damage to the remains; 3) Scaled and labeled, detailed pre-excavation, in progress, and post-excavation black and white photographs and color slides; 4) Detailed sketch maps with measurements (as possible) and notations; 5) Site maps locating burials; 6) Provenience and description of grave goods, including reasons for describing them as grave goods; 7) Notes of anatomical observations and measurements addressing such issues as burial position, burial orientation, bone condition, pathologies, age, sex, and stature, as preservation allows.

C) REMOVAL AND LABORATORY ANALYSIS

The following data should be collected on those remains excavated and removed from their original location. Minimum standards include: 1) All of the minimum standards for Simple Exposure; 2) The services of a qualified Physical Anthropologist or technician experienced in the REMOVAL of human skeletal material (see section B1 above); 3) A thorough documentation of systematically collected observations on morphological and metrical attributes addressing as a minimum the areas of stature, sex, age, and pathologies; 4) Provisions for transport sufficient that the remains are not damaged; 5) Provisions for security and respectful care of the remains during analysis.

D) DESTRUCTIVE OR INVASIVE ANALYSES

It is impossible to anticipate the types of analyses which may become available, but presently, such analyses might include the following: 1) radiocarbon dating, 2) trace element analysis, 3) bio-mechanical stress analysis. These analyses are beyond the minimum and while they might well be of major scientific value, permission to do them must be gained from the appropriate tribe through knowledgeable negotiation.

E) PUBLICATION OF DATA, METHODS AND RESULTS

A description of the analytical techniques used and conclusions drawn from the data must be placed in the literature (preferably a professional journal) and a copy of that report filed with the State Historic Preservation Office and with the appropriate tribe. Also, because the skeleton will most likely be reinterred to remain forever out of the reach of science, the field notes, maps, sketches and photographs should be cataloged and curated in an appropriate facility.

CURRENT RESEARCH

Holocene Volcanic Tephra in the Willamette National Forest, Western Oregon: Results of a Geochemical and Geoarchaeological Investigation

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During the summer of 1990, we initiated a geoarchaeological and geochemical investigation of Holocene volcanic tephra deposits in the Willamette National Forest. The results of the 1990 field work and subsequent laboratory analysis of the volcanic tephra appeared in the 1991 final report to the Willamette National Forest (Skinner and Radosevich, 1991). This article summarizes the major findings and conclusions of that report.

Archaeological Chronologies and the Compelling Need for Tephrochronologic Research in the Willamette National Forest

Prehistoric cultural chronologies are currently poorly-defined and very generalized in most areas of the Willamette National Forest of Oregon. Until 1987, only 13 radiocarbon dates from seven archaeological sites had been recorded in the Willamette National Forest (Minor, 1987:41). Since that time, only a few additional radiocarbon dates have been added. As a result, chronological estimates have been largely dependent on the cross-dating of projectile point sequences developed in adjoining regions (Baxter, 1986:103-126; Minor, 1987:41-

42,159). Recent limited obsidian hydration studies (see Lindberg-Muir, 1988, for example) have also provided some raw data for chronological research. However, without more reliable radiocarbon and tephrochronologic dates with which to calibrate the rates of obsidian hydration, these hydration data can do little more than test for stratigraphic integrity or relative chronologies at archaeological sites.

Tephrochronologic methods offer a relatively simple and cost-effective chronostratigraphic approach for determining relative and absolute age relationships at Willamette National Forest archaeological sites. In addition, because of the geographically widespread distribution of some volcanic ash deposits, tephrochronological methods can provide a valuable tool for the dating and regional correlation of associated materials at archaeological sites. It is absolutely essential, however, that geoarchaeological studies of tephra deposits, their sources, and the appropriate characterization and correlation methods precede any serious tephrochronologic archaeological applications in a given region.

The Volcanic Tephra Project was initiated in order to address several of these issues. We assembled an overview of Holocene tephra deposits and tephragenic volcanic activity within the boundaries of the Willamette National Forest study area to provide background information for future geoarchaeological researchers (see figure 2 for a chronologic summary). We collected tephra samples from locales within the Willamette National Forest and from potential primary sources of tephra deposits that lay outside the boundaries of the study area. Major and trace element studies of these samples were used to ascertain the potential value of atomic absorption spectrophotometry (AAS) and electron microprobe analysis (EPMA) techniques in characterizing and correlating tephra deposits found at archaeological sites within the study area.

