PATTERNS OF LITHIC RAW MATERIAL PROCUREMENT ON THE PAJARITO PLATEAU, NEW MEXICO

By

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A thesis submitted in partial fulfillment of
the requirements for the degree of

MASTER OF ARTS IN ANTHROPOLOGY

WASHINGTON STATE UNIVERSITY
Department of Anthropology

August 1997

To the Faculty of Washington State University:

The members of the Committee appointed to examine the thesis of DOUGLAS R. HARRO find it satisfactory and recommend that it be accepted.

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ACKNOWLEDGMENTS

Many people have contributed to the successful conclusion of this project. Dr. Timothy Kohler, the chair of my committee, deserves many thanks for steering me toward interesting research topics such as this one, and for maintaining a patient and unbendingly optimistic attitude regarding my eventual completion of this thesis. It made all the difference. Dr. William Lipe and Dr. William Andrefsky, together with Dr. Kohler, commented on earlier drafts by pointing out instances of unclear writing, poor grammar, and weak reasoning. Their considerable insight greatly improved this work. I was very fortunate to have had such a skilled and knowledgeable thesis committee.

I also owe a great debt to Matthew Root who taught me, through personal example, how lithic analyses, and scientific archaeology in general, should be conducted. His generously shared knowledge and expertise enriched both my academic studies and subsequent professional career.

Genevieve Head, Janet Orcutt, and Robert Powers, graciously provided relevant portions of their Bandelier Archaeological Survey Project data base. Robert Powers additionally allowed me to tag along on the Bandelier Survey to learn their field methods first-hand. The rumor is true, surveyors really do have more fun. Laura Holt and Tim Seaman gave me access to several hundred site files and other information at the Laboratory of Anthropology, Santa Fe. Max Neri expertly drafted the study area overview (Figure 2.1) with very little advance notice.

This thesis was funded in part by the Don Crabtree Scholarship in Lithic Technology, University of Idaho, and by the Department of Anthropology, Washington State University.

With their help I was able to purchase needed map analysis software as well as fund data gathering forays to the Laboratory of Anthropology in Santa Fe. Dr. Timothy Kohler eased my day-to-day subsistence woes during graduate school by keeping me gainfully employed in his laboratory coding lithic materials from the Bandelier Archaeological Excavation Project.

I must also thank Carole Denardo, Susan Goldberg, Eric Johansen, Clay Lebow, Michael Moratto, and Barry Price of Applied EarthWorks, Inc. for allowing me the luxury of a flexible work schedule during the writing of much of this thesis. Æ also granted me a paid leave while I travelled to Pullman for my final oral exam. Their kind consideration gave me fewer things to worry about.

Finally, I would like to thank Ronald and Helen Harro, my parents, for giving me the family foundation, emotional support, and subtle prodding I needed to finish this project prior to the turn of the millennium.

And for Rebecca, my wife, who volunteered for the undesirable position of in-house technical editor, I have few words that can express my gratitude, appreciation, and admiration for all that you have done (and tolerated) to help me bring this project to its fruition. You have shown me that all things truly *are* possible.

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Abstract

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August 1997

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This thesis explores the complex dynamics of lithic raw material procurement systems within the context of changing patterns of social, political, and economic interaction among prehistoric settlers of the Pajarito Plateau, New Mexico. Isopleth maps are generated for the archaeological distributions of locally available obsidian, basalt, and chert at several hundred sites within the study area. I distinguish differences between specialized, seasonally-occupied sites and residential structures, and calculate how procurement patterns shifted through time. Instead of examining broad trends in procurement and exchange over spaces measured on a scale of hundreds of kilometers, this investigation addresses small-scale variations in procurement patterns. The large number of sites used for analysis provides a high-resolution portrait of these patterns, the details of which show how physiographic relief and social boundaries may have shaped procurement behavior across the study area. I found that social boundaries functioned to restrict access to certain raw material sources and that these divisions were in place earlier than previously thought. In addition, the analysis revealed that obsidian procurement was increasingly emphasized at two discrete settlement clusters relative to neighboring groups signalling the emergence of more specialized production, probably to serve a growing trade relationship known to exist between Puebloan and Plains groups to the east.

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1. INTRODUCTION

The goal of this project is to describe patterns of lithic raw material procurement on the Pajarito Plateau, north-central New Mexico. This thesis evaluates procurement behavior by mapping the archaeological distribution of several locally available raw materials over space. By examining procurement behavior, the emergence of exchange networks and other anthropologically important research topics may be addressed.

This project emphasizes small-scale variations in raw material distributions rather than regional trends. The Pajarito Plateau contains abundant sources of lithic raw materials; specifically, the area is surrounded by outcrops of basalt, obsidian, and chert. By accessing data from over 450 sites from two archaeological periods, I provide a high-resolution look at how distributions for these three commonly exploited toolstones vary over a relatively small study area, and how those distributions changed through time. This detailed analysis reveals instances where, for example, physiographic features of the region and social boundaries between groups shaped the movement of toolstone across the landscape.

Theoretical Context

Archaeological investigations currently being conducted in the Upland Southwest are increasingly couched in the vocabulary of Complex Adaptive Systems (CAS) research (see volumes edited by Gumerman 1994; Gumerman and Gell-Mann 1994; Tainter and Tainter 1996). The CAS approach can be characterized as the most recent example in an increasingly comprehensive progression of "adaptationist" (Schiffer's term [1996:647]) schools of neoevolutionary thought. One thing setting CAS models apart from much previous theory is a co-evolutionary perspective—the view that societies are not simply *responsive* to external changes, but have a role in shaping their own "fitness landscape" through impacts on the social and ecological environment. The ability of an ecosystem (broadly defined) to support a population is recursively affected by that population's interaction with the ecosystem.

> The dynamic concept of carrying capacity integrates environmental, demographic, and behavioral variables in a manner that closely resembles the concept of coupled fitness landscapes in which changes in any aspect of the adaptive system alter relationships among all the components and reconfigure the landscape itself. The internal and external dynamics of these fluid situations provide fertile ground for the adaptive evolution of sociocultural systems [Dean 1996:50].

These models are also typically "agent-based" meaning that they study "the dynamics of the actors at a level below that at which the phenomenon of interest is supposed to have emerged" (Kohler n.d.:3). One avenue of research is the determination of the point at which "agents" (e.g., individuals or small groups) begin to cooperate with one another rather than compete for resources. Evolutionary theory generally frames biological adaptation as an outgrowth of competition; cultural adaptation, in contrast, may contain some seemingly cooperative, altruistic, or even self-sacrificing behavior if such behavior ultimately holds a selfish, selective advantage for the initiating agent (see Axelrod 1984). While the study of cooperative networks, such as exchange systems, is not new to the Southwest, investigating the pre-conditions which led to their emergence, as well as evaluating the extent that cooperative strategies were relied upon to improve group viability are current topics of interest in the literature (see Bronitsky 1983; Kohler and Van West 1996; Spielmann 1991a; Wilcox 1991).

While the goals of this thesis are focused on describing more particularistic aspects of cultural behavior rather than contributing to the broad theoretical perspectives discussed above, this project does show how one class of durable goods, lithic raw materials, were procured and subsequently exchanged among groups. The varying degree of interaction that this process implies is used to define the presence of both cooperative and competitive behaviors among local groups. In addition, this project provides more theoretically-oriented studies with a high resolution spatial data base and some initial observations with which to test future models of adaptive behaviors. The detailed documentation of such patterns is an important first step in model-building.

Cooperation, Conflict, and the Concept of Interaction

Central to all procurement or exchange studies is the concept of *interaction*. Interaction is defined broadly by Green (1985), who conducted a study similar in outlook to this thesis, simply as "action upon one another" (1985:1). Often the more general term of "interaction" becomes semantically merged with a more specific term: "exchange" (Green 1985; Portugali and Knapp 1985; Renfrew 1984). Spielmann (1991a) also acknowledges the importance of interaction in exchange studies; however, she recognizes that it may be manifest in several guises. The chief distinction that she draws is that interaction may be through conflict and warfare as well as through cooperation and exchange.

This thesis seeks to identify and characterize social and economic interaction between groups over space, be it through cooperative interchange or through friction and strife. Both of these processes should be visible in archaeological distributions of lithic raw materials. Toolstone that is traded away from sources should be conditioned less by the cost of physical distance than directly procured materials would be because of the mitigating effects of social interchange. On the other hand, raw material distributions should appear truncated at boundaries separating groups which are in competition with one another (see Bettinger 1982; Lizee et al. 1995; McBryde 1984; Singer 1986). Both cases can be understood through reference to a body of theory based in biology, ecology, and microeconomics that describes how human behavior may become organized in such patterns in response to external conditions.

Spielmann (1991a) asserts that exchange may be characterized in two ways: (1) exchange may be used on a local level to buffer subsistence shortfalls due to small-scale variation in rainfall patterns and crop yields; and (2) exchange may serve to merge subsistence bases across different ecozones such that groups residing in one may exchange for goods produced commonly in the other. These two models of exchange are termed "risk-buffering exchange" and "mutualistic exchange" (Spielmann 1991a:4).

Risk-Buffering Exchange. Most studies of Anasazi exchange systems have focused on the processes of risk-buffering exchange (Braun and Plog 1982; Kohler and Van West 1996; Rautman 1993, 1996). It has been recognized that short-term climatic fluctuations produced annual variation in agricultural yields for Anasazi farmers across the Southwest region. Moreover, rainfall across the region can include a high degree of spatial variability.

Exchange may have emerged as a mechanism to allay these spatially discrete, temporary subsistence shortfalls.

Kohler and Van West (1996) summarize the conditions that influence when it is in the best interest of a producer to cooperate by exchanging food with others, and when the producer should compete for resources. They reason that in areas with high spatial and temporal variability in agricultural production, it is optimal for people to share when production bears a surplus more years than not; if surpluses rarely occur, then hoarding behavior is optimal. Implicit in their logic is that even seemingly altruistic behavior (food sharing) is actually driven by selfish goals which are realized over the long-term. Essential to this model is the presence of spatial as well as temporal fluctuations in crop production. These oscillations provide the economic uncertainty that spurs risk-pooling behaviors such as reciprocal trade. The implications of this model are testable in the archaeological record and are germane to this project. Since the Pajarito Plateau is marginal for farming, and precipitation can be highly irregular annually and areally, the emergence and deterioration of exchange networks may be closely tied to environmental conditions. Kohler and Van West's model describes behavior coupled to food sharing. Lithic raw materials, while not subsistence goods, do hold utilitarian value to prehistoric groups. It may be the case that toolstone flowed along the same trading channels, possibly in exchange for foodstuffs. In this way, the movement of lithic materials may highlight the reverse movement of subsistence goods.

Mutualistic Exchange. Unlike risk-buffering exchange systems which involve the reciprocal sharing of similar resources over relatively short distances, mutualistic exchange systems evolve where dissimilar resources are unevenly distributed across a landscape, usually on a larger scale. These resources are differentially accessible to groups due to the constraints of physical distance, the effects of environmental heterogeneity and societal territoriality, and/or the fact that some cultural lifeways are specially adapted to exploit some resources more productively than other lifeways (Snow 1991; Speth 1991; Spielmann 1991a). Given discrete resource fields, mutualistic relationships may broaden the subsistence bases of participating groups by enlarging the effective catchment areas to include more diverse environmental and biotic zones. The increasing availability of foodstuffs resulting from this latter scenario allows population levels to be buoyed above the carrying capacity of the landscape in which each group resides. As a result, each participant becomes interdependent upon the others.

Long-distance exchange relationships between late-prehistoric Puebloan farmers and Plains hunter-gatherers have been characterized as mutualistic (Spielmann 1991b), implying that trade between residents from each area was more than a casual affair. The Puebloans had easily storable corn which was high in carbohydrates; the Plains groups had bison meat which was high in proteins and fat (Creel 1991; Speth 1991; Wilcox 1984). The food in which each group specialized is complimentary to the other in both nutritional value and the seasonality of its procurement. In addition, the lifeway of Plains hunter-gatherers is much better geared for big-game hunting due to their capacity for residential mobility. Plains hunter-gatherers would have been more efficient bison hunters than would visiting Puebloan poachers. Similarly, Plains hunter-gatherers, due to their mobility, would have had a greatly diminished capacity for horticulture compared to Puebloans (Spielmann 1991b). This, when coupled to the differing benefits that meat and corn contribute to a group's diet allow arguments to be made for the emergence of mutualistic exchange relationships between Plains hunter-gatherers and Puebloan farmers.

It has also been noted that it may be optimal in some instances to restrict access to resources which are found exclusively in its own territory in order to enhance the value of those resources as exchangeable commodities (Spielmann 1991b). Mutualistic exchange is a cooperative endeavor; however, the exchange system's viability is predicated on the enforcement of each group's exclusive rights to resources. Conflict and warfare may sporadically erupt when poachers attempt to breach or "cheat" the exchange system by procuring goods directly. The hunter-gatherers of the Plains are ethnographically known to have enforced exclusive rights to bison hunting on the Plains by attacking Puebloan hunting parties (Spielmann 1991b). The practice of restricting access to commodities is not unique to this example (see also Singer 1986; Torrence 1986:169-171).

Conflict and Competition for Resources. The preceding section has sought to delineate some of the motivations for cooperation between social groups. It is also recognized that each social entity is ultimately self-interested and can be expected to engage in seemingly altruistic behavior such as buffering exchange only when the cumulative benefits of such activity outweigh the costs. As stated above, the bulk of the archaeological research has emphasized the evolution of such cooperative behavior among Puebloan groups possibly due to their rather "Apollonian" portrayal in some ethnographic accounts (e.g., Benedict 1934; Bandelier 1916), or perhaps because Puebloans are generally inferred to have lacked political structures which would be required for efficient war-making (although this is an as yet unresolved issue among Southwestern archaeologists [see Orcutt et al. 1990; Upham and Plog 1986]). Just as some forms of cooperative behavior may be likened to biological mutualism, warfare and raiding tactics may be compared to biological parasitism. Both can be successful under appropriate conditions.

On the Pajarito Plateau, population increases may have spurred increased competition for land and other resources. This is probably one of the reasons people began to aggregate into larger settlements. Aggregation may have provided a means to more equitably apportion access to land and resources among households within villages, thereby reducing conflict. Competition between aggregated villages may have been an increasing source of conflict, however (Crown et al. 1996). Upham (1982) argues that social boundaries emerged due to competition between settlement clusters (e.g., cooperating groups of aggregated settlements). Wilcox (1991) goes further asserting that ethnically defined settlement clusters emerged on the Rio Grande due to competition for exchange goods from the Plains. In this way cooperative exchange behavior oriented toward some groups generated competition between others (see also Bronitsky 1983).

It seems clear that interaction between groups cannot be examined on linear trajectories of increasing cooperation in the form of exchange, or increasing competition, conflict, and warfare. The emergence of cooperative behaviors such as exchange often involved competition and conflict in equal measure with other groups.

Since this project makes use of lithic raw materials as the analytic medium used to assess interaction between groups, the terminology of toolstone procurement and exchange system studies is introduced in the following section.

Procurement Dynamics

This discussion begins by drawing a distinction between *direct* and *indirect* procurement behavior. Direct procurement consists of consumers visiting raw material sources to replenish personal supplies. Indirect procurement involves the acquisition of goods through exchange. The terms "exchange" and "trade" are used synonymously in this thesis. It is important to note that all indirect procurement systems also inherently include a component that acquires goods directly from sources to supply the trade system. Consequently, exchange networks are composite systems consisting of the initial direct procurement of goods which later become distributed away from sources through exchange.

Direct Procurement. The most straightforward form of toolstone acquisition is to access a source directly by uninterrupted travel to the outcrop. This is adequate if sources are near sites, but direct procurement quickly becomes problematic as distance to a source is increased beyond a site's day-use "foraging radius" (sensu Binford 1982). At the agrarian sites studied here, small, intermittently occupied structures (field houses) seem to have been used to extend the effective agricultural catchments of larger villages; other subsistence and procurement activities (such as toolstone procurement) may have been similarly based from these small, outlying sites. Since the time and effort needed for procurement increases proportional to the distance to sources, many groups embedded lithic raw material procurement within other activities that required travel into, or near, a known source area (Binford 1979:272).

Embedded procurement averages the costs associated with direct access among several activities. It is expected that special-purpose trips to lithic sources for the exclusive purpose of gathering toolstone were much less common than procurement embedded within other tasks. Specialized forays might only be expected if toolstone were being procured for supra-household use, such as for exchange (for an alternative view see Gould and Saggers 1985).

Since the location of sources is fixed, the archaeological distribution of raw materials over space is a function of a host of physiographic and cultural constraints/incentives. These include a long (and certainly incomplete) list of factors which can be broken down into three categories: physical distance, social distance, and toolstone desirability (Ericson 1977).

The desirability of raw materials for making stone tools is shaped by many factors. Raw materials differ in quality and knapping characteristics which certainly affect a stone's selection for tool production (Andrefsky 1994a; Bamforth 1992). Some toolstones are preferable for one type of tool but less desirable for another. For example, obsidian was commonly used within the study area to make bifacial cutting tools and projectile points, whereas basalt was the stone of choice for expedient implements and for tools which required a durable working edge (Root and Harro 1993). In some ways, the functional or technological class of tools being made may affect the type of stones sought from the landscape (cf. Andrefsky 1995; Frison and Bradley 1980; Goodyear 1979, 1993; Gould and Saggers 1985; MacDonald 1995), although in some circumstances the fracturing characteristics or quality of raw materials available may dictate the technology of tool production (Andrefsky 1994b).

The size and shape of naturally-occurring clasts of stone found at outcrops may similarly affect a source's exploitive potential (Bamforth 1992). Sources containing small, rounded pebbles are of little use to groups whose tool kit consists of large bifacial tools. However, with the advent of the bow, small pebble sources may be effectively exploited to produce small arrow points (Moore 1989). A source which was little exploited in early times may thus become frequently utilized due to technological innovations.

The desirability of raw materials may also be conditioned by the costs of their extraction from the natural environment. Quarrying bedded deposits from buried substrate is certainly more costly than is casually collecting clasts from rich surface talus deposits or from riverside alluvial sediments (although the search costs involved in the latter may become prohibitive) (Bamforth 1992).

While the factors which contribute to a toolstone's desirability most greatly shape a source's attractiveness, the costs of physical distance forms a critical factor which limits a toolstone's distribution. The constraints of physical distance include both linear distances separating sites and source and ruggedness of the intervening topographical terrain. Physical distances are most severe for pedestrian travellers; transportation costs can be relaxed by more efficient transportation technologies such as boats and horses (Gramly 1984; Portugali and Knapp 1985; Sidrys 1977).

Indirect Procurement. Social factors may accentuate or reduce physical distances. Some raw material sources may be restricted due to hostile territorial control of a competing group (Bettinger 1982; Ericson 1977; Singer 1986). In contrast, exchange networks have made physically distant goods socially more proximate. In order for a formalized economic system such as exchange to emerge, however, traded materials (especially utilitarian goods) must first attain some degree of fungible value, that is, an ability to be freely substituted for something else.

The increase in value of some utilitarian items, such as lithic raw materials, may be positively correlated with increasing distance from its geologic provenance. The basic economic precept of supply and demand dictates that the value of toolstones may exceed their intrinsic utilitarian value at an economically determined distance from their source. Stone artifacts may be traded in raw form, as tool blanks, or as finished implements. Items traded in egalitarian societies tend to be utilitarian/subsistence goods, perhaps also enhancing information flow between groups; in highly stratified societies, status objects may be traded or distributed in return for intangibles such as rank, influence and power (Hodder 1982).

The strategies that prehistoric groups employed to bring raw materials from sources to consumer sites were numerous and varied (Ammerman 1979; Ammerman and Andrefsky 1982; Ericson 1982; Knapp 1985; Luedtke 1984; Torrence 1986). While it is relatively straightforward to identify the presence of association between sites and outcrops through raw material sourcing, it is quite difficult to discern whether stone arrived at sites through direct procurement or indirectly through some form of exchange.

Some researchers have utilized statistical regression techniques to distinguish this difference, and beyond this, to characterize the mode of exchange being practiced (whether it is reciprocal trade, market exchange, centralized redistribution, or prestige-chain exchange, for example). Renfrew (1977) summarized several different mechanisms for exchange and correlated regression models for each. More importantly, he provided exchange studies with a nomothetic concept that the frequency of goods can be expected to regularly attenuate with distance from their sources. He called this the "Law of Monotonic Decrement" (LMD) (Renfrew 1977:72).

Based on the LMD, artifact frequency (the dependant variable) can be plotted against distance (the independent variable). The data, when subjected to regression, express curvilinear fall-off patterns which can be correlated to specific forms of exchange mechanisms (see Bettinger 1982; Brown 1990; Findlow and Bolognese 1982; Renfrew 1977). Through such analyses two zones can be discerned circumscribing a source area. These are the supply zone and the contact zone. The former is the area surrounding a source in which materials are acquired through direct access; it is characterized by a linear fall-off. Beyond the supply zone, groups residing in the contact zone acquire materials through some form of trade. Material densities in this outer zone decay exponentially with distance.

While this approach has many strengths, it is only valid in cases where directionality of exchange is not present. If a source area has widely asymmetric fall-off distributions in different directions, then condensing data into a single fall-off curve will yield erroneous results (Ericson 1977). Moreover, the correlation of various fall-off models with particular types of exchange are overly simplistic and subject to problems of equifinality (Hodder 1982; Knapp 1985). However, as Torrence (1986:15) asserts, using the Law of Monotonic Decrement as a null model from which to measure deviations, is equally, or perhaps more useful, than using it as a simple template to characterize the method of exchange.

In essence, fall-off curves condense three-dimensional spatial data as two-dimensional constructions. The changing abundance of a commodity over space is plotted against its cost of procurement. To examine distributions in three dimensions, and thereby highlight information on directionality, or physical or social impediments to exchange, raw material densities can be plotted on maps rather than referenced only to distance from sources. Typically, three-dimensional analyses have been conducted with trend surface analysis (e.g., Findlow and Bolognese 1982; Kantner 1996; see also Hodder and Orton 1976) or through "synagraphic" mapping of artifact distributions (Ericson 1977), which is a similar regression-based technique. Such representations are generally used on a very large spatial scale, and intended to highlight cultural behavior only on very broad terms. One possible drawback to these approaches is that they typically stop with a verbal model that attempts, in a general way, to fit the mapped distributions. Trend surface analyses are also poorly suited to examine fine-grained patterning in the data. This is the main reason why I chose not to use trend surfaces for this analysis. As detailed in chapter three, the maps generated for this study honor distributional data very closely and highlight variation between sites rather than trends over the study area taken as a whole.

Research Context

This project's time frame is restricted to the Coalition and Classic Periods of the Northern Rio Grande chronology, an interval that captures 450 years of Anasazi prehistory between A.D. 1150 and 1600. Sites predating the Coalition Period are relatively rare on the Pajarito Plateau, and reflect a sparse early occupation of the area. Population on the Plateau escalated slowly during the Early Coalition Period, and then increased suddenly in the late A.D. thirteenth century. Dense occupation of the area continued until protohistoric times when groups apparently moved off the plateau to large pueblos situated on the Rio Grande (Crown et al.1996; Kohler 1989).

The Coalition and Classic Period settlers of the area drew the majority of their subsistence from agriculture. The soils and climate of the Pajarito Plateau, and the Upland Southwest in general, are marginal for maize farming. It is likely that groups settled areas, exploited resources (such as agricultural soils, firewood, etc.) until they were depleted, and then moved a short distance to virgin land when the costs of poor crop yields and increasingly distant wild resources outweighed the costs associated with relocation (see Orcutt in press; Kohler and Matthews 1988). This process of "mobile sedentism" is analogous to hunter-gatherer mobility except that the time frame of residential moves occurs over a couple of generations rather than over a couple of days or months (Kohler and Matthews 1988:560). This type of land use was probably common during the Early Coalition Period (1150-1250) when settlement across the Pajarito was relatively sparse and clustered in small pueblos, or hamlets, of seven to 12 rooms in size. Architectural design of these early roomblocks suggest inhabitants did not intend for them to last for extended periods (Van Zandt 1993).

Beginning in the Late Coalition Period (1250-1325), the population of the Plateau increased at rates which probably exceeded *in situ* growth (Orcutt in press). It is likely that the contemporaneous abandonment of the San Juan region to the northeast partially contributed to this population influx (see Cameron 1995; Cordell 1995; Lipe 1995). With population growth, groups began to form larger, multi-roomblock pueblos. The reasons why people came together to live in aggregated settlements are not well understood but may have been in part a response to environmental stresses brought on by extended periods of drought (Hill and Trierweiler 1986), overuse of nearby subsistence resources (Kohler and Matthews 1988; McKim 1994), or to enjoy increased security or competitive advantage relative to hostile competing groups (Haas and Creamer 1996; Orcutt et al. 1990; Wilcox and Haas 1994). All of these factors were exacerbated by heightened population levels.

Reduction in the size of site catchments and home ranges probably accompanied increasing population densities. Such processes may have given rise to increased territoriality between neighboring sites, or group alliances. Land "ownership" may be marked off or enforced by threat of warfare (Kohler 1992; Wilcox 1991). Increases in territoriality may have fostered and enhanced reciprocal exchange networks which were used to offset restrictions of mobility.

During the Classic Period (A.D. 1325-1600), as people began to band together in larger settlements, exchange networks emerged across the Pajarito and were used to buffer food shortfalls to a greater degree than during earlier times. In addition to reducing subsistence risk when stores at discrete locations grew low, exchange also functioned to reinforce political ties, relay information about conditions in nearby areas, and feed emerging trade relationships with the Plains. Rainfall in the Northern Rio Grande subregion can be very erratic; sites separated only by a few kilometers may experience appreciably different rainfall amounts over the course of a growing season. Exchange was beneficial to Anasazi groups throughout most of prehistory due in large part to highly variable environmental conditions that created annual and spatial variation in subsistence yields. This uncertainty was probably one factor that encouraged groups to practice surplus agriculture in which more crops were planted than would be needed in a given year. The excess was then stored for use when yields fell below expected levels.

