The cultural influence of volcanic eruptions has been emphasized in the archaeological literature. However, the larger effects that Mount St. Helens volcanic eruptions had upon prehistoric populations in the Pacific Northwest is not understood. This thesis asks questions of the archaeological and paleoenvironmental record of the Pacific Northwest to assess the degree of influence Late Pleistocene and Holocene volcanic eruptions of Mount St. Helens had upon the cultural record of human existence in southern Washington and north-central Idaho. The record of eruptive activity at Mount St. Helens is reviewed and its tephra lobes mapped from reports of pyroclastic identification in the Pacific Northwest and western Canada, to gain a temporal and spatial understanding of the eruptions. A general systemic model is presented to identify the factors responsible for the deposition, removal and alteration of tephra. This model illustrates the complexity of tephrostratigraphic deposition, and increases the awareness of its residence within archaeological sites. Several sets of paleoenvironmental data are correlated with archaeological records of human occupation in southern Washington and north-central Idaho, including records of pollen fluctuation, glacial advance, volcanic activity at Mount St. Helens, and the Late Quaternary history of volcanic acidity in Greenland ice. This correlation illustrates an incipient relationship between volcanic activity,
Quaternary history of volcanic acidity in Greenland ice. This correlation illustrates an incipient relationship between volcanic activity, climate change, and cultural behavior. Cultural historical successions and site occupation in areas between the southern Cascades of Washington and the Clearwater River drainage of north-central Idaho appear to be contemporaneous with regional and hemispheric records of volcanic activity, and changing environmental conditions.
Volcanism, Climate Change, and Prehistoric Cultural Succession in Southern Washington and North-Central Idaho

by

Loren G. Davis

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Arts in Interdisciplinary Studies

Completed May 12, 1995
Commencement June 1996
Master of Arts in Interdisciplinary Studies thesis of Loren G. Davis
presented on May 18, 1995

APPROVED:

[Signatures]

Major Professor, representing Anthropology

[Signatures]

Associate Professor, representing Geography

[Signatures]

Associate Professor, representing Soil Science

[Signatures]

Chair of Department of Anthropology

[Signatures]

Dean of Graduate School

I understand that my thesis will become part of the permanent
collection of Oregon State University libraries. My signature below
authorizes release of my thesis to any reader upon request.

[Signature]

Loren G. Davis, Author
ACKNOWLEDGEMENTS

In design, the thesis is the effort of a single person, in the articulation of personal research. In reality, this product has been helped, supported, and improved by many important people. I would like to thank David Brauner for his patience, guidance and insightful comments; this thesis is greatly enhanced by his help. The wise advice and realist perspective of David Sisson allowed me to actually see the end of this project. I thank him for his flexibility and understanding during the past year. For their helpful comments, constructive feedback, and invaluable assistance I thank Scott "Angus MacHaggis" Billings, George Wisner, and Rick McClure. I thank my parents Dianne and Jerry Striefel for their support and encouragement during these years; I owe you both a great deal. Those of you, too numerous to name, who have provided help along the way, I appreciate your efforts.

Lastly, I would like to recognize the heroic understanding and limitless endurance of my lovely wife, Julie. Throughout this process of research and writing, she has been an invaluable source of support. As my strongest advocate, she has been the fundamental source of my energies. This thesis is dedicated to her.
TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION
Definition of Problem
Statement of Purpose

CHAPTER 2: INVESTIGATIVE METHODOLOGY
Research Design
The Geographic and Geologic Setting of the Study Area
Cultural Setting of the Study Area
Investigative Methods
Research Questions
Summary of Following Chapters

CHAPTER 3: CULTURE AND CULTURE CHANGE

CHAPTER 4: THE POST-GLACIAL ERUPTIVE HISTORY OF MOUNT ST. HELENS
Swift Creek Eruptive Period (ca. 13,000 to ca. 10,000 Years B.P.)
Smith Creek Eruptive Period (ca. 4,000 to ca. 2,900 years B.P.)
Pine Creek Eruptive Period (ca. 2,900 to ca. 2,400 years B.P.)
Castle Creek Eruptive Period (ca. 2,400 to ca. 1,620 years B.P.)
Sugar Bowl Eruptive Period (1,200 years B.P.)
Kalama Eruptive Period (470 to >150 years B.P.)
Goat Rocks Eruptive Period (150 years B.P.)
Distribution of Mount St. Helens Tephra Within Study Area
TABLE OF CONTENTS (continued)

CHAPTER 5: MODELING IMPACTS OF VOLCANIC TEPHRA-FALLS UPON PREHISTORIC POPULATIONS.................................................................33

CHAPTER 6: VOLCANIC TEPHRA AND THE ARCHAEOLOGICAL RECORD...............................................................................................38

The Nature of Archaeological Stratigraphy...........................................38

Systemic Modeling of Processes Affecting Tephra Deposits.............40

Epistemological Considerations........................................................43
The Depositional System of Eruptive Tephras....................................44
Materials Properties of Tephra.......................................................48
Geomorphic Influences Upon Post-Depositional Tephra.................50
Pedological Influences and Volcanic Tephra.................................51
Bioturbation and Other Sources of In Situ Tephra Disturbance........53
Cultural Disturbance..................................................................54

Discussion...............................................................................55

CHAPTER 7: CLIMATICALLY-EFFECTIVE VOLCANIC ERUPTIONS: PRODUCT, PROCESS AND PALEOENVIRONMENTAL IMPLICATIONS.........................................................56

Volcanic Aerosols and Climatic Forcing..........................................56
Climatically-Effective Eruptions: Analogous Case Studies................61
The Late Quaternary Record of Volcanic Activity..............................62
Paleoclimatic Implications of Volcanic Eruptions............................67
Summary..................................................................................71

CHAPTER 8: VOLCANIC ERUPTIONS, GLACIAL ICE, AND PALEOENVIRONMENTAL RECORDS OF CLIMATE........................................73

The Glacial Record of Volcanic Eruptions........................................74
Volcanic Acidity and Climatic Forcing: Proxy Data........................79
Proxy Data Revisited: Problems and Considerations......................83
<table>
<thead>
<tr>
<th>TABLE OF CONTENTS (continued)</th>
</tr>
</thead>
</table>

**CHAPTER 9: REGIONAL PALEOCLIMATIC HISTORY ....................... 85**

- The Paleoenvironmental Record of the Study Area .................. 86
  - Wildcat Lake .................................................. 86
  - Fargher Lake .................................................. 91
  - Carp Lake ...................................................... 91
  - Creston Mire .................................................. 95
- The Geomorphological Record of Climate Change .................... 97
- Summary .................................................................... 100

**CHAPTER 10: CULTURAL CASE STUDIES: AN OVERVIEW ................ 101**

- The Culture History of the Study Area .............................. 101
  - The Prehistoric Record of the Middle Columbia River Basin ... 101
  - The Prehistoric Record of the Lower Snake River Canyon .... 104
  - The Prehistoric Record of the Clearwater River Drainage .... 108
  - The Prehistoric Record of the Southern Washington Cascade Range ... 110
- Overview of Case Study Sites to be Presented ..................... 111

**CHAPTER 11: ARCHAEOLOGICAL CASE STUDIES .......................... 114**

- Koapk (45-LE-209) .................................................. 114
  - Site Stratigraphy .................................................. 114
  - Cultural Occupation ............................................. 118
  - Sub-Tephra Component ........................................... 118
  - Above-Tephra Component ......................................... 120
  - The Nature of Human Occupation at the Koapk Site ........... 121
- Sunset Creek (45-KT-28) ............................................ 123
  - Site Stratigraphy .................................................. 124
  - Cultural Occupation ............................................. 125
<table>
<thead>
<tr>
<th>Table of Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Nature of Human Occupation at the Sunset Creek Site</td>
</tr>
<tr>
<td>Granite Point Locality 1 (45-WT-41)</td>
</tr>
<tr>
<td>Site Stratigraphy</td>
</tr>
<tr>
<td>Cultural Occupation</td>
</tr>
<tr>
<td>The Nature of Human Occupation at Granite Point Locality 1</td>
</tr>
<tr>
<td>Windust Caves (45-FR-46)</td>
</tr>
<tr>
<td>Site Stratigraphy</td>
</tr>
<tr>
<td>Cultural Occupation</td>
</tr>
<tr>
<td>The Nature of Human Occupation at Windust Caves</td>
</tr>
<tr>
<td>Marmes Rockshelter (45-FR-50)</td>
</tr>
<tr>
<td>Site Stratigraphy</td>
</tr>
<tr>
<td>Cultural Occupation</td>
</tr>
<tr>
<td>The Nature of Human Occupation at Marmes Rockshelter</td>
</tr>
<tr>
<td>Hatwai (10-NP-143)</td>
</tr>
<tr>
<td>Site Stratigraphy</td>
</tr>
<tr>
<td>Cultural Occupation</td>
</tr>
<tr>
<td>CHAPTER 12: SYNTHESIS</td>
</tr>
<tr>
<td>The Data Explained</td>
</tr>
<tr>
<td>Discussion</td>
</tr>
<tr>
<td>Temporal Perspective of Cultural Succession</td>
</tr>
<tr>
<td>Spatial Perspective of Cultural Succession</td>
</tr>
<tr>
<td>CHAPTER 13: DISCUSSION AND CONCLUSIONS</td>
</tr>
<tr>
<td>Research Questions Addressed</td>
</tr>
<tr>
<td>Cultural Adaptation to Volcanic Events</td>
</tr>
<tr>
<td>Section</td>
</tr>
<tr>
<td>--------------------------------------------------------------</td>
</tr>
<tr>
<td>Systemic Modeling and the Humanist Perspective</td>
</tr>
<tr>
<td>Conclusions and Recommendations for Future Research</td>
</tr>
<tr>
<td>REFERENCES</td>
</tr>
<tr>
<td>APPENDIX: INDEX OF TEPHRA LOCALITIES</td>
</tr>
<tr>
<td>Figure</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>1.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>3.</td>
</tr>
<tr>
<td>4.</td>
</tr>
<tr>
<td>5.</td>
</tr>
<tr>
<td>6.</td>
</tr>
<tr>
<td>7.</td>
</tr>
<tr>
<td>8.</td>
</tr>
<tr>
<td>9.</td>
</tr>
<tr>
<td>10.</td>
</tr>
<tr>
<td>11.</td>
</tr>
<tr>
<td>12.</td>
</tr>
<tr>
<td>13.</td>
</tr>
<tr>
<td>14.</td>
</tr>
<tr>
<td>15.</td>
</tr>
<tr>
<td>16.</td>
</tr>
<tr>
<td>17.</td>
</tr>
<tr>
<td>18.</td>
</tr>
<tr>
<td>Figure</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>19. Record of pollen values through time at Wildcat Lake</td>
</tr>
<tr>
<td>20. Record of pollen values through time at Fargher Lake</td>
</tr>
<tr>
<td>21. Record of pollen values through time at Carp Lake</td>
</tr>
<tr>
<td>22. Record of pollen values through time at Creston Mire</td>
</tr>
<tr>
<td>23. Location of archaeological case study sites</td>
</tr>
<tr>
<td>24. Synthesis of data from Mount St. Helens eruptions and prehistoric occupational succession reported from archaeological case study sites</td>
</tr>
<tr>
<td>25. Synthesis of data from Mount St. Helens eruptions, archaeological case studies, paleoenvironmental proxy records, and the Greenland record of volcanic sulfur production</td>
</tr>
</tbody>
</table>
CHAPTER 1
INTRODUCTION

For as long as humans have been in the Pacific Northwest volcanic eruptions have been a part of their environment. Evidence of these eruptions are present as tephra deposits and many remain in the regional geologic record. Cultural material also shares a place with relict eruptive evidence within regional stratigraphy, highlighting the fact that humans have been impacted by these eruptions numerous times in the past. Questions remain however, as to how prehistoric human populations reacted and, if necessary, adapted to these volcanic events.

The 1980 eruptions of Mount St. Helens provided invaluable examples of both the destructive power of volcanic events and how they might have occurred in the past. Additionally, these eruptions gave observers the chance to view the reactions of biotic, geomorphic, climatic, and sociocultural systems to the event. Although modern geological analogies are useful for predicting the impacts of past eruptions from a uniformitarian standpoint, they fail to suggest how prehistoric human populations might have reacted.

At Mount St. Helens, a total of seven eruptive periods have occurred since about 12,000 years ago (Mullineaux 1986). Some of these eruptions produced tephra in large quantity with dispersal noted as far north as Entwistle, Alberta, near Edmonton (King 1986), as far east as Montana (Carrara et al. 1986) and as far south as the Snake River Plain of Idaho (Davis...
et al. 1986).

By comparison, some eruptions in the past were of a greater magnitude than the 1980 eruptions, as evidenced by the amount of eruptive material produced (Devine et al. 1984; Mullineaux and Crandell 1981). In view of what was learned from the 1980 eruptions, this fact raises some interesting questions regarding the impacts that volcanic events might have had on co-existing prehistoric populations.

To date, the greatest amount of research investigating questions of human adaptation to volcanic events has been accomplished in the context of the Mount Mazama eruptions. In 1964, Harold Malde reviewed several "Unfamiliar geologic processes" along with an assessment of their potential influence upon ecological systems. In his review, a catastrophic picture is provided in an interpretation of the cultural effects of Mazama tephra falls. Judith Bense (1972) analyzed Cascade phase assemblages to determine if adaptive changes were evident among cultures coexistent with the Mazama eruptions. Stephan Matz (1991) provided a detailed assessment of the nature of volcanic hazards and developed a model explaining how these hazards might affect prehistoric populations.


A number of archaeological investigations have been conducted in the Pacific Northwest, which provide valuable site information near volcanic sources. For example, since the 1970's, research conducted in the Gifford
Pinchot National Forest, under the direction of United States Forest Service (USFS) and Cultural Resource Management (CRM) archaeologists have provided significant insights into volcanic hazards impacts on human adaptive strategies (e.g., Daugherty et al. 1987; Ellis et al. 1991; Gowan and McClintock 1993; Jermann et al. 1988; Lancefield-Steeves and Liddle 1992; McClure 1985, 1988, 1992; McClure and Mack 1994). However, these works have investigated the proximal (i.e., near-mountain position--affected the greatest during eruptions) impacts of tephra-falls within the archaeological record. In order to increase awareness of human adaptation to volcanic events, the scope of archaeological investigation must be broadened. An investigation encompassing the proximal, medial (i.e., moderate distance within known volcano impacts), and distal (i.e., maximum limit of known volcano impacts) ranges of impact from volcanic eruptions, needed to provide a wider perspective on the matter, is lacking in the archaeological literature at this time.

In the field of volcanology, work has been done to evaluate human response to volcanic hazards (Chester 1993; Blong 1982; Grayson and Sheets 1979; Sheets 1992; to name but a few), including the reporting of ethnographic histories among native populations (Blong 1982; Dumond 1979). These records, both written and oral, provide an invaluable addition to the understanding of human adaptation during these environmental changes.

The methods of data collection and interpretation in archaeological research provide a powerful means of gaining information about human adaptation to volcanic hazards, and is lauded by Grayson and Sheets (1979:629):

In short, the use of the archaeological record in the study of the impacts of volcanic disasters on people affords the only opportunity available to examine the long-term impact of these
events on human societies, long-term in the sense of centuries or millennia, not years or decades. Using the archaeological record also offers a means of expanding the sample of impacted societies available for study from the relative handful provided by the recent past to the very large, but unknown, number available from all times. In so doing, archaeological approaches increase the potential of generating valid and reliable theoretical statements concerning the responses of human societies to volcanic disasters.

The application of archaeological research to questions regarding the manner in which prehistoric human populations reacted to volcanic eruptions has been attempted by several authors (Dumond 1979; Hevly et al. 1979; Jashemski 1979; Matz 1991; Nolan 1979; Pilles 1979; Sheets 1979, 1992; Renfrew 1979; Workman 1979; to name but a few). Through their specific research approaches, these authors ask important questions of the archaeological record to understand human interaction with volcanic events. The efforts of these authors have been applied beyond the Pacific Northwest, however.

This discussion illustrates the absence of information regarding the effects Late Pleistocene and Holocene eruptions at Mount St. Helens had upon prehistoric populations in the Pacific Northwest. The extent of tephra-falls from Mount St. Helens reaches well beyond the immediate area of the volcano; questions regarding the larger effects of these volcanic events need to be addressed.

Definition of Problem

Although the investigation of prehistoric cultural response to volcanic events has some precedence in the archaeological literature, the depth of this knowledge in the Pacific Northwest is somewhat limited; these limitations
are even greater in the context of prehistoric Mount St. Helens eruptions. The limited archaeological research available addressing the influence of Mount St. Helens eruptive events is restricted to the immediate proximity of the mountain (Daugherty et al. 1987; Ellis et al. 1991; Gowan and McClintock 1993; Jermann et al. 1988; Lancefield-Steeves and Liddle 1992; McClure 1985, 1988, 1992; McClure and Mack 1994). As the influences of Mount St. Helens have been identified within stratigraphic records beyond the proximal reaches of the volcano, an understanding of how the entire geographic range of eruptions relates to the cultural record of prehistoric occupation is needed.

Statement of Purpose

It is proposed that an investigation be made to determine whether the Holocene volcanic eruptions of Mount St. Helens affected prehistoric populations in southern Washington and north-central Idaho. Utilizing a history of volcanic eruptions from Mount St. Helens and the known cultural succession of prehistoric peoples in the study area, initial observations will be generated regarding the effects geologic events might have had upon prehistoric cultures. Through a correlation of archaeological case studies, paleoclimatic data, glacial lithostratigraphy, and paleovolcanic records, the information generated by this thesis will serve to further the understanding of prehistoric cultural adaptation to volcanic events. Suggestions will also be made for future investigations of the relationship between cultures and environmental change in the Pacific Northwest.
CHAPTER 2
INVESTIGATIVE METHODOLOGY

Research Design

This research is designed to provide a preliminary investigation of correlations between prehistoric cultural behaviors and eruptive events within the extent of Mount St. Helens volcanic impacts. This investigation of cultural correlation will be accomplished through the review of selected site reports within the study area. The study area covers what may be thought of as two separate areas: the Columbia River Basin and Plateau; and the southern Washington Cascades. As these two regions are quite distinct in a geographic sense and provide distinctly discordant environments, they require different means of human adaptation. Because of this, these two areas should be considered separate regions and will be so perceived in this context.

Within the Columbia Plateau several regions have been identified, of which only a few are to be considered in this study. A region is defined by Willey and Phillips (1958:18-21) as smaller than an area, but larger than a locality. These regional divisions include: the Middle Columbia River Basin; the Lower Snake River Canyon; and the Clearwater River Drainage. The cultural-historical model developed for each of these regions will be related to the study area.

The process of cultural change viewed through time can be seen in the unique approach afforded by archaeological investigation. Through the analysis of site reports, which describe remnant cultural materials and past
usage of space and resources at the local and regional level, the interaction
between hunter-gatherer groups and their environments may be understood.
Any alteration in these data through time may be a signal of adaptive changes
made in response to imposed difficulties in attaining necessary levels of
subsistence. Changes seen in the archaeological record from the time period
immediately prior to and following eruptive events may be reasoned to
originate from initial environmental stress. The construction of these causal
arguments requires a firm understanding of the mechanisms behind cultural
adaptation and how volcanic eruptions might act as a catalyst for behavioral
change.

To adequately evaluate the manner in which prehistoric peoples of the
Pacific Northwest might have been affected by volcanic eruptions a model
describing the cultural-environmental relationship needs to be applied here.
By understanding how human populations are linked with their
environment it is possible to evaluate the history of human response to
eruptive events. That is, with insight into the effects eruptions have upon an
environment, any changes seen in the cultural behavior of a population
subjected to such pressures may be better explained.

The Geographic and Geologic Setting of the Study Area

The study area covers most of the southern portion of Washington
extending into north-central Idaho (Fig. 1) and includes three major
geographic zones: the Cascade Range; the Columbia River Basin and Plateau;
and the lower Clearwater River drainage. The western margin of the transect
begins at Mount St. Helens, in the southern Cascade Range of Washington
and extends east including the middle Columbia River, the Lower Snake
River Canyon, and the lower Clearwater drainage. This transect is
geologically and geomorphologically diverse.

At the western boundary of the study area lies Mount St. Helens.
Formed by the accumulation of igneous material during several eruptive
periods beginning in the Pleistocene (Mullineaux and Crandell, 1981:7),
geologically, this volcano is a recent addition to the Pacific Northwest, with its
oldest known deposits dated to about 40-50 ka (Chapin and Zidek, 1989:).
Prior to the 1980 eruptions, the face of the mountain showed little evidence of
glacial erosion, unlike many Cascade mountains, further suggesting a young
age for the volcano. A network of river valleys radiate from the Cascades
originating in the larger watersheds of Mount St. Helens, Mount Adams to
the east, Mount Rainier to the northeast, and the smaller drainages of lesser
mountains in between. During periods of greater glacial activity in the
Cascades, ice sheets advanced from the mountains along many of these river
drainages, scouring out their courses and depositing debris along their
bottoms (Crandell and Miller 1964, 1974).

To the east of the Cascade Range, the geography of southern
Washington grades out of rugged mountains into the Columbia River Basin
and Plateau country (hereafter referred to as the Columbia Plateau). The
greater range of this area is bounded to the south by the Blue Mountains of
Oregon, the Clearwater Mountains to the east, the Okanogan Highland in the
north, and by the Cascade Range in the west. Several major rivers have
dissected the Columbia Plateau including the Columbia, Yakima, Palouse and
the Snake. These rivers have eroded local bedrock forming characteristic
canyons, which contrast with the otherwise low relief of the Columbia
Plateau.
The known geologic history of the Columbia Plateau extends back only about 15 million years, beginning with the introduction of the massive Columbia River basalt flows during the Miocene Epoch (McKee 1972:243). The surface of the basalt lavas were later eroded by rivers draining from the surrounding mountain ranges, and the catastrophic Missoula floods creating major canyon drainages.

Glaciation during the Pleistocene affected the Columbia Plateau only indirectly, as the southern advance of the Cordilleran ice sheet was restricted to the Okanogan and upper Columbia river valleys (McKee 1972:281-282). A lobe of glacial ice did manage to enter from the Okanogan valley to a small portion of the region at the Waterville Plateau area. Periglacial materials were distributed across much of the eastern Columbia Plateau during the Pleistocene. Loess comprises the parent material of many soils on the Plateau, found in deposits of about 45 meters thick in some areas (McKee 1972:279), originating from large lake beds in the southern plateau.

As lobes of advancing glacial ice extended southward into Washington, Idaho, and Montana, the courses of some rivers were impeded, causing the creation of large lakes behind ice dams. The Columbia, Spokane and Clark Fork rivers were blocked, creating Glacial Lake Columbia and Glacial Lake Spokane in Washington and Idaho, and Glacial Lake Missoula in Montana, respectively. The lobes of glacial ice impounding these lakes eventually failed, releasing massive quantities of water to drain eastward and southward across the Columbia Plateau to create the landforms of the Channeled Scablands in eastern Washington. The floodwaters continued to drain towards the Columbia River incising the Lower Palouse River canyon and depositing sand, silt, and gravel into the Pasco Basin and other areas. The
floodwaters were restricted at Wallula Gap, a natural constriction, which may have caused temporary hydraulic damming before allowing drainage to the Pacific Ocean (Hammatt 1976:10).

The postglacial environment of the study area after about 12,000 years ago was shaped by changes in climate and the resulting alterations in local geomorphic processes. This period was most important in the formation of river canyon shoreline landforms throughout the Columbia Plateau (Hammatt 1976)

The Clearwater Drainage of north-central Idaho is comprised of several rivers: the Lochsa River, which drains from the Bitterroot Mountains in the east; the Selway River; the South Fork of the Clearwater River; The Middle Fork of the Clearwater River; the North Fork of the Clearwater River; and the Potlatch River—all of which drain into the main stem of the Clearwater River. The Clearwater River flows west, merging with the Snake river in Lewiston, Idaho. The western portion of the Clearwater Drainage is entrenched in Columbia River basalts, representing the some of the easternmost reaches of this Miocene-age flow.

The eastern margin of the Clearwater Drainage is marked by the Clearwater Mountains, formed of Precambrian Belt schists and gneisses dissected by fluvial erosion (Alt and Hyndman 1989:123-128). As expected, landforms in the Clearwater River Drainage are a combination of deep river canyons cut into the local bedrock, divided by steep ridgelines. Terraces and gravel bars in the bottom of the canyon offer extensive stable landforms for prehistoric occupation.
Cultural Setting of the Study Area

In order to attain a primary archaeological understanding of a region's prehistoric human occupation the development of a reference system is required, which orders the succession of cultures through time. This task is referred to as a "Culture-historical integration" (Willey and Phillips, 1958:11) and is the first product of archaeological investigation in a research area. By ordering human occupation through time from sites with corresponding and supporting assemblages of material culture, which contain a manifestation that is "physignomic, recurrent, and internally consistent" (Willey and Phillips, 1958:14), archaeology may serve to provide a historical understanding of a region's cultural succession. These culture histories are crucial to archaeological research as they are the foundation of further scientific inquiry. By defining cultural phases and developing chronologies of succession, cultural steady states and the timing of culture change can be identified. However, these cultural-historical models do not answer questions explaining the reasons for change, or the selection of specific cultural adaptations. Seeking answers to questions of cultural-environmental interaction, which are beyond the scope of cultural-historical models, additional sources of data must be brought to the investigation.

In the case of this thesis, culture histories will be used to compare the mode and timing of cultural occupation within the study area to other environmental records, in an effort to provide possible explanations for change. Cultural records will be viewed from the different perspectives of spatial division including the site, locality, and region level, as defined by Willey and Phillips (1958). By comparing and contrasting archaeological evidence along the lines of spatial division, answers to some of the research
questions outlined earlier will be pursued.

**Investigative Methods**

This thesis will investigate concurrent lines of environmental and cultural evidence to evaluate the adaptive relationship between prehistoric human groups and the eruptions of Mount St. Helens. Paleoenvironmental data relevant to the study area will be presented to investigate the potential for causal influences forced by volcanic eruptions. These data are found in several sources of proxy indicators of environmental condition, including regional pollen records, and glacial lithostratigraphy, as well as the Greenland record of global vulcanism. Each source of proxy data will be discussed in greater detail within the following chapters.

To provide a view of culture process within the zone of volcanic effect during the eruptions of Mount St. Helens, selected well-reported archaeological sites were reviewed. These sites are found in a west-to-east distribution across the study area, which includes the deposition of several volcanic tephra sets from Mount St. Helens and an adequately reported paleoenvironmental record.

Within the study area the following archaeological sites are located at the proximal (i.e., closest to), medial (i.e., moderately away from), and distal (i.e., farthest away from) portions of some Mount St. Helens tephra lobes, as they extend across the region (Fig. 2); the basis for the plotting of these tephra lobes is provided in Chapter 2: the Koapk site (45-LE-209), in the southern Cascade Range of Washington; the Sunset Creek site (45-KT-28), along the middle stretch of the Columbia River; the Windust Caves site (45-FR-46), Marmes Rockshelter (45-FR-50), and Granite Point Locality I (45-WT-41), all
Figure 2. Selected archaeological sites in the study area.
Hatwai site (10-NP-143), along the lower Clearwater River in north-central Idaho.

Regional chronologies constructed by Nelson (1969), Leonhardy and Rice (1970), and Sappington (1994), are compared with the eruptive history of Mount St. Helens and records of paleoenvironmental change, serving as a coarse approach to correlation. From this comparison, individual sites will be investigated and their cultural occupations matched with the same volcanic and paleoenvironmental history to provide a closer look into potential cultural influence. The selection of archaeological sites was based on factors important to providing a satisfactory basis for correlation. These factors include: the presence of a significant cultural occupation in a stratigraphic context; adequate chronometric control of cultural components (e.g., multiple radiocarbon dates of cultural occupation); sound excavation methodologies and data analyses; the position of the site within the delineated sampling transect.

Research Questions

The eruptions of Mount St. Helens may have had some influence upon the manner in which regional prehistoric human populations coexisted with their ecosystems. If so, an evaluation of the archaeological record within the study area, guided by a research design grounded in the consideration of volcanic hazards and paleoenvironmental succession, will provide preliminary observations regarding the degree of correlation between culture change and volcanic eruptions. The following questions will be used to guide this research:
1. Do the eruptions of Mount St. Helens and the production of tephra-falls correspond in time and distribution with observable changes in regional prehistoric cultures of the Pacific Northwest?

2. Can these changes, if observed, be causally linked with Mount St. Helens tephra-falls, or do they represent a coinciding event with a cultural precursor regionally identified prior to the eruption?

3. Might change in prehistoric cultures have been coming slowly, prior to the introduction of tephra-falls, only to be accelerated due to environmental impacts of the eruption?

4. Are there other influences present in the environmental record of the Pacific Northwest which may correspond in time with Mount St. Helens eruptions, and be the true cause of culture change?

5. Are changes in Pacific Northwest prehistoric cultures the result of a combination of multiple factors, including the eruptions of Mount St. Helens, and not a single forcing mechanism?

This research is presented here as an initial investigation into the potential for correlation between prehistoric culture change and eruptive events at Mount St. Helens. This investigation will hopefully contribute new ideas to be considered in regional research and will act as a catalyst, generating questions regarding the relationship between cultures and volcanic eruptions. Applied to future research, these questions may ultimately advance our understanding of prehistoric cultural adaptation in the Pacific Northwest.
Summary of Following Chapters

Chapter 3: An overview of culture and culture change is provided to build a foundation for further discussion regarding the interaction of prehistoric humans and their environment.

Chapter 4: The Late Quaternary eruptive history of Mount St. Helens is presented, with each major eruptive period outlined. A map of Mount St. Helens tephra distribution is also provided, as a means of increasing the awareness of the volcano's eruptive activity in the past.

Chapter 5: Stephan Matz (1991) provides a discussion on the effects and impacts volcanic tephra-falls impose upon ecosystems. Ecosystems, by definition, are comprised of interactions between living (biotic) organisms and their inorganic (abiotic) habitat (Krebs 1972:3-4). Tephra-fall events, depending upon the magnitude, distribution, and other factors, may stress or damage floral and faunal components of an ecosystem. The reduction or loss of portions of the biological community may in turn create difficulties for hunter-gatherer groups dependent upon those communities for their survival. Sociocultural systems in foraging lifeways are effectively adapted to ecosystems particular to their global location. Invariably, the adaptive relationship cultures share with their ecosystems are affected by changing conditions within that ecosystem. As abiotic factors shift from a previous condition, the effects of those changes are manifested through the biotic components of the ecosystem.

An example of this abiotic-biotic shift may be seen in a volcanic context. A volcano erupts tephra, severely damaging or destroying plants by the accumulation of pyroclastic material upon the landscape. This reduces the available food resource for some animal species and may result in the
attrition of local game populations. Human populations dependent upon the biotic component of an ecosystem may experience stress if their subsistence requirements are not satisfied due to these changes. If the change in the biotic system is great enough, the effectiveness of traditional subsistence strategies may be reduced and require modification, or entirely new strategies may be adopted (Sahlins and Service 1960:54). It is through this adaptive behavior that culture change may be viewed in the context of tephra-fall events.

Chapter 6: In an effort to provide an understanding of volcanic tephra as they appear within the archaeological and stratigraphic records, discussion and a general model is presented in this chapter. First outlining some important considerations of archaeological stratigraphy, the chapter proceeds to cover some basic assumptions of geomorphic and pedologic processes as a pretext for the discussion of a systemic model of post-depositional effects upon tephra material.

As this research proposes to investigate correlation between volcanic eruptions and the cultural behavior of prehistoric populations, a usable knowledge of environmental impacts generated during eruptions at Mount St. Helens is required. Although the forces associated with volcanic eruptions may introduce many products, which serve to affect the environment and surrounding life forms in a multiplicity of ways, this investigation will be concerned only with the processes involved with pyroclastic airfall material (namely tephra) and atmospheric aerosols.

The rationale behind this selectivity is linked to the geographic focus of this investigation. Through processes found in the basic mechanics of eruptions, the introduction of tephra and aerosols into the environmental system are considered the most widespread and effective devices of volcanic
stress. This bipart investigation is designed to evaluate the creation of those volcanic products most likely to have affected the greatest number of prehistoric humans in the study area.