Sources of Volcanic Tephra in the Willamette National Forest

By far, the most widespread and voluminous of all Willamette National Forest tephra deposits originated from Mount Mazama (Crater Lake) during a series of explosive eruptions about 6,845 to 7,015 radiocarbon years ago (figure 1). Ash from the Mazama eruptions has been identified in several central western Cascades archaeological sites and has undoubtedly gone unrecognized during numerous other archaeological investigations. When preserved in favorable environments, the ash of this well-dated stratigraphic horizon offers the potential to provide valuable intra- and inter-site chronologic information. Explosive eruptions of silicic tephra also occurred near South Sister volcano at Rock Mesa and the Devils Hill Dome Chain about 2,000 radiocarbon years ago. Small amounts of tephra from these eruptions are found today in the eastern central periphery of the Willamette National Forest, although no tephra from these sources has been identified in any archaeological sites to date.

Less well-known and only moderately well-documented in the geologic literature are the Holocene basaltic eruptions of the central High Cascades. Basaltic tephra originating from cinder cones located within about 10 km of the Cascade Crest was erupted throughout the Holocene (figure 1). Some of the most recent basaltic volcanic activity may have ceased on the southern slopes of Mt. Jefferson only about 1,000 years ago. These basaltic vents and their associated tephra deposits are distributed within the Willamette National Forest from the upper southern slopes of Mt. Jefferson to the southern flanks of the South Sister. The archaeological and chronological significance of this basaltic tephra remains largely uninvestigated to date and only a few archaeological sites have been found in association with the tephra. Despite the fact that deposits of basaltic tephra are significantly more localized in their spatial distribution than the much more geographically dispersed silicic volcanic ashes, they still have considerable potential for use in the development of localized chronologies.

Volcanic Tephra, Central Cascades Prehistory, and Previous Archaeological Research

Several lines of evidence verify that the eruption of both the silicic and basaltic tephra deposits were coeval with human occupation in the present-day Willamette National Forest. The impact of the airfall tephra events on these prehistoric groups is thought to have been minimal because of the seasonally-utilized nature of the areas that were most affected by the ashfalls (though the effects of the Mazama eruptions may have been catastrophic to the northeast of the volcano). Observations of historic ashfalls also suggest that environmental damage caused by tephra falls is quite short-lived. Disruption of aboriginal seasonal procurement of non-critical resources would have lasted only a few years at most and it is likely that the eruption of Mount Mazama and other sources of tephra had little effect on the prehistoric populations utilizing High and Western Cascades resources. Despite the presence of volcanic ash deposits throughout the Western

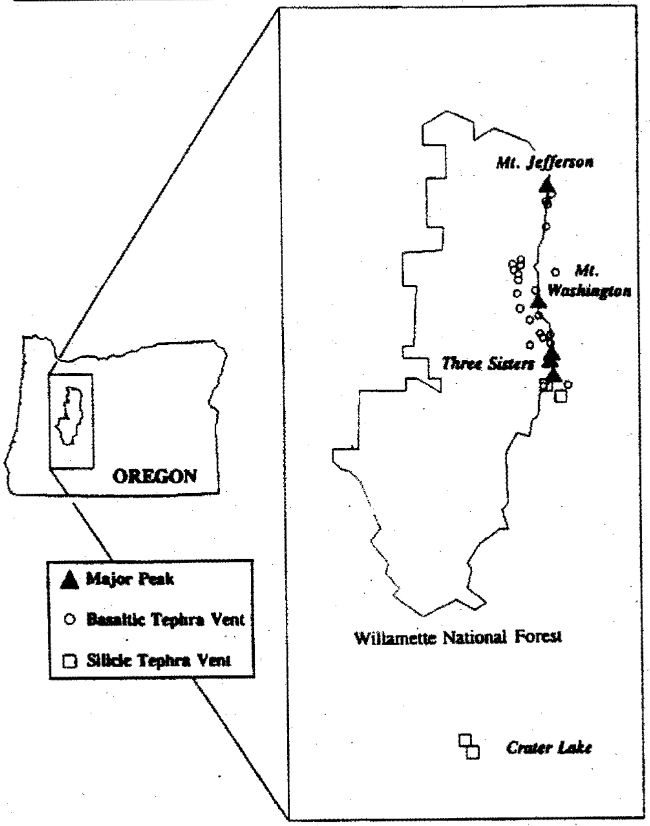

Figure 1. Distribution of Holocene volcanic vents and sources of tephra deposits in the Willamette National Forest.