While storage enabled variation through time to be allayed, variation across space was mitigated by exchange (Braun and Plog 1982; Bronitsky 1983; Kohler and Van West 1996). In this way, reciprocal trade networks served, in essence, as a form of "storage" across space. The guarantee of reciprocity was the uncertain character of the environment itself; if one did not reciprocate, it would not be long before "defectors" suffered poor crops themselves.

Hunting also contributed to the Pajaritan diet. Large game animals such as mule deer and elk are more abundantly represented in faunal assemblages in the Coalition Period than in the Classic (McKim 1994). The decreased presence of these mammals through time appear to be attributable more to anthropogenic causes, rather than to environmental conditions such as drought (McKim 1994). Mule deer generally inhabit forested areas. As the Pajaritan landscape was slowly cleared through time for agricultural fields, mule deer probably retreated to the higher elevations of the Jemez Mountains and became less accessible to plateau-residing groups. In addition, decreasing deer procurement could have been the result of overhunting (see also Speth 1991). Through the effects of receding habitats and/or overhunting, artiodactyls became less available to groups residing on the Pajarito; hunting activities likely became focused farther afield within the densely forested Jemez Mountains.

In addition to food exchange between local trade alliances, which can be characterized as performing a risk-buffering function in society, external trade to Plains horticulturists and hunter-gatherers to the east may have emerged during the Classic (Spielmann 1983; 1991a). Interaction between the Pueblos and Plains has been well documented in both historic accounts and archaeological investigations (Baugh 1984; Baugh and Nelson 1987; Bronitsky 1982; Creel 1991; Wilcox 1984). Long-distance exchange relationships with Plains groups was mutually beneficial to both trading partners, and therefore sustainable, due to the diversity of subsistence bases between the two groups. Plains groups had easy access to bison meat, whereas Puebloans had stores of corn. The relationship between Pajaritans and Plains groups is pertinent to this research because Jemez Mountain obsidian tools and flaking debris are commonly found at late prehistoric sites in Texas, Oklahoma, and Kansas signaling interaction between both populations through obsidian exchange. Obsidian was probably procured and initially reduced at sites on the Pajarito Plateau which must be crossed to reach Jemez obsidians from the east.

Through time, the most obvious change in Pajaritan settlement structure was the emergence of aggregated villages. There are many disadvantages to living in large settlements as opposed to small dispersed pueblos (Kohler 1989). Chief among these is the increasing distance of adjacent farm plots from centralized habitations (Preucel 1987; Orcutt 1993). The optimal solution arrived at by villagers was to build small, intermittently occupied field houses to mitigate the costs of daily travel from pueblo to fields. The start of the Classic Period marks a gradual decline in population on the Pajarito and a continued increase in the aggregation process that began in the Late Coalition Period. Extended periods of drought also plagued the Pajarito during this time. Orcutt (in press) determined that efforts were made to establish fields on both mesa tops and canyon bottoms to minimize agricultural risk. In this way, the distance to fields became an advantage, not a disadvantage; individual site catchments were becoming larger in size to capture greater ecological diversity (cf. Minnis 1996).

Besides being useful for tending crops at increasingly distant fields, the roles that field houses served in the overall settlement structure and in the activities carried on by their occupants are not yet clearly understood. It has been suggested that they functioned in part to mark territory since control of land may have become increasingly contentious between villages (Kohler 1992). In addition they may have been used as "procurement and processing locations for brief hunting or gathering expeditions" (Powers 1988:45, citing Chapman and Biella 1980). Agricultural subsistence was commonly supplemented by hunting and the collection of wild plant foods. This was especially important during times of environmental stress (see Nelson 1996).

In sum, the local lithic resource base provided people living on the Pajarito Plateau with several choices of nearby raw materials: basalt, obsidian, and chert (see chapter two). Changing patterns of settlement, subsistence, and food exchange may have had profound impacts with regard to how these raw materials were distributed at sites via direct and indirect procurement mechanisms. First, irregular crop production spurred by local variation in rainfall amounts over the Plateau paired with increasing population densities and reduced ability to move to more productive land generated a greater necessity for local exchange of subsistence goods. Toolstone may have been traded for food in times of hardship. The escalating size and eventual aggregation of population on the Plateau reduced the ability for groups to move their settlements about the landscape when agricultural soils, firewood, and other local resources became depleted. In such circumstances, exchange would become a more important mechanism to cope with mobility restrictions. Second, diminished abundance of large game animals on the Pajarito Plateau due to the anthropogenic impacts may have led groups higher into the obsidian-laden Jemez Mountains in pursuit of deer and other game. Relative to other toolstones, obsidian procurement would have been more easily embedded within such tasks, thereby increasing its effective accessibility to groups on the Pajarito. Third, if increasing population densities and aggregation on the Plateau increased conflict and territoriality between local groups, or more precisely between ethnolinguistic groups, then raw material distributions may have been affected by those social boundaries. In effect, the social distance between consumers and raw material sources may have had a greater effect than physical distance to sources. Raw material distributions would be expected, given these constraints, to conform to social boundaries. And finally, the emergence of inter-regional obsidian exchange with eastern "gateway" pueblos (such as Pecos and Picuris) and Plains groups may have involved part-time specialization in both obsidian procurement and tool manufacture at select sites which served as production centers in these networks. These sites should show disproportionately large amounts of obsidian compared with nearby sites.

Research Problems

It seems clear from the discussion above that the archaeological distribution of lithic raw materials can serve as an analytic medium through which several research topics may be explored. For this thesis I have chosen to examine only two: (1) whether social boundaries were erected in late prehistory as a response to increased competition for resources, or the emergence of exclusive trade alliances; and (2) whether lithic production became more specialized through time to serve external trade relationships with eastern frontier pueblos, and ultimately with groups on the Plains. These two issues are central to understanding the inter and intra-regional dynamics of the Pajarito Plateau.

The Problem of Social Barriers. The modern Puebloan Indians living in the northern Rio Grande Valley display a complex configuration of linguistic origins. These have been broken down into two basic language groups: Tanoan-speakers and Keres-speakers. The modern Tanoan-speaking pueblos are further subdivided into the Tiwa, Towa, and Tewa language groups; the Keresan pueblos remain linguistically undivided. Presently, the Tiwa-speakers are split into northern and southern sub-groups represented, for example, by Taos and Isleta pueblos, respectively. The Towa are found to the west at Jemez Pueblo; the Tewa and Keresan groups currently reside at pueblos in the Rio Grande valley respectively to the north and south of White Rock Canyon. Ethnographic reports indicate that the Pajarito Plateau was occupied prehistorically by only the Keresan and Tewa ethnolinguistic groups; the remaining Tanoan groups settled other parts of the Rio Grande region. These two groups are said to have maintained a rather hostile boundary which was demarcated by the north rim of Frijoles Canyon (Hawley Ellis 1967; Hewett 1930; Lange, Riley, and Lange 1975). Keresan people inhabited the canyon and areas to the south; the Tewa lived on the northern Pajarito. The Keresan occupation likely predated that of the Tewa. The Tewa intrusion onto the Plateau may have occurred sometime during Late Coalition times, and the Frijoles boundary may have formed concurrently (Hawley Ellis 1967).

If this model is valid, one might expect to see marked changes in the raw materials found at sites just north of Frijoles canyon between the Coalition and Classic periods as high-quality basalt quarries, which are more prevalent to the south, may have become more "socially distant" through time. The Pedernal chert quarry far to the north, on the other hand, may have become more accessible to sites in the Tewa territory north of Frijoles through time, and less so at sites south of the boundary (Kohler 1990:150-151). Previous studies (Head in press; Vint 1993) have shown little evidence of such a break, but both of these studies were spatially limited to sites within Bandelier National Monument, an area centered south of Frijoles canyon that includes a relatively small sample of sites north of the canyon. Since the research proposed here is not areally limited to Bandelier N.M., it may be better equipped to show Plateau-wide trends.

The Problem of External Exchange. Obsidian has been shown world-wide to be a commonly exchanged commodity (Ammerman 1979; Ammerman and Andrefsky 1982; Ericson 1977; Torrence 1986). Southwestern obsidians are no different (Brown 1990; Cameron and Sappington 1984; Findlow and Bolognese 1982; Green 1985; Harry 1989; Peterson 1997). Outcrops of the Jemez volcanic field produce large, high-quality cobbles and boulders that would have been highly-valued for stone tool manufacture. Jemez obsidian was exploited for tool production beginning in early Holocene times (Acklen 1993; Winter 1983). Cameron (1991) found Jemez obsidian to be relatively common in Chacoan assemblages after A.D. 920 (see also Cameron and Sappington 1984). Several researchers (Baugh 1984; Baugh and Terrell 1982; Baugh and Nelson 1987; Spielmann 1983; Winter 1983) have noted the presence of Jemez obsidian in Late prehistoric contexts on the Southern Plains as far away as Kansas.

David Snow (1981) devised an economic model for prehistoric and protohistoric exchange in the region for both internal exchange (reciprocal distribution of materials within the northern Rio Grande region) and external exchange (economic interaction with groups outside the region). According to Snow, internal exchange, involving especially Pedernal chert, increases during the Coalition period, whereas external exchange increases during the Classic period and becomes oriented toward the east. During Late Developmental times (1000-1200), he suggests, extensive trade developed with Mexico and the Pacific coast for ceremonial items. After Casas Grandes fell into decline during the Early Classic period, this exchange network fell into semi-dormancy. It was during this time that exchange networks opened out to the Southern Plains (see also Wilcox 1991).

Since the Pajarito was sparsely settled during the Late Developmental Period when interaction with Chaco and Casas Grandes would have been greatest, the character of those procurement systems cannot be addressed here. It is also likely that the exploitation of the Jemez obsidian sources by these groups would have been centered in the high mountains or on their western slopes; the Pajarito Plateau lies to the east of the largest obsidian outcrops and would have been little travelled by these western groups. In contrast, the emergence of an eastward trading network oriented toward the plains of Texas and Oklahoma during the Classic Period is expected to be highly visible in the sites studied here. The Pajarito Plateau was heavily settled during the Early and Middle Phases of the Classic Period as this exchange network is hypothesized to have begun forming. However, by the Late Classic (A.D. 1550-1600), just as the eastward exchange reached its zenith, the Pajarito was being depopulated as groups migrated to lower elevations along the Rio Grande.

If obsidian was being procured for the exclusive purpose of trade, sites serving as production nodes in the network should contain significantly more obsidian than nearby sites which were not fully engaged in the network. The percentage of obsidian at production nodes for long-distance exchange networks should show a high degree of departure from the LMD (such as illustrated in Renfrew 1977:Figure 5; see also Renfrew and Level 1984; Brown 1990). These differences should be readily apparent on distribution maps and identified as prominent vertices in the distributional pattern. In addition, if production became specialized within a settlement cluster, some degree of centralization may be expected. If more than one centralized production center emerged, competition between centers may also be expected creating strife among local groups as described by Wilcox (1991) (cf. Bronitsky 1983). Hostility between groups produced in this way may have caused social boundaries to be more saliently visible in exchange relationships between local groups.

Significance of Research

Most studies of procurement/exchange systems focus on a single raw material and examine its archaeological dispersal over physiographic regions, culture-areas, or states (Ammerman 1979; Baugh and Nelson 1987; Brown 1990; Ericson 1977; Findlow and Bolognese 1982; Peterson et al. 1997; Torrence 1986). In contrast, this thesis describes the archaeological distribution of several commonly used and locally procured toolstones. Moreover, it explores distributional variation on a smaller scale and with higher resolution. As chapter three explains, the mapping techniques invoked for this analysis are set to highlight fine-grained variation between sites rather than describe collective trends. The patterns expressed by these distributions, such as whether they sharply conform to physiographic or ethnolinguistic boundaries, imply behavioral patterns of movement, trade, and access to resources on the Pajarito.

2. THE STUDY AREA

The Pajarito Plateau is situated high on the western margin of the geologically active Rio Grande Rift Valley in north-central New Mexico. The dominating physiographic feature of the area is the Valle Grande, a 12-mile-wide volcanic caldera that crowns the Jemez Mountain Range and overlooks the study area (see Figure 2.1). Adjacent to the Caldera lies the Pajarito, a broad volcaniclastic apron of ash-fall tuffs and rhyolitic flow breccias that radiate eastward from the Jemez Mountains to the canyons cut by the Rio Grande. The Pajarito Plateau, and the prehistoric populations that once inhabited it, serve as the study area and subject matter for this project.

Physiographic relief across the area is great, extending from approximately 1,650 m in the Rio Grande valley to over 3,100 m at Cerro del Medio on the rim of the Valles Caldera. Consequently, the area hosts a diverse variety of plant and animal life. Piñon-juniper woodlands containing sagebrush, rabbitbrush, and mountain mahogany cover the surface of the Plateau between the elevations of 1,800 and 2,200 m. Ponderosa pines become gradually more common above this point and eventually dominate forests above 2,500 m. The numerous, deep canyons which incise the Plateau hold isolated corridors of riparian plant communities consisting of cottonwood, aspen, Engleman spruce, white oak, and Douglas fir (Powers 1988:18). This vegetation zone, which is restricted to shaded canyon bottoms at lower elevations, becomes typical across the higher elevations of the Jemez Mountains which overlook the Pajarito from the west. Animal species exploited prehistorically included mule

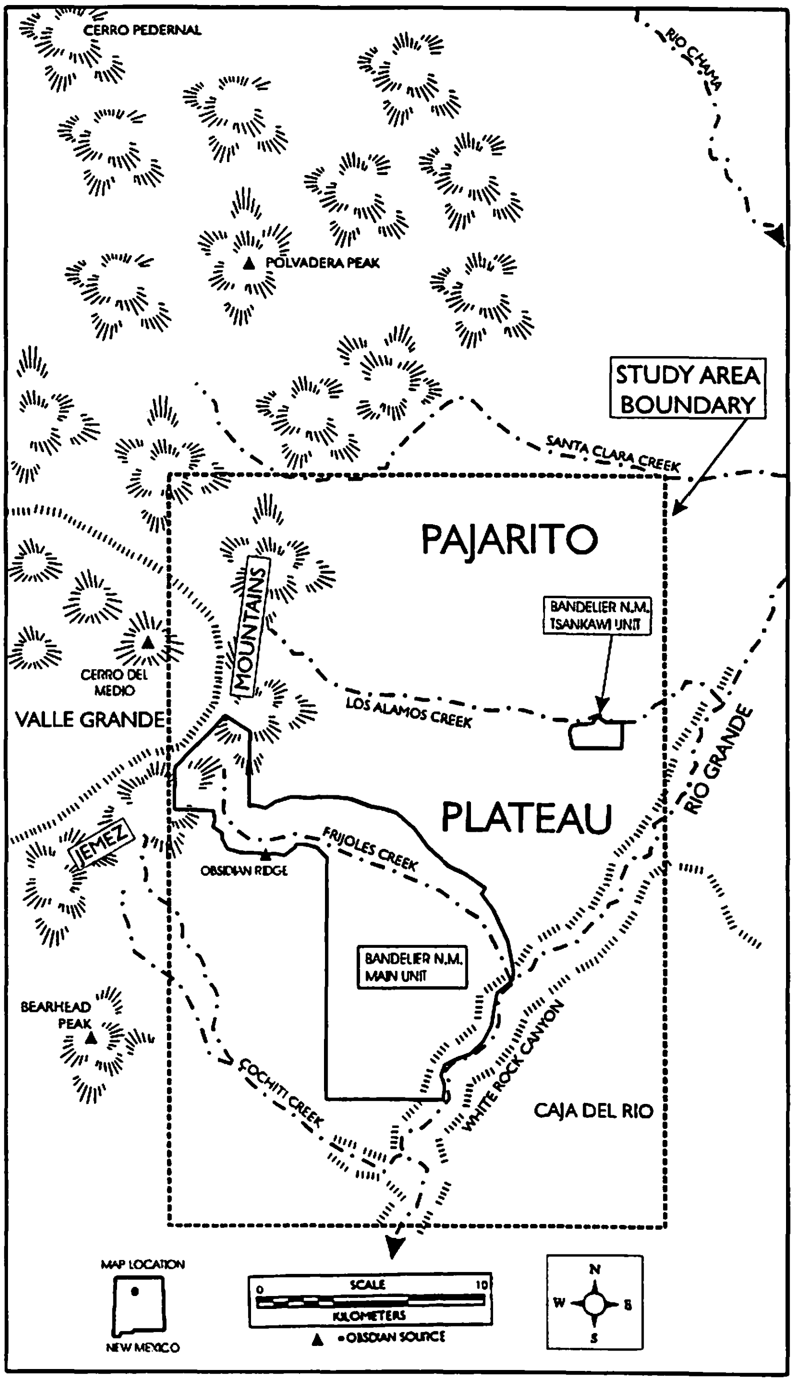

Figure 2.1. Map of the project study area placed in larger regional context. Prominent obsidian sources noted with triangles.

deer, elk, cottontail rabbit, jackrabbit, rock squirrel and wood rat (McKim 1994; Powers 1988:20; Trierweiler 1989).

The Pajarito provides a rich archaeological terrain to study procurement practices for chipped stone raw materials. The region holds abundant sources of fine-grained basalt, obsidian, and a visually distinctive type of chert from Cerro Pedernal. These three raw materials form over three-quarters (76.4%) of the lithic assemblages within Bandelier National Monument located on the central Pajarito (Head in press:Table 9.01).

The possibility of studying the structure of raw material acquisition through archaeology is enhanced by the spatial discreteness of each of these toolstone's geologic sources. These sources are located in opposite extremes of the Plateau and do not spatially overlap. Abundant outcrops of fine-grained basalts occur at lower elevations along the Rio Grande, Rio Chama and on the Caja del Rio Plateau. Obsidian originates at high elevations throughout the Jemez Mountains west of the study area, and Pedernal chert occurs at quarries in the northernmost Jemez Mountains.

Geologic Setting

The Jemez Mountains and Pajarito Plateau formed largely over the last 2 million years during the eruptive episodes of the Valle and Toledo Calderas. The Plateau itself is composed of approximately 800 to 1,200 vertical feet of consolidated pyroclastic debris which cap slightly older Pleistocene basalts of the Cuerbio and Cisneros flows. These igneous strata, in turn, are largely underlain by Miocene/Pliocene sedimentary beds of the Tesuque Formation (Goff, et al. 1990; Kelley 1978).

Due to the softness of the volcanic rocks of which it is composed, the surface topography of the Pajarito Plateau has been incised by numerous steep and narrow canyons. These have left a series of parallel finger mesas that stretch southeastward from the slopes of the Jemez Mountains to White Rock canyon where the Rio Grande flows. Local relief of inter-mesa canyons commonly reaches 800 feet, becoming greater toward White Rock canyon. Canyon walls are quite steep and often impassable making travel "against the grain" of the topography (that is, perpendicular to the canyons) quite difficult and time consuming. Traversing the Plateau from north to south requires a much greater level of effort than moving parallel to the canyons. Alternatively, moving between the mountains and the Rio Grande, parallel to the canyons, is relatively easy.

In contrast to the disadvantages the landscape imposed on its inhabitants, the unwelded volcanic tuffs that make travel so difficult offered the prehistoric populace an excellent source of building stone for pueblo construction. In addition to being ubiquitously available, these rocks are soft, easily shaped, and relatively easy to transport due to their light weight. Unwelded tuff was commonly used to construct freestanding pueblos; however, when habitations were located adjacent to vertical cliffs, small storage chambers, habitation rooms, and even sockets to hold viga roof beams, were excavated directly into the living rock.

The Lithic Resource Base

High quality toolstones are abundantly available across the Pajarito. The lithic resource base is dominated by three easily distinguishable stones: basalt, obsidian, and Pedernal chert. Each of these occur at source fields discrete from one another within or just beyond the study area. What follows is a descriptive overview of each raw material stressing the geologic provenance of each source, and the character, attributes, and exploitive potential of each quarry. A more detailed discussion may be found in Root and Harro (1993:44-47); portions of that earlier discussion are repeated here.

Pedernal Chert

Pedernal chert is the most distant of the raw materials treated here, and by far the most abundant type of chert represented in site assemblages of the area. Its closest primary geologic occurrence is at Cerro Pedernal, located in the northern Jemez Mountains approximately 20 km north of the project area's northern boundary and 40 km from its center (Figure 2.1). Pedernal chert, contrary to what its archaeological designation indicates, is actually a mixture of both chalcedony and chert. It is visually distinctive from local cherts by its dominant translucent-to-opaque white color with mottles of yellow, pink and red. Pedernal chert also frequently contains black dendritic impurities. Acklen et al. (1993) classified chalcedonies with dendrites found at sites on the central Pajarito Plateau as separate types of chert. Dendritic impurities are rare in most types of chert; their frequency in Pedernal chert coupled to their absence in other local cherts suggests that the silicates which Acklen et al. (1993) classed as "dendritic agate" are also from the Pedernal quarries, although they may be an atypical variety.

Other locally occurring cherts are associated with the Tesuque Formation sedimentary beds which are rarely exposed. These latter cherts are opaque red or yellow, and are of lesser quality for toolmaking than the Pedernal chert. Cherts not identifiable as originating from the Cerro Pedernal deposit contribute only 2.1 percent of lithic assemblages examined during the Bandelier Archaeological Survey (or 13.3 percent of all varieties of cryptocrystalline silicates, including Pedernal chert [Head in press:Table 9.01]).

Pedernal chert was formed within a relatively thin, silica-indurated, limestone component of the Abiquiu Tuff Formation. Remnants of this chert-bearing stratum are exposed westward 40 km from Cerro Pedernal in the direction of San Pedro Mountain at elevations in excess of 2500 m (Church and Hack 1939; Smith 1938; Newman 1994). Bryan (1938, 1939, 1950) described three major quarries on the slopes of Cerro Pedernal and a 4-ha quarry on the summit of San Pedro Mountain. The latter is extensively pocked with quarry pits, which are up to 1.5 m deep and 3 m wide. Judging from the density of pits and size of the San Pedro quarry, it was probably the most intensively exploited of the Pedernal chert sources. Quarrying activities where pits are excavated into the substrate are extremely labor intensive. It is unlikely that Pedernal chert acquisition was embedded within other activities which drew people to the mountains. Mining activities are seldom conducted casually and indicate that groups were dispatched directly to these quarries with a singular goal of raw material extraction (Root and Ahler 1993:16).

The natural occurrence of Pedernal chert is not limited to these primary geologic outcrops. Secondarily transported materials can be found in the river gravel deposits at the Rio Chama and Rio Grande. The relative size and frequency of chert cobbles in these river beds decreases with distance from Cerro Pedernal. Near the source, Pedernal chert-rich Pleistocene terrace deposits were utilized for tool production at LA 25424 located along the Rio Chama near Abiquiu Reservoir (Acklen et al.1993). Farther from the source, in White Rock canyon, Pedernal chert comprises only 2.7% of all pebble and cobble-size fractions of Rio Grande alluvium (Warren 1979:Table 3.2). Due to high search costs, these deposits probably presented the Anasazi toolmaker with an unreliable, time-expensive resource for procuring chipped stone raw materials. Moreover, toolstone found in alluvial deposits is generally more heavily cracked, coned, and weathered than bedrock deposits. Within this context, it is expected that procurement efforts directed at these gravels were situational in nature, with cobble selection being guided more by serendipity than focused effort. These gravels probably contributed very little of the Pedernal chert seen in site assemblages across the study area.

An additional source of secondarily deposited Pedernal chert pebbles and cobbles has been recently identified by Moore (1993, cited in Head in press). These materials are said to be associated with the Puye Formation's basal conglomerates and were seen exposed in the walls of Los Alamos Canyon east of the junction of Highways 4 and 502 (G. Head, personal communication 1993). The Puye exposures follow a northerly contour along the retreating, eastern escarpment of the Pajarito Plateau beginning at Los Alamos Canyon. It is not found south of Los Alamos Canyon, nor is it exposed on the surface of the Plateau (Kelley 1978):

> The Puye is composed mainly of volcaniclastic debris derived from the central and northern Jemez Mountains by rapid erosion of Tschicoma quartz latites and by reworking of associated pyroclastic deposits. Proximal facies of the formation consist largely of lithic pyroclastic and laharic deposits, whereas distal facies are mainly fluvial. The base of the formation contains beds consisting predominately of well-rounded boulders of Precambrian granite and metamorphic rocks from distant sources. This unit, the Totavi Lentil of the Puye Formation [Griggs 1964], is a channel deposit

> of the ancestral Rio Grande, which was forced eastward by rapid growth of the huge volcaniclastic fan that forms the Puye Formation [Bailey and Smith 1978:195].

The Puye Formation is volcanic in origin. Exposures are typically "fanglomerates" in which subrounded-to-subangular rock are suspended in a distinctively volcanic matrix. The possibility that Pedernal chert was included within such facies is extremely unlikely. It is more probable that Pedernal chert is represented exclusively within the underlying, fluvial Totavi Lentil gravels. This unit, as pointed out by Bailey and Smith (1978) above, contains a wide spectrum of rock types including granite and metaquartzite. Kelley (1978) adds that this unit also contains "minor fragments of volcanic rocks." There are no references in the geological literature that this stratum includes chert. However, the overall composition of the Totavi Lentil gravels is very similar to the modern axial gravels of the Rio Grande and, as noted by Warren (1979) the latter do contain small amounts of Pedernal chert. Since the Totavi Lentil is an ancient channel of the Rio Grande (Griggs 1964), and therefore analogous in depositional regime to the modern riverbed, it is likely that it too has a small Pedernal chert component. The amounts, however, were too small to be noted in geological descriptions. Considering these geological data, it is likely that the Pedernal chert observed by Moore (1993) was from the Totavi Lentil Unit of the Puye Formation.

The search costs involved in systematically exploiting this source of Pedernal chert were probably greater than for the more recent river gravels and Pleistocene terraces discussed above. Unlike the modern Rio Grande alluvium which is constantly being reworked exposing previously buried sediments, the Totavi Lentil is a static deposit restricted to cliff faces and talus slopes. Once the easily gleaned chert clasts are removed from the surface, access to additional stone requires excavation. The process of erosion would have admittedly revealed new deposits from time to time. At present, these beds are readily exposed in road cuts and a modern roadside rock quarry. During prehistoric times, the gravels may have been substantially less accessible than they seem today.