Chapter 7: Volcanic eruptions have been observed to increase global levels of atmospheric aerosols, resulting in climatic shifts. The study and documentation of explosive volcanic events have allowed researchers to illustrate direct correlations between atmospherically-injected volcanic debris and increases in global albedo. More recent observations of volcanic events have suggested that the introduction of volcanic sulfur into the atmosphere, and its subsequent chemical alteration there, is a significant source of increased global albedo influencing climate on a larger time scale than tephra particles.

Observations of glacial ice cores provide a record of volcanic sulfur produced by atmospheric settling of sulfuric aerosols. Eruptive events are recorded through increases in ice acidity, signifying the presence of significant quantities of volcanic aerosols. Through an overview of the mechanisms involved in the formation of volcanic aerosols, their ability to force climate, and the record of climatic change, further insight into the overall climatic effects of sulfur-rich explosive volcanism will be provided.

Concepts of volcanic aerosol production, albedo enhancement, and solar radiation interception are presented as a precursor to discussion about the ability of volcanic eruptions to force climate. The climatic effectiveness of volcanic eruptions, as recorded in glacial ice cores from Greenland is provided for further investigation of the environment of the Pacific Northwest.

Chapter 8: Through a look at proxy records of paleoenvironmental
change, the Late-Quaternary climatic record is investigated in part with records of volcanic activity and production of aerosols. Relationships between volcanic activity and paleoenvironmental change will be addressed on a hemispheric and regional scale.

Chapter 9: A review of Antevs' general model of climatic succession is tempered with an evaluation of its applicability for this study. Regional sources of paleoclimatic data are presented to build a history of paleoenvironmental condition and change within the study area.

Chapter 10: General models of cultural succession, covering the entire study area give a view of the prehistoric archaeological record, and present the chronological history of culture change.

Chapter 11: Specific archaeological sites are reviewed as case studies to give a clearer look at the nature of human occupation and cultural adaptation to environmental condition within the study area.

Chapter 12: A synthesis of data from pollen, paleovolcanic, glacial lithostratigraphic, and archaeological sources is presented. Discussion follows as the correlated data sets are compared and contrasted. Implications for causal relationships between the cultural, climatic, and volcanic realms are evaluated.
The classic definition of culture, in an anthropological sense, is provided by Edward Tylor (1973:63), broadly encompassing the human experience: "Culture or Civilization, taken in its wide ethnographic sense, is that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society." This definition, however extensive, is too general to be of much use in this thesis. To best understand the behavior of prehistoric peoples, a narrower and more active definition of culture is required.

References to environment and human adaptations are widespread in the literature defining culture. For instance, Michael Howard (1989:4-5) defines culture as, "...the customary manner in which human groups learn to organize their behavior and thought in relation to their environment". Marshall Sahlins and Elman Service (1960:53) explain culture as, "... an integrated organization of technology, social structure, and philosophy adjusted to the life problems posed by its natural habitat and by nearby and often competing cultures". The latter example provides a consideration between the interaction of culture and the environment, and will serve as a working definition within this thesis.

Interactions between volcanic eruptions and their effect upon the environment--representing components of the natural aspect of the world, and the adaptive behaviors of prehistoric human populations--corresponding with the cultural aspect, is to be investigated here. Therefore, a discussion of theory directly addressing the interplay of both natural and cultural worlds is
needed. The paradigmatic standpoint from which cultural phenomena are to be viewed will be provided next, followed by discussion concerning volcanic tephra-falls and their influence on prehistoric human populations.

Marshall Sahlins and Elman Service address the nature of cultural evolution and adaptation in *Evolution and Culture* (1960). The concepts laid forth in this publication are of valuable consideration in the investigation of prehistoric cultures and volcanic hazards. The authors address the nature of cultural adaptation in a manner that is fitting with the environmental implications of this investigation. Cultural adaptation is considered to be the process through which peoples successfully acquire and maintain a measure of control over their environment, producing stability. The maintenance of stability is a driving force within a culture, explain the authors, and is identified within the *principle of stabilization*. This principle states that cultures equilibrated with the particular requirements of their environment are stable and unchanging. Cultures will attempt to maintain this state of equilibrium, resisting forces that might introduce change (Sahlins and Service 1960:59).

Cultures also employ measures of maintenance to cope with overwhelming external influences that introduce stress, requiring a formal cultural reaction to remain at a state of equilibrium. This corollary to the principle of stabilization explains that cultures will only change to a point that is necessary to solve the problem at hand, while striving to retain its original character and organization (Sahlins and Service 1960:54).

Sahlins and Service (1960:53-68) do provide discussion explaining mechanisms cultural groups employ in times of great environmental stress. In the case of large-scale unexpected shifts in the environment, cultures may
be forced to react in a manner that the act of employing certain adaptational responses may require great modifications of the cultural system. These modifications serve to adjust the point of cultural-environmental equilibrium to a new level. This adjusted equilibrium point represents a more efficient manner in which the culture interacts with its new environment and can be considered to embody the core of a changed culture.

The adaptive response to environmental stress is brought about by the new conditions for survival. Successful adaptation to changing conditions often results in the adoption of new cultural attributes, or the improvement of old ones. With the persistence of the new environment, the point of culturally-adapted equilibrium remains at a level differing from past environmental situations. This change in equilibrium creates stresses, which reduce the effectiveness of temporary adaptations. In effect, the environment has changed and a new equilibrium point is set (Sahlins and Service 1960:57-58). Cultural groups specifically adapted to the conditions of the previous environment are faced with the task of devising adaptive responses to attain a state of equilibrium once again.

The mechanisms utilized to reach and maintain this new point of equilibrium can be considered to form aspects of a culture's material, social and ideological manifestation, as observed in the archaeological record (Binford 1972:20-32). The observation of cultural changes from one point of equilibrium to another, in a temporal context corresponding with significant changes in the environment, might be considered clues to the identification of a causal relationship. Along the same lines, Sahlins and Service give these thoughts:

The principle of stabilization as considered here, however, is more than a convenient methodological device for exploring
the prehistoric past; it is a statement about the nature of culture, and becomes in itself a very significant phenomenon for study. It means that cultures tend to persist unchanged, and under the influence of external factors act to maintain their basic structure through adaptive modification (1960:59).

David Hurst Thomas (1979:125) provides analogous discourse dealing with the topic of ecological approaches to the anthropological interpretation of cultural behavior. Thomas introduces the concept of the homeostatic system. When applied to cultural groups, this concept can be considered a mechanism that monitors the value of a regulated variable, compares the value to a known standard, and in an identification of a divergence between the regulated value and the known standard, provides for its adjustment to a point of homeostasis. Just as Sahlins and Service (1960) present a perspective on cultural adaptation in a context of cultural-environmental equilibration, so can the concept of a culturally-adaptive homeostasis be considered relevant to this research.

The prehistoric cultures of the Pacific Northwest very possibly were faced with new and unpredictable environmental stresses when volcanic eruptions occurred. Depending upon the nature of the environmental impacts imposed by these geological processes, cultures might have been affected to a degree requiring the implementation of adaptive changes in order to maintain their way of life. With a consideration of the concepts discussed above, an investigation into the archaeological record may be conducted.
CHAPTER 4

THE POST-GLACIAL ERUPTIVE HISTORY OF MOUNT ST. HELENS

During the Late Pleistocene and Holocene periods, Mount St. Helens has been the most active volcano in the Cascade Range, producing multiple tephra layers from seven periods of explosive eruptive activity over the last 13,000 years (Mullineaux and Crandell 1981; Mullineaux 1986). Mullineaux (1986) describes the eruptive events from Mount St. Helens, which have occurred over the last 13,000 years. Description is limited to those deposits corresponding with eruptions producing a minimum Dense Rock Equivalent (DRE) of 0.001 km³. Distal tephra deposits are associated with many of these eruptions, identified within and beyond the Pacific Northwest. Many smaller eruptive events occurred at Mount St. Helens and have not been identified by Mullineaux (1986) as distinct layers or beds. Instead, only those events considered hazardous to human populations if they were to occur today, in conjunction with the DRE volumetric minimum, have been identified by Mullineaux (1986) and will serve as an acceptable working standard for this thesis. The major eruptive periods from Mount St. Helens to be discussed here have been compiled in a Table and are covered in greater detail below.

Beginning with its first recorded period of activity 40,000 to 50,000 years ago, Mount St. Helens has generated not less than 60 tephra layers (Mullineaux 1986), multiple lahars and other mass-movement events, and a DRE measured at ca. 60 km³. In the scope of this thesis, eruptions are to be compared with available archaeological data; limited to the last 13,000 years.
<table>
<thead>
<tr>
<th>Years B.P.</th>
<th>Eruptive Period</th>
<th>Mt. St. Helens Eruptions</th>
<th>Distal Tephra Layer</th>
<th>Igneous Mineralogy</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Goat Rocks</td>
<td>T (150 B.P.)</td>
<td>T</td>
<td>Dacite</td>
</tr>
<tr>
<td>200</td>
<td></td>
<td>X (&lt;468 B.P.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300</td>
<td></td>
<td>W (470 B.P.)</td>
<td>Wn, We</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>Kalama</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td></td>
<td></td>
<td></td>
<td>Andesite</td>
</tr>
<tr>
<td>600</td>
<td></td>
<td></td>
<td></td>
<td>Dacite</td>
</tr>
<tr>
<td>700</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>800</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>900</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1200</td>
<td>Sugar Bowl</td>
<td>D (1200 B.P.)</td>
<td></td>
<td>Dacite</td>
</tr>
<tr>
<td>1300</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1400</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1500</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>Castle Creek</td>
<td>B (1620 B.P.)</td>
<td></td>
<td>Mafic Andesite, Andesite, Dacite, Basalt</td>
</tr>
<tr>
<td>2500</td>
<td>Pine Creek</td>
<td>B (2220 B.P.) to P (2450 B.P.)</td>
<td>P?</td>
<td>Dacite</td>
</tr>
<tr>
<td>3000</td>
<td>Smith Creek</td>
<td>Y (2930 B.P.) to Y (3510 B.P.)</td>
<td>Yb, Yn, Ye</td>
<td>Dacite</td>
</tr>
<tr>
<td>3500</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4500</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5500</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6500</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11000</td>
<td>Swift Creek</td>
<td>J (10710 B.P.) to S (12910 B.P.)</td>
<td>Jy, Jb</td>
<td>Dacite, Andesite</td>
</tr>
<tr>
<td>12000</td>
<td></td>
<td>S?</td>
<td></td>
<td>Dacite</td>
</tr>
</tbody>
</table>

Table Late Pleistocene and Holocene eruptive history of Mount St. Helens (adapted from Mullineaux [1986:18])
Swift Creek Eruptive Period (ca. 13,000 to ca. 10,000 years B.P.)

Following a dormant period of about 5,000 years, Mount St. Helens produced several explosive eruptive events marked by pyroclastic flows and extensive distal tephra-fall deposits. The pyroclastic air-fall events are divided into eruptive sets J and S. Set S represents the initial tephras, dating at ca. 12,900 years B.P. Closely thereafter, set J tephras are observed beginning at <11,550 years B.P. continuing until a time <10,700 years B.P.

Smith Creek Eruptive Period (ca. 4,000 to ca. 2,900 years B.P.)

Following the Swift Creek eruptive period Mount St. Helens is quiet for almost 6,000 years. The volcano resumes activity again some time after 3,900 years B.P. producing multiple tephra-fall, pyroclastic flow and lahar deposits. This eruptive period is noted for the wide distribution of Ye, Yn and Yb tephras.

Pine Creek Eruptive Period (ca. 2,900 to ca. 2,400 years B.P.)

Soon after the end of the Smith Creek eruptive Period, multiple eruptive events reoccurred, creating new pyroclastic flow, lahar, and tephra deposits. A small amount of dacite-based tephra (set P) was distributed in discontinuous deposits to the northeast of the volcano.

Castle Creek Eruptive Period (ca. 2,400 to ca. 1,620 years B.P.)

Shortly following the Pine Creek eruptions, Mount St. Helens experienced a set of geochemical changes: andesitic eruptive materials were
produced, quickly followed by successions of dacitic and basaltic eruptions; this andesite-dacite-basalt sequence occurred twice during the period. Among the other pyroclastic products correlated to this period, a tephra (layer Bo) was distributed as a limited deposit to the east-southeast of the mountain.

Sugar Bowl Eruptive Period (1,200 years B.P.)

This period is represented by dome-building activity and a lateral blast event, which produced tephra layer D. This tephra is largely limited to the flanks of the volcano with no significant distal deposits. Mullineaux (1986:18) provides a single radiocarbon date for tephra layer D at 1,200 years B.P. The length of this period is not fully stated and may be limited to this single tephra-producing event, with a hiatus before and after its eruption.

Kalama Eruptive Period (470 to >150 years B.P.)

This period produced two extensive distal tephras, one of which (layer Wn) has been identified as far away as Alberta, Canada. The other (layer We) is found to the east and southeast of the volcano. During this period, the size of the volcano increased to its state prior to the 1980 eruption. The second tephra, set X, has not been directly dated, but falls between the W set dates and the succeeding eruptive period.

Goat Rocks Eruptive Period (150 years B.P.)

The distribution of tephra layer T to the northeast marks the beginning of this eruptive stage, and represents the only tephra-fall event of this period.
The length of the Goat Rocks period is not provided by Mullineaux (1986:18); only a single dendrochronological date of A.D. 1800 is given to layer T (Yamaguchi 1983).

**Distribution of Mount St. Helens Tephras Within The Study Area**

By observing archaeological sites within a portion of the known distribution of Mount St. Helens tephra, some constructive insights may be gained. A good deal of work has been done to identify distal localities of Mount St. Helens pyroclastics, with the use of these sites in efforts to delineate the distribution of tephra. Since the accuracy of the plotted tephra-falls is only as good as the number of known tephra sites, maps of Mount St. Helens tephra-falls can only be taken to represent a minimum distribution, based on the level of data available at that time (Donal Mullineaux, personal communication 1994).

Various works concerning the distribution of Mount St. Helens tephras have been published (Crandell et al. 1962; Okazaki et al. 1972; Crandell and Mullineaux 1973, 1978; Mullineaux 1974; Mullineaux et al. 1975; Hyde and Crandell 1978; Shipley and Sarna-Wojcicki 1983). However, the most recent information published regarding the known loci of Mount St. Helens tephras has not been assimilated into a distribution map of tephra-falls.

Much work has been done to develop regional tephrochronologies and eruptive distribution patterns of pyroclastic materials within the Pacific Northwest (Bacon 1983; Fryxell 1965; Mullineaux 1986; Porter 1978, 1981; Stradling and Kiver 1986; Westgate and Fulton 1975; Wilcox 1965). The use of these reconstructions has been limited within the archaeological community, especially among those working on the Columbia River Plateau. Specific
eruptive events have been emphasized over others (e.g., Mazama), resulting in an incomplete view of their impact upon the region. This bias has prevented important questions from being addressed, as to the relationship prehistoric cultures shared with their environment under the impacts of multiple volcanic eruptive tephra-fall events. As well, a lack of regional synthesis is noted concerning this problem. With the limited view provided by site-level observation, a full understanding of the environment, as known by the inhabitants of the Pacific Northwest is incomplete and effectively inaccurate, even within the current limits of archaeological knowledge.

Within the study area, the most recent information regarding Mount St. Helens tephra falls has been complied (see Appendix) and is plotted in a distribution map (Fig. 3). This information is presented to increase the awareness of volcanic hazards within archaeological sites. The residence time of volcanic tephra in archaeological sites is variable. Natural and cultural processes may remove or alter tephra, eliminating or obscuring evidence of its past presence within the site. These processes may change the way archaeologists interpret cultural changes seen in the site and might cause the influences of Mount St. Helens tephra-falls to be overlooked as a source of environmental stress. This is why an accurate distribution of tephra-falls within the sampling transect is necessary; sites may fall within an inferred distribution of Mount St. Helens tephra-falls but lack any stratigraphic evidence of its presence at the site level. By utilizing a distribution map based on tephra localities, indirect evidence of volcanic impacts may be considered in a review of observed culture change within a site.

The residence of tephra within archaeological site stratigraphy is largely dependent upon factors of geomorphology and pedology. These factors
include (but are not limited to) environmental processes such as mass wasting (i.e., landslides), surface erosion during precipitation events, the movement of material by wind, amount of available soil water, degree of frost action, and the tendency of clay to crack when dry. Natural processes as these may alter the form of tephra deposits, removing evidence of their existance from the archaeological record of a site or area. Therefore, in areas where the winds of volcanic tephra are known to have covered, tephra may not be preserved or have been initially incorporated into the archaeological or stratigraphic record. The absence of tephra from deposits may cause the archaeologist and others to overlook the possible impacts volcanic eruptions might have had upon prehistoric culture.

By reconstructing the distribution of tephra-falls within the study area, foresight may be applied to archaeological research. As a predictive tool, the distribution of tephra from Mount St. Helens provides a means of identifying areas in which direct impacts might have occurred. Knowledge of the regional distribution of tephra allows for the expectation of possible influences from eruptive events; especially where evidence of volcanic material may be absent due to environmental factors. The application of tephra maps may help direct important research questions, addressing human interaction with volcanic events in the Pacific Northwest.

It should be noted that the tephra distribution in Figure 4, as applicable to others of its kind mentioned above, represents only a minimum estimation of the actual tephra-fall pattern. As new localities of Mount St. Helens tephra are reported, more accurate representations will succeed this distribution map, providing the next best estimation of the tephra-falls deposits.
Figure 3. Distribution of Late-Pleistocene and Holocene tephra from Mount St. Helens.
CHAPTER 5

MODELING IMPACTS OF VOLCANIC TEPHRA-FALLS UPON
PREHISTORIC POPULATIONS

In 1964, Harold Malde described several sources of what he termed "unfamiliar geologic processes". Largely important in this paper was Malde's discussion of the impacts volcanic hazards, namely gasses and tephra-falls, might have had upon prehistoric populations. Insight is given toward the direct effects volcanic events would have had upon plant and animal populations, upsetting ecosystemic relationships. Malde (1964:10-11) gives an apocalyptic view of the influence Mount Mazama might have had on prehistoric humans living in the vicinity of its eruptions ca. 6,600 years B.P. (Fryxell 1965):

Large ash falls must have been catastrophic for the early Indians. It was doubtless unimportant to them that vegetation eventually could recolonize an area devastated by an ash fall. What mattered was their inability to find food during the interim...

Besides damaging plants and foraging animals, the ash that washed into rivers and lakes probably exterminated most of the fish. The major rivers would have been roily with ash year after year, as the ash was progressively washed from the uplands. With food supplies dwindling, the Indians probably had to move elsewhere.

Malde also makes a call for archaeologists to assess the importance of volcanic events in the lives of prehistoric humans.

Judith Bense (1972) investigated a question of environmental influence, looking at the nature of cultural adaptation of Cascade peoples of
southeast Washington during the xeric conditions of the Altithermal period. Although not directly assessing human-volcanic interaction, the manner in which Bense chose to look at Cascade cultural assemblages provides a means of addressing the influence Mazama eruptions might have had upon cultural groups. Bense compared archaeological data from two sets of Cascade phase cultural assemblages: the pre-Mazama eruptive period and the period immediately following the Mazama eruption. Designed to act as a means of dividing the Cascade phase data into two sets for analysis, this method provided a first look at regional cultural-environmental interaction in light of volcanic hazards. Bense concluded that the two Cascade assemblages, pre- and post-Mazama eruption, failed to show any changes in technology, which is interpreted as a lack of adaptational response to the xeric climatic conditions of the Altithermal; i.e., things were not stressful enough to require cultural changes. Bense's conclusion, when extended, gives her indirect assessment of cultural response to the Mazama eruptions.

In 1991, Stephan Matz provided a model, which operationalizes the relationship between volcanic tephra-falls, ecosystems, and human populations. Matz' systemic model is provided in Figure 4, and is supported here as a means of understanding the effects of volcanic tephra-falls upon human populations:

To understand the effects of volcanic tephra on an ecosystem, a model of state factors is developed much as Jenny (1941, 1980) has done for soil systems. This state factor analysis is not a quantitative, but a qualitative and descriptive model of the factors that are important to an understanding of the effects a volcanic tephra-fall may have on an ecosystem. The equation is as follows:

\[ E_{fl, fa} = f(T, D, M, C, G, ...) \]

Where \( E \) stands for the effects on an ecosystem made up of floral (fl) and faunal (fa) subsystems. The effects on the
ecosystem (E) are a function (f) of the state factors time (T),
distribution of the tephra (D), material properties of the tephra
(M), climate (C), geomorphology (G), and possibly some as yet

To investigate the effect individual state factors might have upon the
model, variations of Matz' (1991) equation may be utilized emphasizing the
implications of any component within the ecosystem. For example, questions
regarding the effects that climate may have upon the ecosystem during
tephra-fall events may be directed in the following manner: \( E = f(C, t, d, m, g, \ldots) \).

Due to the original qualitative approach of Matz' (1991) model, it may
be difficult to quantitatively assess the presence of culture change among the
study sites. Matz attempted to test his model against archaeological data from
sites on the Lower Snake River in southeastern Washington in his Masters
thesis (1987). In his 1991 publication, however, Matz identifies some
problems inherent in testing such a systemic model. One of the greatest
problems lies in the lack of quantitatively expressed data, which satisfy the
state factors. As Matz's model is quantitative in design (concerning the
multivariate equation reviewed above) an adequate test of its fitness and
reliability is unavailable without complementary quantified data. Matz notes:

Such data can be derived from ecological, volcanic
hazards, and archaeological research...although the present state
of theory in each discipline may not allow unequivocal
interpretation of that data. As well, some data that are essential
to answering some of the research questions just do not exist

Matz (1991:97-99) continues his critical evaluation with further
conditions and recommendations for the model including the utilization of
Figure 4. Systemic model of tephra-fall impacts upon ecosystems (from Matz 1991:26)
strict chronometric control, ecological data, subsistence resource data, and information on subsistence technologies. Any changes registered in these components may be investigated in light of volcanic eruptions and their impacts upon cultures to provide an adequate evaluation of any observed changes and to assess degrees of causality.

Furthermore, as the nature of Matz' (1991) model is quantitative its solution requires data from the archaeological and paleoenvironmental records, which satisfy the state factors of his equation. Therefore, information must be gathered to account for the temporal context of both human and eruptive interaction, the geographic distribution of the tephra, the specific physical and chemical features of the pyroclastic materials, the meteorological conditions present during the tephra-fall event, the nature of the landscape upon which tephra is deposited, and so on. The state of archaeological research, although well on its way in developing valuable multidisciplinary investigative methodologies, has not arrived at a point where a quantitative understanding of the above cultural components may be derived from the archaeological record (Matz 1991:97-99).

A synthesis of southern Washington Cascades archaeology is presented by Lewarch and Benson (1991), and holds merit as a model for understanding prehistoric human adaptation to volcanically-active environments. The authors describe archaeological data from several sites near Mount St. Helens. Technological, functional, subsistence, and occupational patterns are investigated in light of the Holocene eruptive history of Mount St. Helens. This investigation has illuminated an occupational hiatus event among prehistoric sites between ca. 5,000 and 2,000 years B.P. (Lewarch and Benson 1991:38); a time coinciding with volcanic reactivation at Mount St. Helens.
The Nature of Archaeological Stratigraphy

Archaeological stratigraphy is considered here as that portion of the geologic record that retains information about human culture and the condition of their regional or global environment. This record, as applied to stratigraphy, is contained within the soils and sediments of a site; matrices providing a direct or indirect understanding of a culture’s past.

A working definition of soil is taken from Birkeland:

A soil is described as a natural body consisting of layers or horizons of minerals and/or organic constituents of variable thicknesses, which differ from the parent material in their morphological, physical, chemical, and mineralogical properties and their biological characteristics; at least some of these properties are pedogenic (1984:3).

The development of a soil is assumed to follow the formation factors, as defined by Jenny (1994), outlined later in this chapter.

Sediments are defined as, “...the solid inorganic and organic particles, accumulated or precipitated by natural or human processes” (Waters 1992:15). Natural processes of sedimentary deposition are:

(1) The mechanical accumulation of solid particles by processes such as flowing water, wind, and gravity; (2) the chemical precipitation of layers of crystals from constituents (e.g., ions and oxides) dissolved in water; (3) decomposition and accumulation of organic material; and (4) the production and deposition of material from volcanic eruptions: (Waters 1992:15-16).
Sediments deposited through the actions of humans are termed *archaeosediments* (Butzer 1982:77-79), and may include the disposal of shells to form a midden, the dislocation and redeposition of natural sediments during the excavation of housepit foundations, or the creation of charcoal lenses through the repeated use of a firepit.

As is the nature of stratigraphic interpretation in archaeology, the sediments observed at the site may not always provide a complete picture of paleoenvironmental conditions present during prehistoric occupation. In an attempt to gain an understanding of the past environment, archaeologists have relied upon a range of multidisciplinary fields, including, palynology, geomorphology, paleobotany, volcanology, glaciology, and zooarchaeology, to name but a few. These other fields serve to offer the researcher a more holistic view of paleoenvironmental data present in the archaeological record.

Interpreting the archaeological record and its inherent clues of past environmental conditions is often limited to that which can be seen or extracted from the site matrix. However, a great deal of information is found beyond the contents of a site, telling the story of past environments. This information can be found in the prehistoric behavior of local glaciers, or in the oscillations of pollen production—proxy clues to the larger picture of paleoenvironmental conditions.

Researchers have often failed to utilize available sources of paleoenvironmental data to reconstruct the past environment. Too often has the archaeologist failed to look beyond the site, unable to recognize that important evidence of regional environmental events are not present within the matrix of the test pit. Through natural processes, tephra deposited at the
site may have a relatively short residence time within the stratigraphic record. Without an adequate view of the paleoenvironmental conditions of a research area—particularly the influence of volcanic eruptive events within the Pacific Northwest—a full understanding of the forces acting upon the adaptive relationship shared between prehistoric cultural groups and their surroundings is denied.

A brief introduction of processes responsible for the removal of volcanic tephras from an archaeological context, or their *in situ* alteration within the site matrix follows. This discussion is designed to increase awareness of the possible transitory nature of volcanic tephra within the archaeological record.

**Systemic Modeling of Processes Affecting Tephra Deposits**

Tephra particles can be viewed from the principles of sedimentology: once delivered into the atmosphere during an eruption, tephra becomes a sediment (Twenhofel 1939:3). As an aeolian sediment, tephra enters into many potential geomorphic situations as it is deposited across the landscape. Each deposit-forming situation inherently influences the way in which tephra is incorporated into the stratigraphic record and determines its locality from the original point of air-fall deposition. To best consider the forces acting upon pyroclastic material after settling from the atmosphere, a systemic model has been developed to provide a means of discussing tephra-inclusive depositional mechanics (Fig. 5).

When pyroclastic material settles to the earth its future as a sediment will vary. A drainage system model will be proposed for the sake of the
following discussion.

Within our hypothetical drainage system, a tephra-fall has blanketed the entire landscape. The fate of the tephra sediments within this drainage initially depends upon the point of air-fall deposition. Following along in the systems diagram provided in Figure 5, it can be seen that in some regards, the ensuing processual effects acting upon the blanketing tephra may come from a multiplicity of geomorphic, pedological, biological, or even cultural sources. Within our hypothetical drainage, any given quantity of tephra material may: settle out at the bottom of a tributary drainage along a terrace as colluvial material; be washed into a stream, and carried along its course out into the ocean; incorporated into a glacier’s mass, to eventually be redeposited within glaciofluvial stratigraphic facies; or deposited on a flat ridgetop, to be included within a slow progression of pedological development, to name but a few possible futures. The point made here is that within a world system, there are many influences that serve to transport, incorporate, change, remove, and otherwise alter the formation of tephra strata from its original blanketing deposit into any future state, as later seen by the archaeologist. The nature of the tephra deposit may be influenced to some degree by geomorphic and pedological processes. These processes may change the original material properties of the tephra, or alter its stratigraphic integrity, making later efforts to correctly identify the identity and origin of the tephra very difficult.

Within the systems model (Fig. 5), those compartments denoted by a heavy black line box are considered to be potential static states of sediment deposition, observable in the archaeological and stratigraphic record. The arrows represent transfer functions from one state to another, in a singular direction. Within some areas of the model, certain compartments share what
Figure 5. Systemic model of tephra-inclusive depositional mechanics
seems to be an infinite loop, with transfer functions exclusively leading to and from each. The loops are included to illustrate those processes that may influence a static state through a multiple event process, eventually changing its previous condition to another.

For example, the Pedological Development with Altered Tephra compartment shares such a loop with the Turbation compartment. This loop function identifies that the dynamic process of turbation is to be considered a device that may alter the manifestation of tephra within soils, while allowing pedological development to continue. The cycle may occur many times, with a return to the static compartment of Pedological Development with Altered Tephra, without compromising its static nature. Such transfer relationships are of little worth in the bigger picture of this model and have been kept to a strict minimum.

The importance of this model lies in its ability to illustrate the many futures of tephra materials once settled to the earth. This model has been developed to increase the awareness of archaeologists working in areas with the potential for the deposition of volcanic material. Although the model is somewhat detailed, it should be used as a general guide for the consideration of tephras and the depositional environment; no model can ever be entirely inclusive of its subject matter, and stand as a definitive work. As archaeologists and others continue their work, this model may be expanded to incorporate new ideas, or to enhance specific viewpoints of the archaeological record.

**Epistemological Considerations**

The aspect of stasis, as applied within this model, does not include
tephra within a dynamic geomorphic process. More precisely: to be considered within a static state, tephra material must be at rest (i.e., not in transit from one point to another) during any given observation of the archaeological or stratigraphic record. As it is impossible to directly observe the dynamics of glaciofluvial deposition, or mass movement events within the archaeological record, such active processes are not investigated here in detail. Rather, an emphasis is placed upon the static manifestations of the archaeological and stratigraphic record; by nature, archaeological investigation of past process is rooted in the interpretation of the static record (Schiffer 1987). With a consideration of the Uniformitarian Principle, we may be satisfied that processes affecting tephra material operated in a manner at any given time as we understand them to behave in modern analogous environments (Bates and Jackson 1984:546). This allowance gives freedom for a greater consideration of the statics of this systemic model.

The Depositional System of Eruptive Tephra

The term *tephra* is used to describe those solid materials that are ejected into the air away from a volcanic crater during an eruption (Thorarinsson 1974). Due to geochemical and geophysical factors, the specific nature of the volcanic eruption determines the type, magnitude, and behavior of the pyroclastic materials produced. The creation of tephras, which are placed into and later settle out of the atmosphere, is contingent upon the presence of conditions specific to the volcano's eruption. Magmatic tephras are produced during the eruption of a gas-charged melt, created by rapidly expanding volatiles such as H₂O during a stage of
decompression (Chester 1993:117). Within the volcano, volatile-rich magma undergoes decompression as it moves closer to the surface (Fig. 6). At this point, the highly viscous nature of the magma hinders the distribution of bubbles throughout the rest of the molten rock. The bubbles accumulate towards at the surface of the magma in a frothy horizon, and continue to form within the melt. As the frothy component approaches about 75% of the original magmatic volume, critical changes occur. The violent action of the froth creates fragments and gasses, which escape through the vent, releasing the pressure built up during initial behavior within the volcano. The fragments, propelled into the atmosphere by the gasses, cool and form solid pyroclastic particles; tephra is simply a pyroclastic particle of very small size (Kittleman 1982).

Those eruptions that produce air-fall tephras are termed *Plinian* and initially place the pyroclastic material high into the Earth's atmosphere through columns of eruption debris following explosive eruptions, and also as a result of sub-aerial clouds produced by pyroclastic flows (Kittleman 1979:52; Wright et al. 1980:317). Plinian eruptions introduce fine particles of pyroclastic material into the atmosphere at greater altitudes, while coarser particles are released at lower elevations to accumulate closer to the vent (Chester 1993:115). From this vertically extended column of tephra particles and gas, prevailing winds move the pyroclasts horizontally at its same velocity and direction.

Gravitational influences, often coupled with atmospheric precipitation, will cause the finer pyroclastic materials to settle out across the landscape in
Figure 6. Diagrammatical model of eruption dynamics (from Chester 1993:116)
accordance to prevailing winds (Kittleman, 1979:55-56, 1982) forming a blanketing deposit on the landscape below (Wright et al. 1980:317). This process of tephra-fall produces distinct deposits identified in the geologic record. The thickness of these deposits have a direct correlation with distance from the volcano: larger particles and greater quantities of pyroclastic material accumulate near the vent, while the smallest materials come to rest farthest away from the eruptive source in thinner deposits (Minakami 1942; Walker et al. 1971; Wilson 1972).

