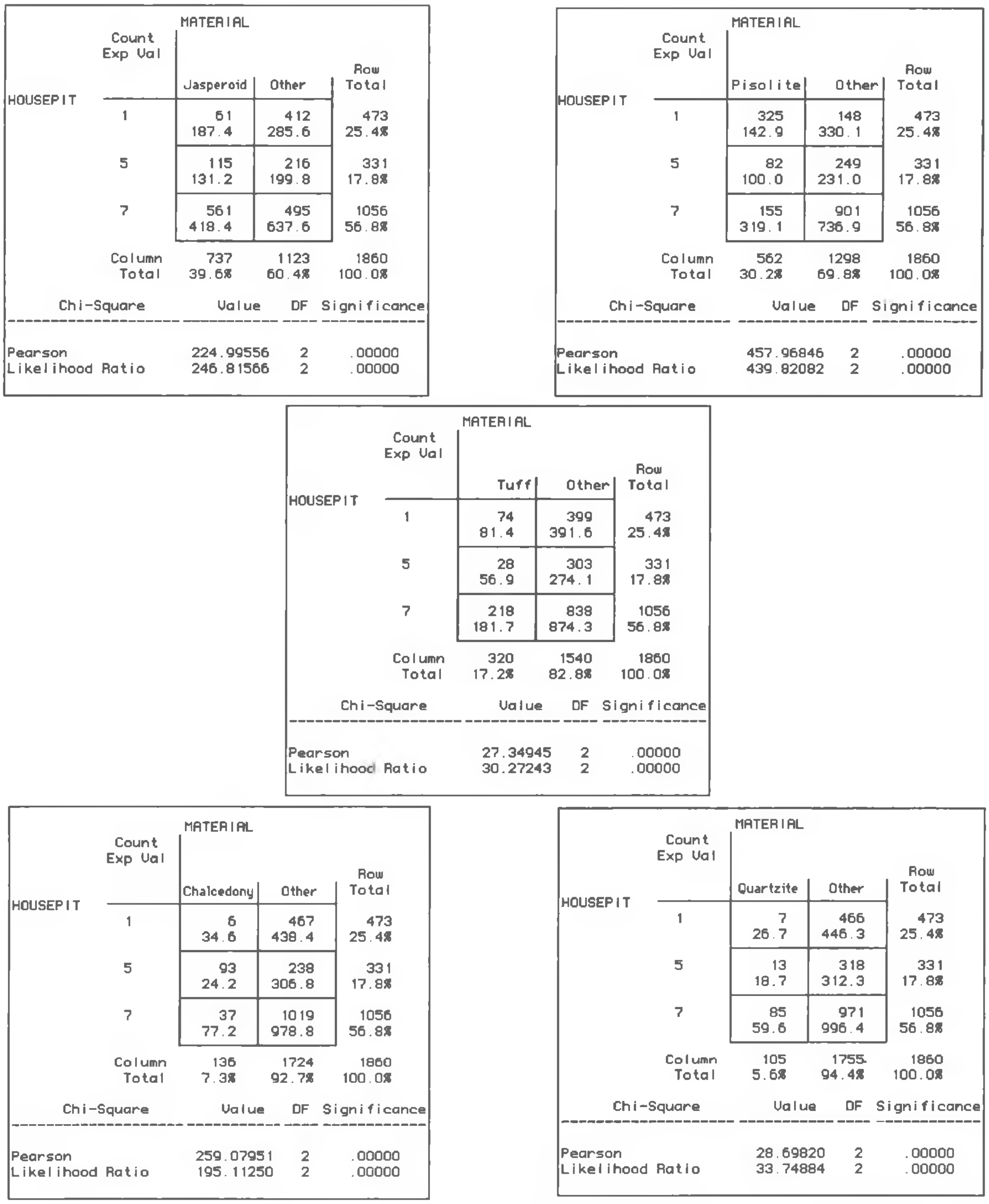
The study of time-sensitive projectile point styles in the deposits of these housepits indicates that they were used during the same span of time (Vol. I, Chap. 3). If we assume that there is no difference of a functional nature (in the engineering sense) in the physical properties of the materials, then we must conclude that the material distribution represents stylistic variation in tool stone between the housepits. Similar stylistic attributes in all deposits within a given housepit imply homologous relationship through time. In other words, the occupants of each large housepit were of the same social lineage throughout the millenia of village occupation, suggesting ownership by specific corporate groups. We could use the distributional characteristics of stone type to analyze other housepits in the village. In this way we might find similarities and differences that could relate to the number of distinct corporate groups in the village, and the number of housepits "owned" by each group. Furthermore, we could hypothesize that sites outside the village (e.g., hunting, fishing, and root-gathering sites) might be recognized as part of the seasonal range of particular corporate groups (assuming that such divisions existed in the landscape) if the characteristic material distributions were present.

If we find that the physical properties of the different types are *not* similar, then perhaps we cannot conclude that material distributions represent entirely homologous relationships. We must then inquire why certain types of materials with different physical properties are distributed consistently through a millenia in what are assumed to be specific domestic locii in the village. Certainly, some of these materials which are preferentially distributed (the quartzite in HP 7 and the chalcedony in HP 5) have quite different physical properties and values, implying that the materials may have been utilized for different functions. It may be possible that both functional and stylistic attributes characterize specific corporate groups in this village.