Root and Harro (1992:117) analyzed the natural surfaces retained by Pedernal chert tools and cores recovered from Burnt Mesa Pueblo, a multi-component Coalition Period dwelling in Bandelier National Monument. Based on the poor representation of stream-rolled cortical rinds in the assemblage, they concluded that Pedernal chert was procured from the bedrock outcrops at Cerro Pedernal rather than from these gravel deposits. These data, coupled to the intensity of quarrying activities evident at Cerro Pedernal and the pitted summit of San Pedro Mountain, strongly suggest that the majority of Pedernal chert originated at the primary outcrops, not the secondary deposits.

The secondarily transported chert clasts found within the ancient and modern Rio Grande river gravels offered local toolmakers a nearby but sparse source of Pedernal chert. Procuring usable toolstone from these alluvial gravels, due to their unpredictable dispersion, allowed only casual gleaning of surface clasts, and not systematic exploitation.

Obsidian

Obsidian outcrops are abundant in the higher elevations of the Jemez Mountains, but also occur across the Pajarito Plateau at low-density, non-localized deposits associated with minor volcanic vents and small rhyolite exposures (Head in press; Root and Harro 1993:44-47; Warren 1979:57). However, these low elevation Pajaritan sources are expected to have supplied relatively little of the obsidian used prehistorically on the Plateau. These sources consist of scatters of small pebble and gravel-sized clasts of stone, most of which probably proved too small for most tool manufacture. Since these sources are typically very sparse, search costs must also be considered when assessing their exploitation potential. It is likely that the added time investment involved in finding suitable stone at these sources rendered them less desirable than the mountain sources. Therefore, obsidian is assumed to have originated west of the study area in the Jemez uplands; its presence at sites represents travel into that area.

The Jemez Mountain source system can be divided into three geologic units according to depositional relationships and age. From south to north they are the Keres, Tewa, and Polvadera Groups (Bailey and Smith 1978; Baugh and Nelson 1987). Because obsidian is an unstable material that hydrates through time, older obsidian deposits contain smaller, less homogeneous nodules than do younger deposits. The oldest obsidian found in the Jemez Mountains is from the Keres Group, which formed during the Pliocene. This includes the source localities of Canada de Cochiti, Paliza Canyon, Bearhead Peak, Borrego Canyon, and Bear Springs Peak, all of which are found in the southern mountains. These older deposits are the most weathered and contain the smallest nodules of any Jemez source. These sources were not used as frequently as were those of the Tewa Group because of the comparatively small sizes of available nodules (Baugh and Nelson 1987:317).

At the beginning of the Pleistocene, the El Rechuelos Formation of the Polvadera Group was extruded. The only prehistorically important source of toolstone in this unit is at Polvadera Peak, north of the Toledo Caldera on the northern margin of the Pajarito Plateau (Baugh and Nelson 1987:317-318; Warren 1979:57).

The latest depositional episode, and the most complex of the three, formed the Tewa

Group volcanic pile. These rocks are centrally located in the Jemez Mountains and are among the youngest rocks in the region (less than 2 million years old). These extrusions are divided into two complexes based on association with two episodes of caldera formation. The first eruption formed the Toledo Caldera during the Pleistocene and extruded the Cerro Toledo rhyolite series. In the Jemez Mountains, these materials produced the Rabbit Mountain and Obsidian Ridge obsidian source localities (Smith et al. 1970).

The second Tewa Group eruptive phase formed several large obsidian-rich rhyolite domes along the rim of the Valles Caldera. These domes are located in the highest mountains and include obsidian sources such as Cerro del Medio, Cerro del Rubio, and the Banco Bonito obsidian flow. Though some large cobbles occur elsewhere, the Valles Caldera domes yield the largest pieces of obsidian found in the region (Winter 1983). The Cerro del Medio dome contains toolstone varying in size from pebbles to boulders. This was the major source of obsidian for the Puebloans who traded the stone eastward to the bison-hunters of the Plains and across the Puebloan Southwest (Baugh and Nelson 1987:18; Winter 1983).

A small sample of obsidian debitage (n=34) from six puebloan sites excavated by the Bandelier Archaeological Excavation Project was analyzed to provide geologic provenance data (Kohler and Linse 1993:Appendix A). These sites range temporally from the Early Coalition to the Middle Classic Periods and all are located in the main unit of Bandelier National Monument. The results of the X-ray fluorescence analysis indicated virtually all obsidian (97.1%) was procured from the Obsidian Ridge/Rabbit Mountain source complex.

These outcrops are the obsidian sources closest to the sites from which samples were taken. The data suggest prehistoric stoneworkers within Bandelier N.M. rarely gathered stone beyond the closest sources to habitations, as would be expected if procurement was embedded within hunting forays into the higher mountains or acquired through specialized trips to sources. These same conclusions were drawn by Genevieve Head after analyzing obsidian source characterization data from sites examined by the Bandelier Archaeological Survey (Head in press). She found that obsidian distributions within Bandelier National Monument's Main and Tsankawi Units were highly responsive to source distance, when the physical topography of the landscape is taken into account.

Basalt

Basalt is the most easily available raw material on the Pajarito Plateau. Extensive flows exist east of White Rock canyon on the Caja del Rio Plateau and at the southern tip of the Pajarito Plateau on Santa Ana Mesa. Basalt is exposed along both walls of White Rock Canyon stratigraphically below the Bandelier Tuff. Some of this rock is poorly suited for flaked stone tool manufacture. However, there is an outcrop of very black, extremely fine-grained Cuerbio basalt with excellent fracturing properties exposed on the slopes of an unnamed mesa at the mouth of Lummis Canyon, a minor drainage situated between Alamo and Frijoles canyons. The area surrounding this exposure is littered with tested cobbles, cores, and early stage manufacturing rejects, indicating its extensive use in the past as a source of raw material (see quarry sites LA 77719, LA 77768, and LA 84023, for example).

Basalt flows or varying quality are also found on the northern Pajarito. The El Alto, Lobato, and Cisneros basalts underlie the Bandelier Tuffs and are common along the Plateau's northern margins (Kelley 1978). In addition, the Cuerbio basalt flows that are common in White Rock Canyon are found as far north as Los Alamos Canyon. The stone here is fine-grained and quite resistant to weathering. The soundness of this rock has attracted local rock climbers to its steep and solid cliff faces.

In sum, the Pajarito Plateau and its surrounding territory contain a wealth of sources from which to draw raw materials for making stone tools. As this discussion has outlined, the majority of Pedernal chert was obtained at primary geologic outcrops situated 20 km beyond the study area's boundaries in the northern Jemez Mountains. Secondarily transported deposits also occur to the east, but due to the low densities of these deposits, they are expected to have supplied only minor amounts of stone. High-grade obsidian cobbles and boulders are readily available in the Jemez uplands. Small scatters of naturally occurring obsidian pebbles may also be available at lower elevations on the Plateau's surface, but these sources are not expected to have been large enough to generate significant amounts of usable toolstone. Basalt can be found on the northern Pajarito, but large, high-quality sources are most prevalent within White Rock Canyon and on the Caja del Rio in the southern half of the study area.

Both the basalt and obsidian source areas contain cobbles and boulders easily exploited simply by picking clasts from the ground or from talus scatters. The Pedernal chert primary source area, however, was more difficult to exploit. The extraction technologies employed for Pedernal chert often included excavating large pits into the substrate. The much greater labor investment involved in this form of extraction indicates stoneworkers were probably visiting the quarry primarily for the procurement of toolstone. In contrast, obsidian and basalt procurement is expected to have been casually embedded within other tasks which took groups near their source areas. An important facet of the geologic distribution of these source fields is that obsidian and Pedernal chert sources are found at high-elevations, whereas basalt occurs in lowland contexts. Biotic resources are also tied to elevation-specific ecological zones in the Southwest. If raw material procurement is embedded within other extractive tasks such as hunting or gathering, then the attractiveness of basalt and obsidian may be coupled to the desirability of acquiring other resources found in these ecozones.

Summary

The local geologic terrain provides an excellent arena from which to observe how basalt, obsidian and Pedernal chert source fields "compete" for the collective demands of prehistoric tool users over a relatively small area. I will examine the extent to which the exploitation of each particular source is shaped by factors such as effective physical distance, group territoriality, and the presence and magnitude of exchange.

Given the geologic distribution of these material sources over space, we can begin to understand what social and behavioral factors guided the selection of toolstone, especially when those decisions did not correspond to simple site-to-source distances. In the next chapter, I delineate my methodology and describe the data bases accessed for the project.

3. METHODOLOGY

This chapter outlines the goals and analytic protocols that guided the project's sampling design, and describes the two archaeological research projects from which site samples were derived. In addition, I also discuss the methodological techniques used to display the data. Data are presented in a quantitative manner by mapping the relative densities of raw materials at sites across space. A correct understanding of the strengths and weaknesses of this method is important because much of the analytic meaning extracted from these maps hinges on the interpolative and extrapolative powers of the computer software which rendered them.

At their most elemental level, procurement studies examine the movement of raw material in two dimensions: (1) the implicit flow of materials through a cultural system as they are procured and later consumed through tool manufacture and use (following Schiffer 1972), and (2) the simultaneous spatial movement of materials from geologic source to activity locus as the material is consumed. Simply put, raw materials enter a cultural system at specific points in space (for example, at geologic outcrops), and later drop out of this system entering the archaeological record at specific points in space (that is, at archaeological sites). The spatial separation between procurement and consumption loci is, then, a by-product of cultural behavior, the processes of which are the focus of this study.

The analysis undertaken here isolates the systemic context of raw materials by examining manufacturing debris rather than finished tools and cores. The latter artifacts can be curated and utilized at many points across a landscape and therefore are not as easily tied to single use loci. By analyzing chipping detritus, this study effectively truncates the contextual breadth of analysis to span only the range from toolstone procurement to tool manufacture. How finished tools are distributed across the landscape is not addressed.

Data Requirements

This thesis examines variation in toolstone distributions over space and through time. I used sites that contain precise site locations and dates of occupation(s). Other necessary data include a characterization of site type (that is, whether a site is a pueblo structure, a field house, etc.), and the relative densities of obsidian, basalt and Pedernal chert debitage represented at each site. In addition to site-specific information, the locations of basalt, obsidian, and chert source areas must also be known, since these provide the structural foundation to which archaeological raw material distributions will be referenced.

The compilation of these variables permit data to be organized according to a three-dimensional, "x, y, z" format. Segregating the data by archaeological period and site type provide a fourth and fifth analytic dimension. In contrast to more commonly used two-dimensional regression analyses of artifact distributions which characterize a site's spatial locality only with reference to its distance from the source being studied (Hodder and Orton 1976:98-126), this analysis places sites in x-y space using the Universal Transverse Mercator (UTM) coordinates of sites, or specific roomblocks within large sites. The z-value is the relative abundance (by count) of each type of toolstone observed at each of these proveniences and is represented as a vertical axis.

When taken together, these data can be used to render "landscapes" which graphically show raw material densities over space. Ideally, the data base must include a large number of sites (>50) that are widely dispersed over the project area. As the site sample increases, so does the resolution and accuracy of the study.

Data Acquisition

The data for this study were gathered from two recently conducted archaeological surveys: the Pajarito Archaeological Research Project (PARP), and the Bandelier Archaeological Survey Project (BASP). Field work for the former took place over a period of 9 years between 1977 and 1985 (Hill and Trierweiler 1986); the BASP occurred more recently, between 1985 and 1991 (see Powers and Orcutt in press).

Access to the Bandelier Archaeological Survey Project data base was kindly granted by Robert Powers of the National Park Service, Santa Fe in 1993. Genevieve Head and Janet Orcutt graciously exported relevant portions of their Oracle data base for my use.

Data from the Pajarito Archaeological Research Project was acquired in two stages: first, the site number, period of occupation, and site functional type data were tabulated from the project's final report (Hill and Trierweiler 1986:Appendix 2); and second, exact site locations and raw material percentages were gathered from site record forms kept at the Laboratory of Anthropology, Santa Fe. Trips to the Lab of Anthropology were conducted in 1993 and 1996 and were supported by the Don Crabtree Scholarship for Lithic Technology and the Department of Anthropology, Washington State University.

Bandelier Archaeological Survey Project

The sampling goal of the Bandelier Survey was to cover 40% of Bandelier National Monument's 132.5 square km. The sampling strategy was stratified to account for differences in elevation and landforms present within the park. Sixty percent of the parcels surveyed were randomly chosen and the remainder were discretionarily selected to document cultural resources that were of management interest to Park Service administrators (Powers 1988). The survey ultimately documented 2,043 sites and covered 32,897 acres or 43% of the Monument's area (Timothy A. Kohler, personal communication 1996).

Site recordation included detailed documentation of lithic assemblages. Flaked stone artifact sampling consisted of temporary collection for analysis of flakes and tools from rectangular collection units, the size and dimension of which were determined by artifact density and the goal of capturing approximately 100 artifacts per unit. If the total surface assemblage was estimated to contain over 10,000 pieces of chipped stone, more collection units were laid out with the goal of capturing 100 artifacts each until 1% of the total number of lithic items estimated to be present or 300 artifacts total were collected, whichever was less. Thirty to forty items were randomly selected for analysis from each 100 artifacts sampled. Debitage, the artifact class of interest here, was coded for cortex amount, condition, technological type, and raw material. Raw material classifications followed standard geologic protocols with additional subdivisions made for cherts and obsidians to separate visually distinctive types, such as Pedernal chert and Polvadera obsidian.

The BASP data base provided an excellent resource for spatial analyses such as this one. It had wide coverage over its study area, a systematic method of sampling the surface artifacts at the sites it encountered, and its recordation protocols used objective, quantified measures to assess site content. Unfortunately, Bandelier N.M. is centered on the southern Pajarito. In order to gain a larger spatial sample, especially covering the northern Plateau, the Pajarito Archaeological Research Project was accessed as well.

Pajarito Archaeological Research Project

The PARP survey was designed to sample a much larger area than the BASP. Its study area covered the majority of the Pajarito Plateau and includes parts of the Caja del Rio, an elevated volcanic tableland located east of the Rio Grande in the southeast corner of the study area. The total area surveyed amounted to 18,310 acres (Hill and Trierweiler 1986). The PARP never gained access to Bandelier National Monument landholdings; for the purposes of this study, the BASP and PARP spatial data are complimentary.

A total of 935 sites was recorded over three survey phases carried out between 1977 and 1986. Phase I, which encompassed the 1977-78 field seasons, sampled parcels of Forest Service and BLM land. Site recordation forms used during this phase did not include information on lithic raw materials and were therefore unusable for this study. During the Phase II and III field seasons (1979-80 and 1982-85, respectively), Los Alamos National Laboratory and Canada de Cochiti Grant lands were made available. More importantly, surveyors began recording raw material types represented within lithic scatters at sites. Unlike the BASP data, these assessments were informal and unquantified; only four raw material classes were used. These were: obsidian, chert, basalt, and quartzite. Additional identified toolstone not fitting one of the above raw material classes was included within an "other" category.

The raw material categories used by the PARP, being more general in definition than those used by the BASP, are adopted here with one exception: chert. The dominant chert type found on the Pajarito, and the most analytically interesting, is the distinctive variety found at Cerro Pedernal. Other types of chert are found in small numbers on the southern Plateau. These latter cherts are mainly associated with Tesuque Formation sedimentary beds and are known to occur in the headwaters of Red and Yellow Canyons which feed Capulin Creek in southern Bandelier N.M.

The BASP data base distinguished between Pedernal and other types of chert; the PARP did not. The difference in chert identification between the projects creates a certain degree of uncertainty as to whether the "chert" percentages listed in PARP site records refers to Pedernal chert (which is of interest to this study) or to other local cherts. If local cherts, as opposed to Pedernal chert, make up a large proportion of the "chert" component within PARP lithic assemblages, then the PARP data may be unusable to assess Pedernal chert distributions. If local cherts are a relatively rare occurrence in site assemblages of the area, then PARP "chert" data can be considered operationally equivalent and used in the analyses.

The effect that local cherts may have on Pedernal chert analyses was evaluated by examining the proportions of chert types tabulated by several studies in the area. At LA 3852, an Early Coalition Period hamlet on the mesa south of Frijoles canyon, Pedernal chert composed 88.9 percent of all cryptocrystalline silicates recovered by excavations (Root and Harro 1992:Table 7.6). Similarly, at LA 60372 north of Frijoles canyon, Pedernal contributed 97.1 percent at its Late Coalition plaza pueblo component and 93.9 percent at its adjacent Early Coalition Period roomblock (Root and Harro 1992: Table 7.11). North of Bandelier, at sites tested for the Ojo Transmission Line Extension (OTLE) (Acklen et al. 1993) which traverses the Jemez mountains and the Pajarito Plateau, LA 6787 contained 88.9% Pedernal chert relative to other cherts. For reasons discussed in Chapter 2, the "dendritic agate" identified at OTLE sites is included here within the Pedernal chert category. Four additional Pajaritan Anasazi sites (LA 82593, LA 82601, and 82612) contained no cherts except for the

Pedernal variety. Finally, the BASP data base was consulted; it showed 84.7 percent of all cryptocrystalline silicates analyzed were Pedernal chert.

Figure 3.1 graphically shows the archaeological distribution of local, non-Pedernal cherts for sites within the Main and Tsankawi Units of Bandelier National Monument, regardless of period. The topography expressed by contours on this map describes the percentage of local chert at sites within Bandelier National Monument. Site locations used for this analysis are shown as small crosses. Note that sites outside Bandelier are not used (and therefore are not shown) because data for those sites (PARP data) did not include chert type differentiation. The specific methods of map generation are discussed in chapter three.

The data presented in Figure 3.1 show that local chert is generally poorly represented, occurring only in the southeastern corner of the park where outcrops of local cherts are known to occur. The lack of local cherts in the Tsankawi Unit, and the sparse representation at the other northern Pajarito sites mentioned above, indicate that these cherts are restricted to the southwestern plateau, and there they are found in relatively small amounts.

Drawing from these data, local cherts seem to have contributed little to the lithic assemblages of northern Pajarito sites. The PARP "chert" data and BASP "Pedernal chert" data are therefore not expected to differ significantly. In contrast, PARP site assemblages on the southern Plateau may contain somewhat larger proportions of local cherts mixed with Pedernal chert. If the PARP chert data are paired with the BASP Pedernal chert data and analyzed as the latter, it is expected that the Pedernal distribution will be inflated to some extent at southern PARP sites due to the added contribution of occasional local cherts.

Since Pedernal chert is expected to decay to the south with increasing distance from its source, the possible presence of local cherts at southern PARP sites will have an effect of

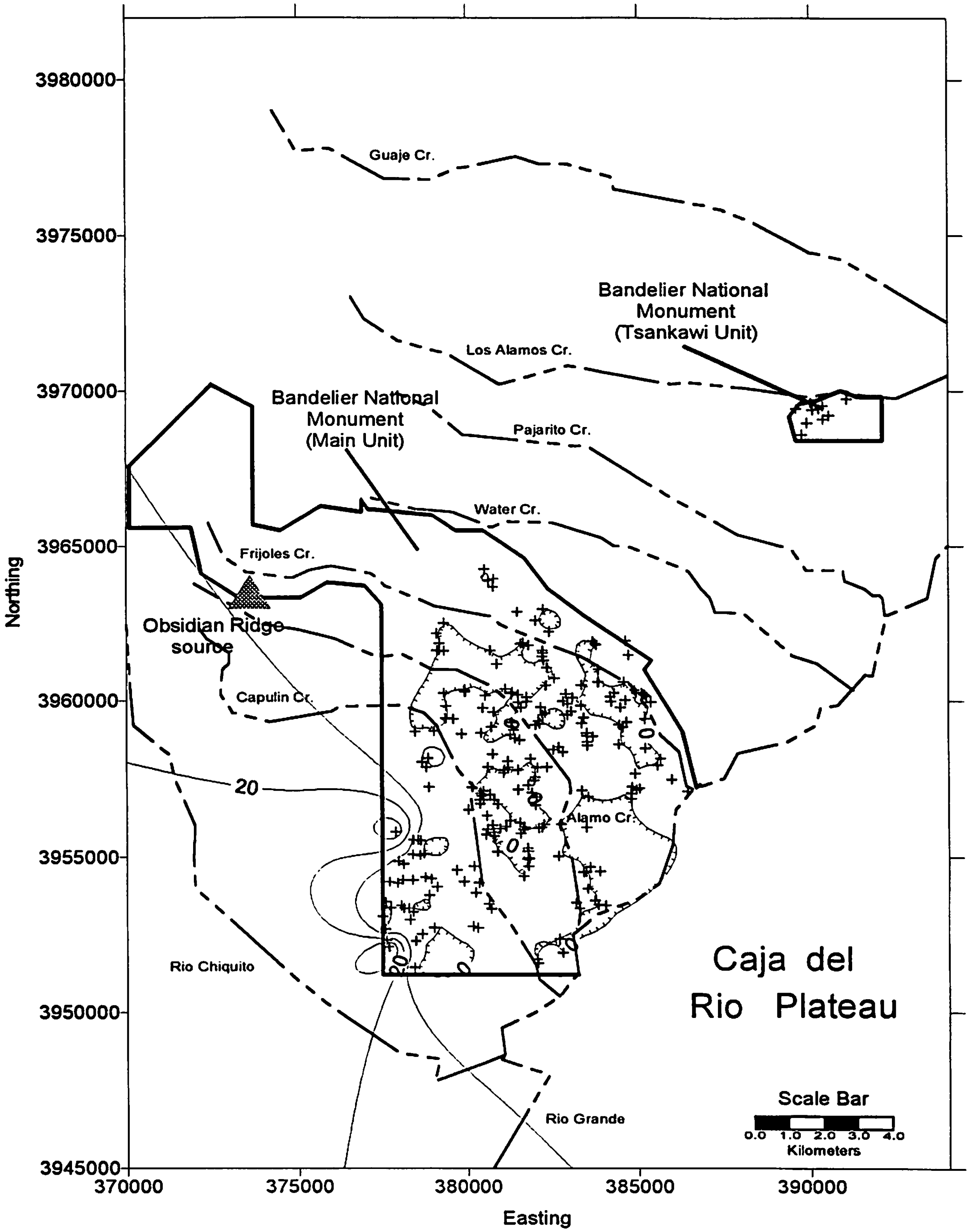

Figure 3.1. Map showing the distribution of non-Pedernal, local cherts at pueblo and field house sites in Bandelier National Monument. Both Classic and Coalition Period sites are represented. Crosses mark site locations; contours describe the percentage of non-Pedernal cherts at sites.

levelling, rather than accentuating its fall-off rate. Therefore, steep fall-offs in Pedernal chert abundance from north to south will still hold analytic meaning even considering these problems since contributions by local cherts will act to reduce such north-south decay patterns.

The Accuracy of Survey Techniques

Important to note is that the two data bases were generated by survey techniques and carry with them all of the methodological baggage inherent in assessing a site's total artifactual remains through the exclusive examination of its surface assemblage. Generally speaking, the accuracy of site surveys is dependent largely upon ground visibility and the obtrusiveness of individual artifacts/ecofacts based on their size, color and contrast with the ground. Other possible biases range from the over-representation of more recent occupations at multicomponent sites, to the casual gleaning of eye-catching artifacts by passers-by. While these factors may have affected the surface assemblages examined here to some degree, any error is expected to be randomly, not systematically, distributed among the sites. When error is randomly distributed between data points, there is no cumulative bias (Wandsnider and Camilli 1992:170). Therefore, the data recorded from these surface assemblages are not expected to be skewed in any consistent pattern. However, it is recognized that the units of measure are surface expressions of much deeper deposits, and the difference between surface and the more substantial subsurface remains may be significant.

In order to test the degree that survey debitage assessments might depart from excavation data, a list of all sites excavated by the Bandelier Archaeological Excavation Project which were also recorded by the Bandelier Archaeological Survey Project (n=4) was assembled. These sites are all located within the Main Unit of Bandelier National Monument. Two are situated on canyon bottoms and two are on mesatops. Debitage data for excavation and survey are presented in Table 3.1 below for comparison.

Overall, the data reveal very little variance between the results achieved by the two projects' collection methods. The average difference between survey and excavation data categories is 4.0 percentage points. Based on these data, methodological collection biases, at least in regard to this study, are not expected to be great.

Site Sampling

The goal of sampling was twofold. First, it was important to generate as large, and as evenly dispersed a sample of sites (data points) from the data bases as possible. This would provide accurate maps with high resolution. Second, it became obvious, due to the wide spectrum of site types, dates, and degree of complexity, that the analyses would require a high degree of refinement in order to generate an accurate set of data points from which to base analyses. I use the term "refinement" to denote a systematic process of removing sites from the data base which have complex occupational histories, small sample sizes, and other characteristics defined below that may add unwanted degrees of variability to the data base.

The sites included in this study were drawn from the BASP data base (2,043 sites) and the PARP database for its Phase II survey (n=596), together totalling 2,639 sites. The Phase I and Phase III PARP surveys were not included because necessary lithic raw material data were not recorded for Phase I, and the Phase III surveys were smaller in scope and would not have added appreciably to the data base already assembled.

Table 3.1 A Comparison of Debitage Percentages as Recorded by Excavation and Survey Projects by Raw Material, Class, and Site.

	Pedernal Chert		Obsidian		Basalt	
	Excavation	Survey	Excavation	Survey	Excavation	Survey
LA 3852	13.1	12.5	10.5	9.4	61.4	68.8
LA 3840	11.0	11.0	33.4	42.7	41.5	38.7
LA 60372 (Area 1)	44.5	38.9	6.1	2.8	44.9	50.0
LA 60550	8.3	10.0	70.9	76.7	19.3	13.3

Since the combined surveys recorded over 2,500 sites, compliance with the first sampling goal (size) was easily satisfied; however, this made the second objective (quality) even more important to the outcome of the analysis. After initially exploring the data, it became apparent that many sites had secondary and tertiary occupations which might obscure the raw material expression left during primary site occupations. Substantial modification to a site's original component through artifact admixture and/or scavenging may create what is, in essence, a palimpsest archaeological record—meaning that the site's most salient component is "overwritten" to some extent by later occupations. This problem is particularly relevant for data gathered by survey techniques, since excavation has a much greater ability to distinguish different occupations.