The nature and shape of this tephra deposit is correlative with the velocity and direction of the winds during the eruption. Winds that maintain a consistent directional bearing produce narrow tephra deposits; longer or shorter depending upon the strength of the wind. Broadly distributed deposits are the work of multi-directional wind patterns. The chance of eruptions producing broader instead of narrower deposits has much to do with the duration of the eruptive event. Eruptions spanning a longer time may be influenced by winds in various directions, causing a broader pattern of tephra-fall (Kittleman 1979:56-62). Inherently, the size and distribution of a tephra deposit from any one eruptive event is partly contingent upon the duration of the eruption and the amount of pyroclastic material ejected from the volcano.

In the context of this thesis, only those air-fall tephra deposits originating from explosive eruptive columns will be considered. This process is overwhelmingly responsible for the creation of distal deposits of volcanic air-fall material in the Pacific Northwest. Other processes including pyroclastic flows and other forms of subaerial pyroclastic transport will not be included in this investigation, as their resultant deposits are largely limited to
the flanks of the volcano.

The Material Properties of Tephra

Based upon their relative proportions of a glass, mineral, or rock inclusion, the material properties of tephra are defined and their source volcano identified (Kittleman 1979:63-78). Mount St. Helens tephra has been analyzed and classified to provide a detailed understanding of its physical and chemical characteristics (Czamanske and Porter 1965; Randle et al. 1971; Smith and Leeman 1982; Smith et al. 1977; Theisen et al. 1968). By understanding the inherent difference among the Mount St. Helens tephra, and between those pyroclastic products from other sources, the known history and distribution of volcanic material in the Pacific Northwest may be put to use in archaeological research (e.g., Butler 1962a; Fryxell and Daugherty 1962).

Post-depositional processes influence volcanic tephra in ways corresponding with their material properties. The size of any given pyroclastic particle present within our hypothetical drainage is dependent upon several factors. First, the height in the atmosphere at which the pyroclastic material was initially placed largely determines the relative distal deposition of the tephra (Chester 1993:115). The atmospheric injection process is controlled by the force of the gas jet expelled during the eruptive event. An eruptive event with a more powerful expulsion of gas, will produce an eruptive column of greater height. This directly proportionate relationship is further modified by the strength of prevailing winds upon the eruptive column. The continuity and strength of wind will determine the relative distal emplacement of pyroclastic particles. The combined amount of
tephra produced and the height of atmospheric placement, coupled with the strength and directional continuity of prevailing winds provide the deterministic factors responsible for the distribution of distal tephra-falls.

Pyroclastic particles forming distal tephra-fall deposits are almost always of a extremely small (i.e., colloidal) size. As explained earlier, gravitational forces and other environmental and eruptive factors work to displace larger particles from their atmospheric emplacement rather quickly. Thus, in most sites beyond the Cascade Range, the consideration of colloidal particles is most relevant.

Once deposited upon the earth, tephra particles respond to geomorphic processes in slightly different ways, based upon their material properties. Particles larger than tephra size will often contain air trapped inside of vesicular cavities. These cavities allow pyroclastic particles to float when introduced into bodies of water. Smaller particles without the benefit of flotation may become quickly incorporated into the load of a river or eventually sink to the bottom of a lake or pond. The flotation will last until the vesicular cavities become filled with water, after which the particle sinks. Water-borne pyroclastic particles may be later deposited as overbank deposits, or as any other alluvial sediment.

Chemical weathering processes affect different mineralogical products unequally. The mineralogical suite of any tephra particle may be subject to differing rates of chemical and physical weathering dependent upon its specific environment. The degree to which the mineral components resist weathering also plays an important role (Birkeland 1984). Given a depositional environment with a strong weathering regime, tephra minerals with low resistance to weathering will be affected relatively rapidly, causing
the alteration of the original structure and composition of the tephra material. The converse is true as well, with the relative resistance to weathering providing a degree of mineralogical longevity to the original tephra material.

**Geomorphic Influences Upon Post-Depositional Tephra**

Geomorphic processes represent a dynamic aspect of tephra incorporation into the stratigraphic record. Therefore, it is important to understand the basic mechanics of geomorphic action within the post-depositional system. In the context of the systemic model in Figure 5, geomorphic processes play several important parts, all of which serve to transfer tephra material between one state of rest to another. Aspects of weathering, also considered within the realm of process geomorphology, have been included within the pedological cycle in this model.

Rather than embark on a lengthy digression of the totality of geomorphic processes potentially affecting post-airfall tephra, a simple solution is presented here. The wide range of mechanisms that may serve to physically remove tephra from one depositional context to another are identified under a universal title: *Geomorphic Transport Mechanism* (GTM). This is acceptable as the important concepts investigated here comprise aspects of material stasis, not dynamic. Therefore, the actual geomorphic mechanism responsible for the transferrence of tephra from one depositional context to another is somewhat irrelevant. For a complete appreciation of the universe of geomorphic processes considered within the GTM cell, the reader is referred to Butzer (1976) and Ritter (1986).
Pedological Influences and Volcanic Tephras

The classic equation outlined by Jenny (1994:15-20) is of particular importance to our understanding of how the processes of soil formation are to be considered as factors for the in situ alteration of tephra. Jenny's equation outlines the environmental components that work to alter sediment into soil:

\[ S = f(c_l, o, r, p, t, ...) \]

Within this equation, \( S \) represents the soil, which is presented as a function of the following factors: \( c_l \) denotes the effects of climate; \( o \) the organic material; \( r \) the applicable relief or topography; \( p \) the parent material; \( t \) the progression of time; and \( ... \) as some undetermined factor.

This equation was developed to account for the factors responsible for the formation and development of soils, and can be used to solve for each particular component. Although the scope of this investigation is not to consider the formation of soils, but to understand the factors present within pedological systems affecting the physical and stratigraphic integrity of post-airfall tephra deposits. An application of Jenny's equation may be used in a slightly altered form to pose specific questions regarding the affects each component has upon tephra deposits:

\[ \Delta T M = f(c_l, o, r, p, t, ...) \]

With \( \Delta T M \) representing the dependent degree of material change within a pedologically-inclusive tephra deposit from its state of original incorporation, the remaining factors in this equation are the same as Jenny's
The consideration of this model, in the same regards as the classic pedological application, may be used to investigate the manner and extent in which tephras are altered by ongoing soil formation processes. These factors are considered the pedological mechanisms responsible for \textit{in situ} change in the material or stratigraphic integrity of tephra deposits. By identifying the dynamics of tephra alteration in a pedological context, the state in which tephras are observed in an archaeological context may be better understood. However, as the nature of soil formation and general pedogenetic processes are understood (Jenny 1994; Birkeland 1984; Brady 1990) digression into this topic will be avoided, and the further products and considerations of \textit{in situ} tephra alteration will be provided.

Tephra, when introduced into a pedological context, is considered to play an initial role as parent material, to some degree. As a parent material, tephras are subjected to weathering processes and based on their relative intensity and duration, may serve to alter the volcanic material.

Investigations into the degree of weathering among Mount St. Helens tephras have been made. King (1986) reports on the weathering of Mount St. Helens Y tephra from a locality in the southern Canadian Rockies, Jasper National Park, and Banff National Park. The tephra were recovered from both secondary depositional (e.g., alluvial fan formations, and alluvial deposits) and primary pedological contexts. Laboratory analyses revealed that weathering processes had produced several identifiable mineralogical products, including hydrous mica and chlorite. The tephra was also beginning to show evidence of being broken down into a fine clay substance (King 1986).

The weathering of tephra to clay is an act of material reduction and
represents one of the more dominant processes occurring during pedological development, along with the transportation of mineral particles in soil water (Birkeland 1984:95). This weathering cycle of mineral dislocation and leaching (i.e., transport), coupled with other processes of material reduction (e.g., the creation of clay minerals), makes the mineralogical identification of tephra layers difficult. Given enough time and an active weathering environment, tephra materials may become altered, broken down and/or scattered throughout the profile to a degree limiting or prohibiting the identification of the mineralogical components.

Bioturbation and Other Sources of In Situ Tephra Disturbance

Turbation within tephra deposits can come from several biological sources. A common source of ground disturbance results from the dislocation of soil or sediment during tree-falls (Malde 1964:11-12; Waters 1992:306-309). High winds, flooding, or any other force which serves to topple a tree from its upright position may cause the removal of the root wad and its inclusive earth. In some cases, this creates a dislocated profile as the soil or sediment is churned and the stratigraphic integrity is often destroyed in the area affected by the tree-fall.

The work of burrowing or digging animals may also cause the stratigraphy of tephra deposits to become obscure, or in the case of thin bedding, remove any trace of the tephra. The influence of earthworms has been reported by Stein (1983).

Frost heaving, or cryoturbation, works to displace soil or sediment through the growth of ice crystals in the stratigraphic matrix (Schweger 1985).
Inclusive tephras within cryoturbated soils are displaced from their previous stratigraphic context.

The actions of shrink-swell clays like vermiculite introduce a degree of pedoturbation into the matrix. As soils dominated by these clay minerals (called vertisols) lose their water, the clay structure greatly contracts, producing vertical cracks in the profile. Through contraction, objects and sediments within the soil are vertically displaced. Upon wetting, the clay minerals expand to a great size, causing the matrix of the soil to move internally (Waters 1992:299-300). This process would destroy stratigraphic tephra features by scattering the pyroclastic material throughout the matrix. Even though these latter processes do not remove the tephra from the soil, they compromise the stratigraphic integrity of their deposits.

Cultural Disturbance

Although the impacts caused by cultural disturbance of the landscape are included within the systemic model, they will not be considered in detail here. It is important to recognize the potential that cultural mechanisms have for the disturbance of tephra deposits when investigating archaeological stratigraphy. Many cultural impacts do not affect tephras on a site-wide scale. However, major impacts to tephra deposits can occur with agricultural development of the land. Tephras found in the plow zone will have been incorporated into the wider matrix of the soil, thereby changing the appearance of the original deposit. Thicker deposits, or those with coarse-grained materials, may retain some of their initial characteristic features.
Discussion

The effects of geomorphic, pedological, biological, and cultural processes upon post-airfall tephras are considered in the presentation of a generalized systemic model. The simple identification of processual effects upon incipient tephra-fall deposits provides a means of articulating the multiplicity of factors responsible for the incorporation, alteration, removal or otherwise changing of tephra from a primary depositional state to an observed state in the archaeological record.

Many of these processes can disrupt the original air-fall deposition of tephra, even following incorporation into a pedological profile. Processes working to dislocate and redistribute tephra material compromise the stratigraphic reference of tephra profiles, and hinder their visual identification in the field. Methodologies for the identification of dislocated tephra particles within a sedimentary matrix have been developed, and serve to assist with the problem of profile disturbance (Takemura and Danhara 1994). This process, although helpful, cannot recreate the necessary stratigraphic and contextual control desired in archaeological research. Instead, its use allows for a more general means of establishing tephrochronological reference within a disturbed profile.
Volcanic Aerosols and Climatic Forcing

Debris produced during explosive volcanic events may be deposited into the atmosphere as aerosols, increasing the optical depth, or the logarithm of light transmission through the atmosphere (Toon and Pollack 1982). Aerosols can effectively scatter and absorb incoming solar radiation. The amount of radiation an aerosol particle may absorb or reflect is dependent upon the inherent albedo of the particle, its asymmetry, and the optical depth of its layer (Ackerman 1988). Aerosols with weak abilities to intercept solar radiation will generally scatter incoming radiation back into space. This reduces the solar energy input to the earth and results in atmospheric and terrestrial cooling. This increased reflecting ability (i.e., albedo) of the atmosphere is a result of the individual size, optical depth and position of the aerosols over the earth. Smaller particles tend to reflect more incoming solar radiation than do larger particles at the same optical depth, increasing planetary albedo rates. However, there is a limiting factor within this relationship. Due to some hindering mechanism, increased optical depth by any given aerosol will improve global albedo to a finite level.

When assessing the effects eruptive events will have on the atmosphere, it is important to identify the composition of the ejected material. Different volcanic materials injected into the atmosphere will have distinctive effects as agents of atmospheric perturbation. Volcanoes can introduce two types of atmospheric products, based on their original
geochemical composition: pyroclastic particles of silica (e.g., tephra); and
gaseous sulfate species, which may condense through chemical reactions in
the stratosphere (Fig. 7).

It has been shown that basaltic-andesitic and andesitic magmas tend to
possess high levels of dissolved sulfur. Other volcanic melts comprised of
dacite or rhyolite tend to produce explosive plinian-type and ignimbrite
eruptions with large volumes of silicate material in the form of pumice and
tephra; usually these are lacking significant levels of volatile sulfur
(Rampino and Self 1984b; Rampino et al. 1988:79; Devine et al. 1984:6310).
High sulfur content has been identified from the dacitic pumices from Mount
Pinatubo and is thought to have been present within the silicic magma prior
to eruption (Bernard et al. 1991; Imai et al. 1993). Crystals bearing oxidized
species of sulfur (SO₃) in relatively high quantities are reported within Mount
Pinatubo pumice and point to the presence of magmatic SO₂ prior to mineral
crystallization. The quantity of sulfur retained within the pyroclasitic mineral
suite implies that a high amount of sulfur was available within the magmatic
melt and subsequently introduced into the atmosphere during the eruption.

The effect that silicic and sulfur-rich eruptive materials have upon
global albedo levels can be similar in magnitude but different in longevity,
due to the behavior of each as an atmospheric aerosol. Volcanic dust injected
into the stratosphere during adequately explosive eruptions form an aerosol
layer, which settles out by aggregational grades; larger particles first, followed
by finer tephras. As these particles fall into the troposphere they are rapidly
removed from the atmosphere by precipitation. The injection of volcanic
tephra into the stratosphere affects the global albedo (Fig. 8) by its residence as
an aerosol layer and has been attributed corresponding changes in global
Figure 7. Diagrammatical model of eruptive aerosol production
Solar Radiation Input

Radiation Reflected

H$_2$SO$_4$  H$_2$O  H$_2$SO$_4$  H$_2$O  H$_2$SO$_4$  H$_2$O

Surface

Net Effect: Reduced Surface Temperatures

Figure 8. Volcanic aerosols and global albedo: net climatic effects
temperature during the several months thereafter.

Sulfur gasses emitted from volcanic eruptions take the form of sulfur dioxide (SO₂) and also as hydrogen sulfide (H₂S), which is changed to SO₂ through oxidation. Upon entering the stratosphere, sulfur dioxide reacts with hydroxyl (OH-) radicals present as a result of photodissociated atmospheric water vapor (water vapor may also be present as a product of the eruption as well). This coagulated form of SO₂, now found as gaseous sulfuric acid (H₂SO₄), forms an aerosol by its subsequent condensation on colloidal dust particles, which may be volcanic in origin, or on available ions or small groups of molecules. This process may be lengthy, with a recognized conversion of volcanically-emitted sulfur into aerosols occurring weeks or months after the initial injection event (Rampino et al. 1988:79). This process is also regenerative, with new sulfuric aerosols created and deposited in the stratosphere for some time following injection (Rampino and Self 1984b:79).

As mentioned above, an important difference between sulfuric acid and volcanic ash aerosols lies in their relative residence times in the stratosphere where they may contribute to increases in global albedo. Sulfuric aerosols are found in the stratosphere at submicron sizes and remain there for a few years (Toon and Pollack 1982) scattering and absorbing solar radiation. This suggests that the influence of sulfur aerosols may be more significant than comparable quantities of silicate ash aerosols, when measured as effective albedo components. This will be addressed through a comparison of the effects of both aerosol types provided by a review of climatic changes following the eruptions at Mount St. Helens in southwest Washington, and El Chichón in southern Mexico.
Climatically-Effective Eruptions: Analogous Case Studies

Mount St. Helens erupted in May of 1980 and was given a Volcanic Explosivity Index (VEI) rating of 5 (Newhall and Self 1982:1237), which is an assessment of its eruptive magnitude or explosive character. Although the Mount St. Helens eruption extruded a DRE of 0.35 cubic km, it produced little in the way of stratospheric effects following the initial eruption.

El Chichón erupted between the end of March and April of 1982 and was assigned a VEI rating of 4 (Rampino and Self 1984a:677). Its explosiveness was, as its low VEI rating suggests, not very remarkable. Producing DRE quantities similar to St. Helens (ca. 0.3 to 0.35 cubic km), El Chichón released a large amount of volcanic material into the stratosphere. Ash and gases sent into the atmosphere were widely distributed as an aerosol cloud. This initially extended completely around the globe in a latitudinally restricted path. Through time, the aerosol was spread over the entire Northern Hemisphere and much of the Southern Hemisphere.

Chemically, the eruptions of Mount St. Helens and El Chichón differ on some important points. The tephras from Mount St. Helens are classified as a dacite composition, while those from El Chichón are labeled as andesitic (Hoffer 1986). The El Chichón tephras contain less silica than the Mount St. Helens materials. Sulfur levels, reported by Lipman et al. (1981), comprise 1.0% of the tephra weight in the El Chichón samples and 0.03% in the Mount St. Helens materials.

The aerosol clouds produced by the Mount St. Helens and El Chichón eruptions were measured at the Mauna Loa Observatory in Hawaii through the application of the lidar (light detection and ranging) system (Rampino and Self 1984b:55-57), which records the amount of light emitted from a laser
pulse emitted back to the instrument, quantifying atmospheric densities. These atmospheric densities are taken to represent relative levels of atmospheric aerosols. Although the Mount St. Helens eruption produced a higher VEI and similar DRE, the El Chichón event registered atmospheric density 140 times greater.

The information presented here shows that the measurement of an eruption event's VEI and DRE may fall short of predicting the effect the resulting aerosols will have upon global albedo. Instead, as many authors argue, (Pollack et al. 1976; Rampino and Self 1982) sulfur-laden, not silicate-rich, aerosol clouds may be the factor deciding the magnitude and extent of atmospheric backscattering and climatic effects.

Mean surface temperatures show a correlated relationship with sulfur materials produced during volcanic eruptions (Fig 9), further adding strength to the relationship between sulfur aerosols and climate change. Since decreases in surface temperature may be directly attributed to increased atmospheric backscattering, a link between increased atmospheric sulfur aerosols introduced by explosive eruptions and the degradation of surface temperatures may be made (Devine et al. 1984). With an understanding of the potential volcanically-introduced sulfur aerosols hold as an agent of climatic forcing the scope of this discussion can be shifted towards what is known about climatically effective volcanism during the late Quaternary through a look at evidence from glacial ice.

**The Late Quaternary Record of Volcanic Activity**

The glacial ice record from Greenland and Antarctica preserve evidence of volcanic eruptions, which can be measured and correlated to
Figure 9. Correlation between observations of volcanic sulfur production and climatic forcing (from Devine et al. 1984:6320)
yearly depositional events within the ice (Dansgaard et al. 1985; Legrand and Delmas 1987). The materials deposited in the glacial ice record immediately following volcanic eruption events largely consist of sulfates (SO$_4^{2-}$) settled on that season's snow layer (Herron and Langway 1985:77-84). Unlike sulfates, volcanic tephras do not clearly document eruptions since they occur in small amounts difficult to discern from other atmospheric particles. Regardless, tephras have been recorded in Antarctic ice cores with some success (Gow and Williamson 1971; Palais et al. 1990). The detection of volcanically-produced SO$_4^{2-}$ may be accomplished through an identification of its characteristic acidity within glacial ice. This occurs by measuring increases in specific conductivity, or peaks in voltage as an electrical current passes through a sample (with acids registering voltage differences at ~1,250 V) (Hammer et al. 1980:231). Other processes involve the analysis of all major ions through an ion chromatography process. By separating out the quantities of the major soluble impurities in the glacial ice, it is possible to calculate the amount of SO$_4^{2-}$ in each core sample (Legrand and Delmas 1987:671), thus providing a control for any errors that may result from the former method.

After establishing an accurate rate of ice accumulation, a history of volcanic activity may be built. This chronologic work may be cross checked on a shorter time scale with great accuracy due to the use of historically documented volcanic events and through comparisons with radiocarbon dated eruption deposits. Legrand and Delmas (1987) report the use of known volcanic events and the observed SO$_4^{2-}$ record as a means of establishing a chronological correlation, providing insight into the accuracy of assumed accumulation rates.
including the Crète and Camp Century ice cores from Greenland, which have been patched to give a record of the past 10,000 years. The Crete core covers the time period between the present and A.D. 553, with an accuracy established at ± 1 yr for the last 900 years and at ± 3 yr for the remainder of the record (Hammer et al. 1980:231). The Camp Century core covers the remainder of the time series between the end of the Crete core and the 10,000 year level. The two cores are not perfectly matched however, with a gap of ~510 years between the two as a result of poor ice conditions, hindering the reliable measurement of acidity. The annual accumulations of ice in the Camp Century core have been correlated with isotope records and are ~98% accurate for the period between 2,000 to 10,000 years B.P. (Hammer et al. 1980:233) (Fig. 10).

By measuring the increased level of acidity in the ice layers, a chronology of sulfur-producing volcanic events can be tracked. Due to the northern location of the ice cores, the relative intensity of each observed acidity signal may be contributed more to the immediacy and latitude of the eruptive source in relation to Greenland. To account for this, Hammer et al. (1980:231-232) explain that through measurements of fallout occurring after Soviet atomic testing in 1962, taking into account the magnitude of the explosion and the total fallout received in the Greenland ice cores, it may be possible to estimate the magnitude of the volcanic sulfur injected into the atmosphere from the recorded levels of acidity. The acidity record of eruptions occurring in lower latitudes should be adjusted by a given factor (multiplied by 2 or 3) to account for the dispersion of the aerosol during its northward journey to Greenland.

An eruption failing to produce significant amounts of atmospheric
Figure 10. Greenland ice core record of volcanic activity (from Hammer et al. 1980:234)
sulfur will not appear in the ice core record, but will be lost in the ever-present background noise of other sources. Background acidity from various global sources lies at 1.25 ± 0.1 μequivalent H+/kg within glacial ice records (Porter 1986:33). Thus, the presence of volcanic acidity is noted by an increase in H+ ions in amounts greater than 0.00000125 parts per kilogram of ice.

With an appreciation of the effects that sulfuric aerosols have upon global albedo, it can be said that sulfur-poor eruptions, although measurable within glacial ice, may be inconsequential due to their low potential for climatic influence. It is assumed then that acidity peaks exceeding 1.25 ± 0.1 μequivalent H+/kg represent eruption events that may have had significant climatic impacts. These impacts might have specifically manifested as lowered surface temperatures, due to the efficient backscattering abilities of sulfur aerosols.

Paleoclimatic Implications of Volcanic Eruptions

Volcanic aerosols reduce the amount of solar energy that reaches the earth, due to their ability to reflect radiation back into space. This inhibited input of solar radiation will bring about reduced temperatures at the earth’s surface. Eruptions of differing magnitude will produce optical depths sufficient to affect surface temperatures. Pollack et al. (1976:1079) have stated that large eruptions may produce optical depths of 0.3 to 0.2 (for comparison: atmospheric purity, lacking any aerosols or other particles, lies at 0.0), at several places on the earth for a number of months; after which optical depths of 0.1 may follow for a year or more. Pollack et al. (1976:1080) explain that the increases in optical depth required to lower tropospheric and surface
temperatures by 1°K is about 0.12, as a result of atmospherically-injected volcanic aerosols.

The above estimates concern volcanic eruptions on a limited event basis. Explosive volcanic activity producing significant atmospheric aerosols, maintained over a long period of time, may decrease mean surface temperatures enough to stimulate feedback mechanisms. As lower temperatures at the earth’s surface are maintained, the amount of high altitude snow and glacial ice may increase significantly. This, in its own right effects a large increase in the already aerosol-enhanced albedo due to the high reflectivity of ice and snow surfaces (Fig. 11). Quantitatively, this increase in global reflectivity could produce decreased surface temperatures by a factor of four (Pollack et al. 1976:1081).

During the change from the Pleistocene to the Holocene, great temperature shifts on the order of ca. 5° K occurred, marking the change from a glacial to an interglacial environment (Pollack et al. 1976:1082). Kennett and Thunell (1975:501) have asserted, after an observation of volcanic events in the late Quaternary, that increased eruptive activity contributed to increases in global ice and snow cover seen during the last glaciation may have promoted its existence through a reduction in mean surface temperatures. Benthic cores collected on a global scale have yielded a record of volcanic eruptions during the last two million years, occurring as ash layers within the oceanic sediments. This record shows a great increase in volcanic activity during the Quaternary Period (Kennett and Thunell 1975).

Volcanic ash layers have been identified in Antarctic ice cores (Palais et al. 1990). As explained earlier, deposits of ash do not signify, in and of themselves, significant climatic effects as a result of their volcanic eruption.
Figure 11. Feedback loops: a model of climatic effectiveness
Figure 12. Comparison between the Antarctic volcanic tephra record and paleotemperature data (from Gow and Williamson 1971:215)
However, they can be a useful record of eruption events regardless of their effects. Figure 12 shows a productive comparison between the Antarctic volcanic ash record and the paleotemperature record of the last 75,000 years; the correlations seen between the two data sets are interesting. The largest record of volcanic ash fall occurs at about the peak of the Late Wisconsin glaciation (Kennett and Thunell 1975). Effects produced by this period of intense volcanic activity cannot be linked with the onset of the last glacial advance but may have augmented the lower temperatures present at the time. Pollack et al. (1976:1082) support the view that Late Quaternary increases in volcanic activity, as recorded in benthic sediments, is direct evidence for its significant role in climate changes observed during the Late Wisconsinan glacial period.

Pollack et al. (1976:1082) point to the fact that the high number of eruptions observed during the Late Wisconsinan glacial period could have, as a result of simple probability, occurred at an interval that would have maintained any degradation in the climate occurring as a result of eruptive aerosols. That is, the eruptions may have been spaced out in a way that by the time the volcanic aerosols from one event were settling out of the atmosphere, a new eruption produced a new set of aerosols preventing climatic recovery.

Summary

Sulfur particles introduced into the atmosphere during explosive volcanic eruptions have important effects upon global albedo levels due to their inherent abilities to backscatter incoming solar radiation and maintain optical perturbation for a longer period of time than other volcanic aerosols
(e.g., tephra). The resulting drop in tropospheric and surface temperature may increase global ice and snow cover, quadrupling the level of global albedo.
CHAPTER 8
VOLCANIC ERUPTIONS, GLACIAL ICE, AND PALEOENVIRONMENTAL RECORDS OF CLIMATE

Describing a model of rapid glacial growth developed by Flohn (1974) and Ives et al. (1974), Bray (1976:414) identifies the ability of volcanic aerosols to reduce global temperatures as a precursor to ice accumulation. Porter (1981) addresses the relationship between volcanic eruptions and the rapid growth response of glacial ice, and in a later paper (Porter 1986), stresses the importance of volcanic aerosols as a primary forcing mechanism on climate, corresponding to advances in glacial ice such as seen during the Little Ice Age.

In this thesis, emphasis has been placed upon the investigation of the regional eruptive impacts of Mount St. Helens. Climate systems in the Pacific Northwest are not independent of the rest of the global system, however, and require a global view to fully appreciate the effectiveness of volcanic eruptions as forcing mechanisms of regional climate. Moreover, the eruptions of a single source should not be viewed independent of other contemporaneous volcanic events, nor implications made without their inclusion.

Hammer et al. (1980:230), and Porter (1981:139, 1986:43-44), have stressed that climatic impacts produced by volcanic eruptions should be viewed as a "build-up" event within this process. Eruptive aerosols are atmospherically loaded through successive closely-spaced injections, bringing about resultant changes in global albedo and providing conditions necessary for other feedback mechanisms including suppressed global temperatures, necessary for the progressive growth of glacial ice.
The Glacial Record of Volcanic Eruptions

Hammer et al. (1980) provide a record of ice-acidity from the Crête core, taken from central Greenland (Fig. 13), which have been correlated with eruptive sources. As discussed earlier, the sulfuric component of volcanic eruptions, when incorporated into the geologic record as atmospheric fallout on ice sheets, provides a history of global volcanism. When this acidity curve is compared with the fluctuations of glacial ice on a global scale, important correlations are presented. Porter (1986) provides a comparison between this acidity record and glacial records since A.D. 500 (Fig. 14). In this, we can see that the acidity peaks are not only indirectly correlated with advances of mountain glaciers, but a lack of volcanism is associated with the interglacial conditions reported during the Medieval Optimum. Observations made at greater lengths of time from the Camp Century ice core (Johnsen et al. 1992) show additional positive correlations between the record of volcanic eruptions, and sulfuric acid levels glacial ice (Hammer et al. 1980). These correlations are presented in Figure 14, providing interesting insight for the interpretation of past Pacific Northwest climates from a global perspective.

The eruptive history of Mount St. Helens (Mullineaux 1986) shows two eruptive periods closely associated with acidity peaks in the Greenland ice record. The Pine Creek eruptive period has been dated at ca. 2,450 years B.P., immediately followed by the Castle Creek eruptive period dated from ca. 2,220 to >1,620 years B.P. The Castle Creek eruptive materials have been noted to be composed of mafic andesitic, andesitic, dacitic, and basaltic rock. The Camp Century acidity peaks in question are observed at 2,210 and 2,160 years B.P. (listed in Fig. 14 as 260 and 210 B.C., respectively), which closely correspond with the Castle Creek eruptive period. With an andesitic and basaltic rock
Figure 13. Greenland record of volcanic acidity from the Crête core (from Hammer et al. 1980:230)
Figure 14. Correlation between the Greenland record of ice acidity and glacial fluctuations in the northern hemisphere (from Hammer et al. 1980:235)
type, the potential for the creation of sulfuric aerosols is likely. Although these correlations to not necessarily prove that the Castle Creek eruptions from Mount St. Helens are identifiable in the record of global ice, the prospect is interesting.

The other Mount St. Helens eruptions of the last 12,000 years should also be addressed in light of the Greenland ice core data. Although Hammer et al. (1980) do not identify the eruptions of Mount St. Helens as a source of observed acidity in the ice core records, Porter (1986) makes reference to their importance in climatic forcing and the resultant growth of mountain glaciers in the northern hemisphere.

Comparisons made between the acid-producing volcanic eruptions identified by Hammer et al. (1980) (Fig. 15) and the history of Mount St. Helens eruptions shows some overlapping events. The most significant of the correlations comes during the Smith Creek eruptive period. This time is contemporaneous with two eruptions in Iceland and the explosion of Mount Thera in the Mediterranean, which is suggested as having accelerated the decline of the Minoan culture (Fagan 1992:532). For a point of regional reference the two Icelandic eruptions, Hekla 3 and 4, and the event at Mount Thera, contributed almost three times the amount of volcanic acid to the Greenland ice record than did the Mazama eruptions. Additionally, the former two sources produced effects for a period of about 1,500 years.

The fact that potential volcanic acidity from the Mount St. Helens eruptions have not been formally identified within the Greenland ice core records is somewhat understandable, with the possibility of other eruptions closely occurring in time. The acidity signal from Mount St. Helens eruptions during the Smith Creek eruptive period may be incorporated into signals
Figure 15. Greenland record of ice acidity from the Camp Century core (from Hammer et al. 1980:234)
interpreted as from another source, or might have lacked enough sulfur to register within the Greenland records. If insignificant levels of volcanic acidity were produced during the Smith Creek eruptive period, the corresponding atmospheric injection of large quantities of silicate material has been recognized as distal tephra lobes in western North America. Although the atmospheric residence time of silica particles is much less than acid aerosols, their presence would increase global albedo, if only for a limited time. This albedo enhancement, synchronized with other acid-producing eruptions, would surely add to the overall effects on global climate.

**Volcanic Acidity and Climatic Forcing: Proxy Data**

A 9,000 year record of glacial SO$_4^{2-}$ and volcanic eruptions is provided by Zielinski et al. (1994). In observation of the comparison between SO$_4^{2-}$ peaks and temperature variation in the northern hemisphere, there is a direct negative correlation between the two records. The temperature curve shows an inversely proportionate relationship with SO$_4^{2-}$ deposition. This suggests that post-glacial warming trends seen in the northern hemisphere were repressed for a period of time, possibly by the production of sulfuric aerosols. Of course, the entire variability of the temperature record presented here cannot be reasoned to have been exclusively the result of SO$_4^{2-}$ generation. The actual cause for shifts in climate are likely to be the result of a complex series of forcing events and feedback mechanisms. However, the strong correlation seen here is presented as a priori evidence for the importance of volcanic eruptive events in the post-glacial paleoclimatic record.