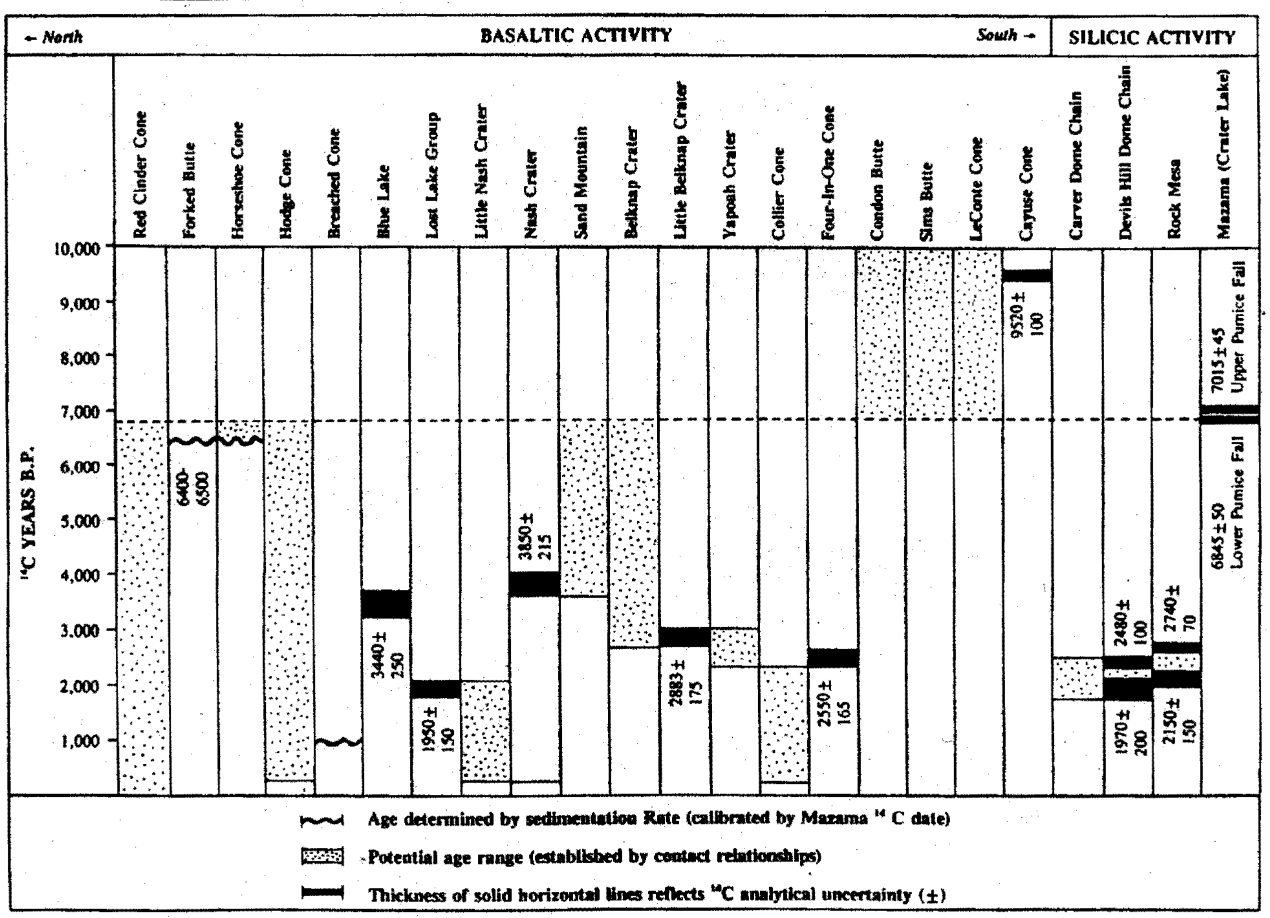

Figure 2. Summary chronology of Holocene volcanic activity associated with Willamette National Forest tephra deposits. Some of the minimum constraining ages are set by the presence of living trees on ash deposits. Radiocarbon ages are from Bacon (1983), Scott (1987), and Taylor (1967).

and High Cascades of Oregon, volcanic tephra has rarely been used for tephrochronological purposes in archaeological contexts, even when it has been recognized within sites. When volcanic ash has been found at a site, the relationship of tephra deposits and artifactual materials has often been insufficiently described. The presence of tephra at sites is commonly overlooked during excavations and volcanic tephra is probably much more widespread in archaeological contexts than the literature would indicate. Potential high-probability occupation areas such as ridges, basins, saddles, and rockshelters are areas in which tephra is often well-preserved and yet its presence seems to be often overlooked.