Another major, but not obvious, problem is created when several features within a large site were sampled individually by site recorders but assigned to the same site number. This thesis seeks to target only domestic features such as roomblock middens. If debitage scatters surrounding non-domestic features as diverse as kivas or agricultural water control devices are combined with roomblock middens to generate an average raw material composition for the site taken as a whole, this will add a significant level of functional variability when compared to smaller sites where only roomblocks are sampled.

The "palimpsest problem" was controlled by removing sites from the data base which displayed evidence of occupations exceeding a single archaeological period (for example, the Coalition or the Classic Period). This standard, when applied to the database, greatly increased temporal control, but did so at the expense of biasing the data base somewhat against sites occupied for very long periods of time, especially those occupied across the Coalition/Classic boundary. However, since the archaeological periods used here each embrace roughly 200 years of prehistory, eligible sites may still have been inhabited over a period of several generations.

The latter problem of isolating and matching site function to individual features within large complex sites was accomplished by searching out and removing records referencing non-roomblock features within more complex sites. The roomblock features within large sites, however, were not removed.

Together, these standards, among others listed below, had the dual result of rendering a great number of sites and features ineligible for analysis and greatly improving the precision of the analysis. The method by which sites were selected for analysis is relatively simple. The following standards were used for their selection:

- All sites are Anasazi habitation structures or field house structures with datable associated ceramic scatters.

- Site occupations were confined to the Coalition or the Classic Periods. No identified primary, secondary, or ephemeral occupations, taken together, spanned more than one of these periods.
- Analyzed debitage samples contained a minimum of 30 flakes. (This is applicable to the BASP data base only; debitage counts were not quantitatively recorded for the PARP).

After these filters were applied to the data bases, a total of 464 sites were left for analysis (or 17.6% of the total). The remaining sites were split into four groups based on site type and period (see Table 3.2). Table 3.2 cross-tabulates the resultant data set by site type and period of occupation. The table shows that while the total number of sites occupied during each period is roughly equal, pueblos are over-represented in the Coalition Period and field houses are more abundant in the Classic Period. This distribution reflects the realities of changing land-use patterns between the two periods as field houses became more common through time (Orcutt 1993).

Field houses were distinguished from pueblo structures based solely on roomblock size. The PARP investigators defined field houses as consisting of three or fewer rooms. The BASP survey classed structures in their data base without assigning functional meaning to class titles. Those with five rooms or fewer were listed as "small" sites rather than field houses. These small structures are inferred here to have been used primarily as field houses since they were probably not large enough for permanent occupations (see Carlson and Kohler 1990). All masonry structures from both data bases larger than these were classed as pueblo

Table 3.2 Number of Sites by Functional Type and Period of Occupation

	Pueblos	Field Houses	Total
Coalition Period	178	70	248
Classic Period	52	164	216
Total	230	234	464

habitations. The slight difference in working definitions of site types between the two data bases is not expected to have a significant impact on analyses.

My decision to group sites temporally along the Coalition/Classic Period boundary was based on the necessity of maintaining large sample sizes for analysis. It may be argued that a more fine-grained examination of diachronic change would be of value when examining the processes of cultural change. However, doing so with this data set would reduce the number of sites per map to such an extent that few distributional patterns would be revealed. Put simply, both spatial *and* temporal detail cannot be attained. Increasing the resolution of temporal variation reduces spatial resolution and vice versa. Only two time periods were chosen for analysis in order to maximize the number of sites per map.

Coalition/Classic boundary was used because it was similarly defined by both the BASP and PARP surveys and because it provided a generalized, but perhaps not precise, analytic division between times preceding and post-dating the emergence of aggregation on the Plateau. The process of aggregation has been tied to several other important anthropological issues including the emergence of small-scale territoriality, the development of long-distance trade networks, and changes in socio-political structure of communities.

Overall, the large number of sites recorded during both surveys provided this project with the analytic material with which to compile a data set of sufficient size and scale to address the research issues at hand. Figure 3.2 plots all eligible sites within the study area and shows that while the site sample is concentrated within the boundaries of Bandelier National Monument, the remainder of the plateau has been adequately sampled; BASP sites are marked with crosses, and PARP sites are shown as diamonds.

Data Presentation

Exploring the cultural movement of lithic raw materials from geologic sources to habitation sites requires data presentation that shows changes in fall-off patterns across space. By generating three-dimensional surfaces to model how raw materials were artificially distributed across the study area, this analysis provides the means to investigate how raw material densities decay along linear transects, and across horizontal space. These distributions can be used to identify directionality of trade, physiographic or linguistic/social impediments to travel or exchange, the emergence of production nodes in exchange networks, and how these change through time.

The mapped surfaces thus created are georeferenced and therefore show distributions in "real space." Moreover, these maps are not "statistical surfaces" that seek to describe trends in the data; the topography described therein honors the distributional data very closely and shows *actual* variation in raw material densities.

Surfaces are not quantified in a statistical sense; fall-off curves are not characterized as linear, exponential, Gaussian, etc., and coupled to mathematical equations (e.g., Findlow and Bolognese 1982; Renfrew 1977); instead this investigation is largely a heuristic endeavor

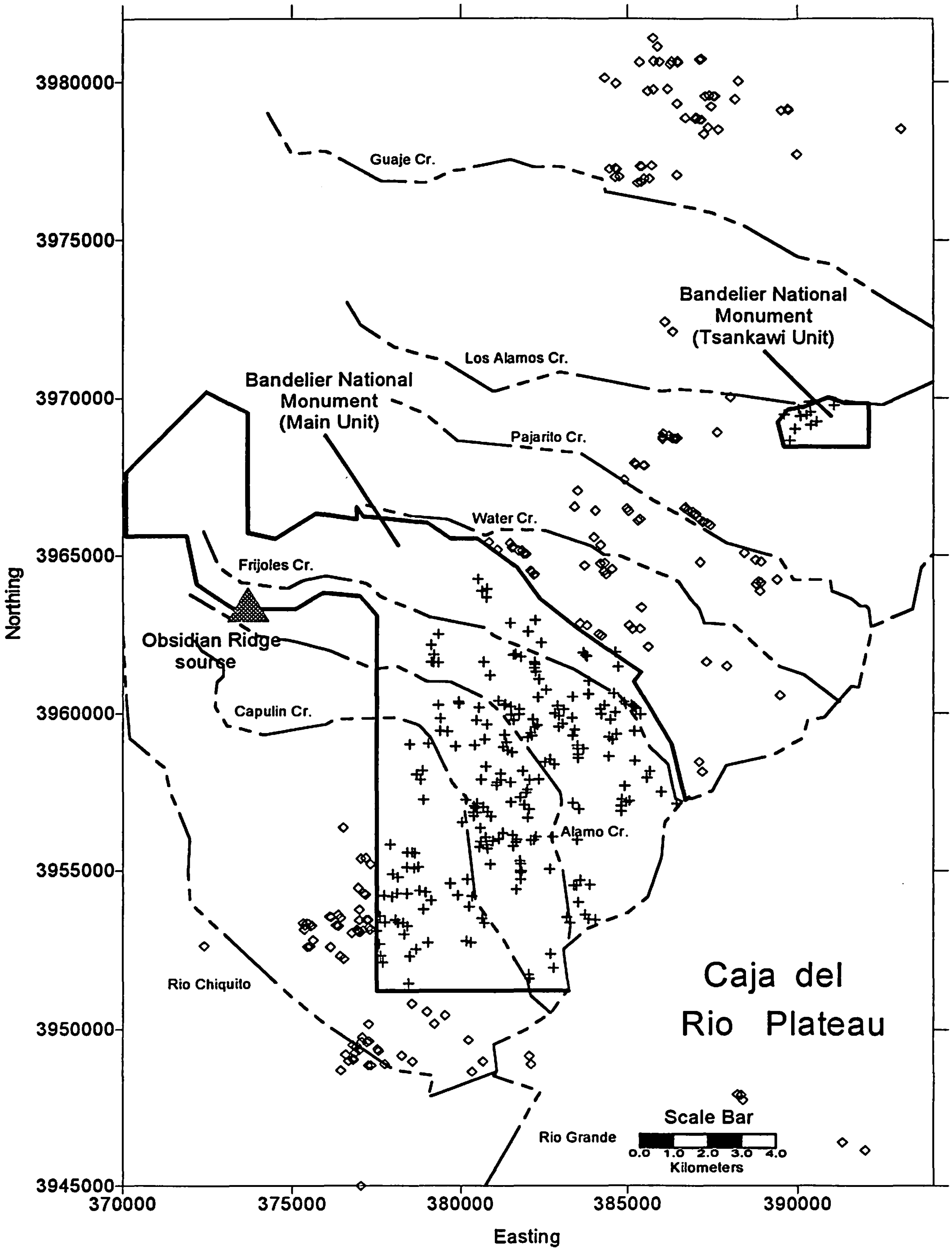

Figure 3.2. Map showing the distribution of sites used in this project. Crosses represent sites from the Bandelier Archaeological Survey Project. Diamonds represent sites from the Pajarito Archaeological Research Project.

seeking to describe anomalies in distance-decay patterns in terms of cultural activity. The quantification of fall-off curves has been shown to differentiate areas of direct quarry access from those areas which obtained toolstone by trade (see Renfrew 1977). Different types of trade, such as down-the-line and prestige-chain exchange, are also possible to distinguish using those methods. While this investigation is a logical first step toward those more specific research topics, the thrust of this study is to describe the *regularity* with which toolstone distributions decay in proportion to distance. Irregularities will highlight physiographic and social barriers to toolstone movement, or may, through a material's increased presence at outlying sites, emphasize its use as a commodity for extended trade.

Maps are produced by Surfer, version 5.01, a spatial analysis software package. Surfer accepts data formatted in 3-dimensional "x, y, z" coordinates and generates maps describing z-values across x, y space. Surfaces are created by generating a regularized "wire mesh" grid which overlays and conforms to the irregularly spaced array of 3-D data points. Since the x, y coordinates of grid nodes do not often coincide with those of data points on the map, the z-values for the grid are interpolated between data points using Ordinary Kriging functions (Golden Software, Inc. 1994:5-1). Kriged algorithms use weighted averaging interpolation and are optimal for use in situations where, for example, "high points might be connected along a ridge, rather than isolated by bull's-eye type contours" (5-32). Kriging was named by G. Matheron (1963) to honor D. G. Krige who modified an earlier technique to more successfully predict the location of subsurface ore deposits for the mining industry (Cressie 1990). Kriging has been used in many other fields, including meteorology, physics, forestry, and cartography. In general, this method readily predicts tendencies between numerous data points while still honoring data closely. Contoured surfaces rendered via kriging techniques are a useful and accurate way to explore spatial variability when inferences must be drawn from irregularly spaced data points.

Kriging functions used in this study have been configured to perform as "exact interpolators." When a rendered grid node coincides with an existing data point with respect to x, y axis coordinates, the z-value of the grid node honors the z-value of the data point *exactly* (Golden Software, Inc. 1994:5-18). When the grid node and the data point do not converge along the x-y axes, the kriged z-value may depart from the actual z-value by a small amount depending on the distance that the data point is from the nearest grid node. Nodes have been spaced at 200 m intervals across the study area to effect high resolution and near exact representation of the data. The maps themselves are presented in contour form which describe the "topography" of raw material distributions across the study area. Contours on the maps are spaced at increments of 10 percentage points.

One of the unique attributes of this project is that it examines raw material movement on a very small scale. Consequently, the study area across which these movements are tracked, compared to the distribution systems at large, is also relatively small. The study area is centered on the Pajarito Plateau and does not include several of the source outcrops where analyzed raw materials were procured. Since Pedernal chert quarries and most of the obsidian outcrops are located beyond the bounds of the study area, the computer-generated surfaces expressed by the data often lacked directional reference to the actual source. In other words, fall-off rates from these sources were seldom uniform. The confined scope of the project area accentuated small-scale anomalies in raw material fall-offs which, in turn, engendered erratic interpretations of site-to-source trends on the part of the computer mapping software. Due to basalt's geologic ubiquity within the study, its generated distributions did not share this problem.

To provide consistency and directionality to the mapped obsidian and Pedernal chert material distributions, several raw material outcrops were included within the data base grid tables prior to surface generation. These external quarries are not shown on the maps proper; however, they affect the gridded surfaces by enabling raw material fall-offs to originate in proportion to their distance from the study area.

Four obsidian sources were selected to exemplify the larger Jemez Mountain source field. These obsidian exposures are the largest and closest to the Pajarito Plateau. They are situated in a north-south line across the eastern Jemez Mountains and represent for analysis the eastern front of the extensive, Jemez obsidian source field. From south to north these are: Bearhead Peak, Obsidian Ridge, Cerro del Medio, and Polvadera Peak (see Figure 2.1). The Obsidian Ridge outcrop is the only one of these that is found within the study area. It is located on its extreme western margin. In a similar way, the chert quarries at Cerro Pedernal far to the north are included in the mapped chert distributions (Figure 2.1). All of these sources were given densities of their respective raw material of 100 percentage points.

Artificially bolstering the obsidian and Pedernal chert distributions by including sources within the grids is necessary. If this were not done, the Krigged algorithms render surfaces which arbitrarily incline or decline from sites to sources depending only on a pattern expressed by relatively few marginal sites. Taken on a larger scale, obsidian and Pedernal chert is more prevalent at sites closer to the primary outcrops of each (Acklen et al. 1993; Findlow and Bolognese 1982; Winter 1983). The resolution and scale of this study is fine-grained and small enough that such broad trends are not readily apparent.

Inferential Considerations

The debitage data used here reflect relative densities (percentages) rather than absolute densities (quantity/m^3). This is the format under which raw material densities were compiled for both survey projects. Organizing data in this way holds the benefit of easily standardizing measures between sites. On the other hand, relative densities create offsetting, and artificial, variance wherein an increase in one raw material must necessarily be reflected as a decrease in the relative abundance of other raw materials. In some cases, all materials may increase in absolute abundance, but placed in relative terms, the material that increases most may reduce the relative amounts of other materials. Where absolute densities in all raw materials increase through time, a plot of relative densities would show an increase for the most prevalent material and register net decreases for all others.

This problem is mediated somewhat by the simple fact that site function is controlled in the analysis. Residential structures are segregated from other more specialized activity areas such as field houses, kivas, and lithic scatters. People involved in similar activities are likely to consume similar amounts of raw materials per capita. Thus, absolute densities of raw materials may scale proportionately with site size, but the per capita use of raw materials should remain the same; hence variation in the use of differing materials should be accurately depicted by relative densities. Under these conditions, relative analyses are appropriate when assessing the net interaction between sites and source fields; it is less appropriate when comparing the magnitude of those interactions, especially between sites of different sizes.

A second inferential limitation stems from the idiosyncrasies of the data presentation methodology. As a result of the interpolative (and extrapolative) power of the mapping techniques used here, the generated plots can be used both as a way to describe the values of the collective sample of data points and as an exploratory tool to infer expected values between data points. While the former use is very accurate, the latter use is potentially very inaccurate. Since the contour lines drawn across the map are guided only by included data points, little variation will be evident in areas with few or no data points. This lack of variation in sparsely referenced map sections should be seen as an artifact of the poor representation of data points rather than a *real* lack of variation in the data. In this way, *map interpretation should emphasize differences between data points*. Map contours are best used as a heuristic device which summarizes these differences. They should not be used to extrapolate what data might be between sites. It is for these reasons that the points used to create the plots are shown on each map. Their position in space and their dispersion can affect the placement of contours as much as the z-values of the data. These factors should be considered when assigning analytic meaning to the plots.

Summary

The PARP and BASP archaeological survey data bases have provided this project with a high-resolution, high-fidelity data set from which to draw anthropological meaning from the spatial disbursement of lithic raw materials. It has been demonstrated that the surficial debitage samples found at Pajaritan sites closely resemble subsurface deposits. Accuracy of the data set was improved by including only the debitage associated with roomblock features within large, expansive sites while also filtering out sites with multiple, potentially corrupting, occupations. The procedures used for data presentation were also reviewed in this chapter; the limitations inherent in these analytic methods were also noted.

4. RESULTS

As discussed in chapter one, this project seeks to address two research problems. The first is to identify whether or not social barriers to procurement existed on the Pajarito. And second, to recognize patterns of procurement associated with emergent long-distance obsidian trade networks. To facilitate assessment of the first research problem, the Plateau is divided into north and south sections along an east-west line which bisects Frijoles Canyon. Universal Transverse Mercator (UTM) coordinates are shown on the margins of each map presented below. The northern and southern Pajarito are demarcated by UTM 39-62-500 N. This line approximates the ethnographically-known boundary between the Tewa and Keres occupants of the protohistoric Plateau. Crown et al. (1996) also frame their treatment of the area in this way, citing the ethnographic differences between northern and southern Pajaritans as noted by Hewitt (1953:41) and Lange, Riley and Lange (1975:57; see also Head in press:68; Carlson and Kohler 1990:9). This division allows the two sub-regions to be easily contrasted with one another. The second research problem is addressed by assessing both the rate of increase of obsidian at Pajaritan sites through time, and the clustering or centralization of obsidian procurement. Obsidian is the only raw material treated in this way because it is the only toolstone known to have been traded great distances.

My treatment of these problems is primarily exploratory; I describe the spatial patterns of raw material procurement and supply possible explanations relative to the two research problems. To meet these ends, I have generated isoplethic contour maps which show raw material densities at sites over space. These maps are similar to topographic maps except that the contours describe relative amounts of obsidian, Pedernal chert, or basalt rather than elevation. Change through time and differences between site types are assessed through the use of "difference maps" which display residual values created when one map is overlain by a second.

This chapter describes the results of the analyses; chapter five returns to summarize each research issue specifically. The discussion that follows is broken into three sections to describe, in turn, the distributional patterns of obsidian, basalt, and Pedernal chert. Each of these three is further divided to assess procurement patterns by period, and their change through time; procurement differences between site functional types is also assessed. Finally, the degree to which high rates of procurement is centralized or clustered spatially is also addressed. Such patterning is evidence for specialized procurement for exchange.

Obsidian

Jemez obsidian was regionally prized for tool manufacture due to its ability to take on a very sharp cutting edge and its excellent knapping characteristics. This is evidenced by its trade throughout the Southwest and the southern Plains (Baugh and Nelson 1987; Baugh and Terrell 1982; Bronitsky 1982; Cameron and Sappington 1984; Findlow and Bolognese 1982; Snow 1981; Spielmann 1983; Winter 1983). On the Pajarito, however, where this material is immediately accessible from sources to the west, obsidian comprises surprisingly little of site assemblages. Figures 4.1 and 4.2 respectively plot the obsidian percentages at Coalition and Classic Period pueblo and field house structures.

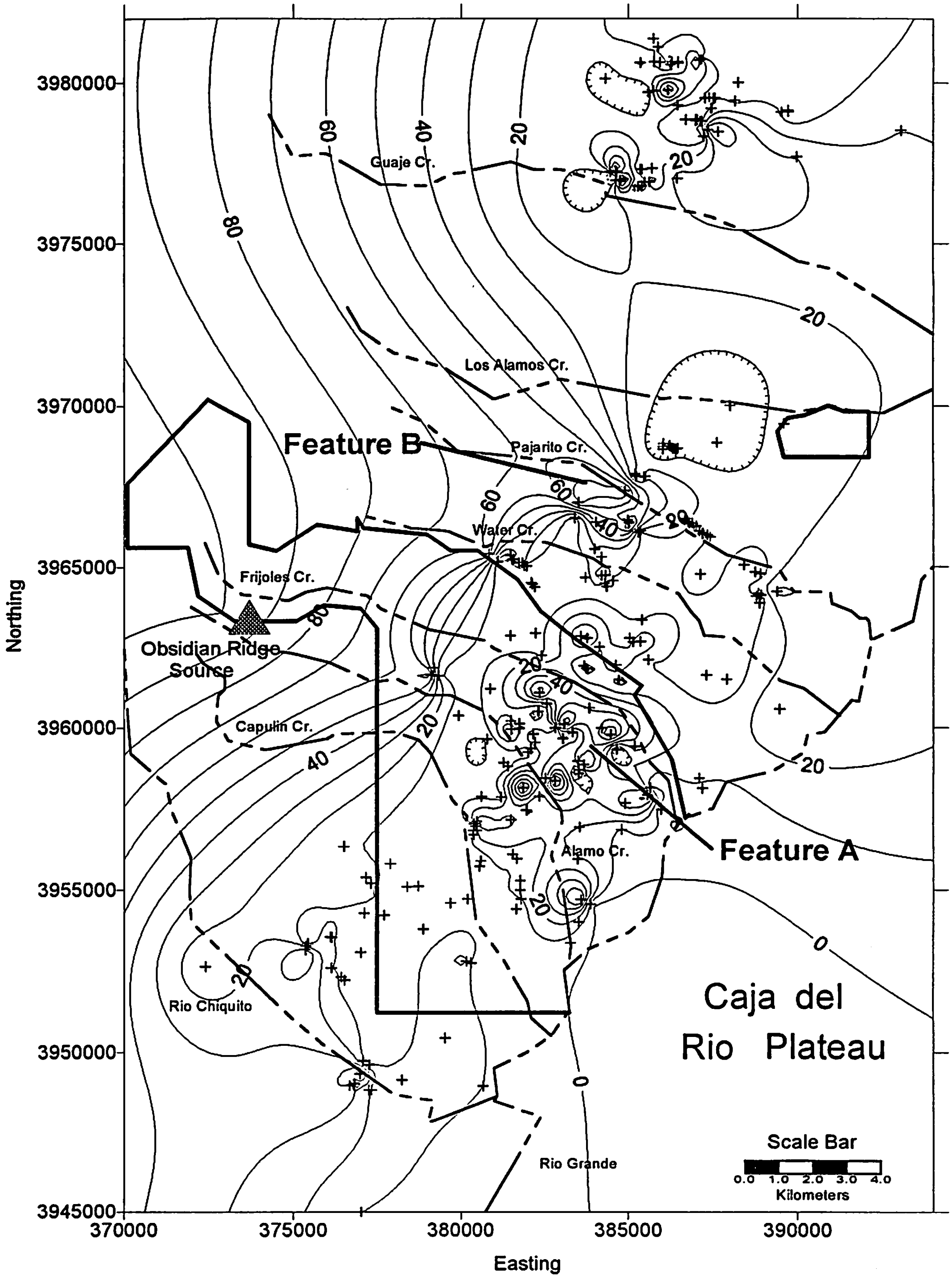

Figure 4.1. Obsidian distribution for Coalition Period field houses and pueblos. Crosses mark site locations

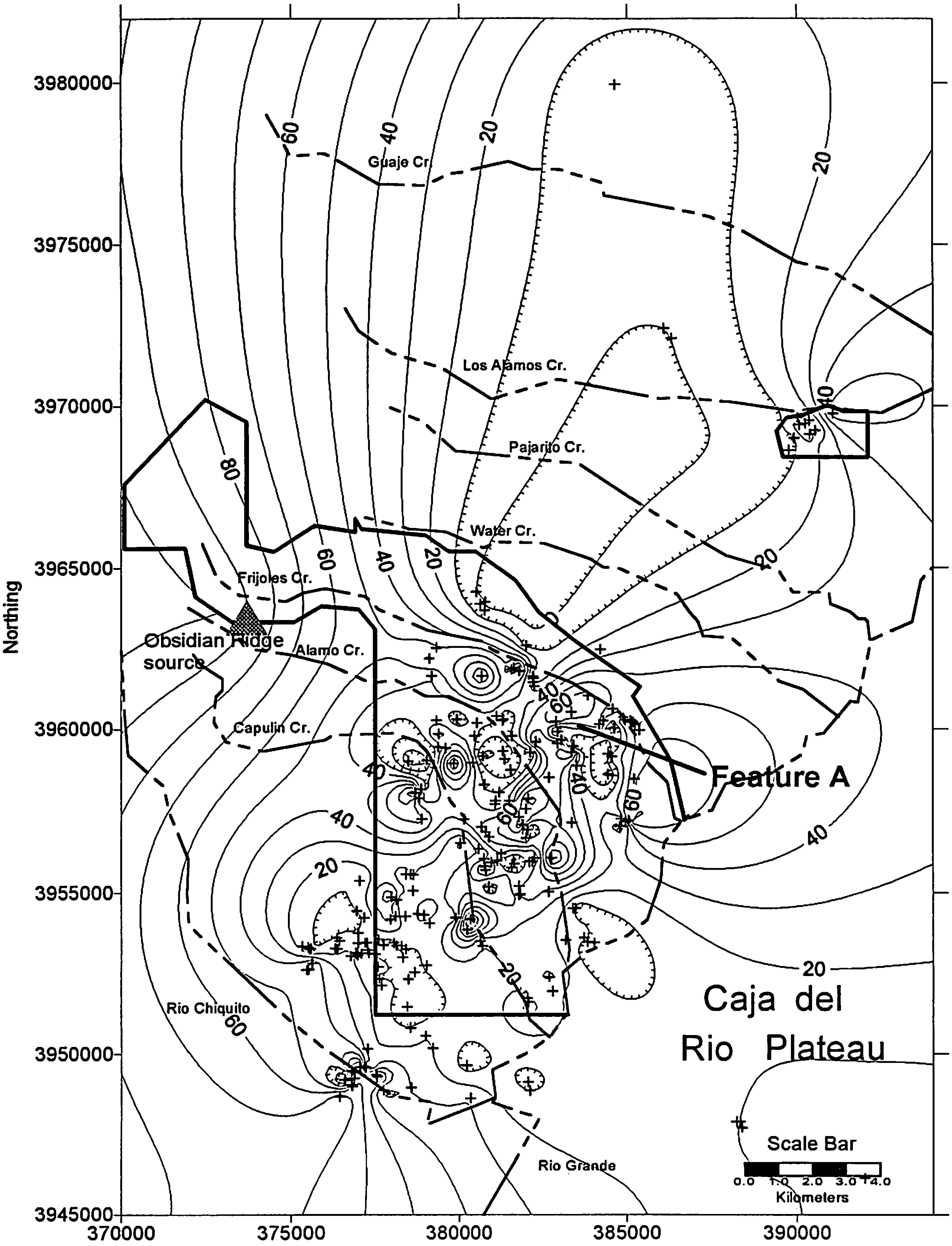

Figure 4.2. Obsidian distribution for Classic Period field houses and pueblos. Crosses mark site locations

Temporal Changes

Figure 4.1 shows that obsidian exploitation was minimal during the Coalition Period. Raw material densities across much of the Plateau descend rapidly from outcrops west of the study area and are generally sparse across the Pajarito. It may be argued that the poor representation of obsidian is not a product of its undesirability as a toolstone, but rather that the resources found in the Canadian zone ecosystems that typify the higher elevations of the Jemez Mountains where obsidian outcrops occur were not frequently exploited during the Coalition Period. It is common for groups to embed lithic procurement within other resource extraction activities (Binford 1979). If high altitude resources were not commonly utilized, obsidian procurement may have been consequently downplayed.