Porter (1986) identifies a correlation between the Greenland acidity
record of volcanic eruptions and the recent history of global glacial fluctuation. He notes that increasing levels of acidity in the ice record predate glacial advance by a lag time of ca. 10 years and "are associated with a rise of acidity to or above a value of 2.4 μequiv H+/kg from a level equal to or below the background level of 1.2 μequiv H+/kg. This rise of ≥ 1.2 μequiv generally occurs within a period of a decade or less" (Porter 1986:33). As volcanic eruptions introduce sulfuric aerosols into the atmosphere, the acidity fallout is incorporated into the ice record for about ten years, adding its H+ value to the already-present background levels. This decadal generation of sulfuric acid is likely resultant from the process of regenerative aerosol generation, discussed earlier.

This increase in acidity, when found to rise above the background levels by a factor of two, is noted to precede an advance in glaciers on a hemispheric scale (Fig. 16 and 17). This record of glacial advance is taken to show the climatic effectiveness of volcanic eruptions, with a corresponding drop in temperatures in the northern half of the globe. Porter (1986:43) proceeds to illustrate that this correlation is quite strong, as reported advances in northern hemispheric glaciers during the period between A.D. 500 A.D. and A.D. 1600 are shown to have occurred only after acidity values rose above background levels by a factor of two; a phenomenon singularly identified as a result of volcanic eruptions during this time period.

Another source of proxy data is found in the record of tree-ring width in upper timberline forests. These forests are sensitive to changes in temperature, with colder climates registering a reduced ringwidth for that year. Louis Scuderi (1990) has provided a comparison between the dendrochronological sequence of trees in the Sierra Nevada mountains of
Figure 16. Volcanic aerosol formation and the precedence of glacial activity (from Porter 1986:35)
Figure 17. Volcanic production of atmospheric sulfur and the Little Ice Age (from Porter 1986:43)
California and the acidity records from Greenland ice cores. His approach shows ringwidth reduction in correspondence with increased volcanic sulfate deposition in Greenland ice. Investigations similar to Scuderi’s (1990) work should be conducted in the Cascade Range of the Pacific Northwest as a test of validity and to provide a greater understanding as to how regional and global volcanoes have affected the environments of the Pacific Northwest.

The eruption of the W tephra set from Mount St. Helens has been noted to precede increases in water level at Wildcat Lake, interpreted as a shift in climate (Davis et al. 1977). The Greenland ice core record (Fig. 13) (Hammer et al. 1980) shows an acidity peak correlating to the production of the Wn tephra dated at A.D. 1480 (Mullineaux 1986). Other small amounts of volcanic acidity are present in the ice core between A.D. 1400 and A.D. 1450 and may correlate with the andesitic-based tephra set X, which is stated to have closely followed the W set eruptions (Mullineaux 1986).

Proxy Data Revisited: Problems and Considerations

Problems exist within the interpretation of proxy climatic data, especially in the analysis of ice cores. The best records from glacial ice come from the latitudinal extremes of the planet, due to the colder temperatures there. However, global air circulation favors the latitudinal distribution of volcanically-produced materials, and is slower to spread aerosols evenly across the globe. As this is the case, eruptions in the Northern Hemisphere deposit more material in ice sheets on the same half of the globe, creating a bias in the record of eruptive magnitude there (Simkin 1994).

Although bias in hemispheric aerosol distribution presents a problem in understanding the global climate record, data on climatic change might be
more precise when viewed from a latitudinal and/or hemispheric perspective. Rampino and Self (1984b:53-55) show that the atmospheric loading process following the volcanic eruption of El Chichón spread first in response to general latitudinal circulation patterns. Within a year, volcanic aerosols were observed to have scattered throughout the entire Northern Hemisphere and much of the Southern Hemisphere. This observation serves as a working analogy for evaluating the relative impacts of volcanic eruptions within a given hemisphere. With an extended residence time within its hemisphere of origin, volcanic aerosols should be expected to have a greater and longer climatic influence there. Thus, climatic affects seen in the Pacific Northwest following eruptions of Mount St. Helens might also be experienced in other areas along a given range of latitude, and lessened with atmospheric circulation.
Central to an understanding of the environment in which prehistoric populations interacted, adapted, and changed is the climatic history of the Late Pleistocene and the Holocene periods. In the past, Pacific Northwest archaeologists have embraced a general model of climatic succession developed by Ernst Antevs (1955), outlining a three-part Neothermal climatic succession for the western United States.

In his Neothermal model, Antevs (1955) identifies three environmental stages: (1) the Anathermal—immediately following the end of the glacio-pluvial maximum, is noted as a time of cooler temperatures and wetter climates than that seen today; (2) the Altithermal—correlated with warmer and drier climatic conditions than present; and (3) the Medithermal—characterized by an amelioration from the aridity of the prior Altithermal period, with climates similar to modern conditions.

This model was developed from data gathered in the Great Basin of the western U.S. Thus, extrapolation of this model to the Pacific Northwest, especially in regards to its temporal details is problematic. Alan Bryan and Ruth Gruhn argue that this model can only be applied to areas outside of the Great Basin after important work has been done to show a correlation with the model’s climatic and chronological sequence:

Clearly the archaeologist must be aware of the fact that the terms Anathermal, Altithermal, and Medithermal are useful only as a convenient way portions of the climatic curve... Furthermore, the dates for these phases must be determined independently for each ecological area. But it must be stressed that, as the actual climatic effects of temperature oscillations
must be expected to vary with latitude and altitude and with particular physiographic and meteorological conditions, any climatic conditions inferred for one area during a particular phase of the temperature curve cannot be projected elsewhere even to a neighboring area. The actual climatic condition in all cases be determined by independent means for each ecological area (1964:314)

In consideration of Bryan and Gruhn’s comments, it is hard to justify the application of Antevs’ model as a primary framework for understanding the paleoclimatic record of the study area. Therefore, the paleoclimatic record of the study area will be presented through a review of proxy environmental data, as reported from regional pollen cores and glacial stratigraphic records.

The Paleoenvironmental Record of the Study Area

Although the existence of the three part climatic curve is accepted in the paleoenvironmental record of the West, the regional timing of each phase is not, explain Bryan and Gruhn (1964:309). To provide a regional-specific record of environment spanning the time between the immediate post-glacial period to the present, the data reported from several pollen cores within Washington and Idaho will be given here.

Wildcat Lake

Located near the confluence of the Palouse and Snake Rivers in southeast Washington (Fig. 18). This coring site has produced a record of pollen fluctuation spanning the last 1,000 years, as reported by Davis et al. (1977) (Fig. 18). During this period, grass and pine populations dominate the paleoenvironmental record. Mount St. Helens W tephra is noted in the
pollen core, followed by what the authors have interpreted as increased lake levels. This interpretation is derived from a reduction in aquatic plant species, which require higher levels of salinity than offered in deeper lakes. The authors state that as lakes become deeper, and dilute the available saline in the water, the floral productivity will decrease, and do so here. An overall decrease in organic matter contributed to the sediment core in the period immediately following the W tephra-falls.

In further comment the authors explain:

Since Wildcat Lake occupies a basin of closed drainage, it seems likely that the greater lake depth was produced by greater effective precipitation. The lack of major changes in terrestrial pollen frequencies prior to the introduction of grazing indicates stability of the vegetation contributing pollen to Wildcat Lake (Davis et al. 1977:26).

It appears that the apparent changes in precipitation following the W eruption did not affect terrestrial pollen producers much at all in this area.

Two radiocarbon dates are provided from the pollen core: The first, 400 ± 60 years B.P. at 1.57--1.85 meters deep; and the second, 900 ± 70 years B.P. at 3.21--3.29 meters deep. These two dates are separated by 1.36 meters of sediment, which, assuming a constant rate of sediment accumulation, works out as 0.272 cm of deposition per year. By dividing the total depth of cored sediments (4.0 meters) by the reported length of time represented by the record (1,000 years), a simple estimate of deposition rates may be attained for Wildcat Lake (deposited sediments = ca. 0.4 cm per year). These calculations do not take into account any effects that may compromise the depositional rate of erosion, and assume a continuous rate of sediment accumulation through time (although a discontinuous rate is shown between the total core
Figure 18. Map of pollen core sites reported within the study area

1. Wildcat Lake
2. Fargher Lake
3. Carp Lake
4. Creston Mire
Figure 19.
Record of pollen values through time at Wildcat Lake (from Davis et al. 1977:22)
and the dated segments). By averaging the calculated depositional rate for the total pollen core (0.4 cm/year) with the rate of deposition of the segment between the bracketing dates (0.272 cm/yr), an estimate of the length of time represented by the climatic change observed after the W tephra-fall may be attained (mean rate = 0.336 cm/year).

Utilizing the above estimates, the inferred period of increased lake levels (i.e., heightened rates of precipitation) begins immediately after the introduction of the W tephra at 1.55 m in core depth and continues until the return of plant species favoring shallower and more moderate conditions at 1.00 m. The calculated difference between these two events is 0.55 meters, or 163 years. This represents a rough estimate, as the exact length of time is uncertain. However, the implications for a climatically-effective eruption remain strong even if the actual number is less than the calculated 163 years.

If Davis et al. (1977) are correct and a regional increase in effective precipitation did occur immediately following the W tephra eruption, then the climatic changes seen at this site might be extended to the entire study area. Other pollen cores throughout the study area must be reviewed to determine whether they hold the same post-W tephra pollen assemblage and decrease in organic matter seen at Wildcat Lake, denoting rising lake levels due to increased effective precipitation. Since Wildcat Lake is interpreted as a relatively shallow and salty water body prior to the eruption of the W tephra, the mechanism of environmental change is clear in the aquatic conditions and the plant populations they sustain.

Pollen cores are needed from sources shallow enough to support indicator plant species prior to the eruption of the W tephra. If the water bodies were already of sufficient depth to be unproductive for salt-loving
aquatic plants at the time of tephra deposition, then the post-W tephra changes reported by Davis et al. (1977) will not be noted, even if water levels do rise in accordance with increased precipitation in that area. The amount of organic material introduced into the sediment record may not show changes with increased water depth if already affected by such factors.

**Fargher Lake**

A pollen core is reported from Fargher lake the southwest of Mount St. Helens and to the north of Battleground, Washington, on the immediate western edge of the Cascade Range (Fig. 18). Heusser and Heusser (1980) present this post-glacial record of paleoenvironment and climate to 7,000 years B.P. An increase in pine, alder, and fir is seen between ca. 10,000 and ca. 7,000 years B.P., while other species including spruce, grasses, composites, and mountain hemlock decline (Fig. 20); interpreted as a wet and cool climate.

Average summer temperatures and yearly precipitation levels increase after 10,000 years B.P. Precipitation levels reach a plateau and then begin an oscillating decline to pre-10,000 year levels by ca. 7,000 years B.P.; temperatures maintain an increase through this time period, however.

As much of this pollen sequence falls outside of the range of applicable time considered in this thesis, correlations between climate and the post-glacial eruptions of Mount St. Helens will be therefore limited.

**Carp Lake**

Cathy Barnosky (1984) has derived a continuous environmental history of the Late Pleistocene and Holocene periods spanning the last 33,000
(Heusser and Heusser 1980:1008)

Record of pollen values through time at Parfet Lake (from

Figure 20.

![Diagram of pollen values through time at Parfet Lake](image-url)
Figure 2.1 
Record of pollen values through time at Carp Lake (from Barmosky 1965:114-115)
years, from a pollen core (Fig. 21) located in the southwestern portion of the Columbia River Plateau (Fig. 18). Between 23,500 and 10,000 years B.P., the Carp Lake pollen record shows the presence of a periglacial environment, with an overwhelming presence of grass (Gramineae) and sagebrush (Artemisia) pollen. This assemblage is interpreted as representative of a steppe or tundra landscape. Trees are not shown to be in much quantity through most of this time. However, Barnosky states that spruce species most likely expanded their range at mountain altitudes after 13,500 years B.P. To the north of the lake, the development of a pine parkland followed the retreat of the glaciers between 12,000 and 9,500 years B.P. This immediately preceded a period of grassland or steppe domination in the southwestern Columbia Basin.

From 10,000 to 8,500 years B.P., pollens denoting the establishment of a warmer and wetter environment increase in the Carp Lake vicinity, during a period of lake lowering. This warming period continued until about 8,500 years B.P. Following 8,500 years B.P., an increase in Ponderosa pine, Grand fir, Douglas fir, and Oak populations, signal a return to wetter and cooler climates in the area.

Between 8,500 and 0 years B.P., Barnosky addresses the pollen frequency of aquatic plant species in Carp lake, but only briefly: "The aquatic flora is quite diverse and undergoes rapid changes that probably reflect fluctuating water level and chemistry" (1985:116). Establishing a chronologic control from which these fluctuations may be compared with the eruptive history at Mount St. Helens is difficult. The available radiocarbon dates extend back only as far as 5,820 years B.P., however, Barnosky identifies lithologic units within the record which provide further chronological reference. The
presence of Mount St. Helens Y tephra (Ye layer dated at ca. 3,000 years B.P.--Mullineaux 1986:page) is noted in the Carp Lake pollen record at 1.02–1.04 meters below surface, while the end of lithological unit 2 is placed at 0.50 meters below surface, and given a date of 1500 years B.P.

Creston Mire

Mack et al. (1976) report a pollen core taken from a mire near the town of Creston, in southeastern Washington (Fig. 18). Their core shows a succession of two major periods of pollen dominance (Fig. 22). From a time following the eruption of Glacier Peak tephra (with an age listed here between 12,000 and 13,000 B.P.), as seen in the sediment core, sagebrush pollen declines over a 4,000 year period. Spruce, and fir pollens also show a reduction in their relative importance in correlation with sagebrush pollens. Pine species maintain their presence with a slight decline, and grass (Gramineae) pollen increase during the same period. Mack et al. (1976:page) describe this pollen assemblage as similar to that seen in modern forests of the central Rocky Mountains. The extension of this analogous vegetative suite produces insight into the temperatures contemporaneous with Zone I pollen, suggesting the presence of a cool and wet climate of steppe environments between ca. 12,000 and 9,390 years B.P. The high proportion of sagebrush and haploxyylon pollen is similar to pollen records from Yellowstone park during this time. The Yellowstone pollen is interpreted as having been within a subalpine or alpine vegetation zone (Mack et al. 1976). Mack et al. (1976:page) interpret the pollen assemblage from Zone I to represent a mosaic pattern of vegetation with both forested and sagebrush-grassland areas.

The beginning of Pollen Zone II, closely corresponding with a
Figure 22. Record of pollen values through time at Creston Mire (from Mack et al. 1976:392)
radiocarbon date of 9,390 ± 480 years B.P., shows the replacement of
diploxylon pine pollen for haploxylon pine pollen, along with the decline in
sagebrush, spruce, and fir pollens. Chenopod pollen maintains its presence
well in Zone II, while Sarcobatus shows irregular attendance in the record.
The authors state that “Pollen Zone II, moreover, resembles modern surface
spectra collected at many steppe localities in the Columbia Basin, where
arboreal pollen attains 50% of the pollen rain” (Mack et al. 1976:395).

Thus, Pollen Zone II represents a time of increased warming in the
Columbia Basin. Mack et al. (1976:page) are able to link their Pollen Zone II
with Hansen’s (1955) Thermal Maximum period through a correlation of
conclusions regarding a warmer and drier climate, and the stratigraphic
presence of Mazama tephra. A fitness between the two is suggested to some
degree, but is inherently weak without commensurable radiocarbon dates on
Hansen’s part. The upper portion of the Creston Mire pollen record is
reported to have been disturbed and is therefore suspect in reference to any
attempts to compare pollen fluctuations with tephra falls.

The Geomorphological Record of Climate Change

In his description of Quaternary stratigraphic units within the Lower
Snake River drainage of southeastern Washington, Hallett Hammatt
(1976:118) provides discussion regarding geomorphic response to climate
change. Over the last 10,000 years, two periods of alluvial aggradation are
noted within the Lower Snake River canyon: the early alluvium from 10,000
to 8,000 years B.P.; and the middle alluvium from 4,000 to 2,500 years B.P.;
each comprising terrace deposits (high and low, respectively). The early
alluvial deposition is closely contemporaneous with glacial advance in the
Rocky Mountains during the Pinedale Stade (Richmond 1960; Birkeland et al. 1971). Middle alluvial deposition is closely contemporaneous with the Neoglacial Temple Lake advance of the Rocky Mountains (Richmond 1960; Birkeland et al. 1971).

Two major periods of erosional activity are noted to occur during times of glacial retreat in the Rockies after ca. 8,000 years B.P. and after ca. 2,500 years B.P., resulting in the abandonment of the high and low alluvial terraces. Of this, Hammatt states:

Both alluvial aggradation and terrace abandonment can be chronologically related to glacial pulsations in the Rocky Mountains. On this basis it is suggested that the regimes and alluvial cycles of the Snake River have a predictable relationship to the glacial pulsations, and that these pulsations are ultimately controlled by regional climatic change (1976:119).

Archaeological investigations in the Kootenai River valley of northern Idaho (Mierendorf 1984) provide a working study of prehistoric adaptation and interaction with changing fluvial landscapes. Paleosols representing landforms adequate for prehistoric occupation are seen in the stratigraphic record of Kootenai River fluvial deposits. Cultural occupation, however, is associated with stable abandoned floodplain surfaces, and not with these paleosol formations. The former are described as “ephemerally stable surfaces between successive floodplain depositional episodes” (1984:20). Thus, human occupation in the Kootenai River valley is limited to periods of fluvial downcutting, and absent during times of flooding and fluvial accretion.

Comparisons are made by Mierendorf (1984) between archaeological sites within the Kootenai River valley and two other sites: Marmes Rockshelter, on the lower Snake River; and the Hatwai site, along the lower
Clearwater River. These two sites were chosen due to the presence of older human components in association with below-floodplain landforms; close to the baselevel of their relative rivers.

In comparison, Mierendorf (1984) regards the differences in post-glacial rates of fluvial incision through valley fill between the Snake and Kootenai River systems. The Snake River adjusted to the introduction of post-glacial valley fill by attaining a near-modern baselevel faster than the Kootenai River, which experienced a longer period dominated by accretion processes. The differences between these two geologically active environments has important cultural implications: fewer stable landforms were offered for humans occupation within the Kootenai River valley than in the Snake River and Clearwater River. Thus, prehistoric settlement of the Kootenai River Valley was limited by active geologic processes.

This discussion is offered as a basis from which riverine adaptions observed in the archaeological record should be observed. When investigating the manner of cultural adaptation along river courses in the study area, due reference should be given to the influences that geomorphic processes present for settlement patterns. This means that a given cultural sequence viewed in reference to climate changes, for example, may not be seen as a direct adaptation to shifting temperatures but rather to alterations in the fluvial behavior of the area. The accommodation of environmental systematics is tedious as the influential components in any given area are numerous and their interrelationships complex (see Matz 1991). However, the incorporation of geomorphic processes and their implications for prehistoric human settlement is a necessary step in understanding the archaeological record of the study area.
Summary

The environmental record of the last 10,000 years as interpreted from pollen cores show a sequence which has been simplified into three parts: (1) an early Holocene period with cooler and moister climates; (2) mid-Holocene with a change to warmer and drier conditions; and (3) late Holocene, showing a shift back to cooler and moister conditions.

Peter Mehringer (1985:167), provides a clear summary of the post-glacial paleoenvironmental progression in the Columbia River Plateau. Prior to 9,000 years B.P., temperatures in the Columbia River Plateau began to rise, accompanied by a developing steppe environment. Although a warming trend was occurring, the presence of steppe environments represented by pollen assemblages, is considered a paleoclimatic indicator of cold and dry conditions. Changes in the vegetation patterns begin 2,000 years later, with a domination of steppe communities by invading sagebrush and shadscale populations. This trend continued until 5,400 years B.P. where it began to slow. By 4,000 years B.P., the sagebrush and shadcale gave way to cooler and wetter climes and the Columbia Plateau was reoccupied again by steppe species.
CHAPTER 10
CULTURAL CASE STUDIES: AN OVERVIEW

The Culture History of the Study Area

To provide an archaeological record of human interaction with Holocene environments in the study area, cultural-historical models are reviewed here from Nelson (1969) for the Middle Columbia River Basin, Leonhardy and Rice (1970) for the Lower Snake River Canyon, and Sappington (1994) for the Clearwater River Drainage. These cultural succession models will be reviewed and later compared with paleoenvironmental proxy records in Chapter 11.

The Prehistoric Record of the Middle Columbia River Basin

Charles M. Nelson (1969:6-100) provides a chronological description of cultural phases encountered during the excavation of the Sunset Creek site (45KT28), located on the west bank of the Columbia River, near the town of Vantage, Washington.

The Vantage Phase: The Vantage phase, adapted from Swanson (1962a) represents the earliest cultural occupation at the Sunset Creek Site, placed between 9,000 and 6,000 years B.P. The artifacts associated with the Vantage phase characteristically fall into two forms: stemmed and leaf-shaped lanceolates. Large leaf-shaped bifacial knives also coexist within this tradition, as do various scraper styles, utilized flakes, and microblades.
**Cold Springs Phase:** This designation is defined by Butler (1961), and originates from sites with reported Cold Springs phase components, including: the Cold Springs site (35UM7) (Shiner 1961); Three Springs Bar (Nelson 1969:26); Windust Caves (Rice 1965); Marmes Rockshelter (Fryxell and Daugherty 1962); 45CO1 (Nelson, 1966); Thorn Thicket (Nelson 1969:27); Weis Rockshelter (Butler, 1962a); and at Meyer's Caves (Bryan 1955). A lower limiting date is provided for the Cold Springs phase, by stratigraphic occurrence directly above Mazama tephra dated at ca. 6,700 years B.P. (Fryxell 1965). Nelson (1969:27) provides an estimated upper date at ca. 4,000 years B.P.

This phase is noted for the presence of the Cold Springs Side-Notched projectile point. Other projectile point forms are found to be associated within this phase, including various lanceolate styles. However, unnotched lanceolates are but a small inclusion, with the Cold Springs point remaining as the type determination of the phase. Nelson (1969:27) mentions that this point is also referred to as the Bitteroot Side-Notched projectile point in other areas of the Pacific Northwest. Other artifacts associated with the Cold Springs tradition include: atlatl weights; burins; utilized flakes; mano and metate; the mortar and pestle; and other assorted bone tools.

**Frenchman Springs Phase:** This phase is associated with Swanson's (1962a) definition from 45KT28 and occurs between 4,000 and 2,750 years B.P. Several projectile point styles are associated with this phase, ranging from stemmed (in which Nelson [1969:29] identifies Rabbit Island Stemmed points), and leaf-shaped, to triangular, semi-triangular, and lanceolate styles. Nelson (1969:34) explains that the Frenchman Springs phase is inclusive of many point styles and may best be identified by the presence of the Rabbit
Island Stemmed point. Other artifacts associated with this tradition include: a relative frequency of knives; several scraper styles; utilized flakes; gravers; microblades and microblade cores; drills; cobble tools; and core tools; bone points; other bone tools; hopper mortar bases and stone grinding slabs.

Quilomene Bar Phase: This cultural tradition is established from material recovered from the Sunset Creek site (45-KT-28) (Nelson 1969:34), and occurs between 2,750 and 1,950 years B.P. The phase is defined mainly by the presence of Quilomene Bar Base-Notched points and the utilization of semi-subterranean housepit structures and other artifacts including: a triangular projectile point/preform; bifacial knives; many kinds of scrapers; gravers; a possible microblade; core tools; a utilized basalt spall; an abundance of utilized flakes; cobble tools; and assorted bone points and tools. As Sunset Creek is the type site for the Quilomene Bar Phase, Nelson (1969) does not provide a great deal of insight into the depth of this cultural tradition, as comparisons with other sites in the region are not made.

Cayuse Phase: Succeeding the Quilomene Bar phase, this tradition is divided into three subphases—Cayuse I, II, and III—ranging from ca. 1,950 years B.P. to the historic period (Nelson 1969:47). Within this span of time, the Cayuse subphase divisions are poorly defined. Notably, this phase is associated with larger site occupations, increased amounts of cultural material, and features including semi-subterranean housepit foundations. This phase has been widely identified throughout the Columbia River Plateau, with site size and population density reaching the greatest proportion thusfar.
Cayuse phase sites are commonly found in association with lakes, streams, and on the floodplains of rivers. In these places, areas offering shelter from the elements are most desired: "This feature appears to be related to the necessity of establishing winter camps and villages in climatically favorable microenvironments near reasonably large winter food supplies, especially game animals such as deer and elk" (Nelson 1969:43). Nelson (1969:43) emphasizes the establishment of winter villages as an important part of this phase, and although thought to be present in earlier cultural traditions, this settlement pattern is now quite visible in the archaeological record. The presence of coastal mollusk shell species shows the development of trading economies within the region. An increase in fish exploitation and its relative importance within the Cayuse phase is argued, based on the apparent increase of fish remains and specialized tools for the harvesting of this resource. Nelson (1969:51-52) also draws parallels to the ethnographic history of the Sanpoil and Nespelem reported by Ray (1954). Ultimately, the Cayuse phase prevailed until the middle of the 1800's with the firm establishment of Euroamerican settlement in the region and the cultural impacts that followed.

The Prehistoric Record of the Lower Snake River Canyon

In an effort to construct a working cultural chronology in the tradition of Willey and Phillips (1958) and Chang (1967), similar to that developed by Nelson (1969), Frank Leonhardy and David Rice (1970) proposed a typology incorporating data from sites excavated in the Lower Snake River Canyon. Leonhardy and Rice (1970) provide a chronology of cultural phases based on work at Windust Caves (Rice 1965) and Marmes Rockshelter (Fryxell
and Daugherty 1962; Rice 1970). Further work on the collections from Marmes Rockshelter (Rice 1970) and Granite Point Locality I (Leonhardy 1970) provided more data.

*Windust Phase:* The Windust phase represents the earliest known culture in the Lower Snake River Canyon sub-region and are typified by an artifact assemblage including “projectile point forms with relatively short blades, shoulders of varying prominence, principally straight or contracting stems, and straight or slightly concave bases” (Leonhardy and Rice 1970:4). Uniface and biface projectile points also occur in a lanceolate form but in uncommon quantities. Other lithic tools include: a variety of large lanceolate and oval knives; end scrapers; burins; utilized flakes; cobble tools; tabular flakes and prismatic flakes derived from polyhedral cores.

The Windust peoples primarily hunted large game like elk, deer, and antelope, secondarily exploiting other smaller animals such as rabbit, beaver, and river mussel. At the time of writing, Leonhardy and Rice (1970) were unable to provide any insight into the plant foods utilized in the Windust phase, lacking archaeological data. Radiocarbon dates have placed the beginning of the Windust phase at ca. 10,000 years B.P. and its end sometime between 9,000 and 8,000 years B.P.

*The Cascade Phase:* Beginning at ca. 8,000 years B.P., the Cascade phase continues until ca. 5,500 years B.P. (Lucas 1994), representing what Leonhardy and Rice (1970:24) consider to be a direct evolutionary step from the prior Windust phase. Cascade phase assemblages are better represented than their predecessor, with its phase designation developed from ten sites. Known in
particular by the presence of its characteristic Cascade lanceolate point (for which the phase is so named), associated artifact assemblages include: large lanceolate and triangular knives of good craftsmanship; end scrapers in both tabular and keeled form; utilized flakes of varying size and shape; the rare occurrence of atlatl weights; and a diversity of cobble tools.

The subsistence habits of the Cascade folk are better known than the Windust as deer, elk, antelope, rabbit, beaver, river mussels, large salmonids, salmon and steelhead are associated with Cascade assemblages. Plant utilization is suggested by the presence of manos, interpreted as used for the processing of seeds.

**Tucannon Phase:** Immediately following the Cascade tradition several changes in technology occur. The appearance of two dominant crudely-made projectile point forms, the reduction in size and number of utilized flakes, and the previous inclusion of well-made knives are most notable. A variety of other technological additions include: small side and end scrapers; cobble tools used for scraper-like tasks; a cobble spall utilization industry; fishing net sinkers; hopper mortar bases; pestles; and assorted bone tools. Important alterations in the evolutionary progression of lithic technology are noted by Leonhardy and Rice in the Tucannon phase assemblages: “Compared to both earlier and later phases, the technology of the Tucannon phase seems crude and impoverished” (1970:14).

The Tucannon peoples appear to have utilized many of the same animal groups as previous cultures, with a continued reliance upon fishes and an increased emphasis on the acquisition of river mussels. This phase is dated between ca. 5,500 and 2,450 years B.P. (Lucas 1994). Tucannon phase
occupations are commonly associated with the confluence of small tributary streams with larger rivers, e.g., the Tucannon-Snake River confluence, and often simply along the Snake River (Lucas 1994:26). Tucannon peoples employed semi-subterranean houses, during their occupation within the Snake River Canyon. A great deal of information was gained regarding the style of house pit construction as a result of excavations at Hatwai (10-NP-143 [Ames et al. 1981]). In general, these houses are found in two styles: (1) a subsquare plan view, excavated to a depth of ca. 70 cm, with a bench ringing the interior; (2) circular, lacking an annular bench, with a floor excavated to a depth of ca. 70 to 100 cm. House style 1 postdates house style 2 at Hatwai.

**Harder Phase:** An introduction of seasonal camps, later followed by house pit villages of increased population and aggregation strongly marks the presence of this tradition. Technological developments associated with Harder culture assemblages include: basal and corner-notched projectile points; variable forms of small end scrapers; the reintroduction of lanceolate and pentagonal knives; cobble scraper-like tools; a continuation of spall utilization; hopper mortar bases; pestles; fishing sinkers; and various bone tools and items of adornment. Bison, mountain sheep, deer, elk, and antelope are present in Harder Phase faunal assemblages, along with a high incidence of fish remains. The utilization of roots are also included here, inferred from the recovery of pestles and mortars. Leonhardy and Rice (1970:14-17) place the onset of this phase at ca. 2,450 years B.P. and its termination at ca. 650 years B.P.

**Piqûnin Phase:** These assemblages are found in Lower Snake River
Canyon sites dating between ca. 650 and ca. 250 years B.P. (Leonhardy and Rice 1970:20) Circular pit houses are maintained from earlier cultural phases and different projectile points occur in various forms, dominated by an assortment of small corner-notched and base-notched types. Other lithic tools include: small end scrapers (in reduced numbers here, however); knives; an increased emphasis on small utilized flakes; the continued usage of various cobble tools; cobble spalls; net sinkers; pestles and hopper mortar bases. Bone tools reveal the usage of awls, needles, and parts of composite fishing harpoons. This technology was applied in efforts to exploit elk, deer and salmon populations.

*Numípu Phase:* Cultures corresponding with the ethnographic period of the Lower Snake River Canyon sub-region have been designated within the Numípu phase, ranging between ca. 250 to ca. 150 years B.P. (Leonhardy and Rice 1970:20) The usage of the horse is indicative of the Numípu culture during this time. Leonhardy and Rice (1970:20) do not describe the lithic technology of this phase apart from a few miscellaneous tools, not including projectile points. Instead they emphasize the the later incorporation of euroamerican material culture into the Numípu lifeway.

**The Prehistoric Record of The Clearwater River Drainage**

In his recent doctoral dissertation, R. Lee Sappington (1994) presents a cultural typology for the Clearwater River Drainage sub-region, on the basis of archaeological evidence from multiple sites. The culture history of the Clearwater River Drainage is broken down into periods of human occupation and includes the cultural phases characteristic through time.
Windust and Cascade Phase: Beginning with his Early Prehistoric Period, Sappington (1994:373) identifies the Windust and Cascade phases defined by Leonhardy and Rice (1970:4-11), as the initial cultures of the sub-region, placing their local occupation between ca. 10,000 and 6,000 years B.P. Both prehistoric traditions are included within this single cultural period due to their reported contemporaneity: "With the exception of isolated finds, both Windust and Cascade occupations co-occur at virtually all early sites in the Clearwater River region" (Sappington 1994:376). Sappington states that these cultural traditions are materially similar in the Clearwater River Drainage to assemblages reported elsewhere in the Columbia River Plateau region.