A review of Willamette National Forest archaeological sites in which volcanic tephra was identified indicates that silicic tephra, almost certainly originating during the climactic eruptions of Mount Mazama, is widely distributed. This is particularly true in the High Cascades and the eastern part of the Western Cascades. Silicic tephra from the Rock Mesa and Devils Hill vents, on the other hand, has not been identified at any known archaeological sites in western Oregon. Tephra from basaltic eruptions, so far found in only a few Western Oregon archaeological sites, still holds some tephrochronologic potential, though only in relatively limited areas within the Willamette National Forest.It appears that a major problem of tephrochronological research lies in the simple identification of volcanic tephra at archaeological sites. The presence of Mazama tephra, in particular, should be anticipated in Cascades archaeological sites. When sites are found in the vicinity of known basaltic tephra vents, site deposits should be carefully evaluated for the presence of datable pyroclastic materials. It is also important in future archaeological studies that the relationship of analyzed artifactual materials, intrasite stratigraphy, and tephra deposits or soils be clearly documented. The well-described provenance of all datable artifactual and ecofactual materials is significant not only for the construction of site chronologies, but for their ability to provide internal cross-checks among different chronologic techniques. Chronologic information from obsidian hydration measurements, volcanic tephra deposits, radiocarbon dates, and temporally-diagnostic artifacts can be used to these ends, though, only when their intrasite stratigraphic relationships are thoroughly documented.

Geochemical Characterization of the Tephra Deposits

AAS (atomic absorption analysis) characterization studies of 50 basaltic and silicic tephra samples from 12 geologic sources resulted in varied degrees of success. Low cost, ease of sample preparation, and rapid turnaround time were important criteria in selecting AAS as the primary characterization method for this study. Major and trace element abundances easily distinguished between silicic and basaltic tephra sources, as expected, as well as between the two major silicic source areas (Crater Lake and South Sister). Characterization studies of Mazama paleosols from several locations were less successful, however (figure 3). These paleosols could not be clearly correlated with the Mazama eruptions, even though their geologic context verified Crater Lake as the source of the ash. Regularities in major and trace element enrichment and depletions relative to the Mazama tephra samples suggest that weathering and contamination by adjoining stratigraphic units played an important role in the differences in chemical composition. However, in locations where larger individual pumice lapillus are available for analysis, AAS characterization should still prove an effective characterization technique. More elaborate pre-analysis preparation of bulk samples of paleosols from secondary contexts such as archaeological sites is also likely to correct most of the problems encountered with the Mazama paleosols. AAS characterization of basaltic tephra deposits showed some promise, although the chemical clustering of different sources was not as marked as for the silicic tephra sources. The chemical characterization of basaltic tephra deposits, however, when combined with a knowledge of the distribution of basaltic tephra sources, may be useful in identifying the geologic source of basaltic tephra in most locations. More elaborate preparation procedures are recommended for any future basaltic tephra AAS studies.

We used EPMA (electron probe microanalysis) studies of a subset of 9 silicic tephra source samples and a single archaeological sample to evaluate the role of this method for future tephra studies in the study area. EPMA, while being more expensive, requiring more elaborate sample preparation methods, and lacking in analytical precision for the trace elements, was of interest because of the very small sample sizes required for analysis. Individual shards of tephra or very small lapilli from archaeological soils can be easily analyzed. Major element abundances were used to characterize pumice lapilli from three geologic sources

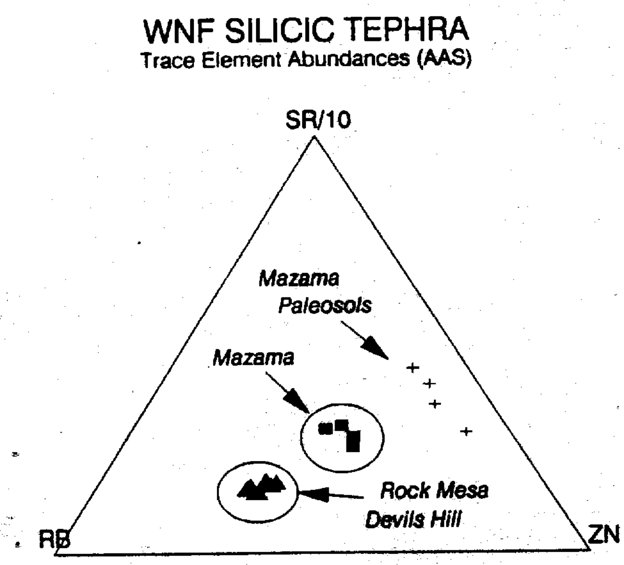

Figure 3. Ternary plot of Na_2O, CaO, and K_2O for all silicic tephra samples characterized by AAS methods. The Mazama paleosols clearly do not visually correlate with the Mazama source samples, although they all appear to share a common source.