During the Coalition Period (Figure 4.1), obsidian is particularly abundant at sites on the mesatop separating Frijoles and Alamo Canyons (referenced as Feature A). Obsidian drops off quickly to the south and north of this mesa. In addition, a less prominent "buttress" of obsidian extends eastward onto the Plateau from the mountain sources near Pajarito Canyon (Feature B). Both of these obsidian rich areas, interestingly, lie immediately downslope and on the same geomorphic feature of two of the most heavily exploited obsidian sources in the Jemez Mountains: Obsidian Ridge and Cerro del Medio (see Figure 2.1). Due to the canyon/mesatop topography that characterizes the plateau, sites situated on finger mesas which adjoin mountain obsidian sources (such as at Features A and B), share significantly reduced transportation costs than sites located a similar linear distance away but are physiographically separated from the source by deep canyons. Judging by the manner in which obsidian distributions conform to landscape topography, access to these sources was severely impacted by the canyons that cross-cut the plateau.

The distances between sites and sources, and the ruggedness of intervening terrain are the chief limiting factors on direct source access. Where stone is procured directly (that is, not exchanged) the consumer must endure all of the costs associated with raw material transport. In contrast, the movement of traded materials is not damped to the same degree by this factor. Exchanged goods are passed among two or more individuals, each of whom incur only a fraction of the total transportation costs (Ericson 1977:120). Framed in this way, physiographic features should more prominently constrain direct access to sources rather than exchange. Situations where canyons strongly define raw material distributions (such as the example shown in Figure 4.1) imply that tool users in that area procured the majority of their stone directly from sources and not through exchange.

This pattern changes through time (see Figure 4.2). During the Classic Period, obsidian shows a wider dispersal within Bandelier N.M. and is not restricted by physiographic features to the same degree. The distribution thus expressed is more irregular and expansive compared to the earlier sites. This is most likely an expression of more variable methods of procurement which possibly included some very localized exchange.

The most significant feature of the Classic Period plot is the difference in obsidian densities on either side of Frijoles Canyon. Compared with densities south of Frijoles, the area to the north contains very little obsidian. These north-south differences are summarized in Table 4.1 below with the boundary set at UTM 39-62-500 N. The tabular data underscore the growing departure through time between the northern and southern regions of the Plateau with regard to obsidian exploitation.. Table 4.1 shows that, on average, obsidian utilization on the northern Plateau decreases 18 percent, whereas obsidian procurement at southern sites increases by 63 percent.

Table 4.1 Average Percent of Obsidian by Period and Area

	Coalition Period		Classic Period		Totals	
	Percent	Number	Percent	Number	Percent	Number
Northern Sites	16.4	130	13.8	18	16.1	148
Southern Sites	19.7	118	32.1	198	27.5	316
All Sites	17.9	248	30.6	216	23.8	464

Figure 4.3 maps change in obsidian procurement as the difference between the Coalition and Classic Period plots to highlight temporal disparities over space. Difference maps are generated by plotting the residuals created when the gridded values from one map are subtracted from those of a second. In this case, Coalition Period data were subtracted from Classic Period data. The resulting contour map has both positive and negative values. Areas of positive relief have greater amounts of obsidian at Classic sites compared to Coalition sites (an increase in obsidian through time). Areas of negative relief contain more obsidian at Coalition sites and highlight areas where obsidian use decreases with time. The zero contour delineates the point where raw material densities between periods are about the same. Areas with negative values (that is, areas containing higher raw material densities during the Coalition), have been shaded dark grey. Areas in positive relief (higher densities during the Classic) are white. The region between +10 and -10 percentage points is shaded light gray to indicate little change through time.

As Figure 4.3 shows, obsidian becomes more common through time on the southern portion and eastern periphery of the Plateau. In contrast, the western-most sites on the northern Pajarito see a marked decrease in obsidian with time. Since obsidian outcrops are

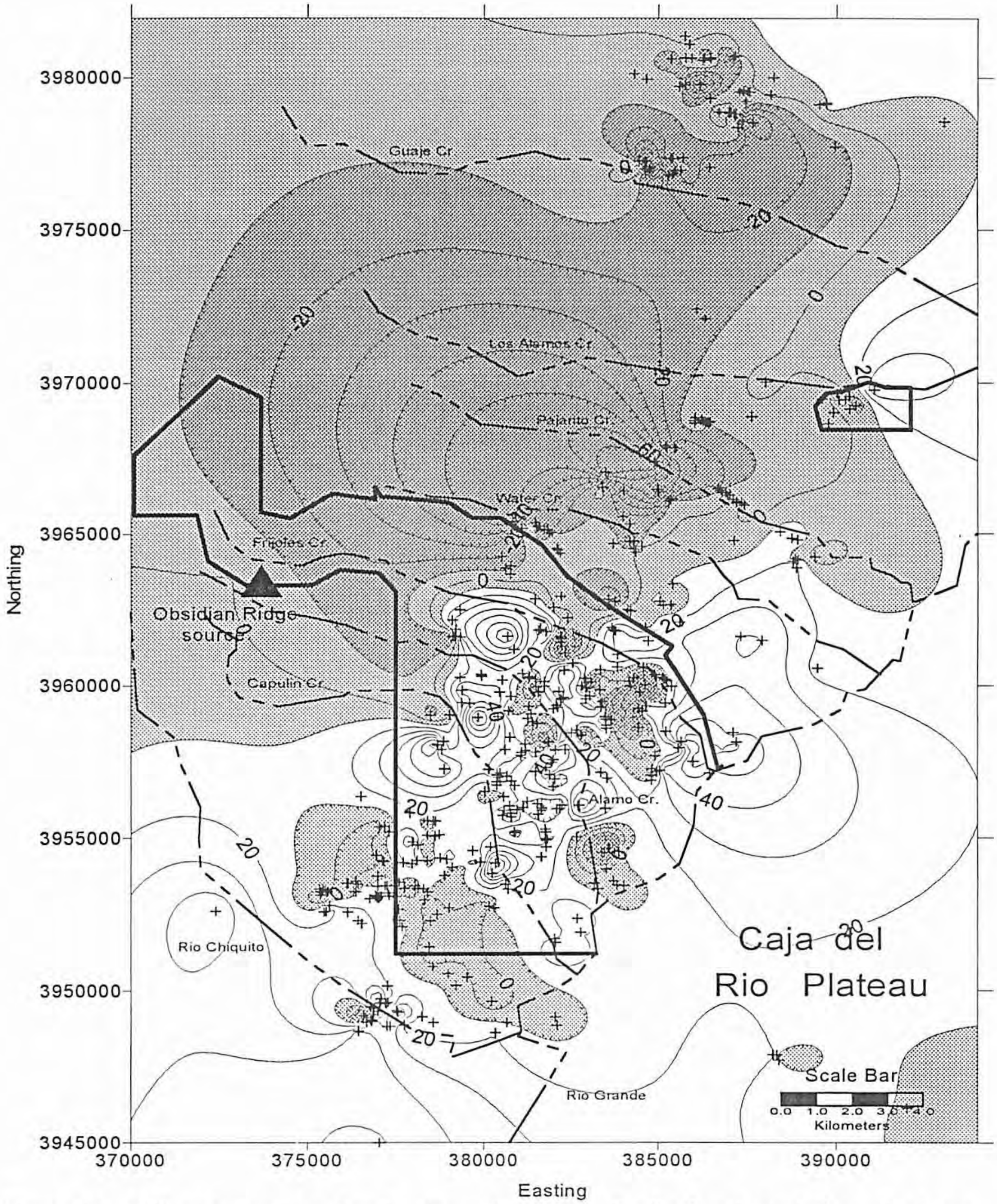

Figure 4.3. Difference map showing the change in obsidian distribution through time. Dark grey areas show where obsidian densities decreased through time. White areas show where obsidian densities increased through time. Light grey areas show where little change in obsidian densities occurred.

located west of the study area, this change can be characterized as obsidian becoming more accessible to groups further east and farther away from the sources. In a converse fashion, groups located near to the outcrops (especially the Cerro del Medio source) became comparatively less reliant on the stone. This pattern is especially marked on the northern Plateau; to the south, obsidian increases ubiquitously.

The increasing abundance of obsidian at southern and eastern sites through time (as shown in Figure 4.3), suggests either that obsidian began to be traded away from sources in the Classic, or that eastern sites began making increasingly frequent trips into the Jemez Mountains to procure toolstone, possibly in combination with other extraction activities such as large game hunting.

McKim (1994) argues that mule deer were abundant and form a large component of Coalition Period faunal assemblages on the Pajarito. Due to heavy deforestation, and extensive field cultivation in the Classic Period, mule deer populations thinned or moved higher into the forests of the Jemez Mountains. She asserts that the recession in mule deer habitats was not due to climatic factors, but was a response to human impact. If obsidian procurement was frequently embedded within high-altitude hunting forays, then the pattern of spatially expanding obsidian exploitation through time may be an artifact of increased access to sources due to more frequent contact with montane resources.

Site Functional Differences

To further dissect changes in procurement patterns, differences between pueblos and field houses are examined. These two site types were combined for the above maps; below, each is treated separately. The next phase of the discussion acknowledges the different functional roles that each site type served in the settlement system and seeks to delineate differences in raw material procurement practices associated with specific site functions. Pueblos are residential sites and should therefore contain archaeological expressions of domestic activities; residential pueblos are also more likely to have been engaged in exchange networks (if they existed). Field houses were more specialized sites—in terms of the range of activities carried out there—and were occupied only temporarily. Groups living at field houses, due to their detachment from village resources and supplies, may have also accessed a wider variety of wild resources. During the off-season field houses may have served as temporary camps from which to base forays into extended catchment zones (Chapman and Biella 1980, cited in Powers 1988:45). Departures in raw material inventories between these two site types may reveal differing associations between specific raw material sources and site function.

Table 4.2 cross-tabulates obsidian densities at pueblos and field houses by sub-area. Overall, both the northern and southern sections of the study area contain more obsidian at field houses than at pueblos. Figures 4.4 and 4.5 display difference plots similar in construction to figure 4.3 discussed above except that they express differences between site types rather than time periods. To produce figure 4.4, the Coalition Period field house data grid was subtracted from the grid describing Coalition Pueblos. Figure 4.5 is identical except that it presents data for Classic Period sites. The resulting maps show areas as white where obsidian densities at pueblos were greater than obsidian densities at field houses. These are marked by contours with positive values. In contrast, areas where obsidian densities at field houses were greater result in negative values on the map and are marked dark gray. Areas

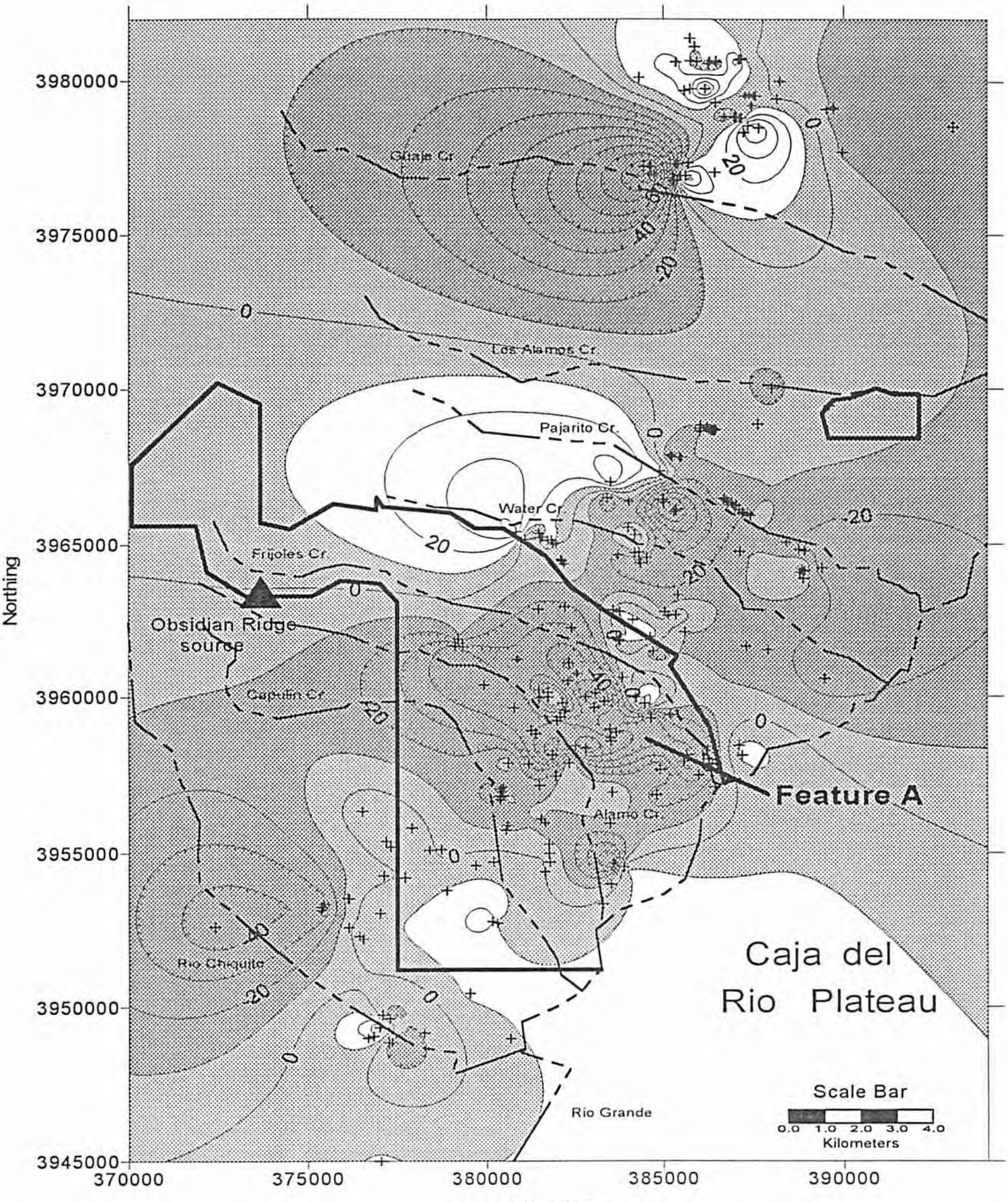

Figure 4.4. Difference map comparing obsidian densities between site types during the Coalition Period. Dark grey areas where field houses contained more obsidian than pueblos. White areas show where pueblos contain more obsidian than field houses. Light grey areas show where little difference is expressed between site types.

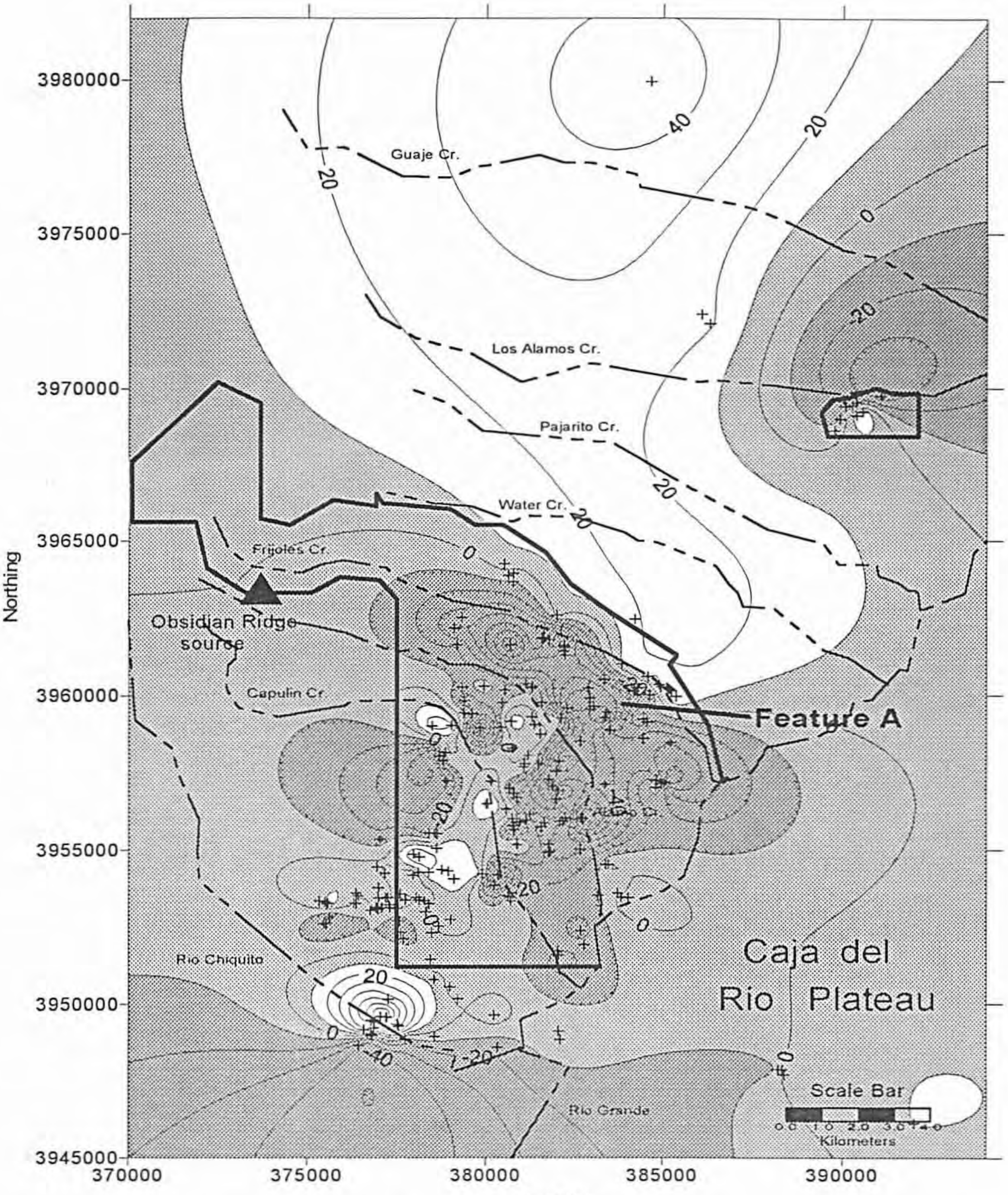

Figure 4.5. Difference map comparing obsidian densities between site types during the Classic Period. Dark grey areas show where field houses contained more obsidian than pueblos. White areas show where pueblos contain more obsidian than field houses. Light grey areas show where little difference is expressed between site types.

Table 4.2 Average Percent of Obsidian by Site Type and Area

	Pueblo		Field House		Totals	
	Percent	Number	Percent	Number	Percent	Number
Northern Sites	13.7	110	22.8	38	16.1	148
Southern Sites	20.6	120	31.7	196	27.5	316
All Sites	17.3	230	26.9	234	23.8	464

showing similar proportions of obsidian (that is, within ±10 percentage points) are colored light gray. These plots show how the data presented in Table 4.2 play out over space while controlling for time period.

During the Coalition Period, the pattern expressed between site types is patchy and lacks any easily discernable patterns. However, the study area taken as a whole is dominated by areas with greater obsidian densities at field houses compared to pueblos. One area of interest is the aforementioned mesatop separating Frijoles and Alamo Canyon (Feature A). Obsidian at field houses here is fifty percentage points higher than at pueblos. This discrete area, as shown in the obsidian distribution overview map (Figure 4.1) discussed above, also contains very high obsidian densities. Taken together, these plots, indicate that the high obsidian values shown in Figure 4.1 are in large measure due to high frequencies at field houses. These data indicate that the raw material procurement at field houses on this mesa were directed west into the mountains where obsidian is found. And, as is shown below, the majority of toolstone found at pueblos in this area was basalt which occurs at low elevations to the east. This small mesatop most strongly characterizes a pattern expressed over the entire southern plateau. Specialized field house structures, presumably occupied most commonly in the summer, have a high mobility pattern directed towards the high mountain ecosystems to the west; residential structures are most connected to lowland valleys to the east by their mobility pattern.

In the Classic Period (Figure 4.5) field houses also hold greater relative densities of obsidian compared to pueblos south of Frijoles Canyon. However, across most northern areas, obsidian is more prevalent at pueblos. It must be stressed that the northern area is defined by relatively few sites; therefore, a degree of tentativeness should accompany this inference.

On the southern plateau obsidian procurement was primarily linked with field houses during both time periods; to the north obsidian was associated with field houses early, and with pueblos in later times. The recurrent difference between raw material distributions north and south of Frijoles canyon in the Classic Period is intriguing. In contrast to southern Pajaritan sites, obsidian was less frequently represented at sites north of Frijoles (Figure 4.2), especially at field houses (Figure 4.5). During the Coalition Period, these differences had not yet emerged. The minimal exploitation of obsidian in the north contrasts with the availability of obsidian throughout the Jemez mountains. In fact, most of the obsidian traded out to the southern Plains is from the large sources on the rim of the Valles Caldera, such as Cerro del Medio, which overlook the northern Pajarito as it is defined here (Baugh and Nelson 1987:319).

The generally strong positive correspondence between obsidian and field houses, especially on the mesa immediately below Obsidian Ridge between Frijoles and Alamo Canyon (Feature A) suggests that local obsidian gathering forays were commonly based from field houses rather than pueblos. This implies that activities conducted at field houses, aside from tending fields and processing crops, also included travel into the high mountains, possibly to gather wild plant resources or to hunt. In this way, field houses were used to extend the catchment radii of more permanent sites (pueblos). A likely scenario is that obsidian arrived at pueblos through procurement trips staged from field houses. Alternatively, pueblos could have been more actively engaged in exchange systems which imported other raw materials into the settlement system which then offset their relative densities of obsidian, although it is less likely that basalt was a highly traded commodity (see also Green 1985:78).

These alternate hypotheses cannot be tested without using absolute measures of raw material proportions at sites (e.g., count or weight standardized by volume). The analytic difference between the two hypotheses hinges on which site type exhibits greater amounts of obsidian weighted against an index of other activities carried out at the site, such as debitage/sherd ratios. For this study, relative measures (percentages) of raw material frequencies were used. This method cannot distinguish whether a raw material's proportion increased due to a real increase, or due to a corresponding decrease of another material.

Pedernal Chert

Pedernal chert is a visually distinctive cryptocrystalline silicate which was mined at bedrock outcrops located over 20 km northwest of the study area. As discussed in chapter two, Pedernal chert pebbles and cobbles can also be found scattered within channel deposits of the ancient and modern Rio Grande river beds north of Los Alamos Creek. I consider the exploitation potential of these latter deposits unreliable; they probably provided only small quantities of toolstone to the prehistoric populace of the area.

Pedernal chert represents the most distant source examined here. It is also the only source located to the north for which raw materials would have had to move across the length of the Plateau. Through studying this raw material, changing patterns of social interactions between groups occupying the northern study area from those occupying the south may be revealed most precisely.

Temporal Differences

The distribution of Pedernal chert at Coalition Period pueblo and field house sites is shown in Figure 4.6. This plot shows very high Pedernal chert densities across the Northern Pajarito contrasted with very low densities across the southern plateau. A pronounced decrease in Pedernal chert proportions is revealed by the isopleths along a linear monoclinic feature adjacent to Water Canyon (noted as Feature C). Sites to the north and south of this monocline display generally smooth surfaces accentuating the sudden change at Water canyon. This break is defined over a space of less than five km where chert densities drop, on average, from 60 to 10 percentage points.

This monocline occurs in close proximity to Bandelier National Monument's northern boundary, which also divides the PARP and BASP study areas. The feature is not, however, an artifact of differing sampling protocols between these two survey projects. If this were the case, the change would straddle the Monument's border. Upon close inspection, the discontinuity is entirely expressed north of Bandelier N.M. within the PARP study area; its proximity to the Monument's border is merely coincidental.