Hatwai Phase: This tradition is identified in the Clearwater River archaeological record between ca. 6,000 and 3,000 years B.P. (Sappington 1994:377). Hatwai phase sites notably include the utilization of semi-subterranean pit houses, and the development of broad-based subsistence technologies allowing for the exploitation of deer, elk, bison, bear, sheep, lynx, coyote, some small fish species, and plant populations.

Ahsahka Phase: The Late Prehistoric Period, dated between ca. 3,000 and 500 years B.P. (Sappington 1994:381), is introduced during the Ahsahka phase, with its upland/lowland seasonal subsistence round concentrating on fishing, root collecting, and hunting. Housepit villages are maintained during this period and projectile point styles proliferate, which is thought to infer "individual preferences rather than rigid cultural dictates" (Sappington 1994:382-383). The bow and arrow is believed to have been introduced during
this period and a wide variety of large game and smaller animals have been recovered from Ahsahka phase faunal assemblages. The presence of net sinkers at multiple sites suggests the importance of fishing, while the gathering of river mussels was apparently of little consequence.

*Kooskia Phase:* This tradition, associated with the Protohistoric Period, appears immediately following the Ahsahka phase at ca. 500 years B.P. and continues until ca. 200 years B.P. (Sappington 1994:387). Multiple changes, including the introduction of the horse, Euroamerican trade goods, and disease, influenced the material culture of the Clearwater River Drainage during this time. The increased mobility offered by the acquisition of the horse brought about changes in the mode of occupation, from more scattered housepit villages to settlements of greater population density with an emphasis on above-ground house structures. The lithic technology does not appear to have changed from the previous Ahsahka phase, suggesting a continuation of earlier subsistence activities.

*The Prehistoric Record of the Southern Washington Cascade Range*

Discussion regarding a regional perspective of culture-history for this portion of the sampling transect has been reserved for last, due to its particular circumstances, which differ from the other areas. Limited archaeological work in the southern Cascade Range of Washington has hindered for the construction of a working typology. In its absence, other nearby chronological culture histories have been adapted for the area. Jermann et al. (1988) apply the cultural sequence developed from middle Columbia River Basin sites (i.e., Nelson 1969; Lohse 1985). Daugherty (1987a;
1987b) also selects the general western Columbia River Plateau cultural model i.e., Nelson (1969) as being applicable to occupations identified at Judd Peak rockshelters and Layser Cave. Ellis et al. (1991) follow in this manner by identifying general similarities between the Judd Peak and Layser Cave cultural assemblages and that recovered from Koapk, also showing favor towards the application of Nelson's (1969) model.

I do not feel that enough data has been gathered to make strong correlations between assemblages noted from the southern Cascades of Washington to those reported from the Columbia River Plateau--or elsewhere for that matter. Therefore, in reference to the case study presented from the southern Cascade Range of Washington, a simple occupational sequence as seen at the Koapk site will be provided in lieu of a more solid typology.

Overview of Case Study Sites to be Presented

The following chapter will present case studies from archaeological sites along a west-to-east transect within the study area (Fig. 23), including: the Koapk site (45-LE-209) (Ellis et al. 1991), in the southern Cascade Range of Washington; the Sunset Creek site (45-KT-28) (Nelson 1969) in the middle Columbia River Basin; Marmes Rockshelter (45-FR-50) (Rice 1969), Windust Cave (45-FR-46) (Rice 1965), the Granite Point Locality I site (45-WT-41) (Leonhardy 1970), all within the Lower Snake River drainage of southeaster Washington; and the Hatwai site (10-NP-143) (Ames et al. 1990) in north-central Idaho. These particular archaeological sites have been selected, as they represent the data used to construct regional cultural-historical typological
Figure 23. Location of archaeological case study sites

KEY

Δ Mount St. Helens

J

Yb

Te

Yb

Yb

Preferred Indicia

⊙ 46LE809
⊙ 46K125
⊙ 46FR45
⊙ 46FR60
⊙ 46WT41
⊙ 10RF143

PACIFIC OCEAN

WA

CASCAD

OR

ID

RANGE
models, or as in the case of the Koapk site, provides a thorough view of extensive stratigraphic evidence of prehistoric occupation prior to and following eruptive volcanic activity at Mount St. Helens. The Sunset Creek site was used as a basis for the definition of most cultural components outlined by Nelson (1969). Granite Point Locality 1, Windust Cave, and Marmes Rockshelter were used as integral sources of data for Leonhardt and Rice's (1970) Lower Snake River cultural typology. Important for the greater understanding of Clearwater River prehistory, the Hatwai site has been included here, due to its contributions in Sappington's (1994) typological model. Furthermore, these sites have been chosen for their well-documented and far-reaching prehistoric occupations.

Each site will be reported as a case study with a data summary presented first, followed by discussion regarding the degree of correlation between the cultural occupation and regional paleoclimatic and paleovolcanic records. This discussion will serve to highlight any links between the environment and culture change, as a means of identifying potential causality. The case study chapters will be followed by a synthesis, which will investigate the trends occurring among the sites, and to observe any difference and/or similarities between the sites at their proximal, medial, and distal positions from Mount St. Helens.
Koapk (45-LE-209)

The Koapk site (45-LE-209) is located near the Cowlitz Falls in the Cowlitz River Valley, approximately 20 miles north of Mount St. Helens (see Fig. 22) and includes prehistoric and historic components within alluvial terraces along the southern bank of the Cowlitz River. Excavations were conducted during the field seasons of 1988 under the direction of Charles Hibbs, Jr. and in 1989 under the direction of David V. Ellis (Ellis et al. 1991).

Site Stratigraphy

The Cowlitz River valley began to infill with glacial outwash sediments sometime before 35,000 years B.P. This depositional period was followed by an advance of the Evans Creek valley glaciation into the area of Cowlitz Falls about 13,000 years B.P. The modern geomorphology of the site is comprised of a series of fluvial terraces, which were cut by the Cowlitz river following the retreat of the Evans Creek valley glacier between 18,000 and 10,000 years ago (Ellis et al. 1991:73-81). The immediate landscape of the Cowlitz Falls locale is broken down into four areas: (1) Upper Terrace zone; (2) Mid Terrace zone; (3) Lower Terrace zone; and (4) Lower Bench zone.

Stratigraphic exposures at the Koapk site revealed a deposit of Mount St. Helens tephra, identified as Yn. This deposit occurred in most places within the site, found in a continuous distribution over the Upper Terrace zone and in a series of discontinuous deposits on the Mid Terrace zone. The
Yn tephra found in Lower Terrace and Lower Bench deposits are fluvial in nature, representing secondary deposition along with other sediments. This tephra, in place with other lithological deposits, provided a means for determining the formation history of the site and its chronological ordering. Stratigraphic nomenclature assigned to deposits at Koapk will be presented here, providing a means for discussing cultural occupations in relation to tephra-falls from Mount St. Helens. In the context of this research, descriptions of the Koapk site lithostratigraphy (Ellis et al. 1991:92-116) will be limited to major units, and efforts will be made to provide a full understanding of the geologic history of the site.

**Stratum I:** comprised of igneous bedrock of an unknown thickness, this unit is assumed to represent the basal deposit within the entire site.

**Stratum IIA:** this unit is attributed to glacial drift from the Evans Creek stade. Comprised of massive poorly sorted boulders, gravel, sand and silt, it is reported to have been deposited at or prior to ca. 18,000 years B.P. (Crandell and Miller 1974) and is largely limited to the Middle and Upper Terrace portions of the site.

**Stratum IIB:** similar to Stratum IIA in material composition, this unit is observed to retain evidence of reworking in a fluvial context: fine glacial sands and silts are removed, with fluvial sands replaced in an interstitial context. Deposits from Stratum IIB can be found in the Mid Terrace area, the Lower Terrace and Lower Bench areas.

**Stratum IIIA:** this unit is formed of massive sand, silty sand, and volcanic tephra. Due to the presence of differences in morphology within the same stratum designation, seven substrata designations have been applied here. These will not be discussed entirely, but a few comments will be made
on select substrata representing volcanic material. Substratum IIIa7 is reported as:

...variably composed of fine gray volcanic ash and black carbon-rich soil. The ash may have emanated from one of the eruptions of Mt. St. Helens at or before 3,500 years B.P., such as the Yb tephra deposits of 3,900 years B.P. (Mullineaux, Hyde and Rubin 1975). The black soil which overlies the ash where both are present, may represent a cultural anthroposol, an ancient "A" horizon, natural charcoal from the burn, or combinations thereof. This layer undulates over the hummocky surface of Stratum IIIa, ranging from 1 cm to 15 cm thick (Ellis et al. 1991:95).

Stratum IIIa was located in the Upper Terrace and in some areas of the Mid Terrace, varying in thickness from 140 cm to 30 cm. The age of this stratum is provided by the bracketing events of the Evans Creek glaciation below in Stratum IIa is dated at ca. 18,000 years B.P. (Crandell and Miller 1974) and of the Yn tephra above in Stratum IV, dated to ca. 3,500 years B.P. (Mullineaux 1986). Three radiocarbon dates were returned from Stratum IIIa substratum deposits: 4,270 ± 80 years B.P. (WSU-4078); 4,200 ± 80 years B.P. (WSU-4080); and 3,970 ± 100 years B.P. (Beta-37042).

Stratum IIIb: identified as a landslide deposit, this unit is composed of poorly sorted angular andesite clasts within a poorly drained compact gray brown silty clay. Found only in Upper Terrace excavations, this mass movement event is dated by its stratigraphic position inferior to the Yn tephra in Stratum IV, placing its occurrence at a time prior to 3,500 years B.P.

Stratum IV: "pale yellow, highly vesicular pumice nodule, and smaller particles" (Ellis et al. 1991:99) comprise this deposit of pyroclastic material, corresponding with the tephra-producing eruption of Mount St. Helens during the Smith Creek eruptive stage (Mullineaux 1986). This
deposit is found as a continuous layer across the Upper Terrace and in a more discontinuous deposit on the slope of the Middle Terrace. Fluvial deposits in the Lower Terrace and Lower Bench stratigraphy include tephra attributed to the Yn eruption. Thicknesses of this tephra were found to range between ca. 120 cm and 180 cm on the Upper Terrace and to a maximum of 40 cm in Middle Terrace stratigraphy. The tephra of Stratum IV represents a chronostratigraphic unit dated to some time between 3,350 and 3,510 years B.P. (Mullineaux et al. 1975).

Stratum Va: identified as a mixed colluvial deposit, loose pumice with a sediment inclusion grades upwards to a sandy loam soil. The age of this stratum is inferred from its position superior to Stratum IV, placing this unit's inception shortly after 3,350 years B.P. Three radiocarbon dates were returned from materials recovered within Stratum Va: 850 ± 90 years B.P. (WSU-4077); 1,550 ± 100 years B.P. (Beta-37041); and 510 ± 80 years B.P. (WSU-3942).

Stratum Vb: this unit is comprised of overbank and levee formation deposits with visible bedding structure. Multiple alternating sand and silt deposits, representing what might be flood events are identified in Lower Terrace stratigraphy, calling for the assignment of twenty-two individual substrata determinations within Stratum Vb; several of the substrata deposits contained reworked tephra within bedding structures. Material from Substratum Vb8 returned a radiocarbon date of 1,060 ±60 years B.P. and provides a minimum date for reworked tephra within Substratum Vb9. Occurring in thicknesses of ca. 4.0 meters within Lower Terrace stratigraphy, the time of formation is estimated at ca. 3,300 years B.P. from Substratum Vb7 upwards (ca. 2.4 meters down), due to the presence of Yn tephra with the
matrix. However, other radiocarbon dates suggest that the entirety of Stratum Vb was formed during the last 1,500 years, beginning with a Substratum Vb6 radiocarbon date of 1,280 ± 75 years B.P.

Stratum VI: representing the last stratigraphic unit, Stratum VI is largely comprised of humic material of the forest duff. The fluvial sands and silts present at the surface of the site in the Lower Terrace and Lower Bench areas are also included within this unit designation as well. Stratum VI is quite thin, with thicknesses between 1 and 5 cm in all areas of the site; this is thought to represent the last 40 to 13 years of deposition.

Cultural Occupation

Ellis et al. (1991:219-246) provide a synthesis of field data to illustrate the nature of prehistoric occupation at the Koapk site through time. Examining the manner in which cultural materials and features are distributed in a horizontal and vertical fashion in relation to the presence of Mount St. Helens tephra, an understanding will be sought of how such a volcanic event might have affected prehistoric cultures present at the Koapk site.

Sub-Tephra Component

By observing the horizontal and vertical distribution of artifacts and comparing data between above-tephra and subtephra contexts, Ellis et al. (1991:219-232) generate several insights into the activities performed at this site. Comparisons made from recovered quantities of fire-cracked rock, cobble tools, debitage, unifaces, bifaces, projectile points, and faunal evidence, gave
relative percentages and weight per cubic meter. The results of these comparisons showed that the initial human occupation of this site was limited to the Upper Terrace, with other activities such as flintknapping occurring in higher densities near the slopes above the Lower Terrace. The use of the site is determined as well and Ellis et al. (1991:234) suggest that the lack of evidence for structures or storage pits show that the site was used as a temporary camp, occupied on a seasonal basis.

Seriation analyses show a progression of technological style throughout the occupation of the Koapk site from an initial dependence upon a series of projectile points including small lanceolates (classified as "Unstemmed Cascade Points" [Ellis et al. 1991:148]), slightly shouldered with simple stems, and barbed, open corner-notched forms in Strata IIIa. Later, the dominant inclusion of stemmed points (identified as "Upper Columbia Stemmed Complex" [Ellis et al. 1991:148]) and a reduction of previously mentioned forms in Strata Va is seen with the abandonment of lanceolate points and slightly shouldered and simply stemmed points for the usage of all other points found in Strata Va is noted in Strata Vb13. The seriation concludes with Strata Vb18 with its a heavy inclusion of "Columbia Plateau Side-notched points" (Ellis et al. 1991:148) and some slightly shouldered, simply stemmed points, and barbed, open corner-notched points. These projectile point designations have been compared with the projectile point typology from the Sunset Creek site (Nelson 1969).

Faunal and floral evidence show an emphasis on species available during the late summer-early fall months: deer, fish, berries, and nuts. Subtephra data of relative fish bone quantities of show that "With 148 recovered bones and a density of 9.8 bones per cubic meter, fish processing
seems clearly to have figured into the activities represented in the initial occupation of the site..." (Ellis et al. 1991:194). The authors further argue for a consideration of a late summer-early fall occupation at the Koapk site, based on their own field observations made at the site during the late fall and early winter months. Reportedly, the Koapk site location is wet and cold, being in the shadows during part of the year. Ellis et al. (1991:234-235) state that lacking stored foods, human groups would have a difficult time procuring adequate levels of subsistence from the paucity of local resources available during the inferred season of occupation. With this in mind, the absence of evidence for shelters or storage pits bring the authors to the conclusion that winter occupation would have been unlikely at the Koapk site.

Above-Tephra Component

Archaeological materials recovered from deposits above the Yn tephra show similarities to the evidence observed in the subtephra occupation. Inferred activities continue, along with an apparent late summer-early fall seasonal site usage. Reoccupation of the site following the post-Yn hiatus includes smaller stemmed "Rabbit Island" points, noted as an indication of bow and arrow weaponry (c.f., McClure 1992:13). Additional technologies include what appears to be an improved lithic reduction technique at the site inferred from the addition of smaller-sized tools (which produce less debitage in their creation) and the first evidence of bone-point fishing methods. Ellis et al. (1991:235) attribute this latter technological development as possibly being the cause of a more successful method of fish procurement as seen in increased representations of salmon and salmonid remains in above-tephra strata. Through time, the Koapk site was occupied more broadly,
incorporating the lower reaches of the river terraces more intensively.

**The Nature of Human Occupation at the Koapk Site**

The imposing presence of Mount St. Helens tephra within the stratigraphy of the Koapk site provides a striking representation of the hazards of volcanism in the southern Washington Cascades. With a post-depositional thickness observed at ca. 180 cm in some areas, the results of such a tephra-fall upon this area must have been catastrophic indeed. With the availability of multiple radiocarbon dates from culturally-inclusive strata, the nature of the temporal occupation can be understood in light of the Yn tephra-falls:

The early use of the Koapk site may have ended by ca. 3,900 years B.P., a date that may correlate with the estimated age of the Yb tephra set. The deposit from this eruption of Mt. St. Helens is thin and has not been reported (Mullineaux et al. 1975:333) in the upper Cowlitz drainage, however. More likely the Koapk site continued to be occupied until ca. 3,500 years B.P., when the massive fall of the Yn tephra probably obliterated virtually all life in the site area.

It was almost 2,000 years before people returned to Cowlitz Falls. It may have taken those many centuries for the land to recover and offer the resources that brought people back up the Cowlitz. The first evidence of this reoccupation is at the eastern end of the Upper Terrace. Much of the activity reflected in this occupation is little different from that of 2,000 years earlier. Although the occupations at the eastern end of the Upper Terrace appear to have been as frequent and lengthy as those at the heart of the earlier occupation, there is still no evidence of structures of any kind. The archaeological record again suggests use of the area primarily for late summer-fall camps. The Falls appear to have been part of a seasonal round that brought people to the site only when the seasonal juxtaposition of fish, game, nuts, and berries made the Falls a convenient base camp (Ellis et al. 1991:235).
The evidence shows quite clearly that prehistoric populations at the Koapk site were greatly affected by the tephra-falls of Mount St. Helens. So much in fact that occupation patterns and subsistence economies were disrupted for almost 2,000 years. The humans that had frequented the Koapk site prior to the eruption of the Yn tephra were forced to make a change in their spatial exploitation of the area by avoiding usage of this site and deriving their subsistence instead from other areas in the region. This pattern of site avoidance lasted until a period coinciding with the development of newer and more effective hunting technologies: the bow and arrow and the bone-tipped fishing spear. Perhaps these technologies were required for their greater efficiency in meat procurement within areas like the Koapk site. Quite possibly, the floral and/or faunal populations had been affected in a manner requiring more successful means of hunting. This is not to say that the bow and arrow hunting method might not have been acquired during the period of environmental regeneration in the effected area near the volcano. Descendants of the previously displaced Koapk peoples may have simply developed new adaptations to other areas outside of the tephra-falls and were resistant to leaving without reason.

Reoccupation of the Koapk site nearly 2,000 years later might have been a result of pressures for space in the region, created by a growing regional population. Or, natural resources in proximity to Mount St. Helens might have been affected to a degree by eruptions, requiring a lengthy period of regrowth to produce exploitable subsistence levels; hindering long-term occupation of the area during this 2,000 year period. Human groups, faced with growing population pressures and armed with more efficient subsistence technologies might have more easily moved into areas that were
previously considered marginal, when older technologies were in use.

Questions raised regarding the post-eruptive cultural behaviors seen within the archaeological record at the Koapk site remain unanswered here. Although physical evidence of eruptive events predates occupational hiatiuses at sites like Koapk, it is not entirely clear why prehistoric populations avoided portions of the southern Washington Cascades during most of the late Holocene. Just as prehistoric site avoidance is problematic in this area, incidents of reoccupation await explanation. Answers to these questions are important for understanding the nature of human adaptation to tephra-falls in the southern Cascade Range of Washington and must be pursued in future research.

**Sunset Creek (45-KT-28)**

The Sunset Creek Site (45-KT-28), located near the town of Vantage in south-central Washington (Fig. 22), was excavated between 1957 and 1963 by the Washington Archaeological Society, with the results of this work reported by Charles M. Nelson (1969). The site is located on the western bank of the Columbia River within the floodplain and alluvial deposits of Quilomene Bar, near the mouth of Sunset Creek.

Excavations revealed a cultural continuum spanning the last 10,000 years or so of human occupation along the Columbia River. The material evidence of human presence at this site is described here in reference to cultural assemblages and their corresponding stratigraphic units. As the following discussion will present a closer look at the cultural typology outlined by Nelson (1969), derived from the archaeological data of the Sunset Creek Site, emphasis will be placed upon cultural assemblages associated with
each phase and how they differ through time.

Site Stratigraphy

For ease of association, the stratigraphic units defined at the Sunset Creek site (Nelson 1969:7-8) will be briefly discussed with reference made to the strata during a review of the cultural occupation. Of the general stratigraphy observed at the Sunset Creek site, Nelson states: “The geological section at the site reveals interbedded floodplain and alluvial (sic) deposits which are frequently altered by aeolian processes” (1969:7). Six major units of stratigraphy were interpreted, with the assistance of Roald Fryxell.

Stratum 1: is comprised of the Sunset Creek alluvial fan. This unit forms the site’s foundation and contains alluvial gravels attributed to the Altithermal period (Antevs 1955).

Stratum 2: deposition of a brownish-yellow sand marks the formation of an alluvial beach at the site immediately overlying the fan feature.

Stratum 3: is composed of a fine grey-brown sand and represents a continuation of alluvial deposition.

Stratum 4: overlies these earlier units in a thick deposit of sand and alluvial loess. This stratum is correlated with the initial stages of the Medithermal period (Antevs 1955). Multiple deposits representing cultural occupation were noted in this unit.

Stratum 5: the accumulation of cultural debris in a midden deposit and infilled housepit features are present here in a matrix of floodplain loess.

Stratum 6: historic artifacts and secondarily deposited native American materials within flood sediments are noted with this relatively thin
stratigraphic unit.

**Cultural Occupation**

*Vantage Phase:* The initial cultural occupation at the Sunset Creek site has been defined under the Vantage phase, with an assemblage largely typified by the presence of leaf-shaped projectile points and knives of varying size, a "rudimentarily stemmed point", and an industry of utilized flakes and blades (Nelson 1969:9-10). Two typologically similar components of the Vantage phase (Cultural Components I and II) are identified at this site on the basis of apparent redeposition of a portion of the assemblage within younger sediments. Cultural Component I artifacts were recovered from Stratum 3 and deemed a product of redeposition, due to their association with fluvial cut-and-fill features.

Cultural Component II was reportedly found in what is considered its correct stratigraphic position, associated with the basal portion of stratum 4. Nelson provides a date for the Vantage phase in a relative manner: "Indeed, based on the few comparisons of material culture that can be made, Cultural Component I is probably no more recent than ca. 4000 B.C. (5,950 B.P.) and very possibly as old as 7000 B.C. (8,950 B.P.)" (1969:12). This attributed date is provided from the DjRi 3 site (Borden 1957) of British Columbia, which produced morphologically similar artifacts placed between ca. 6,950 and 8,950 years B.P.; provided from geologic estimates and radiocarbon samples. The Vantage phase is succeeded by the Cold Springs phase within Nelson's (1969) typology presented in Chapter 10. However, Cold Springs phase components were not found at the Sunset Creek site.

*Frenchman Springs Phase:* The Frenchman Springs phase occupation
(Cultural Component III) was found at the site on the surface of Stratum 3 and into the lower portion of Stratum 4. This occupation is placed between ca. 4,000 and 2,750 years B.P., with two periods of transition (Cultural Components IV and V) occurring between the end of the prior Cold Springs phase derived from Nelson's cultural typology and the inception of the following Quilomene Bar phase. Nelson (1969:28) states that defining the characteristics of the Frenchman Springs phase is difficult. The technological developments attributed to the Frenchman Springs phase are recognized mainly by the appearance of the Rabbit Island Stemmed Point. There is apparent difficulty in defining the entire spectrum of this phase's assemblage at the Sunset Creek site due to the small number of artifacts recovered. The use of cobble choppers and plane-like scraping tools declines at the introduction of the Frenchman Springs phase, while other tools including leaf-shaped points continue to appear in assemblages until the end of the phase after which their use is discontinued.

The remainder of the Frenchman Springs phase assemblage includes the use of: semi-triangular knives or projectile points; gravers; scrapers; pecked and ground stone tools; variously-shaped core tools; bone points and other bone tools; and a variety of ornamental objects. Nelson (1969:34) stresses that although the presence of Frenchman Springs assemblages seen at the Sunset Creek site are similar to economic patterns of the initial historic period (e.g., Sanpoil and Nespelem ethnographic examples), they are not associated with the development of winter village occupation and the seasonal exploitation of fishing resources, thus suggesting another means of subsistence.

Quilomene Bar Phase: The Quilomene Bar phase follows the
Frenchman Springs phase, beginning at ca. 2,750 years B.P., extending until ca. 1,950 years B.P. These dates are provided from the estimated end of the prior Frenchman Springs phase and the known inception of the following Cayuse phase, respectively. This occupation (designated as Cultural Component VI) was found entirely within Stratum 5 in several adjoining lenses of cultural debris. The nature of the assemblage is described by Nelson:

As of the writing of this report, the single reliably diagnostic artifact type is the Quilomene Bar Base-Notched projectile point (Type 5), which is also of minor importance very late in the Frenchman Springs Phase and the Cayuse Phase. During the quilomene Bar Phase it appears to be restricted largely to Type Variant 5A, a particular variation characterized by deep base-notches and large, square barbs. However, at the beginning of the Cayuse Phase a whole new series of variants appear to develop out of this early form (1969:37).

Many other artifacts, including: pentagonal and triangular knives; core tools; many kinds of scrapers; gravers; utilized spalls; cobble tools; hammerstones; bone and antler projectile points; and scrapers and wedges. Several features were also located in association with the occupation including a hearth and a post mold, multiple other fire hearths, and a cache with many stone tools.

Cayuse Phase: The Cayuse phase is divided into three cultural occupations identified within Strata 5, 4 and 3, termed the Cayuse I, Cayuse II, and the Cayuse III subphases. The initial Cayuse occupation (Cultural Component VIIa-VIIe) in the Columbia River Plateau dates from its discovery at the Vantage locale (Swanson 1962a) and is placed at 1,715 years B.P. Nelson (1969:47-48) argues that this date is not likely representative of the initial Cayuse I appearance in the archaeological record, and suggests an earlier estimation closer to ca. 1,950 years B.P. The remaining two phases
occur between the close of the Cayuse I phase and the beginning of the historic period. Due to the lack of reliable dates for the end of the Cayuse I phase, the chronological ordering of the Cayuse occupations is uncertain:

The deposits at 45KT28 give the impression that the Cayuse I period is of longer duration than any other of the Cayuse subphases. However, many extraneous factors such as differential rates of midden accumulation and shifting settlement terms may be at work prejudicing this impression. In the absence of C\textsuperscript{14} dates extreme caution must be exercised in assigning chronological limits to the termination of the Cayuse I Subphase and the beginning of the Cayuse II Subphase. On the basis of our present knowledge of the area, I would place this break between 600 and 1300 A.D. (Nelson 1969:80).

The cultural assemblages of the Cayuse subphases retain similarities in certain categories, while others are more ideal as cultural horizons. The Cayuse I subphase is well known for the construction of semi-subterranean pit houses with level floors, vertical walls and bench-like features ringing the structure. The presence of three distinct styles of projectile points are noted throughout the three subphases. In the Cayuse I subphase, the presence of Quilomene Bar Base-Notched, Coumbia Plateau Corner-Notched, and Biconical antler projectile points are noted.

Other artifacts also recovered from Cayuse phase deposits include: knives; scrapers; core tools; gravers; utilized flakes; spall tools; hammer stones; ground and pecked stone tools; bone tools; antler tools; and objects of ornamentation. Due to the continued use of many tools throughout the subphases, the values of comparison between these general portions of the Cayuse assemblage is quite reduced. Differences among the Cayuse subphases are mainly made in reference to house style and the relative proportion of reliance upon specific projectile point forms. Nelson (1969:55) states that the
beginning of the Cayuse phase marks a greater dependence upon the acquisition of fish, due to an increase of both fish remains and fishing tools within assemblages.

The designation of the Cayuse II subphase (Cultural Components VIIf-VIIg) is made with reference to the contemporaneous usage of a weapons system reliant upon Quillomene Bar Base-Notched and Columbia Plateau Corner-Notched projectile points and the construction of house pits with level floors and vertical walls lacking benches. Appearing at the Sunset Creek site immediately after the Cayuse I subphase at ca. 1,950 years B.P., the Cayuse II subphase persists until sometime between 1,350 and 650 years B.P. (Nelson 1969:85), succeeded by the Cayuse III subphase.

The introduction of the Cayuse III subphase (Cultural Components VIIh-VIII) ushers in a period of diversity among projectile point manufacturing styles, which, in the opinion of Nelson (1969:95), reflect the presence of diverse ideas about the nature and form of hunting tools within the culture; similar opinions have been voiced by Sappington (1994:382-383). The structural composition of housepit foundations changes from a continued usage of the older style with flat floors and vertical walls early in the Cayuse III period, to the adoption of a saucer-shaped form appearing later in the Cayuse III subphase. The final stage of the Cayuse III subphase is noted by the presence of trade artifacts, representing interaction with contact-period European peoples.

The Nature of Human Occupation at the Sunset Creek Site

Nelson provides comment on the prehistoric occupation at the Sunset Creek Site, recognizing trends among the succession of cultural components:
The site is situated along the Columbia River and will, therefore, reflect slightly different adaptations than sites located on tributary streams to the west or in the more arid country to the east. Cultural Components I through VI represent the seasonal camps of whole or fragmentary bands which were always small in size. Deer hunting was evidently the major economic activity in the area. Cultural Component VII, on the other hand, represents the winter village pattern which Ray (1932) has described for the Sanpoil and Nespelem (1969:101).

Nelson draws parallels between the late archaic archaeological components at Sunset Creek (1969:51-54) and Ray's (1954) ethnographic account of the Sanpoil and Nespelem, with a mode of subsistence centered upon a seasonal scheduling of activity. During the early spring, the hunting of game and the collecting of river mussels complemented the gathering of the first root crops and other edible plants for the Sanpoil and Nespelem peoples. As the season progressed, an emphasis was placed upon the exploitation of root fields and called for the establishment of new camps away from the Columbia River. Shelter was provided by erecting temporary conical-shaped pole structures, which supported an exterior of woven matting.

The beginning of summer marked the start of the fishing season, with the availability of salmon soon following. Groups journeyed back to favored spots along the river where they set up mat lodges. The largest portion of the time remaining until the beginning of fall was spent in the catching, cleaning, cooking, drying and storing of salmon for the upcoming winter months. This harvest, along with the surplus of root crops, would insure a season without starvation.

By the time the fall season had arrived, some groups left their camps for other fishing areas while others made a last excursion into the mountains.
to gather more roots and to hunt, sheltered in their spring season conical huts. By late fall, the hunting and gathering groups returned to the site of the winter village where preparations were made for the winter's stay. The semi-subterranean pit houses were repaired and cleaned, or preparations for the habitation of mat lodges were made. Some hunting was done during these winter months, but the majority of the time spent indoors. The winter village would be occupied until the coming of spring, when the seasonal cycle would start anew.

Granite Point Locality I (45-WT-41)

Granite Point Locality I (45-WT-41) occupies 600 meters of a sand and gravel bar along the eastern bank of the Snake River (Fig. 22). The site was excavated in the summers of 1967 and 1968 by archaeological field school expeditions from Washington State University. The first season was directed by Roderick Sprague, and the second by Frank Leonhardy, with both years operating under a contractual salvage project prior to the creation of the Little Goose and Lower Granite reservoir areas (Leonhardy 1970:iii).

Site Stratigraphy

As the extent of the cultural occupation was widespread at Granite Point Locality I, a site-wide stratigraphic nomenclature was applied incorporating specific geologic processes identified within local deposits (Leonhardy 1970:50-59).

Boulder Gravel: comprises the lowest stratigraphic unit at the site and is represented by large (≤ 1 meter diameter) subangular boulders derived from
the local basalt bedrock.

**Gravel Bar and Alluvial Fans:** as both landforms were thought to have been synchronously accreted, this deposit has several components formed through differing processes. Within the gravels, rounded basalt clasts were deposited by fluvial processes of the Snake River, while angular gravels were transported as short distance fan deposits from the side canyons.

**Fan Gravel:** is recognized as poorly sorted basalt clasts (up to boulder size) and an inclusive interstitial matrix of small gravels and sands.

**River Gravel:** comprised of rounded clasts of basalt and other rocks, interstitial sands, gravels, silt, and imbrication and forset structures; maximum thickness at 7.5 meters.