Summary

Elsewhere (Bakewell 1995), I have shown that chert sources vary by stoichiometric parameters perceptible through analysis of major and minor element chemistry. I have only hinted at theoretical causes specifying which minerals drive variation in the cases I examined since this would require an inordinate expenditure of time and money not available or necessary in the context of the problems addressed by this study.

In this study, I have shown that it is possible to model material types of lithics from archaeological sites using petrographic and geochemical criteria without reference to characteristics found at any particular known bedrock source, but on the nature of the phenomena themselves.



```
                  MATERIAL
           Count |
         Exp Val |
                 |                        Row
                 | Jasperoid |  Other   |  Total
HOUSEPIT         +-----------+----------+
            1    |      61   |    412   |    473
                 |   187.4   |  285.6   |   25.4%
                 +-----------+----------+
            5    |     115   |    216   |    331
                 |   131.2   |  199.8   |   17.8%
                 +-----------+----------+
            7    |     561   |    495   |   1056
                 |   418.4   |  637.6   |   56.8%
                 +-----------+----------+
          Column       737       1123       1860
           Total      39.6%     60.4%     100.0%

        Chi-Square            Value      DF   Significance
-------------------------  -----------  ----  ------------

Pearson                     224.99556     2      .00000
Likelihood Ratio            246.81566     2      .00000
```

```
                  MATERIAL
           Count |
         Exp Val |
                 |                        Row
                 | Pisolite |   Other   |  Total
HOUSEPIT         +----------+-----------+
            1    |     325  |    148    |    473
                 |   142.9  |  330.1    |   25.4%
                 +----------+-----------+
            5    |      82  |    249    |    331
                 |   100.0  |  231.0    |   17.8%
                 +----------+-----------+
            7    |     155  |    901    |   1056
                 |   319.1  |  736.9    |   56.8%
                 +----------+-----------+
          Column      562       1298        1860
           Total     30.2%     69.8%      100.0%

        Chi-Square            Value      DF   Significance
-------------------------  -----------  ----  ------------

Pearson                     457.96846     2      .00000
Likelihood Ratio            439.82082     2      .00000
```

```
                  MATERIAL
           Count |
         Exp Val |
                 |                        Row
                 |    Tuff  |   Other   |  Total
HOUSEPIT         +----------+-----------+
            1    |      74  |    399    |    473
                 |    81.4  |  391.6    |   25.4%
                 +----------+-----------+
            5    |      28  |    303    |    331
                 |    56.9  |  274.1    |   17.8%
                 +----------+-----------+
            7    |     218  |    838    |   1056
                 |   181.7  |  874.3    |   56.8%
                 +----------+-----------+
          Column      320       1540        1860
           Total     17.2%     82.8%      100.0%

        Chi-Square            Value      DF   Significance
-------------------------  -----------  ----  ------------

Pearson                      27.34945     2      .00000
Likelihood Ratio             30.27243     2      .00000
```

```
                  MATERIAL
           Count |
         Exp Val |
                 |                        Row
                 | Chalcedony |  Other  |  Total
HOUSEPIT         +------------+---------+
            1    |        6   |   467   |    473
                 |     34.6   |  438.4  |   25.4%
                 +------------+---------+
            5    |       93   |   238   |    331
                 |     24.2   |  306.8  |   17.8%
                 +------------+---------+
            7    |       37   |  1019   |   1056
                 |     77.2   |  978.8  |   56.8%
                 +------------+---------+
          Column       136       1724       1860
           Total       7.3%     92.7%     100.0%

        Chi-Square            Value      DF   Significance
-------------------------  -----------  ----  ------------

Pearson                     259.07951     2      .00000
Likelihood Ratio            195.11250     2      .00000
```

```
                  MATERIAL
           Count |
         Exp Val |
                 |                        Row
                 | Quartzite |  Other   |  Total
HOUSEPIT         +-----------+----------+
            1    |       7   |    466   |    473
                 |    26.7   |  446.3   |   25.4%
                 +-----------+----------+
            5    |      13   |    318   |    331
                 |    18.7   |  312.3   |   17.8%
                 +-----------+----------+
            7    |      85   |    971   |   1056
                 |    59.6   |  996.4   |   56.8%
                 +-----------+----------+
          Column       105       1755       1860
           Total       5.6%     94.4%     100.0%

        Chi-Square            Value      DF   Significance
-------------------------  -----------  ----  ------------

Pearson                      28.69820     2      .00000
Likelihood Ratio             33.74884     2      .00000
```

Figure 27. Crosstabs analysis of individual material.

Finally, I have demonstrated that such an exercise can provide useful information above and beyond description of either source models or lithic types. The resulting lithic types can become immediately useful as tools for analysis of cultural phenomena, such as the demonstration of long term differences in lithic procurement and use on the part of residents of different housepits at Keatley Creek.

Acknowledgements

First and foremost, I would like to thank Brian Hayden for his infinite patience. The money helped, too. Hopefully, he will acknowledge my gratitude and indebtedness in the latter regard to the appropriate funding sources.

I must also thank the faculty and staff of the Departments of Geological Sciences and Anthropology at the University of Washington for aiding and abetting this interdisciplinary research. Square pegs may, at times, fit into round holes.

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