Considering the geological realities of the study area, this chert distribution is confounding. Pedernal chert contributes well over half of the debitage inventories at sites

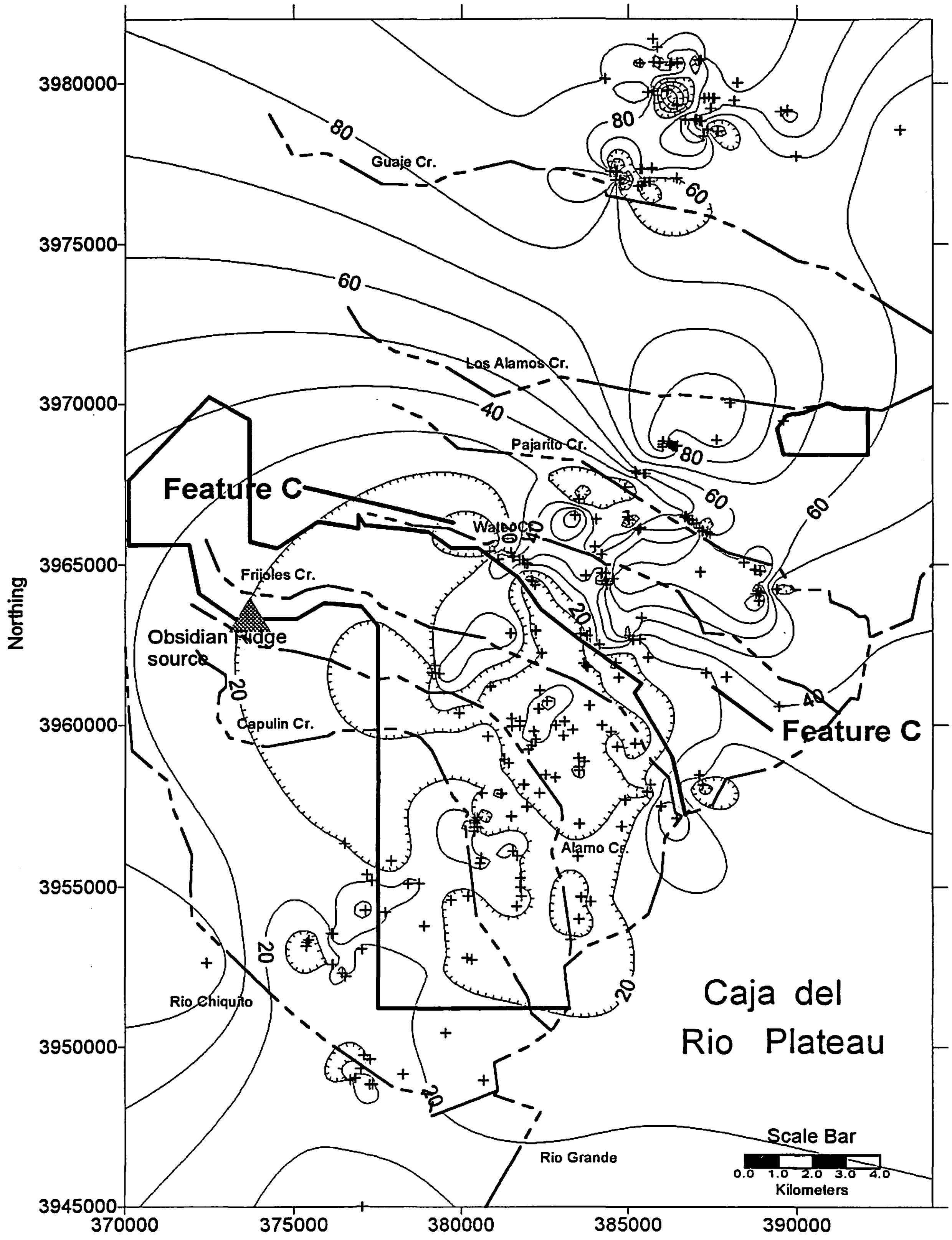

Figure 4.6. Pedernal chert distribution for Coalition Period field houses and pueblos. Crosses mark site locations.

across the northern study area. These sites lie between 20 and 40 km from the primary Pedernal chert source area. The densities remain relatively stable and are not affected by the physiographic features of the landscape. Obsidian and basalt are located much closer to sites on the northern Plateau than is the chert source. It is counter-intuitive that these closer sources of toolstone were not more heavily exploited. Their attractiveness, based simply on decreased physical distance, may have been eclipsed due to an active, northward-oriented exchange network which mitigated the greater physical distance of the Pedernal outcrop by lessening its social distance.

Alternatively, secondarily deposited chert pebbles and cobbles, such as those contained within the Totavi Lentil, may have been more heavily exploited than previously thought. Even if this were the case, however, it would not explain the abrupt change in chert densities at Water Canyon. The Totavi Lentil gravels occur along the eastern escarpment of the plateau only as far south as Los Alamos Canyon (Kelley 1978). If the majority of Pedernal chert were selected from these gravels, then a gradual southerly decay of Pedernal chert densities would be expected to begin there. Instead, Pedernal densities maintain a consistent pattern five kilometers beyond the most southern Totavi Lentil exposures; they then decline rapidly at Water Canyon.

The pronounced drop in Pedernal chert at Water Canyon is quite unexpected. Since Water Canyon is not a particularly deep or formidable canyon to cross, especially when compared to Frijoles or Alamo Canyons, it is unlikely that it presented a unique obstacle to travel that would warrant such a drastic change in chert decay rates. Since the change cannot be attributed to physical distances or terrain impediments, the best remaining explanation involves a sudden change in social distance. It is likely that the areas south and north of the canyon were occupied or controlled by different competing groups within which materials were commonly circulated, but between which materials were less often exchanged. The abrupt truncation of the Pedernal chert distribution at Water Canyon is best explained by the presence of a semi-permeable social boundary that restricted the southward flow of stone.

This interpretation contrasts with conclusions reached by Head (in press), who found few differences in raw material densities north and south of Frijoles Canyon which could not be explained by impediments to north/south travel created by terrain. However, she examined only sites within Bandelier National Monument and predicated her analyses on the assumption that a social boundary existed at Frijoles rather than Water Canyon to the north. The pronounced drop-off of Pedernal chert revealed in this analysis is expressed almost entirely north of her study area. Therefore, it is not surprising that this pattern was not detected from those data.

As discussed in chapter one, the ethno-linguistic boundary dividing Keres and Tewa-speaking groups is thought to have solidified sometime in the Late Coalition Period along the northern rim of Frijoles Canyon. In order to examine whether the Water Canyon monocline (Feature C) developed concurrently with these changes, I produced figures 4.7 and 4.8.

The Early Coalition plot (A.D. 1150-1250; Figure 4.7), as well as the Late Coalition plot (A.D. 1250-1325; Figure 4.8), clearly show that Feature C existed prior to the early A.D. thirteenth century. These figures also indicate that the feature pre-dates the substantial population immigrations to the Plateau during the Late Coalition and the emergence of large aggregated settlements during the Early Classic Period. This is surprising, since both population increase and aggregation are generally considered to precede enforcement of group territoriality

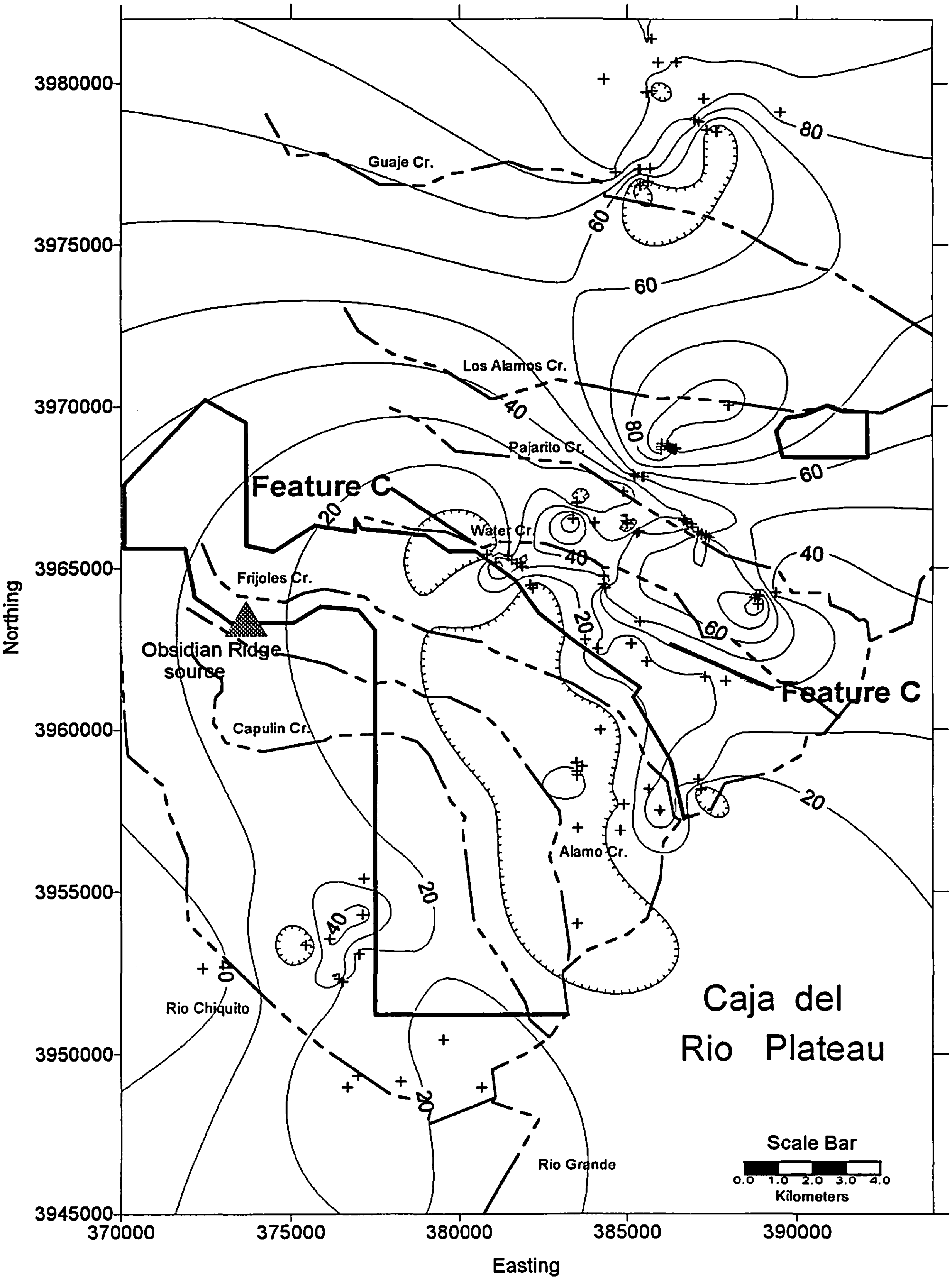

Figure 4.7. Pedernal chert distribution for Early Coalition Period field houses and pueblos. Crosses mark site locations.

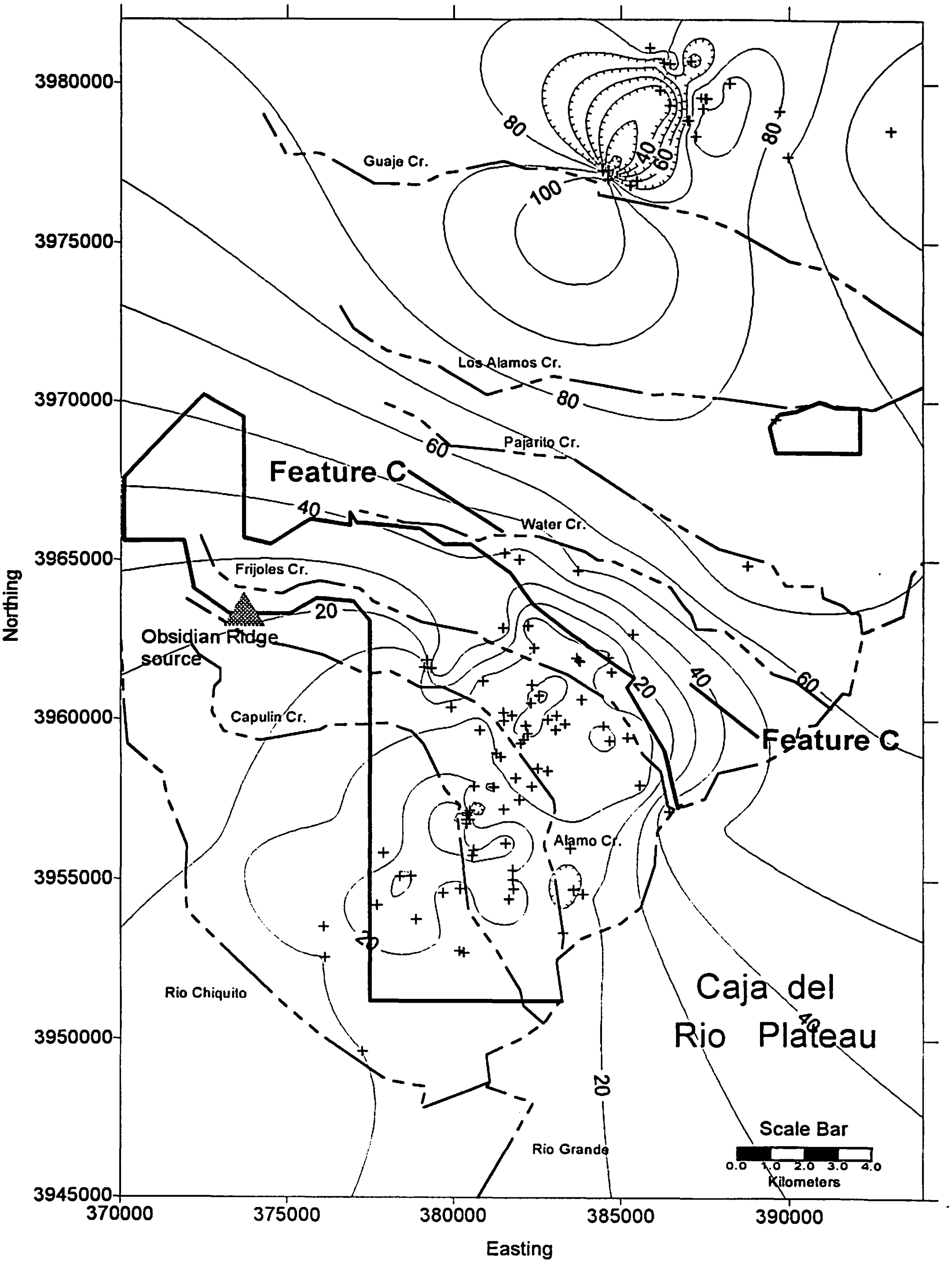

Figure 4.8. Pedernal chert distribution for Late Coalition Period field houses and pueblos. Crosses mark site locations.

due to increases in conflict and competition for resources (see Crown et al. 1996; Haas and Creamer 1996; Head in press; Kohler 1992).

Unfortunately, for the Classic Period (shown in figure 4.9) we lack data points between Los Alamos and Water Canyons. Therefore, meaningful comment regarding the persistence of the discontinuity observed in the Coalition Period plots is not possible. However, the areas bracketing both sides of this region that do contain data points, exhibit patterns similar to the early plots. Pedernal chert is sparse within and south of Bandelier. Densities at Los Alamos Canyon and further north are variable, but generally high.

Pedernal chert proportions are cross-tabulated in Table 4.3 by gross temporal and spatial divisions. While highlighting the pronounced difference in Pedernal chert frequencies between sub-areas on the Plateau, this table also shows that chert decreases markedly across the Plateau through time, both north and south. Important to note is that even in light of the abrupt distributional shift at Water Canyon, the division between northern and southern sub-areas remains drawn at UTM 39-62-500 N. Due to the southeastward curve of both Frijoles and Water Canyons, this line still serves to separate sites on both sides of the steep Pedernal chert fall-off.

Figure 4.10 summarizes the changes through time in Pedernal chert percentages as the differences between Figure 4.6 and 4.9 (the Coalition and Classic Period plot, respectively). White areas represent increases in chert through time; dark gray areas, reduced percentages. Light gray regions showed little change.

As indicated in Table 4.3, Pedernal chert decreased in proportion over most of the Pajarito; this is reaffirmed in Figure 4.10. On the southern Plateau, Coalition Period sites

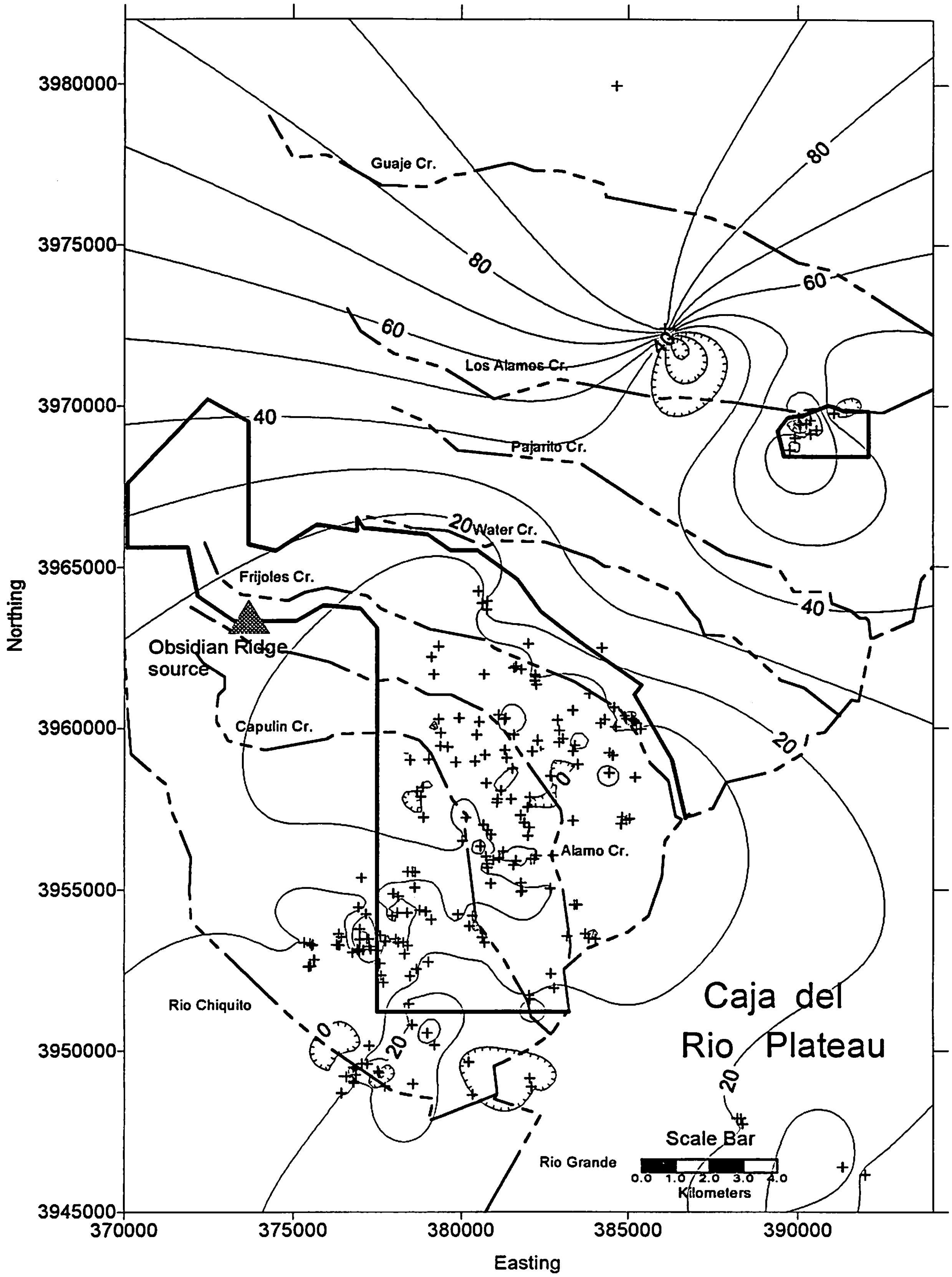

Figure 4.9. Pedernal chert distribution for Classic Period field houses and pueblos. Crosses mark site locations.

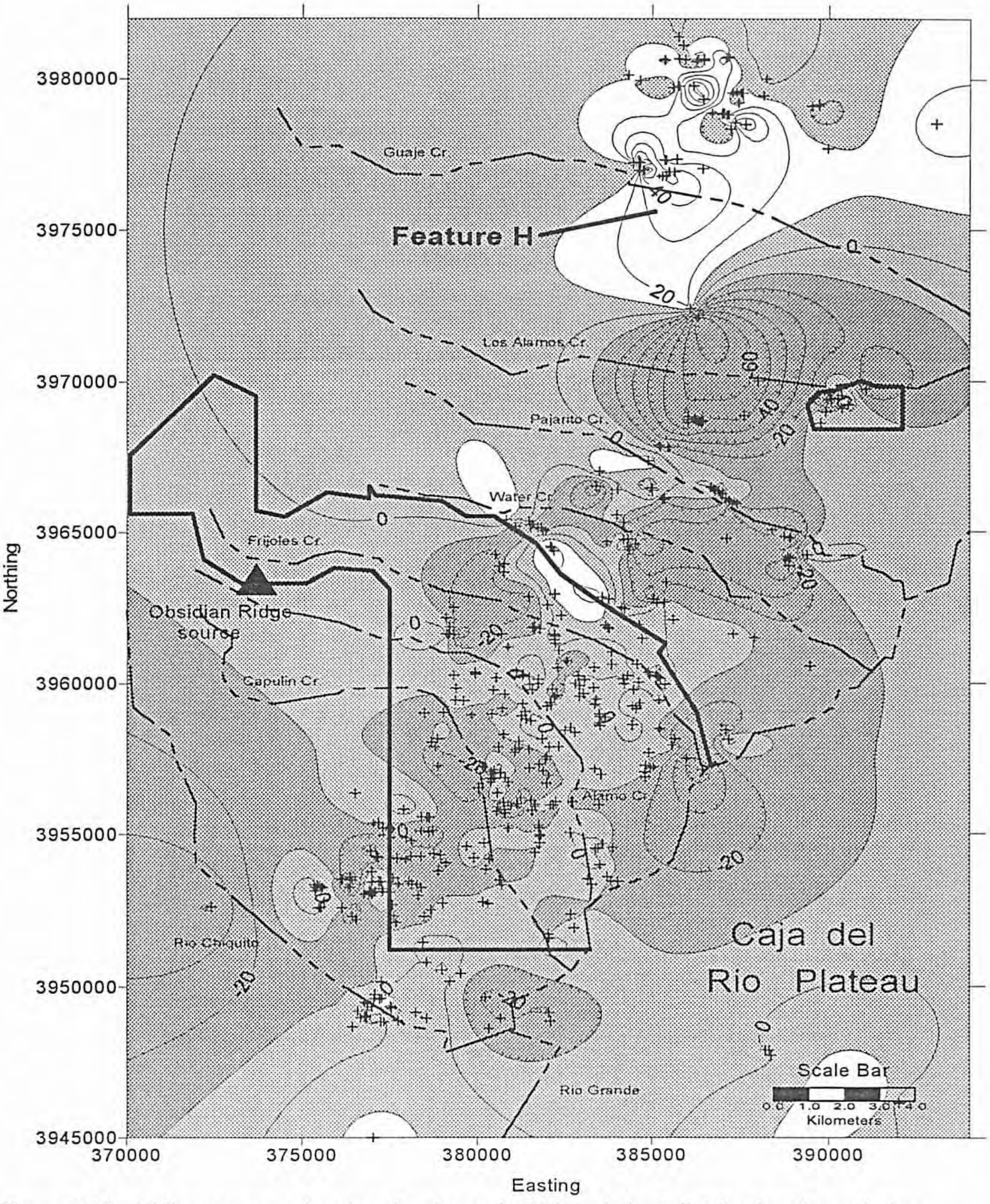

Figure 4.10. Difference map showing the change in Pedernal chert distribution through time. Dark grey areas show where Pedernal chert densities decreased through time. White areas show where Pedernal chert densities increased through time. Light grey areas show where little change in Pedernal chert densities occurred.

Table 4.3 Average Percent of Pedernal by Period and Area

	Coalition Period		Classic Period		Totals	
	Percent	Number	Percent	Number	Percent	Number
Northern Sites	60.9	130	44.4	18	58.9	148
Southern Sites	16.8	118	9.5	198	12.2	316
All Sites	39.9	248	12.4	216	27.1	464

averaged only 17% Pedernal Chert (Figure 4.6; Table 4.3). Figure 4.10 shows net losses over much of this area of 10 or more percentage points. Through time then, Pedernal chert exploitation fell by half on the southern Pajarito.

In contrast, sites along the extreme northern margin of the study area (Feature H) show marked increases through time in Figure 4.10. It is important to note that whereas the Coalition Period site sample in this area is substantial, the Classic Period sample is quite small. Therefore, the assertion that chert use increased is somewhat tentative. These increases observed in the extreme north may have extended further south, but the lack of Classic Period sites in general, and especially in the interesting area between Los Alamos and Water Canyons, prohibits such characterizations. In sum, the plots show that Pedernal chert became restricted across the south Plateau, but increased only north of Los Alamos Canyon.

Site Functional Differences

Distributional variations between pueblo sites and field houses are summarized in Figures 4.11 and 4.12. These plots, in common with Figures 4.4 and 4.5 for obsidian, are difference maps wherein the values gridded for field house sites were subtracted from those

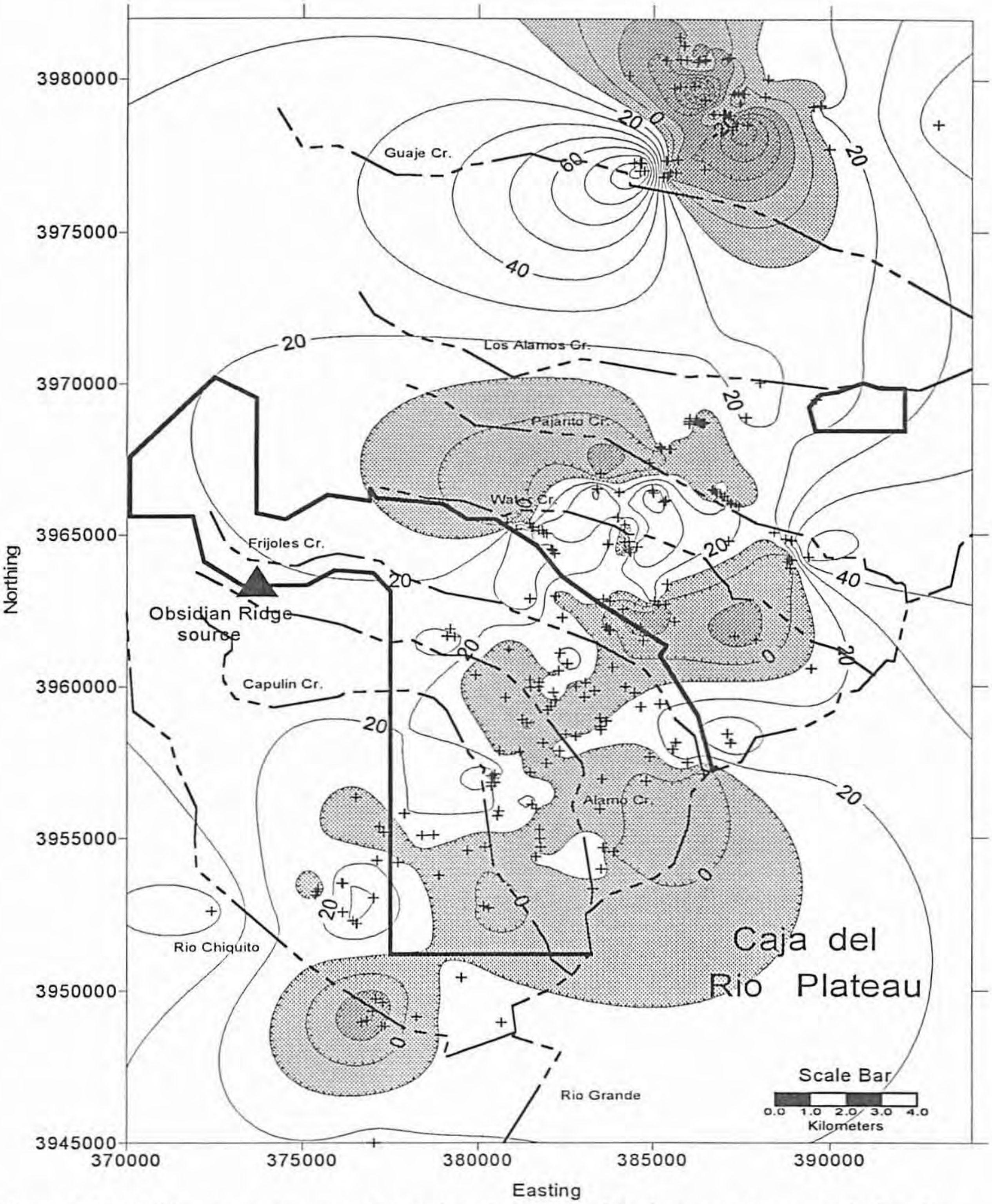

Figure 4.11. Difference map comparing Pedernal chert densities between site types during the Coalition Period. Dark grey areas show where field houses contained more Pedernal chert than pueblos. White areas show where pueblos contain more Pedernal cherts than field houses. Light grey areas show where little difference is expressed between site types.