**The Early Floodplain:** nearly 2 meters of overbank sand and silt deposits caps the river gravels here. A period of stability is noted in the moderate development of a pedological horizon. Prior to the deposition of the successive stratigraphic unit, the floodplain sediments were truncated by river erosion; maximum thickness at 1.6 meters.

**Pre-Ash Aeolian Sands:** overlies the early floodplain unit in many areas. Composed of massive sands, the degree of particulate sorting and bulk density diverge from The Early Floodplain deposits. Leonhardy (1970:page) reports this unit as being deposited by an aeolian process; maximum thickness at 60 cm.

**Volcanic Ash:** attributed to the eruptions of Mount Mazama, tephra is present here in various forms of purity. Those unit sections with a pure tephra component are interpreted as initial airfall material, while those with inclusive non-volcanic material are described as secondarily deposited; maximum thickness at 75 cm.
Pale Loess: this unit is classified on its textural and structural characteristic of "ash-rich silt loam...fine texture and massive bedding" (Leonhardy 1970:58). This unit also contains a weakly developed paleosol; maximum unit thickness at 1.25 meters.

The Later Floodplain: similar to that noted previously, this unit contains coarsely bedded overbank silts; maximum thickness at 1.6 meters.

Post-Ash Aeolian Sands: multiple successions of massive aeolian sands with texture and color varying across the site; maximum thickness at 1.9 cm.

Thin Colluvium: angular to subrounded very coarse basaltic sands and gravels are noted within a matrix of silt loam; maximum thickness at 20 cm.

Historic Deposits: noted as railroad construction fill, this unit dates from the first decade of the 20th century.

Cultural Occupation

Component 1 is estimated to fall between 9,000 and 10,000 years B.P. (Leonhardy 1970:82), showing similarities to other artifact assemblages found at Windust Caves (Rice, 1965), Marmes Rockshelter (Rice, 1969), Wildcat Canyon (Cole, 1968), and the Lenore sites (Leonhardy 1970:97).

Component 1 was found in association with the Boulder Gravel stratum, and lacked any evidence of occupational features. Artifacts associated with this component include: projectile points in lanceolate and stemmed styles; few large bifacial knives; burins; the creation of blades from prismatic cores; and the abundant utilization of flakes. Large quantities of debitage associated with a large proportion of broken preforms suggests the importance of tool manufacture at the site. Associated faunal evidence includes elk, rabbit, beaver, and river mussels.
Cultural Component 2 is placed between 8,000 and 6,700 years B.P. (Leonhardy 1970:118), limited to the Early Floodplain and Pre-Ash Aeolian Sand stratum. This cultural occupation is markedly different from the preceding occupation as it contains a homogeneous projectile point style. The exclusiveness of Cascade lanceolate points within the Cultural Component 2 assemblage is complemented with other new additions including: a small population of end scrapers made on large tabular flakes; the increased usage of large lanceolate knives; the presence of edge-ground cobbles; and an emphasis upon a varied cobble spall industry.

Leonhardy (1970:150-151) gives reference to other sites within the Columbia River Plateau producing assemblages similar to Component 2, including Ash Cave (Butler 1962), Thorn Thicket (Sprague and Combes 1966), Marmes Rockshelter (Rice 1969), 45WT2 (Nance 1966), and Windust Caves (Rice 1965).

Cultural Component 3 is estimated to fall between 7,000 and 5,000 years B.P. at Granite Point Locality 1 (Leonhardy 1970:151), found in association with the post-Mazama tephra Pale Loess stratum with its weakly developed soil horizon. Leonhardy (1970:151) refers to this assemblage as provisional due to its retention of strong similarities to the Cultural Component 2 assemblage; differing only with the inclusion of side-notched Cold Springs projectile point. The feeling is given by the author that this arbitrary designation of a separate component is made with some reservation and that the similarities rather suggest a continuation of the Cascade phase.

Cultural Component 4 is bracketed in time between 5,000 and 2,500 years B.P. within the Later Floodplain strata (Leonhardy 1970:158-159). Great changes in culture occur between Component 3 and Component 4, seen with
the introduction of smaller and crudely-made shouldered and notched projectile points. Other changes include: an almost total absence of formed knives; a flourishing of cobble spall utilization; the introduction of mortars and pestles; and the presence of a living floor, seen by concentrations of bone,debitage, and the accumulation of mussel shells. No structural features are reported, however. Associated faunal material included elk, deer, antelope, rabbit, coyote, rodents, unidentified fish, and mussels. Leonhardy (1970:170) notes a strong similarity to Component 4 assemblages within the Lower Snake River Canyon at the Tucannon site (Nelson 1966), and at 45WT2 (Nance 1966).

Cultural Component 5 is placed between 2,500 and 1,500 years B.P., found in association with the Post-Ash Aeolian Sand stratum. Identified as provisional, this cultural occupation is characterized by several assemblages found throughout the site area, combined on the basis of stratigraphic correlation and likeness in artifact style. Leonhardy (1970:170) states that the amount of material recovered from the site attributed to this component is too small for any insight into its place within regional prehistory. The assemblage does include "relatively large, relatively well made basal-notched...(and) crude stemmed and corner-notched forms" (Leonhardy 1970:189). The author identifies Component 4 as its cultural precursor but notes several technological changes warranting its provisional distinction. Faunal remains associated with Component 5 assemblages include elk, deer, bison (Bison bison), other smaller mammals, river mussel, and unidentified fish.

A number of other assemblages in stratigraphic position were recovered at Granite Point Locality 1, estimated to date between 1,000 and 0
years B.P. Due to their small sizes, they were placed within an inclusive set named The Unassigned Assemblages. These artifacts include "small corner-to-base-notched projectile points... also some small side-notched projectile points and several peculiar forms...(and) One large side-notched projectile point (which) resembles a Cold Springs point. It may be an intrusive..." (Leonhardy 1970:190).

The Nature of Human Occupation at Granite Point Locality 1

As Leonhardy’s aim was "to demonstrate that it is possible to analyze archaeological material typical of the Lower Snake River Region in terms of culturally meaningful, distinctive units" (1970:223), efforts to reconstruct the past lifeways and otherwise clarify the archaeological data from Granite Point Locality 1 were not included in this report. This is largely attributed to the relative paucity of comparable data in the surrounding region at the time of Leonhardy’s (1970) publication.

Inferences made from Leonhardy’s reported data will be used to expand on his limited description of the human occupation at Granite Point Locality 1. The long occupation at this site provides an excellent basis for evaluating culture change through time. Although Leonhardy does not detail the cultural succession reported here, a brief summary can be made.

(1) Initial human occupation at Granite Point Locality 1 is seen in correspondence with the basal gravel stratigraphic unit. This gravel likely formed an exposed bar, not far above the flood stage level of the Snake River, but beyond the general influences of ongoing fluvial process (c.f. Mierendorf 1984). Lacking evidence of structural
occupation features, this archaeological component might have been a hunting or seasonal foraging camp, due to the presence of formed artifacts, the widespread utilization of flakes, and the diversified presence of faunal remains.

(2) Later utilization of the site is found in context with incipient floodplain deposition and aeolian sand accretion. These depositional events mark the beginning of an increase in site usage. Cascade phase components, although lacking structural remains, suggest a continuation of activities from the earlier Component 1 cultures. Formed tools, and an industry of local lithic utilization, in the form of a river cobble spall technology represent a change in culture from the initial site occupation.

(3) Following the deposition of Mazama tephra, a continuation of sediment accretion is seen at the site. Cultural occupation continues in a technological mode apparently descendant from the initial Cascade component. Shortly thereafter, a great diversification of stone technology is seen along with an intensification of site usage is seen. The latter developments are correlated with Tucannon culture.

(4) Following the presence of Tucannon occupation, cultural components are less dynamic and small and poorly defined. Changes in technology are evident from the presence of new projectile points. A technological evolutionary continuation is seen from the prior Tucannon phase, but is deemphasized at Granite Point Locality 1.
Windust Caves (45-FR-46)

The Windust Caves site (45-FR-46) is located along the north shore of the Snake River in southeastern Washington, near a Northern Pacific Railroad sidetrack junction named Windust (Fig. 22). The site was excavated from 1959 to 1961 under the direction of Harvey Rice (1965), this project was part of the archaeological salvage work conducted in anticipation of the construction of the Ice Harbor Dam and the resulting creation of an upstream reservoir in 1962, which submerged the site. Nine caves were located within the parent basalt, in various states of preservation. Most of the caves had been infilled by colluvial material, both natural and as a result of railroad construction directly upslope. The remaining caves not greatly impacted by rock rubble had been vandalized by collectors in all but one case.

Site Stratigraphy

The stratigraphic components of the Windust Caves site were defined by Roald Fryxell and follow a basic stratigraphic nomenclature with roman numeric unit designators (Rice 1965:28-32).

Bedrock: basalt comprises the foundation of the cave floor in all areas of the site.

Stratum I: subangular to subrounded basaltic gravels with some poorly defined bedding; texture grades finely downward toward the basalt floor. This deposit has been interpreted as Late Wisconsin age gravels deposited by fluvial processes. No cultural materials were found within this stratum.

Stratum II: this unit is comprised of grayish brown sand with
subangular basaltic gravels. Rock fragments from the surrounding cave structure are also noted within this deposit. The formation of this stratum is interpreted as "an early anathermal drop in the river and erosion of the gravels of stratum I" (Rice 1965:29). The initial cultural occupation of the site was found in this stratigraphic unit.

Stratum III: grayish brown sands with rockfall fragments make up this deposit, interpreted as a continuation of Anathermal conditions (see Antevs 1955). Cultural materials were found within this stratum.

Stratum IV: the continuation of Anathermal climatic conditions resulted in the accumulation of subangular basalt gravel and few rockfall fragments here within a gray sand matrix; cultural material was found associated within this unit.

Stratum V: a discontinuation of gravel deposition and an increase in the accretion of sand is noted here. This stratigraphic unit is comprised of a firm light brownish gray sand, which, although largely massive in structure, reveals finely formed cross bedding features in localized sections of the deposit; some rockfall debris is associated within. Interpreted as an Anathermal stage of sandy beach construction along the river, this unit contained a greater proportion of cultural materials than in previous stratigraphic units and has been defined as a midden deposit.

Stratum VI: brown subangular to subrounded basalt gravels slumped at a 10 to 15 degree dip toward the mouth of the caves from deposits in the rear make up the body of this stratum. The formation of this deposit is placed mostly within the Altithermal and continues into the inception of the Medithermal period. Fire blackened areas with associated cultural material were found associated with this stratum.
Stratum VII: the formation of these yellowish brown silt loam sediments with inclusive charcoal and fragmentary bone bedding structures are interpreted as partly cultural in origin. Rice (1965:31) states that the stratum was formed of extensive fire lenses with debitage and other organic materials.

Stratum VIII: a culturally-sterile deposit of brownish gray fine sandy loam, with a soft, massive structure is recorded here. This deposit is thought to represent the accumulation of loess within the cave.

Stratum IX: cultural occupation of the cave continues with the deposition of very dark grayish brown fibrous organic material, which grades downward into a loess component with some rockfall fragments. Cultural features observed in this stratum include multiple fire hearths with broken bone, fibrous plant and wood debris, and a grass-lined pit containing burned and shattered bone pieces, rock fragments, and ashes.

Stratum X: this stratigraphic unit was formed during railroad construction and is comprised of coarse angular basalt fragments, some loess matrix, and cultural materials associated with the building activities.

Cultural Occupation

Rice (1965:33-51) identifies five successive cultural traditions at the Windust Caves site representing about 10,000 years of occupation. The dates provided for the prehistoric occupations are generated by comparisons between Windust Cave projectile point styles with other known radiocarbon dated occurrences of the artifact type from other sites in the region. Additional temporal insight was provided from the stratigraphic association
of cultural material, allowing for geological age estimations. Coupled with the assigned paleoclimatic depositional environment as outlined by Antevs (1955), the inferred context of stratigraphic deposition provided a further means of bracketing the cultural occupations at Windust caves. The attributed dates from Antevs' (1955) Neothermal model were extrapolated to stratigraphic units interpreted as formed under specific climatic regimes. These age estimates were then applied to those units associated with the corresponding cultural assemblages. This presents a loose timeline from the human presence at Windust Caves, allowing for the comparison of the cultural succession with other regional typologies.

Tradition 1, recovered from Stratum I, represents the first cultural occupation at the site and is placed between ca. 9,950 to 8,950 years B.P. by its morphological similarity with a projectile point recovered from the Roadcut site near The Dalles, Oregon, which was radiocarbon dated to ca. 9,735 years B.P. (Rice 1965:35-36). The projectile points associated with this tradition are designated as the Windust type form and are described as "Broad lanceolate blade with shoulders approximately one-third the distance from the base to the tip. Stem expands immediately below the shoulders giving the specimen a 'waisted' appearance. Lenticular in cross section. Concave base" (Rice 1965:72). The assemblage recovered at Windust Caves is considered indicative of the type site for Leonhardt and Rice's (1970) designation of the Windust Phase. Other artifacts associated with Tradition 1 include: a possible drill fragment; and three discoidal basalt cores, from which the removal of large flakes by a strong percussive action was observed to have occurred.

Tradition 2, recovered from Strata IV and V, is identified to have occurred between ca. 8,950 to 7,450 years B.P. (Rice 1965:37), represented by a
cultural occupation including several projectile point styles described as such:

While the basic manufacturing technique employed in the production of projectile points of this tradition seems to be fairly consistent, the specific forms of the specimens are quite diverse. A lanceolate blade shape and a general correspondence in size is noted, however, which transcends the various typological categories. Grinding on the edges of the stem and base of those specimens which may be regarded as being stemmed is a frequent attribute which is confined to this tradition (Rice 1965:38).

Rice (1965:38) notes that projectile points with a form similar to those seen in Tradition 2 have been recovered from other sites in the Columbia Plateau in comparable stratigraphic context. Cressman's (1960) attribution of such points to his Full Early Stage is cited, dated by the radiocarbon method to sometime between ca. 9,735 and 7,265 years B.P. The presence of large oval/lanceolate knives is also noted, as are: unifacial scrapers; a drill; a graver; a pebble chopper; and several flake cores.

Tradition 3 was found in the lower majority of Stratum VI, and is temporally placed between ca. 7,450 to 6,450 years B.P. (Rice 1965:40). One projectile point style is found associated with this tradition, described as: “thickly lenticular to diamond-shaped in cross section; lanceolate, ‘willow-leaf’ shaped, or, as an alternate term, ‘bi-convex’ in plan view. This tradition includes the types called Cascade points by Butler (1962a:36)” (Rice 1965:41). Other artifacts recovered include: a crudely-made knife, or preform; a drill fragment; concave scrapers; spokeshaves; steep-end scrapers; a graver; notched pebbles; utilized cobble spalls; and pebble choppers.

Tradition 4, associated with Stratum VI and the lower portion of Stratum VII, was found to have occurred between the dates of ca. 6,450 to 4,450 years B.P. (Rice 1965:46). Of the 32 projectile points assigned to this
assemblage, several forms are present, including large side-notched points in association with Cascade-type lanceolates. These are thought to represent Butler's (1961) Cold Springs Horizon, which is noted to occur immediately after the inception of the volcanic eruptions of Mount Mazama. Other artifacts recovered from Tradition 4 assemblages include: a fully-formed triangular knife; three knives made on flake edges; scrapers; burins; edge-ground cobble; a utilized cobble spall; and cobble choppers.

Tradition 5 is identified to have occurred between 4,450 years B.P. and the beginning of the historic period, found within the upper portion of Strata VII and IX (Rice 1965:48). This span of time represents an exceedingly long period of occupation for a single culture in the Columbia Plateau and in later works, beginning with Leonhardy and Rice (1970), was further divided into multiple cultural traditions. This assignment of a 6,400 year span for Tradition 5 comes from want of chronometric control. As there were no radiocarbon dates available for the strata (VII and IX) associated with this tradition, age estimates are provided from an extrapolation of Antevs' (1955) model of climatic change to site strata. Rice (1965) does explain the nature of the artifacts recovered from the site, as attributed to Tradition 5. Using the description provided by Rice (1965) in conjunction with the regional typology, developed by Leonhardy and Rice (1970), the nature of this last tradition becomes somewhat clearer:

Tradition 5 includes a manufacturing technique in which pressure flaking is applied to a thin flake in order to produce a triangular shape. This triangular "blank" was then notched to achieve the desired final form. Points with either corner or base notches which form a stem and barbs predominate in this tradition. Early in the tradition, projectile points are comparable in size to those of earlier traditions, but there is a tendency toward reduction in size which leads to the small, well-made
points found in the cultural deposits attributed to the time immediately preceding contact (Rice 1965:49).

The time period associated with the occurrence of Tradition 5 is represented by the initial onset of the Tucannon Phase and continues with the Harder and Numípu Phases as defined by Leonhardy and Rice (1970). So, it is expected that if this cultural model allows for the inclusion of these assemblages, they might be observed in Rice’s (1965) descriptions. The above statement is a general summary of the projectile point styles recovered from the site. Discussion is provided in reference to the two stratigraphic units associated with Tradition 5.

Stratum VII produced projectile points styles attributed to the Ice Harbor barbed type and one standout form described as “a rather large specimen with a lanceolate blade and a contracting stem” (Rice 1965:50). Other artifacts associated with Stratum VII include: a drill; “thumbnail” end scrapers; a “cutting-scraping tool”; a hammerstone; and a pebble utilized as a chopper. Projectile points associated with Stratum IX are described as representing the Columbia corner-notched and Desert side-notched styles, and as being small and triangular with a converging stem. Other artifacts include: formed triangular knives; cobble choppers; a utilized cobble spall; and a variety of organic items.

The Nature of Human Occupation at Windust Caves

Rice gives valuable insight into the occupational behavior of the prehistoric human inhabitants of the Windust Caves site. Although no structural features were recovered from the site, its use is noted to have
occurred over a period of ca. 10,000 years:

Windust Cave C, in all probability, was utilized primarily as a temporary shelter for nomadic groups. Small hunting parties were probably the most frequent occupants of the cave during all periods in which the cave was occupied. The total artifact assemblage from the site suggests little in the way of permanent occupation by family groups. There is a notable absence of many of the stone artifacts which are typical of habitation sites in the Columbia Plateau. Some very common and usually numerous artifacts found in Plateau habitation sites which either are not found or are very meagerly represented at the Windust site are cobble hopper bases, pestles, fractured cobbles, pebble sinkers, and hammerstones. The assemblage from the Windust site has very little in the way of food preparation implements.

On the other hand, the relatively large number of projectile points suggests a hunting camp (1965:54).

The site represents a habitation occupation, more suggestive of a temporary shelter used during hunting trips. The manner in which cultures were interacting with a changing environment can be seen in an expanded time frame at the Windust Caves site.

**Marmes Rockshelter (45-FR-50)**

Marmes Rockshelter (45-FR-50) is located along the Palouse River almost 2 miles upstream from its confluence with the Snake River in southeastern Washington (Fig. 22), and represents one of the more important sites excavated in the Columbia River Plateau due to its long sequence of well-dated cultural occupations. The rockshelter appears to be an erosional feature cut into the face of the local basalt flow bedrock, while the remainder of the site is found within the floodplain, which extends downslope to the Palouse River immediately adjacent to the rockshelter.
Excavations at Marmes Rockshelter were supported through reservoir survey and site investigation prior to the construction of hydroelectric dams within the Lower Snake River Canyon, directed by Richard Daugherty during the summers of 1962 to 1965 and later in 1968. In his 1969 doctoral dissertation, David G. Rice provides data and discussion on the rockshelter and will be referenced here.

**Site Stratigraphy**

Geological analyses provided by Roald Fryxell (Rice 1969:2-6) subscribe to a standard stratigraphic nomenclature summarized below.

*Stratum VIII*: with its abundant manure (from domestic animals) and organic material, suggests an incipient plaggen-type horizon. Displaced sediments from earlier disturbed deposits are also found here.

*Stratum VII*: contains several cultural features including hearths and pits. Organic materials, rockfall clasts, and an aeolian matrix are also noted here. Samples of charcoal and shell were recovered from this stratum: the first from just below the upper boundary of the stratum returned a date of 1,110 ± 50 years B.P.; and the other recovered from a deeper position, provided a date of 4,250 ± 150 years B.P.

*Stratum VI*: shows evidence of further cultural occupation with the presence of excavated sediments and hearth features. These features were incorporated into the stratigraphic record with the accretion of aeolian sediments. Rockfall clasts are also present within this stratum. A single radiocarbon sample of charcoal returned a date of 1,300 ± 60 years B.P.

*Stratum V*: consists of an aeolian sand matrix with some inclusive rockfall clasts and reworked Mazama tephra. The poorly sorted nature of this
unit, coupled with obvious sediment displacement is attributed to cultural activities associated with the excavation of graves. No chronological dates are present within this unit.

*Stratum IV:* is entirely composed of Mazama tephra. No comment on depositional features are provided to suggest air-fall or secondary transport formation processes as responsible for its emplacement within the site. Thus, the exact date of stratigraphic formation is limited to a point within the bracketing radiocarbon dates. Fryxell (1965) places the inception of this tephra-fall at ca. 6,600 years B.P.

*Stratum III:* contains evidence of cultural deposition with the presence of several shell and bone lenses within an aeolian sediment matrix. Well-rounded clasts in sizes ranging from pea-gravel to cobble are noted with scoria. Three radiocarbon dates are reported from Stratum III: shell dated to 7,400 ± 110 years B.P.; and shell dated to 7,870 ± 110 years B.P.; shell from a pit feature at 10,750 ± 90 years B.P.

*Stratum II:* is largely associated with coarse rockfall clasts infilled with aeolian sediments. Some well-rounded pea-gravel to cobble sized clasts with a scoria and basaltic rock inclusion are also noted here. Two radiocarbon dates are returned from shell material recovered in association with these large rockfall clasts at 10,475 ± 270 and 10,810 ± 275 years B.P.

*Stratum I:* is composed of coarse rockfall clasts in a heavy occurrence, lacking an interstitial matrix at the upper portion of the stratum. The unit grades into a lacustrine deposit below, identified by its inclusion of rounded cobbles, pea-gravels, and coarse well-rounded rockfall bedded within a matrix of gray silt; which was observed to possess a platy structure. This stratum is bounded below by basalt bedrock.
Cultural Occupation

As Rice (1969) only provides a catalog of artifacts, features, and other associated materials, restricting his commentary on the cultural occupation at Marmes Rockshelter, his provided information will be compiled into an applicable discussion here. For lack of a better alternative, the description of cultural occupation will be made in reference to its associated stratigraphic context following with the nomenclature described above.

*Stratum I:* dated by an upper limiting radiocarbon sample, placing the inclusive occupation at a time older than 10,810 ± 275 years B.P., this unit revealed the earliest occupation at the site. The cultural assemblage from this unit is composed of several distinctive projectile points in shouldered and stemmed forms.

Other artifacts were also recovered and include: a crude biface; a drill; a graver; scrapers; utilized flakes; core scrapers; a flake core; cobble choppers; hammerstones; a mano; a shaft smoother; ochre; a bone awl; assorted worked bone pieces; shell beads; and shell pendants.

Two hearths were also noted, containing bones of fish, bird, mammal species, and mollusk shell. Charred fragments of human bones attributed to two adults and three children were also found in the hearth features.

Although not stated by Rice in this report (1969), the cultural assemblage recovered from Stratum I is strongly suggestive of Leonhardy and Rice’s (1970) Windust Phase; with this site named as the type locality in their definition of the cultural component.

*Stratum II:* dated between 10,475 ± 270 and 10,810 ± 275 years B.P., this component includes several types of projectile points. Lanceolates in various shouldered, stemmed forms seen in Stratum I are also noted here. Stratum II
does have new additions to the cultural assemblage: mainly as Cascade-type lanceolate forms lacking the basal modification seen in Windust points. Stratum II appears to be a transition zone between the Windust and Cascade phases as a greater proliferation of lanceolate points follows in the next stratigraphic unit.

Other artifacts recovered from Stratum II show a rich material assemblage in use during the time of occupation and include: a leaf-shaped knife and fragments; crude bifaces; drills; gravers; burins and burin spalls; scrapers and utilized flakes; a corescraper; flake cores; cobble choppers; cobble spall scrapers; talus spall knives; hammerstones; manos; milling stones; an edge-ground cobble; a cobble with a red ochre stain; several bola stones; pieces of ochre; bone awls; bone needles; assorted worked bone pieces; an antler pressure flaker; and shell ornaments.

Several features were also found in this stratum including hearths with associated faunal remains and lithic artifacts. Many fire pits were also observed with similar cultural materials in association. Charred fragments of human bone were also noted throughout the unit matrix, of the same nature as that described in Stratum I.

*Stratum III:* dated between 7,400 ± 110 years B.P. and the end of Stratum II, this unit is associated with a culture likely descended from the prior occupation. This hypothesis is built from an observed increase in previous projectile point forms--specifically, slightly-shouldered lanceolate and small lanceolate styles at the expense of abandoning other forms. Several new additions to the artifact assemblage are seen in Stratum III including obsidiandebitage, as well as unifacially-flaked lanceolate, ovate, and lozenge-shaped projectile points. Other components of the assemblage include: many knife
forms; several crude bifaces; a graver; the largest number of scrapers found at the site, in all varieties; flake cores; cobble choppers; a large number of cobble spall scrapers; a talus spall knife; the first occurrence of a cobble core; the highest frequency of hammerstones; manos; a milling stone; multiple edge-ground cobbles; a cobble with a red ochre stain; bolas stones; many pieces of ochre; manuports of exotic rock material; bone awls; a needle; assorted worked bone pieces; an atlatl spur; two antler splitting wedges; shell beads; and a fragment of woven matting.

Many cultural features were located in Stratum III, producing further evidence of an extensive occupation. A total of 20 hearths were found containing charred bones of fish and other species, shell, artifacts, and pieces of ochre. Four firepits and two storage pits were also found, with associated bone, shell, charcoal, and artifacts.

The skeletal remains of several individuals were located both within recognized burial features and as disarticulated remains in a small area, lacking any formal grave preparation. The burial features consisted of an infant and an individual of unstated age, found in association with duck remains (shell from this burial has dated at 7,870 ± 110 years B.P.). Fragments of another individual were found as well but lacked any visible burial features.

The skeletons of two other adults were found in a rather interesting context. They were without burial pits with one individual positioned “face down with one arm under the rib cage,” and both observed to be resting “on a shell layer immediately underlying undisturbed pumicite” (Rice 1969:77-78). The pumice material Rice refers to in this description has been identified as Stratum IV and is comprised of tephra from the Mount Mazama eruption.
dated at ca. 6,600 years B.P. (Fryxell 1965). Rice does not comment on the nature of these sub-tephra skeletal features, so it is unknown whether the remains are to be considered contemporary with the tephra-fall event. The fact that the remains are without formal burial features and are directly underneath Stratum IV is rather suggestive of a death associated with the eruptive event. This subject requires further investigation to affix the contemporaneous context of the death of the individuals and the deposition of air-fall tephra in the rockshelter. Radiocarbon assays upon the skeletal remains could shed some light upon this problem, showing a close fitness of chronological events.

The artifact assemblage, in association with the radiocarbon dates and the presence of the Mazama tephra, identifies this occupation as associated with Leonhardy and Rice’s (1970) Cascade phase. The perpetuation of what seem to be Windust phase projectile points into Stratum III may appear to be the result of omitted reported vertical control among artifacts, rather than a curation of Windust technologies within Cascade phase toolkits. It is not unlikely that these cultural phases could occupy the same stratigraphic unit (c.f. Sappington 1994). Without reference to the vertical position of the type artifacts (in this case, projectile points) the lines between phase occupations become blurred.

Stratum V: with a date of ca. 6,800 years B.P. on Mazama tephra in Stratum IV, acting as a lower limiting date, this unit is constrained above by a series of radiocarbon dates: one within Stratum VI at 1,300 ± 60 years B.P.; and three from Stratum VII at 4,250 ± 150 years B.P., 1,300 ± 140 years B.P., and 1,110 ± 50 years B.P. The anomalous date of 4,250 ± 150 years B.P. from Stratum VII is taken from shell material. Due to the disturbed nature of the
unit, with its multiple hearth, firepit, storage pit, and burial pit features, it is feasible that the shell material has been displaced from a lower stratigraphic position into Stratum VII. This leaves Stratum V in a rather loose chronological context, constrained between the dates of ca. 6,800 and ca. 1,300 years B.P.

The addition of two new projectile point forms is seen in Stratum V, along with the previous forms. Shouldered rectangular stemmed points and a triangular point style, which may also be a preform, are introduced during this depositional period. Side-to-corner notched points reach a peak frequency here, and the presence of many lanceolate forms is noted including many side-notched forms.

Several new additions to the cultural assemblage are noted in Stratum V from anvil stones and a large mano, to abrading stones and several atlatl weights. Other artifacts recovered here include: the highest frequency of formed bifacial knives; crude bifaces; drills; many scrapers; flake cores; the most obsidian debitage; cobble choppers; cobble spall scrapers; talus spall knives; a cobble core; many hammerstones; manos; milling stones; edge-ground cobbles; a shaft smoother; the highest percentage of ochre; manuport lithics; long, polished antler shafts; bone awls; a worked bone piece; an antler splitting wedge; nearly 400 shell beads, the most of any stratum; a piece of matting; a dart shaft fragment; and a buckskin fragment.

Many features were located within Stratum V, notably in the frequency of burials. Several hearths and firepits contained charcoal, bone (including fish vertebrata), choke cherry pits, shell, red ochre, and assorted artifacts. Two storage pits with remnant evidence of having been lined with grass were found as well containing ash, charcoal, shell and rockfall fragments. Anvil
stones were also found in association with considerable obsidian debitage. Eight human burials were discovered, each with interment artifacts.

Stratum VI: is dated by a radiocarbon determination at 1,300 ± 60 years B.P. With reference given to the stratigraphically inferior position of Stratum V and its lack of inclusive dates, a better chronological context may be obtained from the upper limiting dates from Stratum VII: at 4,250 ± 150 years B.P.; 1,300 ± 140 years B.P.; and 1,110 ± 50 years B.P. As stated above, the date of 4,250 ± 150 years B.P. on shell material is most likely displaced from a lower stratigraphic position. With the commensurable dates present between Stratum VI and VII at ca. 1,300 years B.P., a tighter chronological control is afforded here than in previous strata.

Stratum VI marks the entry of several new projectile point forms in addition to features unlike any in prior occupational deposits. These new projectile point styles include shouldered contracting stemmed, crude lanceolate, slightly shouldered lanceolate, large triangular basal notched, two varieties of corner-notched, and a small side-notched form. The presence of previously noted point forms including many lanceolate forms is also seen here. Given the constraining chronological dates and a simple comparison of Rice’s (1969) reported artifact forms with Leonhardy and Rice’s (1970) typological definitions, it appears that Stratum VI contains assemblage components attributable to the Tucannon and Harder phases.

Other artifacts were also found within Stratum VI: many formed bifacial knives; crude bifaces; a graver; many scrapers and utilized flakes; a core scraper; several flake cores; cobble choppers; cobble spall scrapers; a talus spall knife; multiple hammerstones; anvil stones; several manos, a cobble with a red ochre stain, and pieces of red ochre; bone awls; a needle; a tubular
bone bead; several shell beads; and a brass/copper firearm shell casing (obviously intrusive).

Five hearths and six firepits were noted, filled with charcoal, shell fragments, bone, debitage, a choke cherry pit, projectile points, and assorted artifacts. A storage pit was also discovered, filled with stones. Unarticulated bone fragments were found scattered throughout the unit's matrix, lacking any visible burial features.

*Stratum VII:* several radiocarbon samples returned dates of 4,250 ± 150 years B.P., 1,300 ± 140 years B.P., 1,110 ± 50 years B.P., and 0 ± 110 years B.P. The two outliers in this sequence are, as stated before, likely the result of intrusive material introduced during the excavation of the many features located here.

Projectile point styles recovered from Stratum VII are of past forms, retained in this new occupational stage. Several lanceolate forms, some stemmed varieties, and the peak occurrence of small corner-notched points are seen in this unit. This deposit likely postdates Leonhardy and Rice's (1970) Tucannon/Harder phase boundary at ca. 2,250 years B.P., based on the artifacts reported at Marmes Rockshelter. Lacking a detailed analysis of the point forms present, the assemblage of Stratum VII probably represent the Harder and Piqúnin phases.