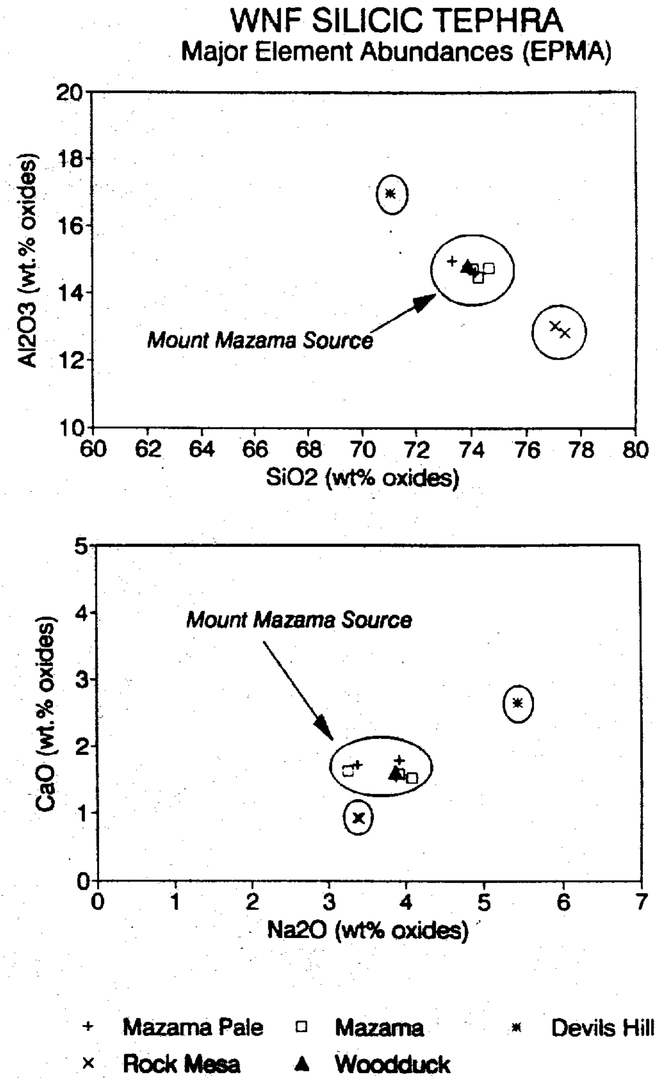

Figure 4. Scatterplots of different major element pairs for silicic source tephra samples and paleosols. The three sources of silicic tephra in the study area that were characterized with the electron microprobe are clearly distinguishable. The three Mazama paleosols (Mazama Pale in the figure above), as well the Woodduck archaeological site sample, all fall within the range of the Mazama source samples.

(Mazama, Rock Mesa, and Devils Hill), paleosols from three secondary geologic contexts, and a paleosol from the Woodduck Site near Mount Jefferson. Visual and statistical analysis of the major element data from this small sample demonstrated that all three sources can be easily distinguished from one another (figure 4). Additionally, the suspected Mazama paleosols from the geologic and archaeological contexts were clearly correlated with the Mazama source. Based on the success of the EPMA characterization of silicic volcanic ash in the Willamette National Forest, we recommend that further studies be undertaken with a larger geologic source sample. EPMA characterization studies of basaltic tephra remain largely unexplored. The results of AAS analyses of basaltic tephra suggest that major element composition can be used to characterize basaltic tephra and we recommend a preliminary research program if further EPMA studies are undertaken.

CONCLUSIONS

We conclude that tephrochronologic methods should prove to be a useful and valuable component in archaeological studies in the Willamette National Forest. The chronologic information that these ash deposits hold should definitely be utilized in future archaeological research in this region. Further geochemical studies of basaltic and silicic volcanic ashes in the Willamette National Forest are highly recommended. We also conclude, though, that these geochemical studies, however compelling they might be to the archaeological researcher, may be needed only on rare occasions. A familiarity with the Holocene volcanic history of the region, with basic geological field techniques, and with tephra identification methods may be all that is usually needed to identify the geologic sources of most encountered tephra deposits. We recommend further research not only in the chemical characterization of regional basaltic and silicic volcanic ash sources, but in the geological study of Holocene tephra sources. Of particular importance for future geoarchaeological and geological studies of volcanic tephra is the detailed identification of the areal distribution of ash from these sources and continued geochronological study of the tephragenic volcanic activity in the study region.

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