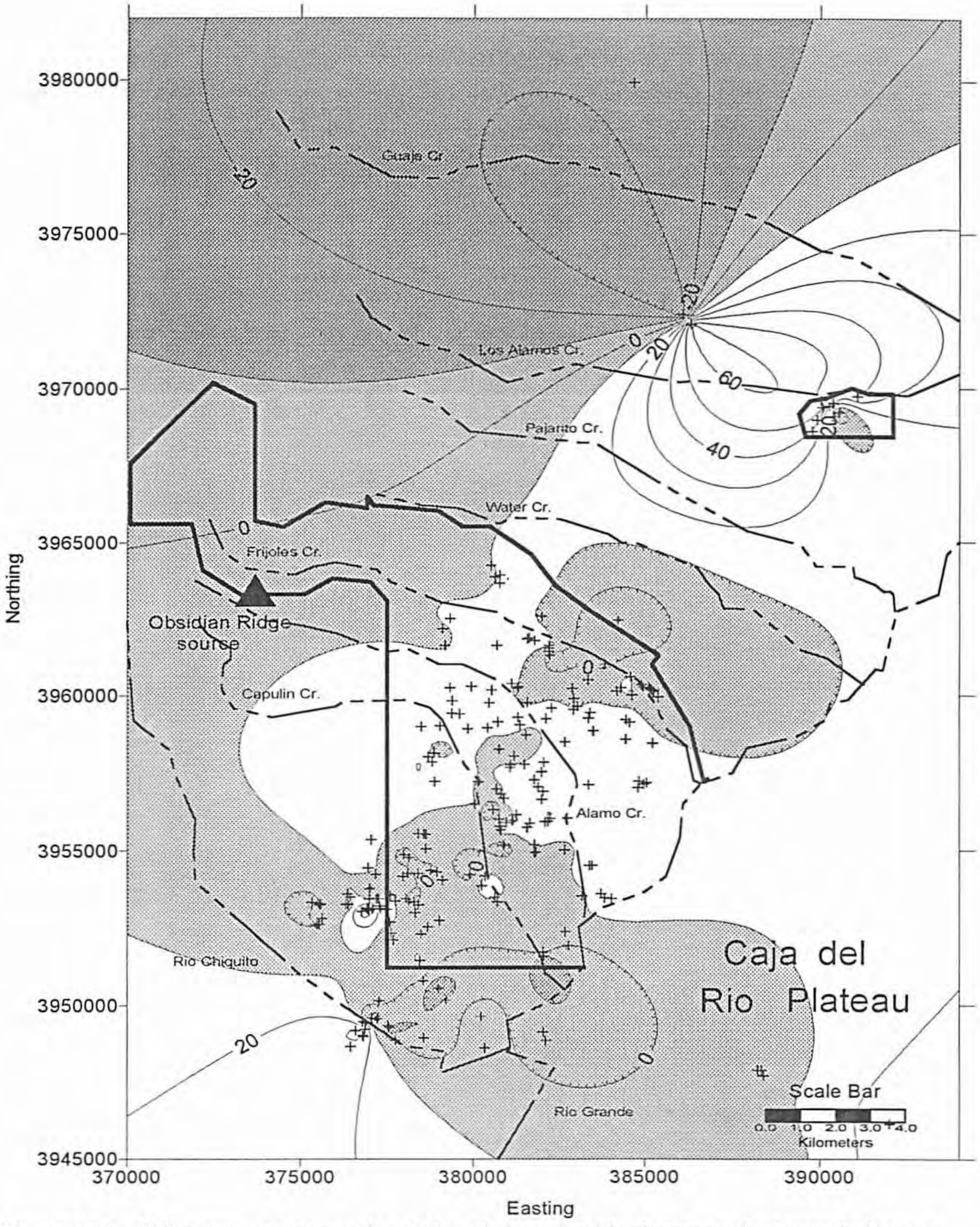

Figure 4.12. Difference map comparing Pedernal chert densities between site types during the Classic Period. Dark grey areas show where field houses contained more Pedernal chert than pueblos. White areas show where pueblos contain more Pedernal chert than field houses. Light grey areas show where little difference is expressed between site types.

generated from pueblo data. White areas have greater Pedernal chert densities at pueblos; dark gray areas mark areas wherein field houses held high proportions of chert. Light gray regions showed little difference between site types (i.e., ±10 percentage points). Figure 4.11 presents the difference map for the Coalition Period; Figure 4.12 displays data for the Classic.

During both archaeological periods, Pedernal chert is strongly associated with pueblo sites, as compared to field houses. However, on the northernmost periphery of the study area, Pedernal-chert-rich field houses occur (Figures 4.11 and 4.12). These field houses are the closest to Cerro Pedernal suggesting that as the distance to sources decreased, raw materials from that source begin to occur more frequently at field houses relative to pueblo habitation sites. A similar pattern was revealed by the obsidian data. In areas close to sources, non-habitations (field houses) contained more obsidian than nearby residential sites. This pattern associates field houses with the direct procurement of nearby raw materials (though on the southern plateau where both basalt and obsidian are abundant, field-house-based exploitation is diverted towards the latter). Residential habitations, in contrast, are less connected to the closest raw material source and receive greater amounts of more distant toolstones, such as Pedernal chert, than do field houses. Table 4.4 provides a numeric summary for the patterns observed in the plots.

Basalt

Basalt is the most abundant lithic resource on the Pajarito Plateau. It is also the most variable in quality. While high-quality Cuerbio and Ortiz basalts are common within White Rock Canyon and on the Caja del Rio east of the Rio Grande in the southeast corner of the

Table 4.4 Average Percent of Pedernal Chert by Site Type and Area

	Pueblo		Field House		Totals	
	Percent	Number	Percent	Number	Percent	Number
Northern Sites	63.2	110	46.2	38	58.9	148
Southern Sites	18.1	120	8.6	196	12.2	316
All Sites	39.7	230	14.7	234	27.1	464

study area, basalt also occurs on the northern Pajarito. The Cisneros and Lobato flows are exposed at numerous low elevation loci along the Plateau's northern and northeastern margins (Kelley 1978), though outcrops are found in fewer numbers than in areas to the south.

Temporal Differences

The Coalition and Classic Period distributions for basalt are presented respectively in Figures 4.13 and 4.14. As Figure 4.13 shows, the Coalition Period basalt plot is, in essence, a mirror image of the corresponding Pedernal chert distribution (Figure 4.6). Basalt densities are high on the southern Plateau, and very low to the north. The two areas are again demarcated by Water Canyon.

Since the data used for this project are configured as *relative* densities rather than *absolute* densities, this counter-variance between two raw materials is expected to some extent since a preponderance of one material class causes a necessary diminution of the other. However, the presence of a third major material (obsidian), and several other minor raw materials should operate to break up such relationships. The obsidian adds a degree of freedom to data variability, thereby giving some analytic meaning to the bipolar coupling

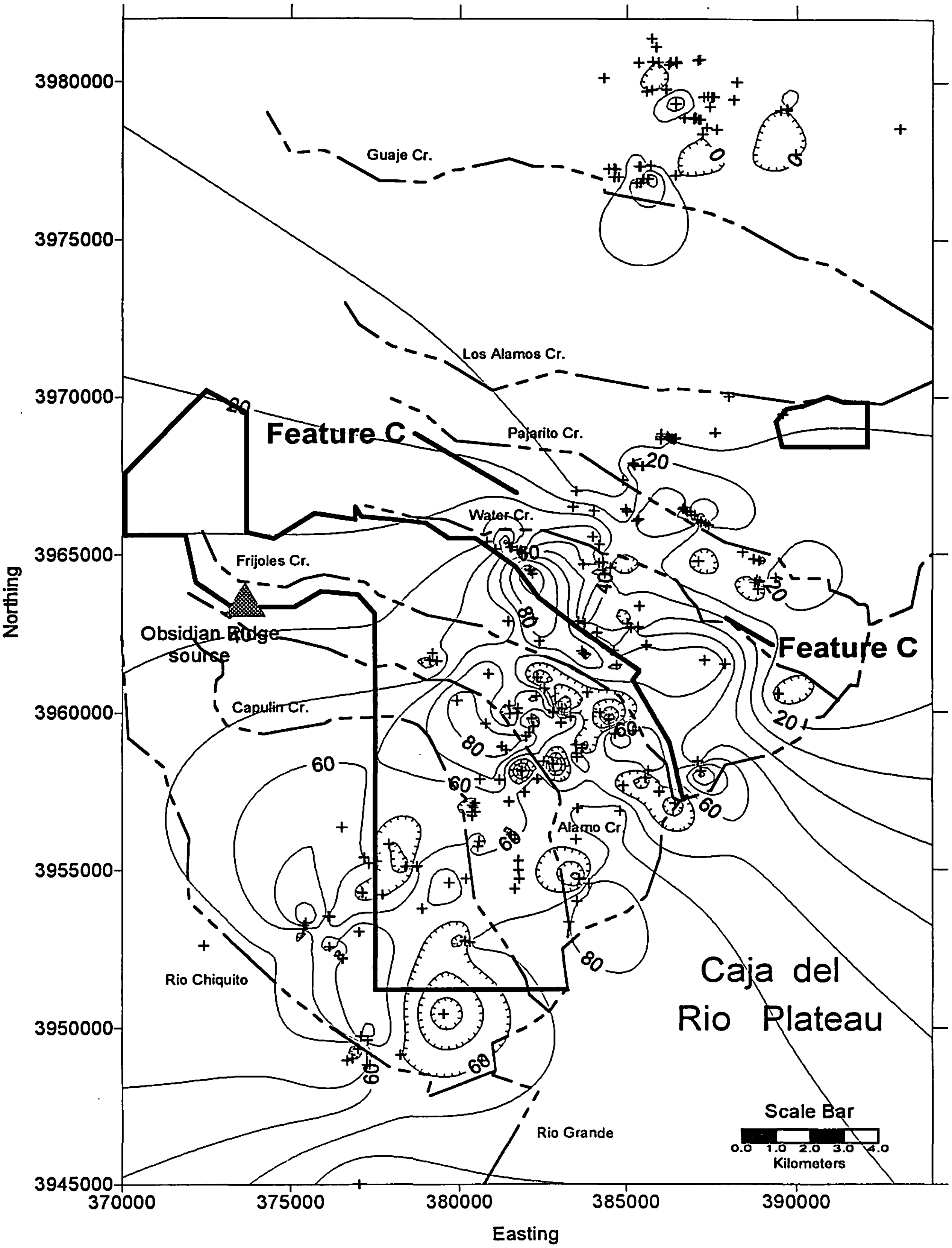

Figure 4.13. Basalt distribution for Coalition Period field houses and pueblos. Crosses mark site locations.

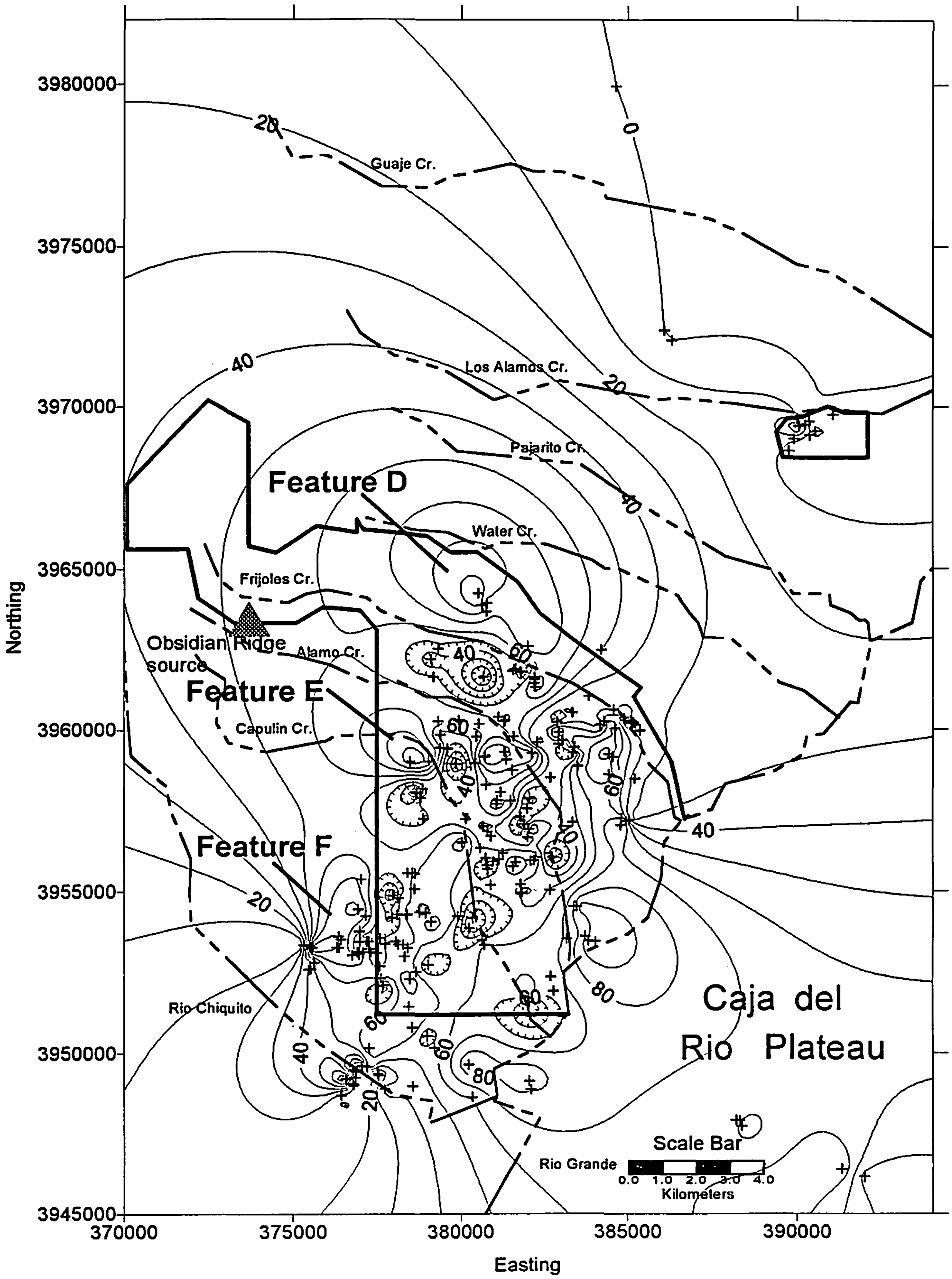

Figure 4.14. Basalt distribution for Classic Period field houses and pueblos. Crosses mark site locations.

between basalt and Pedernal chert. In other words, these two raw materials do not countervary simply because the data are organized as relative densities, though this probably had some degree of influence on the analysis.

The pattern observed in the Coalition Period continues into the Classic as shown in Figure 4.14. Basalt is abundant in the southern Pajarito and rare to the north. While the width of the transition zone between north and south cannot be inferred due to lack the of data points between Frijoles and Los Alamos Canyons, the general trend of northward decay of basalt densities recurs in the Classic.

Basalt densities are especially high throughout White Rock Canyon and on the Caja del Rio. Surprisingly, basalt is also very common archaeologically near obsidian sources along the western boundary of Bandelier N.M. (Features D, E, and F). These data emphasize that even at sites close to the Jemez Uplands where obsidian is easily procured, there was significant interaction with lower elevation zones along the Rio Grande to the east.

Table 4.5 cross-tabulates basalt percentages by period and sub-region. These data summarize the spatial information presented below in Figure 4.15. Through time basalt proportions increase by one-half across the northern Pajarito, whereas to the south, on average, it remains relatively unchanged (Table 4.5). The differences in basalt consumption between sub-areas, that are so clearly represented in Figures 4.13 and 4.14, are also quantified here.

Figure 4.15 spatially describes changes through time for basalt. This map is a difference plot created using the same procedures as Figure 4.3 discussed above. White areas join locations with basalt through time; in dark gray areas basalt decreased across the Coalition/Classic boundary. Light gray regions showed little change.

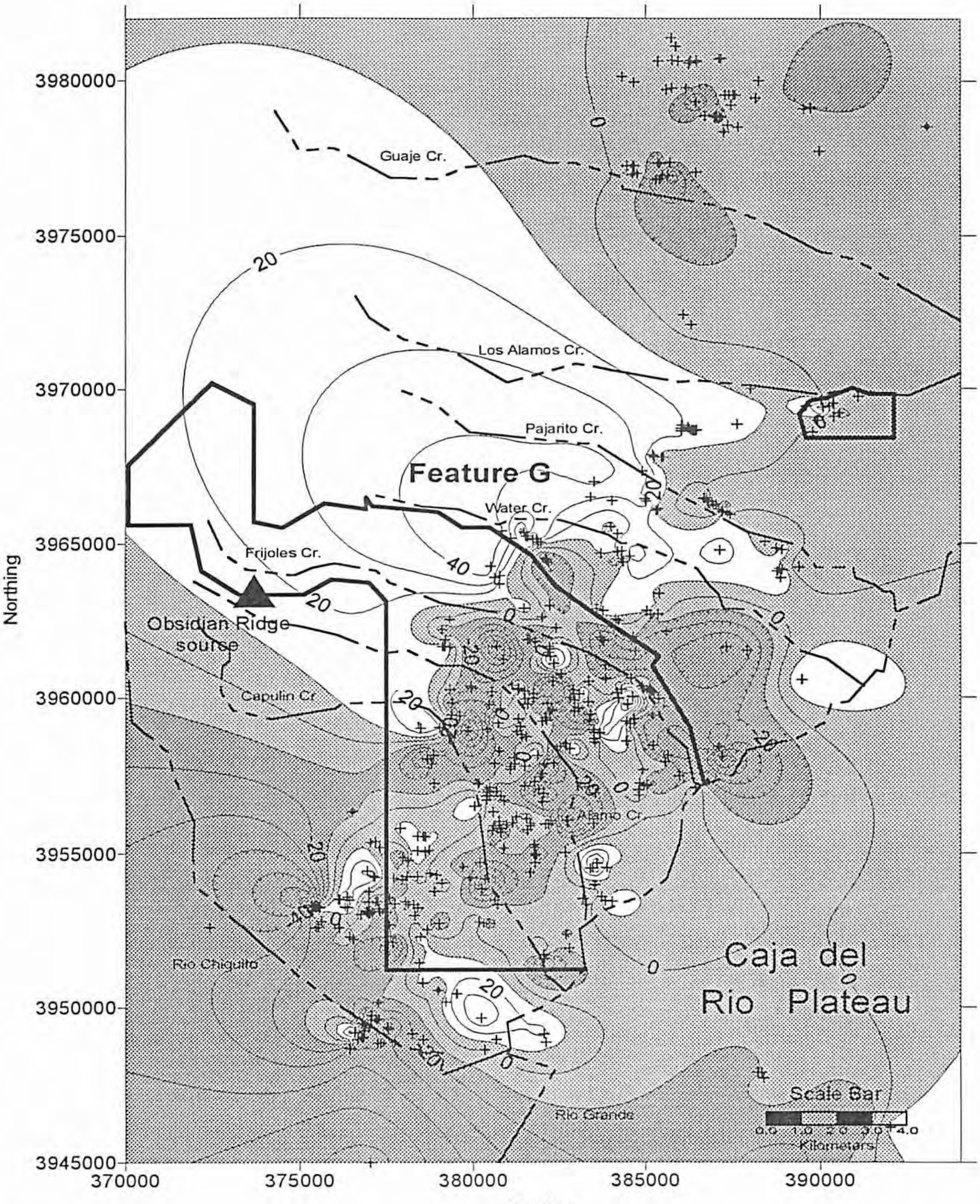

Figure 4.15. Difference map showing the change in basalt distribution through time. Dark grey areas show where basalt densities decreased through time. White areas show where basalt densities increased through time. Light grey areas show where little change in basalt densities occurred.

Table 4.5 Average Percent of Basalt by Period and Area

	Coalition Period		Classic Period		Totals	
	Percent	Number	Percent	Number	Percent	Number
Northern Sites	21.3	130	32.5	18	22.7	148
Southern Sites	59.8	118	53.4	198	55.8	316
All Sites	39.6	248	51.6	216	45.2	464

Figure 4.15 shows the spatial patterning for changes in basalt through time. This plot also contains an artifact of the highly clustered data points which are used to generate the plots in the large white area (signifying increasing basalt proportions through time) in the northwest corner of the map. This area, marked as Feature G is predicated only on sites clustered along the feature's southeastern margin, and holds little relevance to this analysis. The data do show an increase in basalt use through time in Feature G, but the extent of its manifestation is spatially limited only to the area which has been tested as marked by the presence of data points.

Taking this into consideration, Figure 4.15 shows a clear pattern wherein proportions of basalt increase through time at sites along the western-central edge of the Pajarito near the Jemez Mountains (Feature G). As Figure 2.1 shows the physiographic demarcation between the Plateau and the Jemez Mountains lies in this area. Net increases in this area range up to 40 percentage points and extend northward from Capulin Creek along the foot of the Jemez Mountains. These sites are situated away from basalt sources which are located along the Rio Grande. The areal extension or broadening of basalt procurement away from its source area in the Classic parallels a similar pattern observed for obsidian (Figure 4.3), although from a different direction. Both raw materials show an enlargement of the local procurement system "footprint." Generally, sites across the Plateau share increased accessibility to both obsidian and basalt sources at the expense of Pedernal chert, which decreases through time.

On the southern Plateau, the changing patterns of basalt exploitation was highly chaotic through time. The surface rendered by the data is quite uneven and shows that net gains or losses over time frequently amounted to ±50 percentage points within very small, discrete areas. This high degree of variation suggests that the practices which governed basalt procurement were more stochastic in nature than those guiding the acquisition of other raw materials. More likely, this variability was accentuated by the proximity of basalt sources to these southern sites. Whereas the procurement of obsidian and Pedernal chert was conditioned by the mechanisms of trade and/or the effects of increased distance, basalt procurement was conditioned only by utilitarian necessity and the competing availability of other, probably more desirable, raw materials.

Site Functional Differences

Table 4.6 presents relative densities of basalt by site type and sub-region. On both the southern and northern Pajarito, basalt proportions between the two site types vary relatively little. Field houses contain slightly more basalt across the Plateau taken as a whole, probably reflecting its geologic ubiquity and availability.

The differences between site types can again be further elucidated by using difference plots to uncover interesting variations. These plots, like Figures 4.4 and 4.5 above, are difference maps wherein the values gridded for field house sites were subtracted from those generated from pueblo data. White areas have greater basalt densities at pueblos; dark gray

Table 4.6 Average Percent of Basalt by Site Type and Area

	Pueblo		Field House		Totals	
	Percent	Number	Percent	Number	Percent	Number
Northern Sites	21.3	110	26.8	38	22.7	148
Southern Sites	57.5	120	54.7	196	55.8	316
All Sites	40.2	230	50.2	234	45.2	464

zones mark areas wherein field houses held higher proportions of basalt than pueblos. Light gray regions showed little difference between site types (i.e., ±10 percentage points). Figure 4.16 presents the difference map for the Coalition Period; Figure 4.17 displays data for the Classic. These plots show variation undetected by tabular representation of the data.

The maps reveal temporal patterns that the tabular data (table 4.6) do not. During the Coalition, basalt was ubiquitously consumed at field houses (figure 4.16). Only isolated areas are shown where pueblos contained larger amounts of this toolstone. In later times, during the Classic Period, this pattern is reversed (figure 4.17). Pueblo sites become the chief consumers of basalt, especially at sites along the western edge of the Pajarito which border the high mountains where basalt is not known to naturally occur (see figure 2.1). These data suggest that through time Pajaritan interaction with the Rio Grande lowlands (where basalt is most commonly found), shifted from field houses to pueblos across all but isolated portions of the Plateau.