Other artifacts recovered from Stratum VII include: bifacially-flaked knife fragments; crude bifaces; drills; gravers; burin spalls; many scraper styles including multiple utilized flakes; a core scraper; flake cores; cobble choppers; cobble spall scrapers; the first instance of a pebble sinker; many hammerstones; the initial occurrence of pestles; manos; an edge-ground cobble; an abrading stone; a shaft smoother; stone beads; an incised pebble;
many ochre pieces; a bone awl; needles; a worked bone piece; tubular bone beads; a bone pendant; many shell beads; a piece of fiber cordage; a wooden cradleboard; a lead bullet; and a strip of leather.

Many features were noted in Stratum VII including 15 hearths, 20 firepits, and 16 storage pits. Some of the storage pits were grass lined and filled with rockfall fragments, bones, shell and assorted artifacts. Burial features were not recognized here. However, scattered disarticulated human bones and fragments of bones were noted in this stratum.

Stratum VIII: the presence of manure from domestic cattle, historic artifacts, and recent firepits provided a relative age estimate for this stratigraphic unit. Constrained below by a radiocarbon date of ca. 1,110 ± 50 years B.P., this surficial stratum likely dates to a period of less than the last millennium. A paucity of prehistoric artifacts is noted here, along with the presence of historic materials. These include: corner-notched points; bifacially-formed knife fragments; a drill; scrapers and utilized flakes; a cobbler chopper; a cobbler spall scraper; a hammerstone; some shell beads; and several Euroamerican artifacts ranging from bullet casings, a wire fragment, a piece of a rifle barrel, and a cow bell.

The only features observed in Stratum VIII are attributed to intrusive pits dug by pothunters and a recent firepit. The skeleton of a domestic cow was also discovered in this unit.

The Nature of Human Occupation at Marmes Rockshelter

Rice’s 1965 report currently stands as the only published information on the Marmes Rockshelter site. This single publication takes the form of an interim report, and lacks insightful detail, or insight beyond its basic
descriptive standpoint. This fact seriously limits any effort to provide an understanding of the nature of human occupation at Marmes Rockshelter. The information as Rice has reported is quite tabular in format, and has been gathered together in this thesis in a working summary of the archaeological record from 45-FR-50. Deficient as the Marmes report is, its inclusion within this thesis is important, since valuable information was gleaned from its assemblages to construct Leonhardy and Rice's (1970) cultural typology of the Lower Snake River Canyon.

Hatwai (10-NP-143)

Located along the northern shore of the Clearwater River, upstream from Lewiston, Idaho (Fig. 22), the Hatwai site (10-NP-143) was excavated between 1977 and 1978, directed by Kenneth Ames. The results of the excavations at Hatwai are compiled in an unpublished manuscript (Ames et al. 1990), which combines the information of several Masters theses dealing with aspects of the site.

Site Stratigraphy

A larger understanding of the Late Quaternary stratigraphy of the Lower Clearwater River Canyon is presented and correlated to the cultural occupation seen at Hatwai (Ames et al 1990). A summary of the lithostratigraphic units will be presented here.

_Late Pleistocene Alluvium (Qpa):_ This unit contains bedded silts with alternating lenses of very fine sand and granule basalt gravels with few intermittent angular basalt clasts. A horizon of Mount St. Helens set S tephra
(dated between ca. 12,000 and 13,000 years B.P. by Mullineaux et al. [1978]) was found in the upper portion of the unit. The Qpa deposit is about four meters thick and unconformably overlies basal bedrock comprised of Columbia River Basalt.

**Scabland Flood Deposits (Qss):** This depositional unit is composed of rhythmically bedded silt and sand. The Qss is described as "multiple beds (8-35 cm thick) of poorly sorted, coarse sand, parallel laminated medium sand, in phase ripple drift laminations, trough cross bedded fine sand, parallel laminated medium sand, and massive fine sand and silt (Ames et al. 1990:72)."

The Qss unit also contains gravels of many types; many of which are mineralogically exotic to the Lower Clearwater valley. The Qss is interpreted as originating from the terminal Glacial Lake Missoula floods. The unit lacks direct dates, but is provided a lower limiting age of 13,000 years B.P. from the presence of Mount St. Helens set S tephra in the stratigraphically inferior Qpa deposit.

**Early Alluvium (Qae):** An upward fining sequence from cobble gravels to sand and silt forms the Qae deposit. Combined with imbrication features, this upward fining deposit is interpreted as fluvial in origin. A series of direct and indirect dates allow for some chronological control of the Qae deposit. A lower limiting age of 13,000 for the Qae comes from the stratigraphically inferior Qss silts and sands with its inclusive Mount St. Helens set S tephra. Qae deposits have yielded primary Glacier Peak tephra (dated at 11,200 years B.P. [Fryxell 1965]) substantiating the use of an older age estimate. Radiocarbon dates of 9,160 ± 230 years B.P. (TX-3265) and 8,800 ± 1,310 (TX-3265) were recovered near the silts. Developed soil horizons are also evident in the Qae unit. A direct upper limiting date is missing for the Qae, however
this unit predates primary deposits of Mazama tephra, dated at ca. 6,600 years B.P. (Fryxell 1965) found in an upper unit.

_**Early Middle Alluvium (Qam):**_ The Qam deposits include alternating parallel beds of sand and silt, varying in thickness and texture; comformable overlying the Qae unit. Bioturbation is evident in the upper sediments of Qam, while primary deposits of Mazama tephra are also present.

Weakly formed paleosols are also seen in the Qam unit. A lower limiting age of ca. 6,600 years is provided for the Qam unit, with an inclusive primary deposit of Mazama tephra. A direct upper date is lacking here, with age estimates coming from a radiocarbon date at ca. 4,300 years B.P.--recovered from the middle of the stratigraphically superior Qal unit.

_**Late Middle Alluvium (Qal):**_ Moderately sorted beds of fine and very fine sand and silt comprise the Qal unit, which unconformably overlies the Qam unit. The internal stratigraphic integrity of Qal units are compromised by biotic and cultural turbation; the latter from the construction of housepit foundations in some localities.

A paleosol observed on the Qal is weakly developed upon sediments interpreted as originally deposited in a fluvial environment, as evidenced by the sharp, clear boundaries between beds. A radiocarbon age of 4,300 years B.P. from bulk sediment organics provides a direct middle date for the Qal; a direct lower limiting date is lacking. The 4,300 year date is somewhat substantiated by dates taken from intrusive cultural debris in the middle of the Qal radiometrically dated to 3,130 ± 90 (WSU-1878) and 3,440 ± 100 years B.P. (TX-3264). A firm upper limiting date is unavailable here, but is known to be older than ca. 1,000 years B.P., derived from the overlying Qap unit.

_**Late Alluvium and Colluvium (Qap):**_ this unit is described as
"composed of an angular, poorly sorted, clast supported, non-impact marked, open framework, basaltic cobble-pebble gravel at the base that is disconformably overlain by finer textured deposits" (Ames et al. 1990:78-79). The finer textured deposits exhibit an upward fining sequence from coarse sand to very fine sand and silt.

The Qap unit retains evidence of bioturbation and features of cultural activity. This deposit is interpreted as an initial short distance fluvial transport of gravels, later followed by alluvial overbank river flooding. The Qap unit is dated below only by the underlying, older deposits, placing it at >3,100 years B.P. A radiocarbon date of 970 ± 80 years B.P. (WSU-1879) was returned from the upper Qap gravels. Upper limiting dates are provided by additional radiocarbon dates at 360 ± 60 years B.P. (TX-3089) and 150 ± 70 years B.P. These latter two ages are further substantiated by the presence of late archaic and historic cultural material. A middle-range age is provided by a date of 2,270 ± 150 years B.P. from section 30.

Cultural Occupation

The record of cultural occupation of the Hatwai site has been developed from the presence/absence of specific artifacts termed "cultural time stratigraphic markers" (Ames et al. 1990:88), which usually are projectile points. Cultural occupation at the Hatwai site has been divided into four phases.

Hatwai I: encountered in association with the Qae gravels, this occupational unit bears three radiocarbon dates between 10,800 and 9,800 years B.P. Characteristic projectile recovered from this cultural stratum are divided into morphological groups: shouldered lanceolates with concave bases;
shouldered lanceolates with basal notches; reworked shouldered lanceolates; basal notched lanceolates; and shouldered lanceolates with convex bases.

On the basis of the projectile points recovered, Ames et al. provide this classificatory statement regarding cultural affinity: "The Hatwai I materials are characterized by stemmed lanceolate points typical of the early portion of the Windust Phase on the lower Snake River" (1990:88). The recovery of other artifacts associated with the Hatwai I stratum provide a depth of understanding for this cultural unit. Artifacts recovered include: a knife; a large number of bifaces; drills; gravers; a burin; burin spalls; triangular bifacial scrapers; many end scrapers; denticulate scrapers; a high number of utilized flakes; cores and core fragments; bifacial preforms; and various forms of cobble tools.

A great many charred and uncharred bone fragments were recovered within the context of the Hatwai I component. Species identification was hindered due to the fragmentary nature of the bone. Deer (Artiodactyl) and duck (Anas sp.) were positively identified. The status of the bone, in its highly fragmentary condition, suggests intensive faunal processing (c.f. Binford 1978a) within an efficient system of subsistence acquisition.

Hatwai II: The designation of this cultural occupation is provided by the recovery of a small number of artifacts within the Early Alluvium (QaeII), dated between 9,600 and 8,600 years B.P. Typological assignment of the Cascade phase is allowed by the presence of a single Cascade lanceolate projectile point. Other evidence of human presence is rare in the Hatwai II occupational unit.

Ames et al. describe the Hatwai II stratum as "a very small component of the early subphase of the Cascade phase based upon its stratigraphic
Hatwai IIIa: Located almost exclusively within the Qam, this cultural component is represented by a rich assemblage of artifacts and features, including four housepits. Chronologically, Hatwai IIIa spans the time between 5,550 and 4,100 years B.P., provided by a series of radiocarbon dates.

Cascade phase projectile points recovered from the Qam are explained away as intrusive; a result of prehistoric excavations of housepits. Associated with housepit floor surfaces, Hatwai IIIa assemblages contain a number of diagnostic artifacts in addition to Hatwai Eared and large Columbia Corner (or side) notched projectile points. Among the living floor features are other lithic tools, including: seam knives; a variety of scrapers; various cobble tools; and a “sizable number of large, heavy basalt slabs (hopper-mortar bases/anvils) on the floors of the houses” (Ames et al. 1990:509). A concentration of diversified bone tools also comes largely from a single house feature.

Ames et al. describe the lithic technology from Hatwai IIIa in the same manner as Leonhardy and Rice (1970) do for the Tucannon phase:

The small lithic tools have an opportunistic quality to them. Projectile points are rather “arrow head” in size and quickly made. There appears to have been little energy investment in lithic technology. Large lithic tools include an array of cobble tools; ground stone is limited to pestles (1990:509-510).

Ames et al. (1990) attribute the Hatwai IIIa assemblage to Leonhardy and Rice’s (1970) Tucannon phase, but assign the component to the "Hatwai Complex" (see Sappington 1994).

The Hatwai site produced a great deal of data from the Hatwai IIIa
component, allowing for a greater deal of resolution in reconstructing past events. Ames et al. (1990) provides discussion on the nature of the Hatwai IIIa occupation, which is summarized below.

(1) The construction of pithouses along the shore of the Clearwater River is seen throughout a 900 year period represented within the Hatwai IIIa component; reoccupation of a pithouse structure is determined to have occurred only once during this time—otherwise, new houses were built. Ames et al. (1990) estimate that 3 out of 4 Hatwai IIIa housepits were constructed between 4,500 and 4,100 years B.P., with a new structure established once every 25 years; suggesting a multi-family village.

(2) The construction of housepit structures and the presence of basalt slabs represents a degree of labor investment uncommon in the regional archaeological record. The total processing of animal carcasses, as evidenced by the large amount of fragmentary and utilized bone, suggests a subsistence paradigm devised for efficiency in resource exploitation.

(3) The ideas of a relatively “opportunistic” Hatwai IIIa lithic technology is supported by the reliance upon local lithic sources and the predominance of utilized flakes over more formed tools. On this point, Ames et al. elaborate:

Leonhardy and Rice (1970) noted what they regarded as a change, or even a decline, in lithic workmanship which marked the end of the Cascade Phase and beginning of the Tucannon Phase. I would suggest rather that the change marks an important shift in the replacement or a loss of technical skills. It simply was no longer crucial to produce well-made projectile points (1991:512).

(4) Ames et al. promote the concept of combining the Hatwai IIIa component with the occupation of House 4a at the Alpowa site in

Hatwai IIIb: The remainder of the archaeological evidence within the Hatwai III component is included here. Although lacking the diagnostic Rabbit Island Stemmed projectile point, Hatwai IIIb, for all intensive purposes, can be considered as representative of the Tucannon phase (Leonhardy and Rice 1970). Unlike the Hatwai IIIa component, Hatwai IIIb assemblages are largely indicative of non-structure features and activities; although a small number of housepits are associated with Hatwai IIIb.

An apparent period of site abandonment occurs between the Hatwai IIIa and Hatwai IIIb occupations:

The occupation appears to represent an intensive reoccupation of the site after a period of abandonment. I have shown elsewhere (Ames in press) that there is a gap in radiocarbon dates from excavated housepits on the Plateau between ca. 3900 and 3500 B.P. which I argue represents a shift in residential strategies. Whatever the cause, it is now evident that the gap in dates from Hatwai is not a local phenomenon (Ames et al. 1990:513).

The authors also explain that following the end of the Hatwai IIIa occupation at ca. 4,100 years B.P., housepits were not constructed in the Hatwai IIIb period until after 3,000 years B.P. This is identified as a shift in occupation, with prior traditions of house building at the Hatwai site postponed for a time following the end of the Hatwai IIIa period.

Hatwai IV: Cultural materials assigned to the Hatwai IV component are associated with two areas—noted as A and C. In these areas, Hatwai IV components are found within the Qal and Qap units, respectively. Chronological control for this cultural occupation is provided from the
associated lithostratigraphic units. Therefore, a lower limiting date for Hatwai IV of 2,270 ± 150 years B.P. is derived from the Qal stratum, while an upper limiting date of 150 ± 70 years B.P. is provided by a radiocarbon dated hearth feature (see below).

A modest 109 artifacts were recovered from this component. Of these, the presence of Desert Side-Notched and Mid-Columbia Basal Notched projectile points allow for a typological classification. The contextual association of the Desert Side-Notched point with a hearth feature dated to 150 ± 70 years B.P. (TX-3090) provide an upper date for the Hatwai IV occupation. A lower limiting date comes from a hearth dated at 1,060 ± 80 years B.P. (WSU-1880). Ames et al. (1990) assign Hatwai IV to Leonhardy and Rice's (1970) Harder phase designation.

In comment, the authors describe Hatwai IV:

It is obvious that this small fragment of a site appears to have been lightly used, or used in ways which left no evidence. Area A contains two meters of alluvial deposits, all postdating 1,000 B.P. This intense alluviation alone explains the sparse occupational record in area A (1990:570).
Within this thesis, an understanding of the effects of volcanic eruptions on the cultural-environmental relationship of prehistoric populations in southern Washington and north-central Idaho has been sought through the investigation of volcanic tephra-falls and the production of sulfuric aerosols during the Late Quaternary period. This bipart investigation requires the assessment of data on both levels: (1) observing the relationship between the production of tephra from Mount St. Helens and contemporaneous cultural successions at individual case study sites in an area of known pyroclastic deposition; and (2) a broader correlation of eruptive events, regional culture change, pollen fluctuations, glacial lithostratigraphy, and ice acitivity. This two-part process will give a desired level of resolution, offering a picture of both the site-level reaction to tephra-falls, and regional cultural interaction during periods of local and global volcanism.

By comparing relevant sources of information, discussion regarding correlative events in Pacific Northwest prehistory may be directed in a manner highlighting implications for the effects of volcanic eruptions as both direct and indirect sources of environmental stress upon cultural groups in the study area. The succession of cultural occupation, as reported from the archaeological case study sites is compared through time with the eruptions of Mount St. Helens in Figure 24. This comparison will serve as the basis for observing potential chronostratigraphic correlations between volcanic eruptions and cultural behavior. Although a great deal more work is needed to determine the fitness of what might appear to be correlations between
tephra-fall events and cultural succession from one tradition or component to another.

To underscore a point, it is not the intention here to attribute direct lines of causality among specific or general period of eruptive activity at Mount St. Helens and the reported archaeological record of culture change at case study sites. This data is presented to illustrate the differences and incipient correlations between the eruptive history of Mount St. Helens and the site-level record of prehistoric occupation in the study area. Later, wider comparisons will be made among paleoenvironmental, paleovolcanic, and culture successional data.

Figure 25 incorporates several lines of data including the eruptive history of Mount St. Helens, the archaeological occupation of the Koapk site, cultural successions of typological models, the paleoclimatic history of the study area as seen through pollen records and glacial lithostratigraphy, and the acidity record of Greenland glacial ice; plotted over the last 12,000 years. For clarity, the plotted nature of each data set will be explained, as a full understanding of the presentation is desired here.

The Data Explained

The columns of data in Figure 24 are presented for a comparison of tephra-falls and cultural succession at the site level. The eruptive history of Mount St. Helens is derived from Mullineaux (1986), and is followed by the cultural components reported from Koapk (Ellis et al. 1991), Sunset Creek (Nelson 1969), Windust Caves (Rice 1965), Marmes Rockshelter (Rice 1969), Granite Point Locality 1 (Leonhardt 1970), and Hatwai (Ames et al. 1990). The
information provided within each site column represent reported cultural components from the respective sources. Those periods listed as Hiatus have been identified by the authors as a lack of cultural occupation between dated archaeological components.

Each author, in an effort to identify characteristic periods of archaeological occupation, have applied a variety of concepts to denote the manifestation of culture ranging from Cultural Component, Tradition, Component, or attributed a distinct name, e.g., Hatwai IIIa.. These titles will be assumed as equal descriptions of cultural steady states, and treated as equal values, allowing for constructive inter-site comparisons to be made. The cultural boundaries separating distinct periods of occupation and cultural manifestation are presented as reported by each author; thus the insights provided here are only as good as the original data.

The eruptive history of Mount St. Helens outlined in Figure 25 is derived from the work of Mullineaux (1986) and is presented here as a reference to the well-dated volcanic events there. The letters and dates correspond to the production of tephra layers, identified by set.

The following five columns represent the cultural successions reported from typological models and archaeological sites across the study area, arranged here in a west-to-east manner. The Southern Washington Cascade Range data are derived from the Koapk site (45-LE-209). Since the southern Washington Cascades area has only recently began to be greatly investigated through extensive archaeological research (Lewarch and Benson 1991), a unified cultural typology is lacking from which cultural successions may be referenced. Other culture histories have been utilized, developed from sites in the outlying regions (e.g., Nelson 1965) but fall short of an exact
representation of the archaeological record observed in this area. Therefore, lacking a formal and applicable cultural typology, the simple presence of cultural evidence will be plotted here, denoted by shaded periods of occupation through time. The remaining columns of cultural data are derived from the typological models developed by Nelson (1965), Leonhardy and Rice (1970), and Sappington (1994) for the Middle Columbia River Basin, Lower Snake River Canyon, and Clearwater River drainage, respectively.

The Paleoclimatic History column is divided into palynological and glaciological data. The pollen summary was developed from vegetative successions reported from Wildcat Lake (Davis et al. 1977), Fargher Lake (Heusser and Heusser 1980), Carp Lake (Barnosky 1984), and Creston Mire (Mack et al. 1976). These pollen successions are plotted here as proxy data for climatological inference. The Glaciation data are provided by lithostratigraphic records reported from the Wallowa Mountains (Kiver 1974; Williams 1974; Burke 1978), and at Mount Rainier (Crandell 1969; Crandell and Miller 1964, 1974). Evidence of glaciation is plotted here in relation to specifically reported periods of activity. With the exception of the Glacier Lake advance seen in the Wallowa Mountains representing a single short-term event, glaciations are presented here as delineated periods of activity.

The Greenland Acidity Record data presented in the final column has been adapted from Hammer et al. (1980) and represents acidity signals from the Camp Century and Crête ice cores. The horizontal bars denote periods of acidity deposition in excess of 4 µequivalent H⁺ / kg of ice and are important indicators of climatically-effective volcanic eruptions.
Figure 24. Synthesis of data from Mount St. Helens eruptions and prehistoric occupational succession reported from archaeological case study sites
### Figure 25.

Synthesis of data from Mount St. Helens eruptions, archaeological case studies, paleoenvironmental proxy records, and the Greenland record of volcanic sulfur production.
Discussion

Interesting correlative events can be tracked with the data synthesis presented in Figure 25. Paleoclimatic successions show some important correlations with eruptive events of a local and global nature. As explained earlier, the maximal climatic effectiveness of volcanic eruptions is best considered in the perspective of atmospheric loading, with concomitant effects registering in decadal time intervals. With this in mind, closely-spaced eruptive events might have extended their climatic effects through repetitive aerosol production.

Periods of major glaciation seen in the Wallowa Mountains and at Mount Rainier correspond almost entirely with the eruptions of Mount St. Helens and closely-spaced acidity peaks in Greenland. The McNeely Glaciation and the Glacier Lake advance correspond initially with the eruptions of the J tephra, and terminate at ca. 10,700 years B.P.. Following the end of a major eruptive period in the Cascade Range of Washington, producing the J tephra sets from Mount St. Helens, and notably at Glacier Peak (although not plotted in Fig. 25) (Fryxell 1965), intense global volcanism is registered in the Greeland ice record after ca. 10,000 years B.P.. Again, the concept of atmospheric loading by successive eruptive events is of importance here. In a zonal perspective, the Mount St. Helens eruptions before ca. 10,000 years B.P. might have coupled with larger hemispheric effects of global volcanism to affect regional climate toward colder conditions. Given favorably cooler climatic conditions, opportunistic glacial growth might have triggered its own negative feedback loop; promoting its own advances, assisted by hemispheric volcanic activity.

The Neoglacial advance seen in the Pacific Northwest also corresponds
with regional and Greenlandic volcanic records. Reported from Mount Rainier and in the Wallowa Mountains, glacial advance immediately follows the deposition of Y tephra from Mount St. Helens. As this volcano enters its most active period of the Holocene, so can an overall increase in eruptive activity be seen in the Greenland acidity record. In combination, these two eruptive records show a closely-spaced succession of events nearly 4,000 years long, matching the period of Neoglacialation seen in regional mountains. This correlation deserves some serious attention in archaeological research.

Other acidity events are observed during the interglacial period between ca. 10,700 and 4,000 years B.P. However, the timing of sulfur peaks are widely-spaced as compared to other periods. Notably, this global volcanism lacks correspondence with local eruptions, except Mount Mazama at ca. 6,600 years B.P. (Fryxell 1965). Although undoubtably massive, the Mazama event might not have had much of a climatic affect due to its highly silicic short-lived impact upon the atmosphere. This hypothesis is not explored herein, however.

The idea that volcanic eruptions serve to effect prehistoric populations in multiple ways has been presented in this thesis. In consideration of the direct effects of tephra-falls, the reaction of human groups is expected to be different than that seen to volcanically-effective climatic forcing. With an appreciation of the more direct effects of tephra-falls (e.g., Matz 1991), and the potential that volcanically-produced aerosols have as a catalyst for climate change, the investigation into cultural adaptation to volcanic hazards may be better staged.
Temporal Perspective of Cultural Succession

Cultures changed through time in the archaeological record of the study area, but at unequal rates, retaining their characteristic integrity for differing lengths of time. On the topic of cultural succession in the Granite Point Locality I site Leonhardy states:

So far as the rate of change is concerned, it probably was not a constant, more-or-less random phenomenon. The fact that stationary states can be recognized implies that there were relatively long periods of comparative stability, each followed by rather rapid changes which produced another period of stability (1970:221).

In reference to Figures 24 and 25, a correlative relationship can be seen between periods of relatively long cultural stability and levels of volcanic inactivity at the local and global scale. It is argued here that later periods of volcanic activity, associated with both a readvance of regional mountain glaciers and a change to cooler climates, might be interpreted as evidence of an important mechanism of cultural forcing. Cultures prior to the Neoglaciation period possessed adaptive systems effective within a warmer and drier environment. Therefore, it is not unexpected that these cultural groups might experience stress in dealing with a changing environment. It is expected that those cultural adaptations to warmer and drier environmental conditions would require improvement or alteration to most effectively exploit a changing world.

Although the greatest proportion of observed culture change occurs in the last 4,500 years or so, other events not directly linked to environmental conditions may be identified as influential during this period. The last half of the Holocene period in the Columbia Basin is marked by increasing
prehistoric populations, which, as an event in itself could be a source of culture change. With increasing local populations cultural groups inevitably encounter different ideas, customs, and adaptive strategies through contact with other peoples. Whatever the degree of influence, the diffusion of cultural traits and adaptations is to be considered as a likely source of cultural diversity during this time.

A different perspective on the implications of population growth and diffusion of cultural traits provides other suggestions. Columbia Basin populations increasing during the late Holocene appears to be substantiated by archaeological evidence (see Nelson 1969 and Lewarch and Benson 1991). This geographic aggregation would have serious ecological implications, and is suggested here as being an important factor in the larger process of rapid succession from one late archaic cultural tradition to another.

Increasing human populations demand a corresponding improvement in the acquisition of natural resources. Within a given ecological system, natural limits are present to curtail the settlement density of any given species (Krebs 1972); human hunter-gatherer groups would be limited by the same mechanisms. These limits are subject to fluctuation in response to given changes in the environment. Climatic shifts, depending upon their direction, intensity, and duration, may reduce or weaken the carrying capacity of a given area exploited by a given cultural adaptation. Faced with ecological pressures from a changing environment, several options are presented to cultural groups, including the adoption or alteration of subsistence technologies, migration to more favorable areas, or at worst, extinction.

It is suggested here on a preliminary level that cultural groups in the Columbia Basin experienced ecological stress during the time corresponding
with both increased local and global volcanism and the readvance of mountain ice in the Neoglaciation period. With locally-growing populations, cultures were likely affected not only by increasing demands upon subsistence resources, but by a lack of unoccupied areas in which a migration option might be exercised. Some areas that were reoccupied during this time include the previously abandoned region around Mount St. Helens in the southern Washington Cascades, e.g., Koapk. Faced with these difficulties, the modification of subsistence strategies occurred with an importance placed upon increased efficiency within traditional areas. Simply put, cultural groups had to make the best of what they had.

Spatial Perspective of Cultural Succession

Just as the deposition of pyroclastic material is seen to decrease with distance from Mount St. Helens, the amount of stress directly imposed by tephra-falls upon cultural groups is lessened beyond the proximal area. Viewing the cultural record among the archaeological case studies in perspective of their distance from Mount St. Helens shows the effects of tephra-falls over a great distance. Reasonably, those sites in positions more proximal to the impacts of a volcanic source are expected to show different types of cultural reaction to eruptive events than those in medial and distal reaches of effect. Ultimately, the degree to which cultural groups react to any given eruption is dependent upon the relative explosivity of the eruption, its duration, the amount of pyroclastic material produced, the scale of its distribution, and the successive reoccurrence of volcanic events. The influence of volcanic events must also be viewed beyond the zonal area of effect, incorporating the potential effects from cumulative hemispheric
eruptions—e.g., atmospheric loading and alterations in albedo.

In a zonal context, the presentation of cultural phase successions in a west-to-east (southern Washington Cascades to the Clearwater River Drainage) fashion provides a template for observing the relative cultural reactions to the eruptions of Mount St. Helens from a proximal to distal position. Viewing the archaeological data of the study area in a hemispheric perspective demands that all sites be viewed equally in their potential for cultural effect. That is, the concept of proximal to distal positions are not applicable in a view of hemispheric effects.

Notably, the hiatus period seen at the Koapk site and other southern Washington Cascade sites present what are argued to be the reactive abandonment of the area immediately following the fallout of Y tephra from Mount St. Helens beginning at ca. 3,900 years B.P. (Ellis et al. 1991). Stratigraphically, this hiatus period is precluded by the deposition of almost two meters of pyroclastic air-fall material. The implications such a volcanic hazard presents for the prehistoric inhabitants of sites in this proximity during the accumulation of Y tephra cannot, perhaps, be overstated. It is not hard to accept that the initial reactions of these peoples was to simply and quickly leave the area. As Mount St. Helens continued its activity until ca. 2,450 years B.P., native populations might not have had much incentive to return to these areas. As well, the spoken history among local inhabitants concerning the initial Y tephra-falls could have easily remained in the minds of successive generations on the scale of millenia, with constant reminders throughout the Smith Creek eruptive stage and beyond into the Pine Creek stage.

Lewarch and Benson provide an overview of prehistoric occupation
reported from eight sites, not including the Koapk site. They present evidence of an occupational hiatus similar to that seen at the case study site reported herein, which is attributed to the volcanic activity of Mount St. Helens:

In searching for causal mechanisms to account for changes in land use, intensity of vulcanism in the region appears to have had an important role. The decline in dated components corresponds to a period of intense volcanic activity by Mt. St. Helens. There were three major periods of extensive eruptions between 4000 and 1700 BP, each lasting 500 to 700 years (Mullineaux 1986; Mullineaux and Crandell 1981). These eruptive episodes were characterized by pyroclastic and lava flows; dormant periods averaged 300 years between major active periods. Environmental degradation attributable to large-scale volcanic eruptions may have made the southern Washington Cascades an uncomfortable if not impossible region to inhabit. The 1980 St. Helens event certainly provides an example of the kinds of impacts that can occur near active volcanoes (1991:33-34)

Further consideration of the spatial perspective of cultural adaptation to volcanic eruptions within the study area must be given to the limitations of eruptive stress. With an understanding that the relative depositional thickness of tephra decreases with distance from the volcano, the direct impacts of pyroclastic accumulation are framed. It is understandable that the deposition of pyroclastic material at Koapk, given its proximity to Mount St. Helens, is expected to be more influential than might be seen at Hatwai. This observation is somewhat pedestrian, but important when compared with the indirect influences of volcanic sulfur production. The limited archaeological literature dealing with volcanically-produced stress within the Pacific Northwest has failed to address the production of sulfuric aerosols during eruptive events (Matz 1991 is an exception here). This process has the
implication of influencing cultures beyond the limits of tephra-fall deposition.

As Hammer et al. (1980) and Porter (1981) have stressed, the process of atmospheric loading is important in consideration of volcanic sulfur production. The regional application of this process in the investigation of volcanically-produced environmental stress must include coinciding global eruptive records; as with most atmospheric mechanisms, a wider perspective must be applied.

As hunter-gatherer groups were reliant upon their ability to adapt cultural measures to exploit a given environment as a means of successful survival, insight into the archaeological record of these adaptations should be viewed in reference to the environmental situation. Just as Hammatt states, “People function and make choices framed by opportunities and constraints devised by the changing nature of their land” (1976:190), so should our perception of their record be directed.
CHAPTER 13
DISCUSSION AND CONCLUSIONS

Research Questions Addressed

In the introduction of this thesis, a series of research questions were posed, in an effort to guide the research problem, and to adequately address the proposed research problem. Through the consideration of data presented within the previous chapters, answers to the research questions may be provided here.

(1) Do the eruptions of Mount St. Helens and the production of tephra-falls correspond in time and distribution with observable changes in regional prehistoric cultures of the Pacific Northwest?

As noted in Chapter 11 and illustrated in Figure 25, three stages of volcanic activity at Mount St. Helens from ca. 12,000 to 10,710 years B.P., at ca. 3,900 to 2,450 years B.P., and later intermittently between 1,200 and 150 years B.P. strongly correspond with increased deposition of SO$_4^{2-}$ in Greenland ice. These periods of local and global eruptive intensity also share a temporal correspondence with glacial advance and pollen shifts noting a change to cooler climates within the study area.

Cultural models and case study sites show a successional pattern, which suggests the possibility of a correlation with the effects of local and global volcanism. Long periods of cultural stability are noted during the first half of the Holocene. As eruptive activity increases at ca. 4,000 years B.P., closely followed by a readvance of regional glacial ice in the Pacific Northwest, cultural succession increases with rapid short changes occurring, especially
within Nelson's (1969) model. Whether Nelson's changes can be attributed to its relative proximity to Mount St. Helens, as compared with the Lower Snake River Canyon and the Clearwater River Drainage, cannot be adequately assessed here. However, this observation of cultural change is expected in my hypothesis that the closer archaeological sites are to the effects of Mount St Helens the better the potential for correlation of cultural behavior with eruptive impacts.

Adaptive cultural behavior at medial and proximal positions away from Mount St. Helens show a stronger correlation with the Neoglacial advance after ca. 4,000 years B.P., than with specific tephra-falls as observed at the Koapk site. This glacial activity in the Wallowas and at Mount Rainier is argued here to have been influenced to some degree by eruptive activity. The climatic effectiveness of volcanic events appears to have the widest influence upon cultures in the study area.

(2) Can these changes, if observed, be causally linked with Mount St. Helens tephra-falls, or do they represent a coinciding event with a cultural precursor reginally identified prior to the eruption?

The eruptions of Mount St. Helens show some correspondence with culture change on two levels: extreme reaction to tephra-falls as evidence in the archaeological record of proximal sites; and the Late Holocene shifts in culture during periods of increased regional cooling.

In regards to the degree of cultural correspondence to Mount St. Helens tephra-falls, distance from the volcano appears to have been a controlling factor in the apparent intensity of stress from, as communicated through cultural reaction immediately following the airfall event. Cultures near the volcano (e.g., Koapk) show reactions clearly in correspondence with the
eruption of the Y tephra after ca. 3,900 years B.P. Beyond the Cascade Range, cultural typological models and case studies provided across the study area show a gradation of what might be considered a correspondence between Mount St. Helens tephra-falls (see Figs. 24, and 25), and increased cultural succession (especially reported by Nelson [1969]) during the last 4,000 years.

(3) *Might change have been coming slowly, prior to the introduction of tephra-falls, only to be accelerated due to environmental impacts of the eruption?*

Observing the pollen record reported from the study area, a change at around 5,000 years B.P. from hot and dry conditions to a cooler and moister regime predates both the Y eruptions at Mount St. Helens and does not correspond with the deposition of acidity in the Greenland ice record (see Figure 25). The pollen record clearly shows a climatic change predating the potential for volcano forcing.

However, the fact that regional glacial lithostratigraphic records do not show correlative evidence of ice advance during the change in pollen records is interesting. The record of glacial advance at Mount Rainier and in the Wallowas corresponds in time after ca. 4,000 years B.P. with volcanic activity at Mount St. Helens and with increased deposition of acidity in the Greenland ice record.

This temporal correlation between the records of glaciation and volcanism, postdating the change in pollen records, suggests that the trend toward colder climates had begun prior to the eruptive increases following ca. 4,000 years B.P. This further suggests that if the eruptive period was effective in forcing climates to colder conditions it might have been able to promote a Neoglacial advance due to established post-Altithermal climates; representing
an opportunistic forcing mechanism. Thus, the development of colder climates after ca. 5,000 years B.P. show some evidence of being accelerated after ca. 4,000 years B.P. with increasing regional and global volcanism.

(4) Are there other influences present in the environmental record of the Pacific Northwest, which may correspond in time with Mount St. Helens eruptions, and be the true cause of culture change?

Following the change of climate to cooler and moister conditions after ca. 5,000 years B.P., the intensification of many geomorphological processes and postulated cultural responses are noted in the Lower Snake River Canyon by Lucas:

In addition to the reactivation of small stream courses choked with debris and sediment, large stream channels began downcutting and scouring older terrace faces incorporated with large accumulations of Mazama-ash. The resulting degradation of aquatic habitats forced concurrent changes within human economies adapted to the local riverine environments. These adjustments reported for the Tucannon phase time period along the Lower Snake River are notable and demonstrate the degree to which Cascade phase culture was unsuccessful in coping with environmental instability during the Altithermal time period (1994: i-ii).

In his assessment of Tucannon phase cultural adaptation within the Lower Snake River Canyon, Lucas (1994) provides arguments, which in the context of Question 4, can be constructively considered. Identifying processes thought to be responsible for the alteration of the Lower Snake River ecosystem and landscape, Lucas notes influences in the environmental record that might have been correspondent with any stress imposed by later activity at Mount St. Helens and beyond. Geomorphological shifts reported around 5,000 years B.P., and their resultant influences on the Cascade phase
adaptive strategy represent a causal argument for the latent adaptive success of the Tucannon phase.

Further changes in the environment could be argued to account for later cultural adaptive shifts, seen in the Harder phase, which occurs during the Neoglacial period. The Neoglacial advance might have increased environmental stress through the perpetuation of colder climates, forcing culture change. However, the Tucannon-Harder transition occurs about 1,000 years after the Neoglacial onset at ca. 3,500 years B.P. Therefore, a direct line of causality cannot be drawn to the change to colder climates after ca. 3,500 years B.P.; other factors are undoubtedly involved.

(5) Are changes in the Pacific Northwest cultures the result of a combination of multiple factors, including the eruptions of Mount St. Helens, and not a single forcing mechanism?

This question signifies my initial understanding of the implication of volcanic eruptions hold for forcing environmental conditions. Initially, an appreciation for the influential abilities of eruptive aerosols, the process of atmospheric loading, and the hemispheric perspective of volcanic activity (as recorded in the glacial ice of Greenland) was missing in my research. Later incorporation of these important factors, representing sources of stress in addition to the impacts of tephra-falls, was critical to viewing the potential link between prehistoric culture process and the environment of the study area. This enhanced perspective allowed for a broader investigation of the potential prehistoric cultural stresses introduced by the Mount St. Helens eruptions.

Although a wider appreciation for the influences of volcanic eruptions and their record in proxy data has been gained through this research, the
determination of causality between external environmental forces (singular or multiple) and the record of prehistoric culture change is not possible here. Further work is required to build strong arguments to assign direct or indirect causality between eruptive events and culture change.

Cultural Adaptation to Volcanic Events

As discussed in Chapter 3, an understanding of the cultural group, when thought to utilize an internally-regulating system of environmental adaptation (Sahlins and Service 1960; Thomas 1979; Matz 1991), is enhanced by considering the temporal correlation between tephra-falls and climate change in the Pacific Northwest. If the standpoint is taken that cultural groups will most effectively interact within their own environment when a state of adaptive equilibrium is maintained, investigation should be directed at those periodic changes in the archaeological record corresponding with volcanic eruptions, and shifting climatic conditions. Possibly, these periods of culture change represent reactions to states of environmental disequilibrium. Evaluation of the paleoenvironmental record prior to culture change provides a basis for understanding the choices made in implementing the cultural adaptation that follows (c.f. Matz 1991).

A review of the paleovolcanic record presented by Zielinski et al. (1994) suggests that the influence of volcanic eruptions on the environments and ecosystems must be viewed on multiple levels. Regionally, it is reasonable to investigate the effects of tephra-falls upon ecosystems (Matz 1991). As such events are limited in influence on a geographic scale. When considering the climatic implications of volcanic eruptions, one cannot simply look at
regional sources as the key to any observed shifts in temperature, precipitation, or other meteorological manifestations. Climate, although affected by multiple regional factors, must ultimately be viewed in a larger perspective. In the Pacific Northwest, questions regarding changes in climate following volcanic eruptions and their effects upon prehistoric populations have been pursued from a limited geographic standpoint (e.g., Bense 1972; Matz 1987; Lewarch and Benson 1991). Furthermore, greater consideration has been given to singular large-scale eruptions (e.g., Mazama), rather than the effects of multiple volcanic events closely corresponding in time.

As Hammer et al. (1980) and Porter (1981) have stated, when examining the impacts of volcanic eruptions upon a climate system, consideration must be given to the effects of atmospheric loading. The effects of closely spaced events of aerosol production over an extended period of volcanic activity may introduce greater levels of climatic effect than a single large-scale eruption.

An emphasis upon temporally-restricted large-scale eruptions like that seen at Mount Mazama has dominated regional archaeological research. An overall lack of emphasis has been placed upon investigating the impacts of Mount St. Helens and the wider effects of the tephra-falls and volcanic aerosols associated with its many Holocene eruptions; or for that matter, the combined effects of volcanic eruptions at the regional and global scale. Ultimately, this limited effort has restricted our knowledge of prehistoric cultural adaptation within the Pacific Northwest. If advances are to be made into determining the nature of human adaptation and its material assemblages in the Pacific Northwest, a wider perspective of the human experience in the natural world of the past must be developed.

The pioneering work of individuals like Stephen Matz (1991) and the
incorporation of diverse datasets are crucial to understanding the *whys* of regional archaeology. An overemphasis is not to be placed upon ecosystemic forcing as the causal mechanism for culture change. However, important aspects of the prehistoric environment have been neglected in regional research. Combined with a consideration of cultural exchange among groups, increasing population pressures, individual innovation, and many other important aspects, the effects of volcanic eruptive events will serve to enhance our understanding of the archaeological record of the region

**Systemic Modeling and the Humanist Perspective**

Oral history of the Sanpoil and Nespelem Indians of the northeastern Washington Salishan tribes describes the remembrance of a tephra-fall event and the reactions to its arrival:

> When my grandmother was a small girl a heavy rain of white ashes fell. The people called it snow. After they got wheat flour they said it was just like that. The ashes fell several inches deep all along the Columbia and far on both sides. Everybody was so badly scared that the whole summer was spent in praying. The people even danced--something they never did except in winter. They didn’t gather any food but what they had to have to live on. That winter many people starved to death. Besides that an epidemic of smallpox (?) killed a lot of people. And the next spring some warriors from the south came and killed still more (Ray 1954:108).

Informants disagree as to the exact time of this tephra-fall, referring to dates of A.D. 1770 and a period just after A.D. 1800. Mullineaux (1986) reports dates for the beginning of the Goat Rocks eruptive period at Mount St. Helens, which correspond to the informants’ remembrance. Tephra layer T, identified within the Goat Rocks period has been traced from its source at the mountain, along a northeasternly pattern into the northern reaches of Idaho.
(Okazaki et al. 1972); layer T has a dendrochronological date of A.D. 1800 (Yamaguchi 1983, 1985).

It is important to consider that the tephra was said to be only a few inches thick. The relatively thin deposit of tephra would have had little immediate impact upon the local ecosystem (Matz 1991; Blong 1982). It is most likely that the tephra-falls elicited a cultural response superseding all potential environmental impacts. The reaction of the Sanpoil and Nespelem to these tephra-falls created the true problem. The tribes were notably hunter-gatherers, dependent upon the storage of food for the winter’s subsistence.

Responding to the tephra-falls by abandoning the seasonal work of gathering food for storage to perform ritual activities, they put their future at risk. This scenario highlights the important fact that cultural reactions to volcanic events are plausible in themselves as being responsible for adverse effects on cultural populations. Furthermore, the timing of any disruption in the seasonal round is crucial to understanding the subsequent effects. In the case of the Sanpoil and Nespelem starvation ensued, promoting poor health and likely a greater susceptibility to disease.

Although Stephen Matz’ (1991) systemic model is important in its assessment of the negative impacts of tephra-falls upon ecosystems and resultant stresses upon cultural groups, components of the world system are overemphasized as influential forces. Cultural reactions are solely identified as resulting from ecological stress, originating from an altered post-tephra-fall environment. This interpretation is ecocentric, failing to identify the inherent cultural potential of human groups as a factor directing post-tephra-fall behavior. More simply, the ethnographic accounts of the Sanpoil and Nespelem (Ray 1954) are not predicted by this model, nor is the potential for
such behavior allocated within its systematics. Instead, the model exclusively emphasizes latent cultural reactions to tephra-falls as a result of ecosystemic pressures upon the subsistence base of prehistoric human populations.

In the case of the Sanpoil and Nespelem, humans reacted in a culturally-derived fashion to a perceived impact of tephra-falls. The resources available to them remained abundant following the event; the decision-making hierarchy was altered in reaction. The Sanpoil and Nespelem opted to pray and dance during the fishing season, interpreting the tephra-falls as a crisis requiring a spiritual solution. In doing so, resources were not accumulated for the winter season and the resultant self-imposed stresses created a real subsistence problem.

The ethnographic accounts of the Sanpoil and Nespelem exist as an example of culturally-forced behavior in reaction to tephra-fall events. Matz' (1991) model is an excellent tool for predicting and evaluating the archaeological record of areas with the potential for past volcanic hazards, however, it lacks a humanistic quality. The inclusion of systemic compartments dedicated to the consideration of cultural behavior, in and of itself, are needed within Matz' model to make it truly compatible for the investigation of prehistoric human behavior in reaction to tephra-falls.

It is questionable as to how visible the sort of cultural reactions reported by Ray (1954) might be within the archaeological record. The adaptive modifications of cultural groups in reaction to more tangible changes in the associated ecosystem, as outlined in Matz' (1991) model, might be better identified. Changing ecosystems, even to a minimal degree, might effect an adaptive change in prehistoric subsistence technology and quite possibly in other forms of human adaptation. The investigation of cultural
and environmental changes in the Pacific Northwest offer the opportunity to test the causality of volcanic eruptions as a catalyst for change if the archaeological clues can be recovered and correctly interpreted (see Matz 1991).

The success of gaining insight into the archaeological record of human interaction within a volcanically-active environment will come from the implementation of research questions sensitive to the issues raised by this thesis. Just as an understanding of the applicable environment is a crucial component of understanding the archaeological record of any site, so is an appreciation for regional volcanic eruptions.

Conclusions and Recommendations for Future Research

The information presented in Figures 24 and 25 suggest an important degree of cultural-environmental correlation within the study area. The issue of whether a causal relationship may be attributed between successive cultural phases and volcanic eruptions as mechanisms of climatic change is beyond the scope of this thesis. What was ultimately desired has been presented: a simple correlative study giving attention to the importance of volcanic events in a cultural-environmental context. The larger questions of causality must be addressed through further research.

It is somewhat disturbing that the correlations offered here have not been illuminated before, given that many of the bodies of knowledge referenced during this research have been readily available. If archaeological research in the Pacific Northwest is to seek answers to explain the nature of cultural manifestation through time, new frontiers of information must be included in the investigative effort. Of course, the ultimate implications that
volcanic hazards present in helping to explain the archaeological record of the Pacific Northwest are but a part of a complex world system of the prehistoric past. The emphasis of volcanic eruptions is not to be taken as touting a linear forcing model, which attempts to universally explain culture change. It should be considered as a small contribution to a much-needed larger direction of archaeological research.

To gain a clearer perspective on the big picture of prehistoric life in the Pacific Northwest, other lines of inquiry are required to further our knowledge of past influential environmental mechanisms. Future archaeological research should capitalize on the efforts of other disciplines to view cultural-environmental interaction with a more critical and knowledgable perspective.

In closing, it should be understood that the relationship cultures maintained with their world could not have been strictly determined by changes in temperature, geomorphology, vegetational or animal patterns, but by an orchestrated interaction among these and other environmental compartments. Through the successful alliance and wise implementation of multidisciplinary research efforts, a clearer view is available of the relationship humans shared with the dynamic world system of the past. With this clarity, the archaeological perspective will be enhanced and greater questions may be asked of the evidence at hand.
References

Ackerman, Thomas P.

Alt, D. D., and D. W. Hyndmann

Ames, Kenneth M, Ricky G. Atwell, Bruce Cochrane, R. Lee Lyman, and Paul Sanders
1990 The Archaeology of Hatwai (10-NP-143) and the Southeastern Columbia Plateau, Ms. on file, Department of Anthropology, Portland State University, Portland.

Antevs, Ernst

Bacon, Charles R.

Baker, R. G., and G. M. Richmond

Barnosky, Cathy W.


Bates, R. L., and J. A. Jackson (editors)
Bense, Judith

Bernard, A., D. Demaiffe, N. Mattielli, and R.S. Punongbayan

Binford, Lewis R.

Birkeland, Peter W.

Birkeland, P. W., D. R. Crandell, and G. M. Richmond

Blong, Russell J.

Borchardt, G.A., J.A. Norgren, and M.E. Harward

Borden, C. E.

Brady, Nyle C.

Brauner, David R.
Bray, J. R.

Bryan, Alan Lyle

Bryan, Alan Lyle, and Ruth Gruhn
1964 Problems Relating to the Neothermal Climatic Sequence.

Burke, R. M.
1978 Comparison of Relative Age Dating (RAD) Data From Eastern Sierra Nevada Cirque Deposits with those from the Tephrochronologically Age Controlled Deposits of the Wallowa Mountains, Oregon. *Geological Society of America, Abstracts with Programs*. 10:211.

Burke, R. M., and P. W. Birkeland

Butler, B. R.


Butzer, Karl W.


Carrara, Paul E., Susan K. Short, and Ray E. Wilcox
1986 Deglaciation of the Mountainous Region of Northwestern Montana, U.S.A., As Indicated By Late Pleistocene Ashes. *Arctic and*
Carrara, Paul E., Ray E. Wilcox, and G. M. Richmond
1984 Deglaciation and Revegetation in the Glacier National Park
Region, Montana. *Geological Society of America Abstracts With
Programs*. 16:217

Carrara, Paul E., Ray E. Wilcox, and Susan K. Short
1986 Deglaciation of the Mountainous Region of Northwestern
Montana East of the Continental Divide. *Arctic and Alpine

Cas, R. A. F., and J. V. Wright
1988 *Volcanic Successions, Modern and Ancient*. Unwin Hyman,
Boston.

Chang, K. C.
1967 Major Aspects of the Interrelationship of Archaeology and

Chapin, C. E., and J. Zidek (editors)
1989 Field Excursions to Volcanic Terranes in the Western United
States, Volume II: Cascades and Intermountain West. *New

Chester, David

Clague, John J.
1981 Late Quaternary Geology and Geochronology of British
Columbia, Part 2: Summary and Discussion of Radiocarbon-

1989 Character and Distribution of Quaternary Deposits. In,
*Quaternary Geology of Canada and Greenland, Geology of Canada 1*,

Cole, D. L.
1968 *Archaeological Excavations in Area 6 of Site 35GM9, the Wildcat
Canyon Site*. Museum of Natural History, University of Oregon,
Eugene.

Crandell, D. R.
*U. S. Geological Survey Bulletin 1288*
Crandell, D. R., and R. D. Miller

Crandell, Dwight R., and Donal R. Mullineaux

Crandell, Dwight R., Donal R. Mullineaux, and M. Rubin

Crandell, Dwight R., Donal R. Mullineaux, C. D. Miller, and M. Rubin

Crandell, Dwight R., Donal R. Mullineaux, and M. Rubin

Cressman, L. S.

Czamanske, G. K., and S. C. Porter

Dansgaard, W., H. B. Clausen, N. Gunderstrup, S. J. Johnsen, and C. Rygner
Daugherty, Richard D., J. Jeffrey Flenniken, and Jeanne M. Welch


Davis, Jonathan O.

Davis, Jefferson D.

Davis, Owen K., D. A. Kolma, and Peter J. Mehringer, Jr.

Davis, Owen K., J. C. Sheppard, and S. Robertson

Devine, J. D., H. Sigurdsson, A. N. Davis, and S. Self

Dumond, Don E.

Ellis, David V., Jeffrey Scott King, David E. Putnam, David Francis, and Gail Thompson
Fagan, Brian M.

Flohn, Hermann

Foit, Franklin F. Jr., Peter J. Mehringer Jr., and John C. Sheppard

Fryxell, Roald

Fryxell, Roald, and Richard D. Daugherty

Fulton, R. J. (editor)

Gow, Anthony J., and Terrence Williamson

Gowan, Amy, and Robin McClintock

Grayson, Donald K.

Grayson, Donald K., and Payson D. Sheets
1979 Volcanic Disasters and the Archaeological Record. In *Volcanic Activity and Human Ecology*, edited by Payson D. Sheets, and
Hammatt, Hallett H.

Hammer, C. U., H. B. Clausen, and W. Dansgaard

Hansen, H.P.

Harris, Marvin

Hay, R. L.

Herron, Michael M., and Chester C. Langway, Jr.

Heusser, Calvin J., Linda E. Heusser

Hibbert, Dennis M.

Hoblitt, R.P., D. R. Crandell, and D. R. Mullineaux
1980 Mount St. Helens Eruptive Behavior During the Last 1,500 yr. Geology. 8:555-559.

Hoffer, Jerry M.

Howard, Michael C.

Hyde, Jack

Hyde, Jack H, and Dwight R. Crandell

Imai, A., E. L. Listanco, and T. Fujii

Ives, Jack D., John T. Andrews, and Roger G. Barry

Jashemski, Wilhelmina F.
Jennings, Jesse D.

Jenny, Hans

Jermann, Jerry V., James R. Benson, and Dennis E. Lewarch


Kennett, James P., and Robert C. Thunell

King, Roger H.

Kittleman, Laurence R.


Kiver, E. P.
Krebs, Charles J.

Lancefield-Steeves, Phyllis E., and Janet A. Liddle

Legrand, M. & R.J. Delmas

Leonhardy, Frank C.

Leonhardy, Frank C., and David G. Rice

Lett, James

Lewarch, Dennis E., and James R. Benson

Lipman, P.W., D.R. Norton, J.E. Taggart, E.L. Brandt and E.E. Engleman,

Lohse, E. S.
Luckman, B.H., M.S. Kearney, R.H. King, A.B. Beaudoin

Mack, Christopher B.

Mack, R. N., V. M. Bryant, Jr., and R. Fryxell

Mack, Richard N., N.W. Rutter, and S. Valastro

Mack, Richard N., N.W. Rutter, Vaughn M. Bryant, Jr., and S. Valastro

Major, J. J., and K. M. Scott

Malde, H. E.

Matz, Stephan


McClure, Richard H. Jr.,
1988 Archaeology in the Mineral Block, Gifford Pinchot National
McClure, Richard H. Jr., and Cheryl A. Mack

McDonald, E. V., and A. J. Busacca

McKee, Bates

Mehringer, Peter J., Jr.

Mehringer, Peter J., Jr., E. Blinman, and K. L. Petersen

Mierendorf, R. R.

Minakami, T.

Moody, Ula L.
Dissertation, Department of Anthropology, Washington State University, Pullman.

Mullineaux, Donal R.


Mullineaux, Donal R., and Dwight R. Crandell

Mullineaux, Donal R., Jack H. Hyde, and Meyer Rubin

Mundorff, M. J.

Nance, C. R.


Nelson, Charles M.

Newhall, Christopher G., and Stephen Self

Nolan, Mary Lee


Okazaki, R., H. W. Smith, R. A. Gilkeson, and J. Franklin

Palais, Julie M., Severine Kirchner, and Robert Delmas

Pilles, Peter J. Jr.

Pollack, James B., Owen B. Toon, Carl Sagan, Audrey Summers, Betty Baldwin, and Warren Van Camp

Porter, Stephen C.


Rampino, Michael R., and Stephen Self
1982  Historic Eruptions of Tambora (1815), Krakatau (1883), and Agung (1963), Their Stratospheric Aerosols, and Climatic Impact. *Quaternary Research.* 18:127-143.


Rampino, Michael R., Stephen Self, and Richard B. Stothers

Randle, K., G. G. Goles, and L. R. Kittleman

Ray, Verne F.

Rees, John D.

Renfrew, Colin

Rice, David G.

Rice, Harvey

Richmond, G. M.

Ritter, Dale F.

Sahlins, Marshall D. and Elman R. Service (editors)

Sappington, Robert Lee
1994 *The Prehistory of the Clearwater River Region, North Central Idaho*. University of Idaho Anthropology Reports No. 95, Alfred W. Bowers Laboratory of Anthropology, University of Idaho, Moscow.

Sarna-Wojcicki, Andrei M., D. E. Champion, and J. O. Davis

Schiffer, Michael B.

Schweger, Charles

Scuderi, Louis A.

Sheets, Payson D.
208


Shiner, J. L.

Shipley, Susan, and A. M. Sarna-Wojcicki

Simkin, Tom

Smith, D.G.W., and J.A. Westgate

Smith, D. R., and W. P. Leeman
1982 *Mineralogy and Phase Chemistry of Mount St. Helens Tephra Sets W and Y As Keys to Their Identification.* Quaternary Research. 17:211-227.

Smith, H. W., R. Okazaki, and J. Aarstad

Smith, H. W., R. Okazaki, and C. R. Knowles

Sprague, R., and J. D. Combes
1966 *Excavations in the Little Goose and Lower Granite Dam Reservoirs, 1965.* Washington State University Laboratory of Anthropology Reports of Investigations No. 37, Pullman.

Stein, Julie K.
1983 *Earthworm Activity: A Source of Potential Disturbance of*

Stradling, Dave F., and Eugene P. Kiver

Swanson, E. H.

Takemura, Keiji, and Tohru Danhara

Theisen, A. A., G. A. Borchardt, M. E. Harward, and R. A. Schmitt

Thomas, David Hurst

Thorarinsson, S.

Toon, O.B., and J.B. Pollack

Twenhofel, W. H.

Tylor, Edward B.

Walker, G. P. L., L. Wilson, and E. L. G. Bowell
1971 Explosive Volcanic Eruptions I. The Rate and Fall of Pyroclasts.

Waters, Michael R.
The University of Arizona Press, Tucson.

Westgate, J. A.
1977 Identification and Significance of Late Holocene Tephra from
Otter Creek, Southern British Columbia, and Localities in West-

Westgate, J. A., and A. Dreimanis
1967 Volcanic Ash Layers of Recent Age At Banff National Park,

Westgate, J. A., and R. J. Fulton
1975 Tephrostratigraphy of Olympia Interglacial Sediments in South-
Central British Columbia, Canada. Canadian Journal of Earth

Wilcox, R. E.
1965 Volcanic Ash Chronology. In Quaternary of the United States:
Review Volume for the Seventh Congress of the International
Association for Quaternary Research. edited by H. E. Wright Jr., and

Willey, Gordon R., and Philip Phillips
1958 Method and Theory in American Archaeology. The University of

Williams, L. D.
1974 Neoglacial Land forms and Neoglacial Chronology of the
Wallowa Mountains, Northeastern Oregon. Unpublished Masters
thesis, Department of Geology, University of Massachusetts,
Amherst.

Wilson, L.
1972 Explosive Volcanic Eruptions--II: The Atmospheric Trajectories
of Pyroclasts. Geophysical Journal of the Royal Astronomical
Society. 30:381-392.

Workman, William B.
1979 The Significance of Volcanism in the Prehistory of Subartic
Northwest North America. In Volcanic Activity and Human
Ecology. edited by Payson D. Sheets, and Donald K. Grayson, pp. 339-
Wright, John V., Alan L. Smith, and Stephen Self

Yamaguchi, David K.


Yent, Martha E.

1994 Record of Volcanism Since 7,000 B.C. From the GISP2 Greenland Ice Core and Implications for the Volcano-Climate System. Science. 264:948-952.
<table>
<thead>
<tr>
<th>Tephra Locality</th>
<th>Tephra Set</th>
<th>Sample Site</th>
<th>Thickness</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>We</td>
<td>Wildcat Lake, WA</td>
<td></td>
<td>Davis et al. 1977</td>
</tr>
<tr>
<td>2</td>
<td>Yn</td>
<td>Nisqually Lake, WA</td>
<td></td>
<td>Hibbert 1979</td>
</tr>
<tr>
<td>3</td>
<td>T</td>
<td>Hager Pond, ID</td>
<td></td>
<td>Mack et al. 1978</td>
</tr>
<tr>
<td>4</td>
<td>J</td>
<td>Hager Pond, ID</td>
<td></td>
<td>Mack et al. 1978</td>
</tr>
<tr>
<td>5</td>
<td>J</td>
<td>Hager Pond, ID</td>
<td></td>
<td>Mack et al. 1978</td>
</tr>
<tr>
<td>6</td>
<td>J</td>
<td>Hager Pond, ID</td>
<td></td>
<td>Mack et al. 1978</td>
</tr>
<tr>
<td>7</td>
<td>Yn</td>
<td>Tonquin Pass, B.C.</td>
<td></td>
<td>King 1986</td>
</tr>
<tr>
<td>8</td>
<td>Yn</td>
<td>Sunwapta Pass, Alberta</td>
<td>3 cm</td>
<td>King 1986</td>
</tr>
<tr>
<td>9</td>
<td>Yn</td>
<td>Pocahontas, Jasper Nat'l Pk, Alberta</td>
<td>2 cm</td>
<td>King 1986</td>
</tr>
<tr>
<td>10</td>
<td>Yn</td>
<td>Otter Creek Bog, B.C.</td>
<td>2-3 cm</td>
<td>Westgate 1977</td>
</tr>
<tr>
<td>11</td>
<td>Yn</td>
<td>Entwistle, Alberta</td>
<td></td>
<td>Westgate 1977</td>
</tr>
<tr>
<td>12</td>
<td>Ye</td>
<td>Lake Cleveland, ID</td>
<td></td>
<td>Davis et al. 1986</td>
</tr>
<tr>
<td>13</td>
<td>Jy</td>
<td>Marias Pass, MT</td>
<td>1 cm</td>
<td>Carrara et al. 1986</td>
</tr>
<tr>
<td>14</td>
<td>Yn</td>
<td>Banff, Alberta</td>
<td></td>
<td>Westgate and Dreimanus 1967</td>
</tr>
<tr>
<td>15</td>
<td>Ye</td>
<td>Carp Lake, WA</td>
<td>4 cm</td>
<td>Barnosky 1985</td>
</tr>
<tr>
<td>16</td>
<td>We</td>
<td>St. Joe Bog, ID</td>
<td></td>
<td>Smith et al. 1977</td>
</tr>
<tr>
<td>17</td>
<td>Wn</td>
<td>Bonaparte Meadows, WA</td>
<td>1-2 cm</td>
<td>Mack et al. 1979</td>
</tr>
<tr>
<td>18</td>
<td>Wn</td>
<td>Mud Lake, WA</td>
<td>20 cm</td>
<td>Mack et al. 1979</td>
</tr>
<tr>
<td>19</td>
<td>Yn</td>
<td>Near S. Thompson River, B.C.</td>
<td></td>
<td>Nasmith et al. 1967</td>
</tr>
<tr>
<td>20</td>
<td>Yn</td>
<td>Near S. Thompson River, B.C.</td>
<td></td>
<td>Nasmith et al. 1967</td>
</tr>
<tr>
<td>21</td>
<td>Ye</td>
<td>Hurricane Creek, OR</td>
<td>5 cm</td>
<td>Borchardt et al. 1973</td>
</tr>
<tr>
<td>22</td>
<td>Yn</td>
<td>Jasper Nat'l Park, Alberta</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>23</td>
<td>W</td>
<td>Road N92, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>24</td>
<td>W</td>
<td>Clearwater Road, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
</tbody>
</table>

Appendix A: Index of Tephra Localities
<table>
<thead>
<tr>
<th>Tephra Locality</th>
<th>Tephra Set</th>
<th>Sample Site</th>
<th>Thickness</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>W</td>
<td>Meadow Creek, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>26</td>
<td>W</td>
<td>Council Lake, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>27</td>
<td>W</td>
<td>South Prairie, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>28</td>
<td>W</td>
<td>Sandhills, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>29</td>
<td>W</td>
<td>Sulphur Lake, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>30</td>
<td>W</td>
<td>Timberline, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>31</td>
<td>W</td>
<td>Road 100, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>32</td>
<td>W</td>
<td>Road 109, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>33</td>
<td>W</td>
<td>Ohanapecosh, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>34</td>
<td>W</td>
<td>Cayuse Pass, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>35</td>
<td>W</td>
<td>HWS 300, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>36</td>
<td>W</td>
<td>Red Top, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>37</td>
<td>W</td>
<td>RR228, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>38</td>
<td>W</td>
<td>Handy Spring, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>39</td>
<td>W</td>
<td>OKAN17, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>40</td>
<td>W</td>
<td>OKAN36, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>41</td>
<td>W</td>
<td>OKAN24, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>42</td>
<td>W</td>
<td>OKAN31, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>43</td>
<td>W</td>
<td>RR222, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>44</td>
<td>W</td>
<td>RR223, WA</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>45</td>
<td>W</td>
<td>Mitchner Pass, B.C.</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>46</td>
<td>W</td>
<td>Nancy Greene Lake, B.C.</td>
<td></td>
<td>Smith and Westgate 1969</td>
</tr>
<tr>
<td>T</td>
<td>T</td>
<td>Multiple Localities</td>
<td></td>
<td>Okazaki et al. 1972</td>
</tr>
</tbody>
</table>

Appendix A: Index of Tephra Localities (continued)