One area, Feature A, consistently maintains a higher percentage of basalt at pueblos compared to field houses through time. This is the same area in which field houses contain high amounts of obsidian, and is the most accessible area to the Obsidian Ridge source

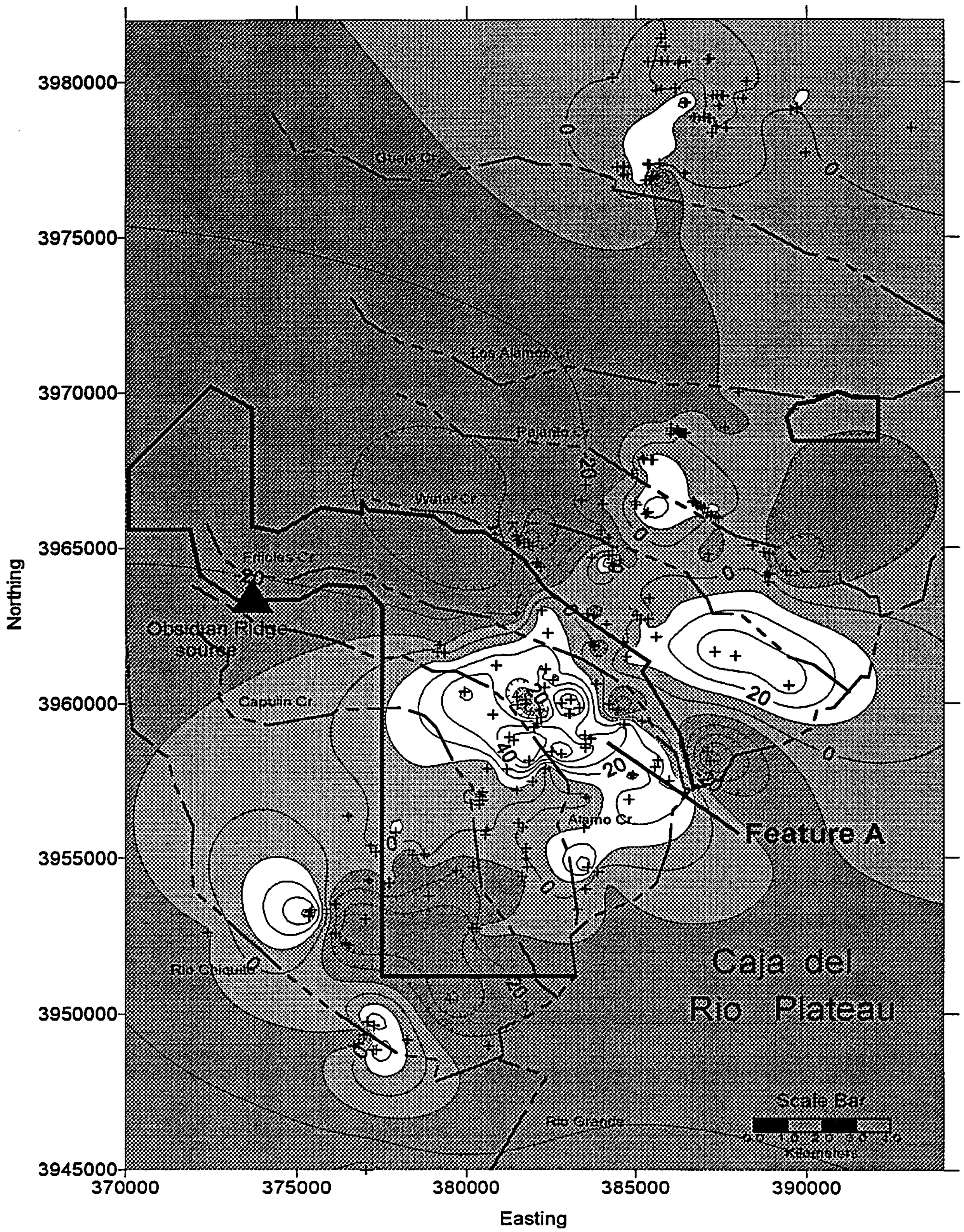

Figure 4.16. Difference map comparing basalt percentages between site types during the Coalition Period. Dark grey areas show where field houses contained more basalt than pueblos. White areas show where pueblos contain more basalt than field houses. Light grey areas show where little difference is expressed between site types.

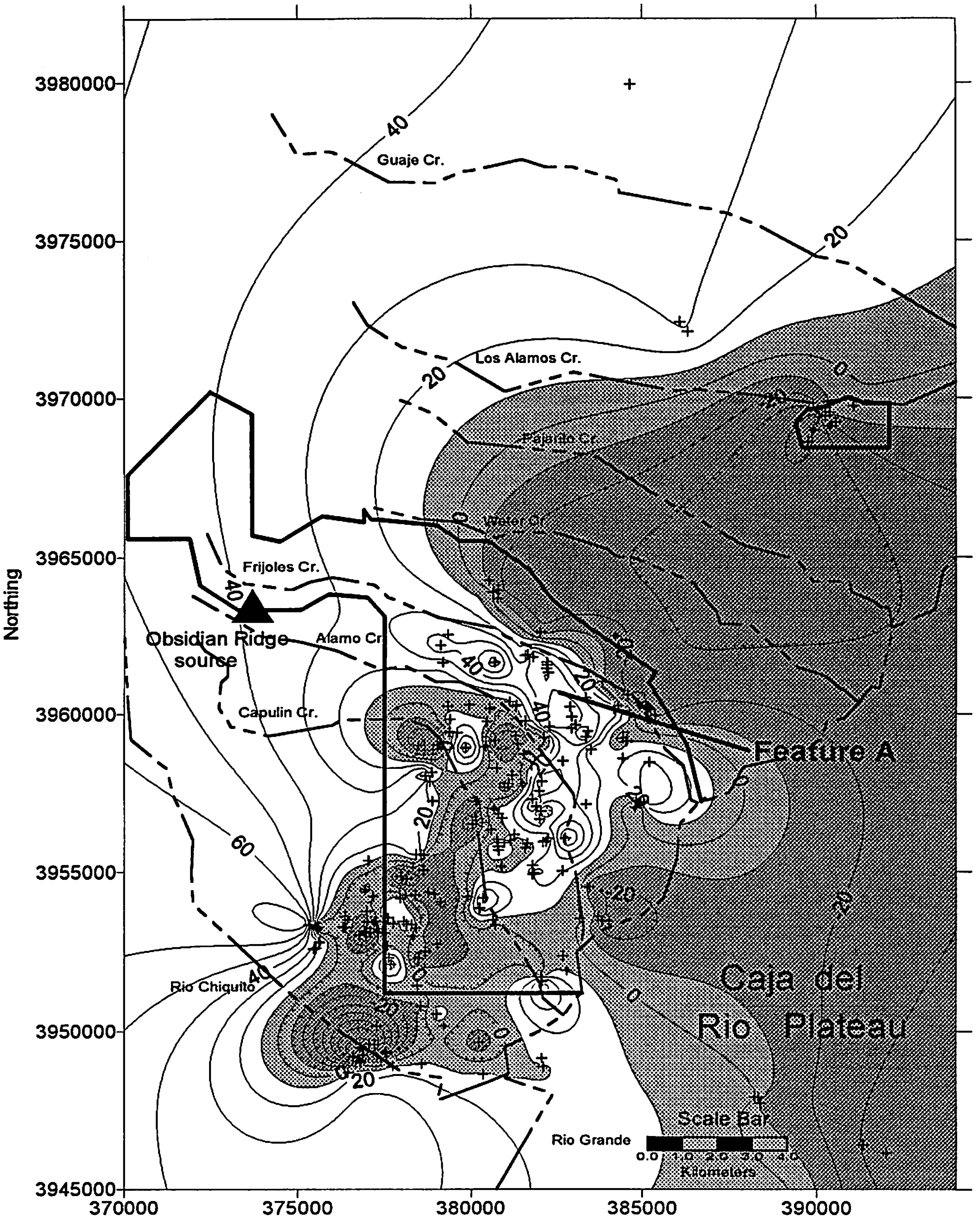

Figure 4.17. Difference map comparing basalt percentages between site types during the Classic Period. Dark grey areas show where field houses contained more basalt than pueblos. White areas show where pueblos contain more basalt than field houses. Light grey areas show where little difference is expressed between site types.

locality. In this area, field houses were strongly associated with high mountain obsidian sources, namely Obsidian Ridge. Nearby pueblos, in contrast, interacted more often with low elevation basalt sources. This pattern highlights an important functional difference between site types. Catchment directionality for field houses here was oriented toward mountain forests; habitation site catchments, on the other hand, were oriented toward the Rio Grande with its perennial water source and abundant clay supplies. As Figures 4.16, 4.17, 4.4, and 4.5 show, this pattern becomes prevalent across the entire southern plateau. The northern plateau is hard to characterize due to its smaller site sample in the Classic Period and the general lack of basalt at northern sites.

Procurement for External Exchange

The following series of maps is intended to highlight the degree of clustering between sites which exhibit high densities of a particular raw material. If specialized, or semi-specialized, production for external exchange is not present on the Pajarito, no organization should be evident in the spatial patterning of toolstone-rich sites. Instead, these sites should occur adjacent to raw material sources. If specialized production was in place, then spatially discrete production centers away from sources may be visible. Obsidian is the only raw material expected to have been exchanged in this way, but all three raw materials are examined here for comparative purposes.

Generally speaking, due to their intermittent and seasonal occupations, field houses are not expected to have been used as procurement and production nodes in exchange systems. Therefore, unlike the maps above, only pueblo sites are examined for this analysis (Figures 4.18-4.23). Each raw material is treated separately and by time period. Pueblos having less than 50% of the raw material in question noted as crosses; pueblos containing 50% or greater are plotted as diamonds. By examining the degree of clustering evident of the diamonds relative to the dispersion of total data points, cultural patterning may be discerned.

The Coalition and Classic period maps for Pedernal chert and basalt reflect patterns already delineated in the maps discussed above. Basalt-rich sites occur on the southern Pajarito (Figures 4.18 and 4.19), and Pedernal chert-rich sites are found to the north (Figures 4.20 and 4.21). Subjectively speaking, sites containing over 50% of these respective materials (marked by diamonds) are stochastically dispersed in proximity to their respective source areas. No clustering is evident in either the Coalition or the Classic Period plots.

The Coalition Period obsidian plot is similar; no patterning is easily recognizable (Figure 4.22). Obsidian-rich sites are dispersed across the plateau. However, in Figure 4.23 (the Classic Period obsidian map), spatial clustering of obsidian-rich sites is quite evident. Of the eleven sites in which obsidian contributed over half of the debitage inventory, ten were clustered in either Rio Chiquito (Cochiti) Canyon or Frijoles Canyons. The sites in Rio Chiquito Canyon are LA 9821, LA 9849, LA 9850, LA 9851, LA 9856, and LA 29869. In Frijoles Canyon the sites are LA 10942, LA 60550, LA 77716, and LA 84146. The sole outlier is LA 70963.

It is beyond the scope of this study to examine specific data for all of these sites to more thoroughly explore whether or not these sites participated more fully in external exchange systems than other sites in the area. This would be a worthwhile avenue for future research. However, one of these sites (LA 60550), which was tested in 1988 by the Bandelier Archaeological Excavation Project, was found to contain a large number of bifacial blanks

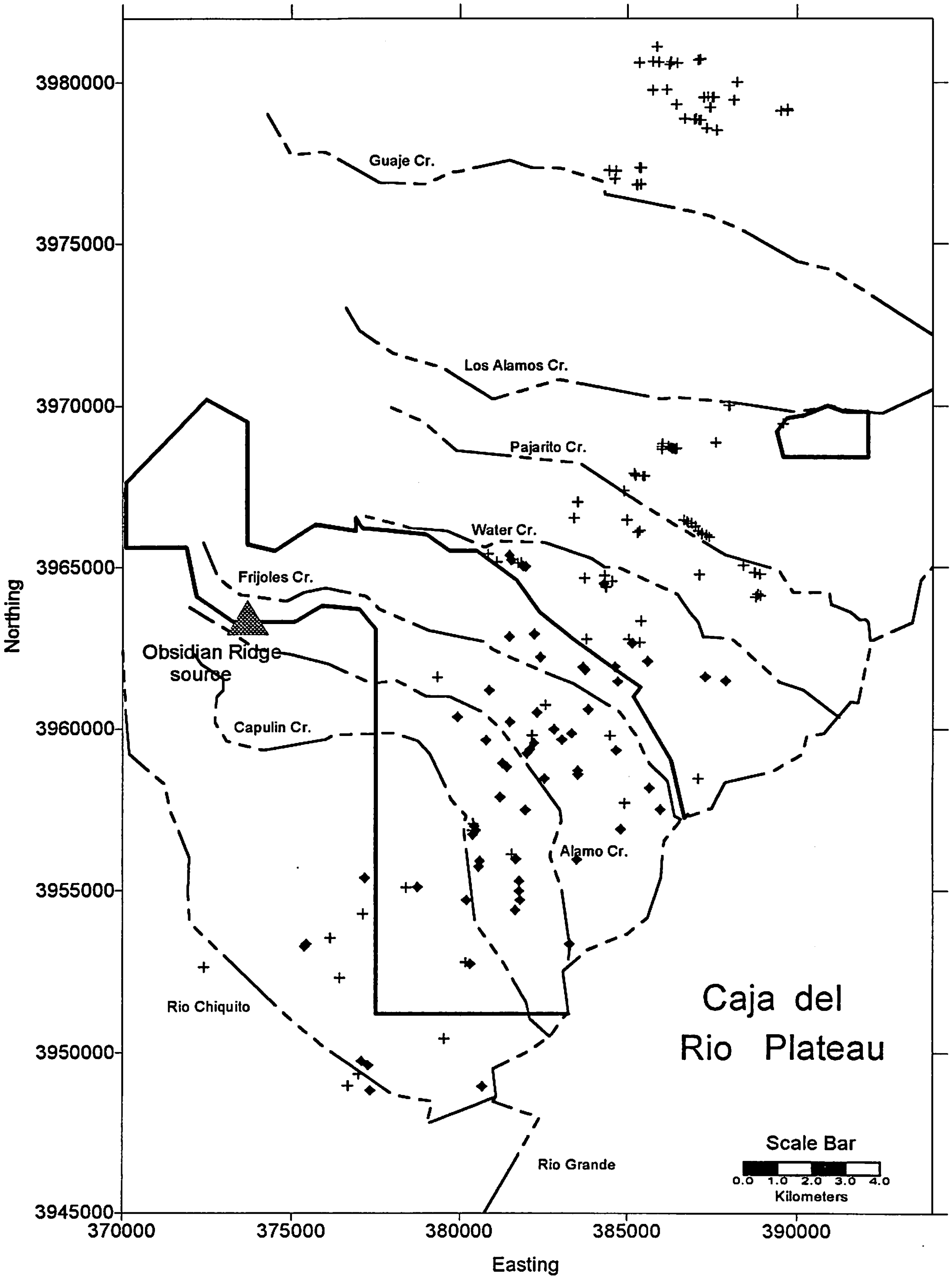

Figure 4.18. Site distribution plot for Coalition Period pueblo sites. Crosses mark sites with less than 50 percent basalt; diamonds show sites with 50 percent or greater basalt.

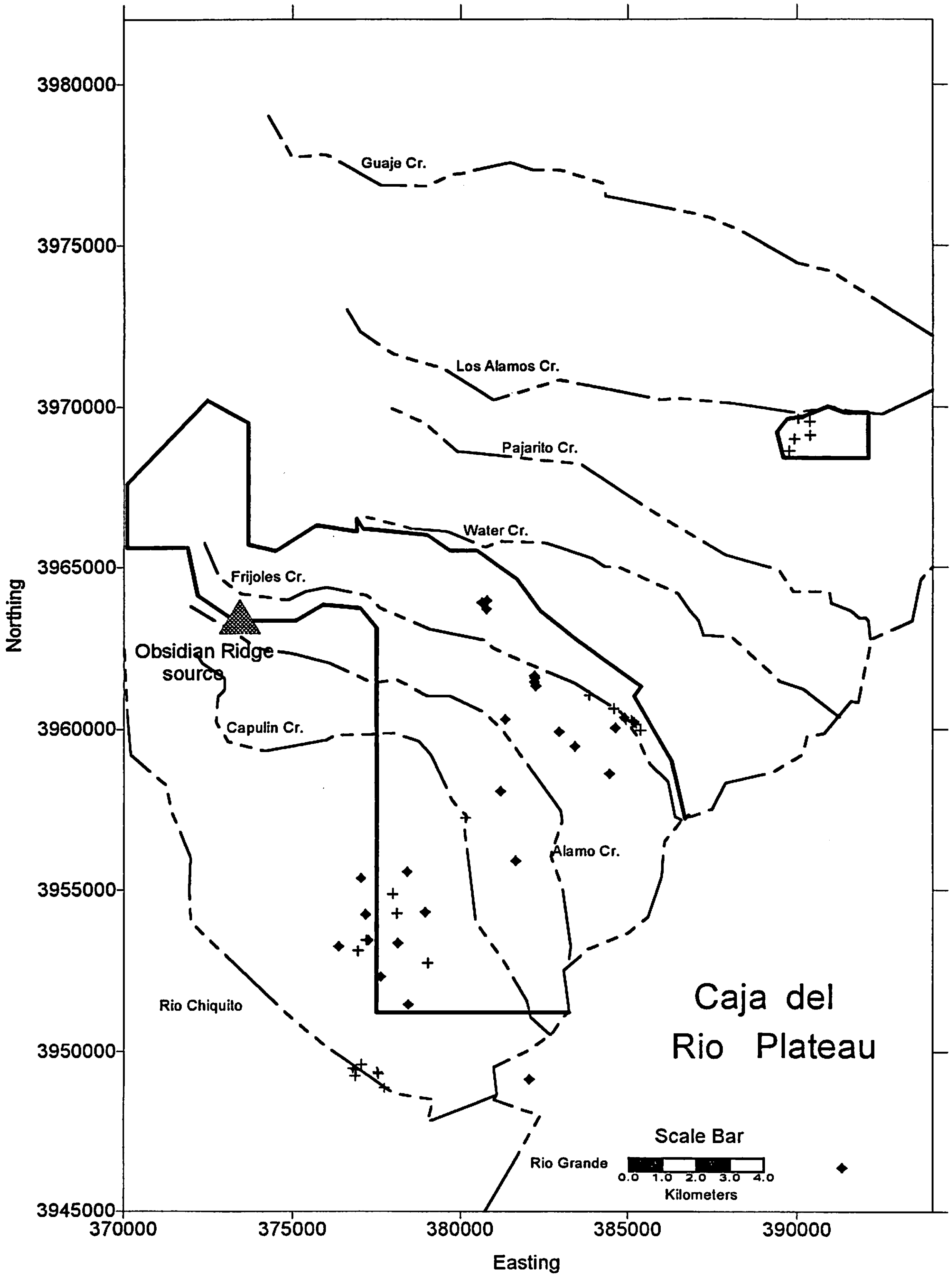

Figure 4.19. Site distribution plot for Classic Period pueblo sites. Crosses mark sites with less than 50 percent basalt; diamonds show sites with 50 percent or greater basalt.

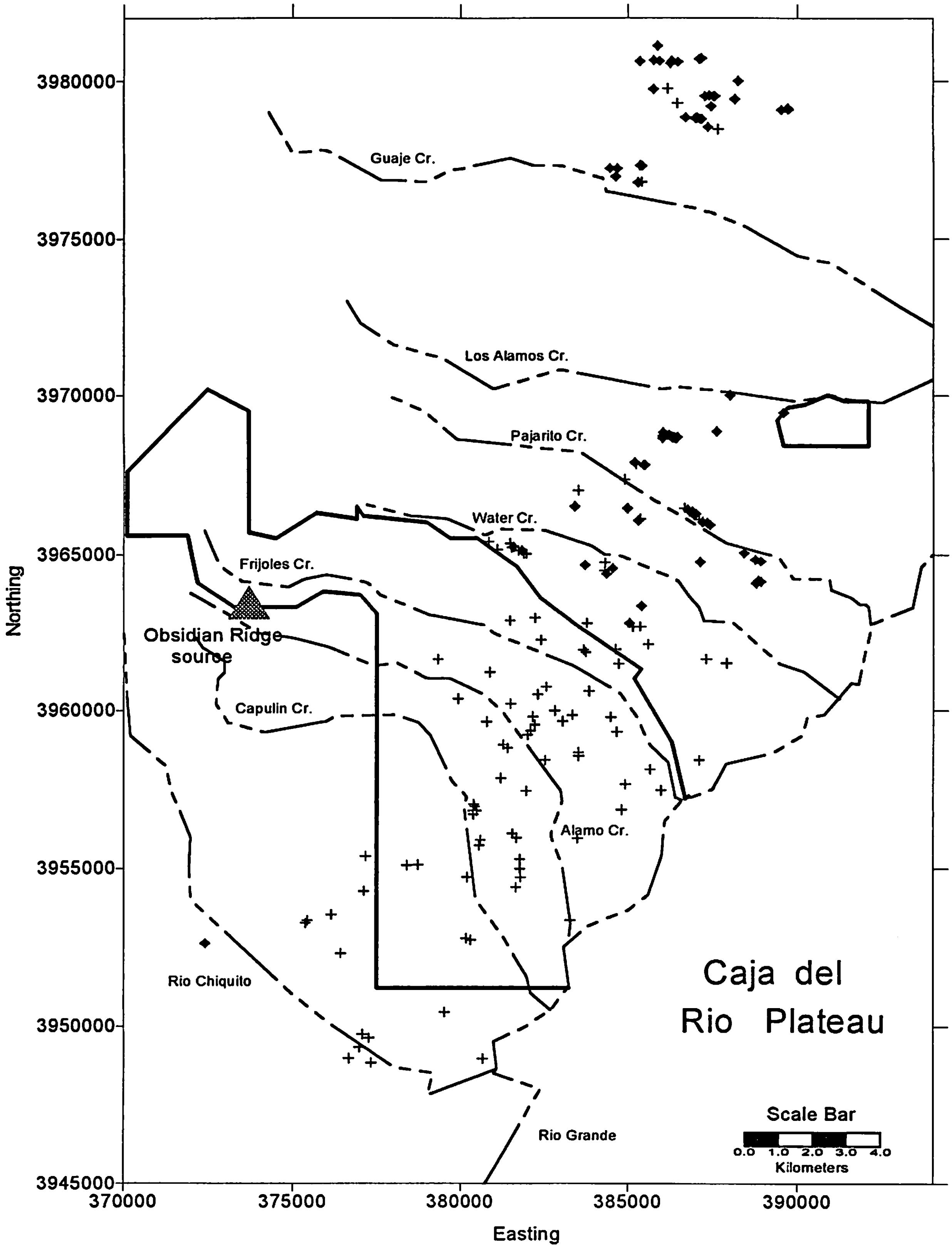

Figure 4.20. Site distribution plot for Coalition Period pueblo sites. Crosses mark sites with less than 50 percent Pedernal chert; diamonds show sites with 50 percent or greater Pedernal chert.

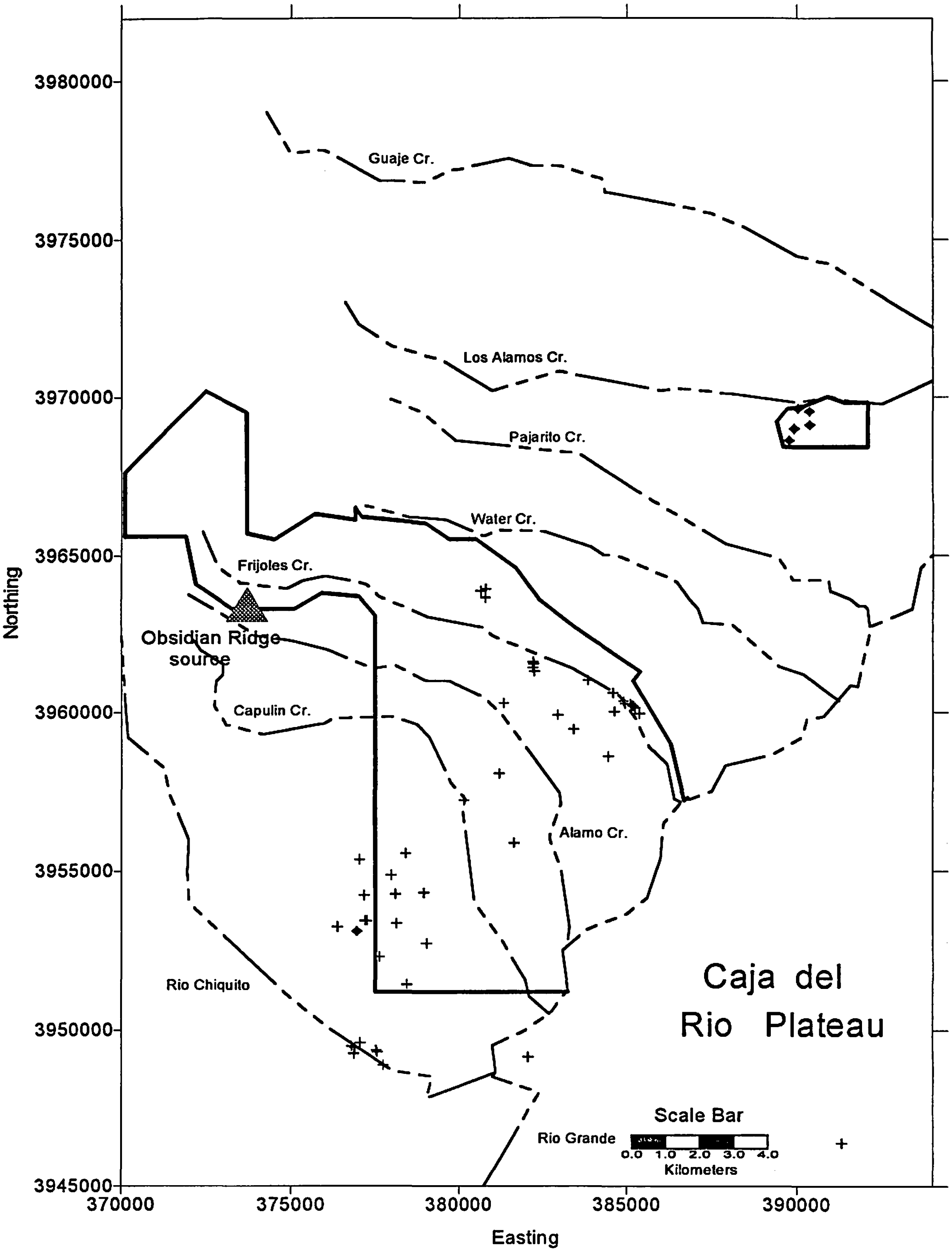

Figure 4.21. Site distribution plot for Classic Period pueblo sites. Crosses mark sites with less than 50 percent Pedernal chert; diamonds show sites with 50 percent or greater Pedernal chert.

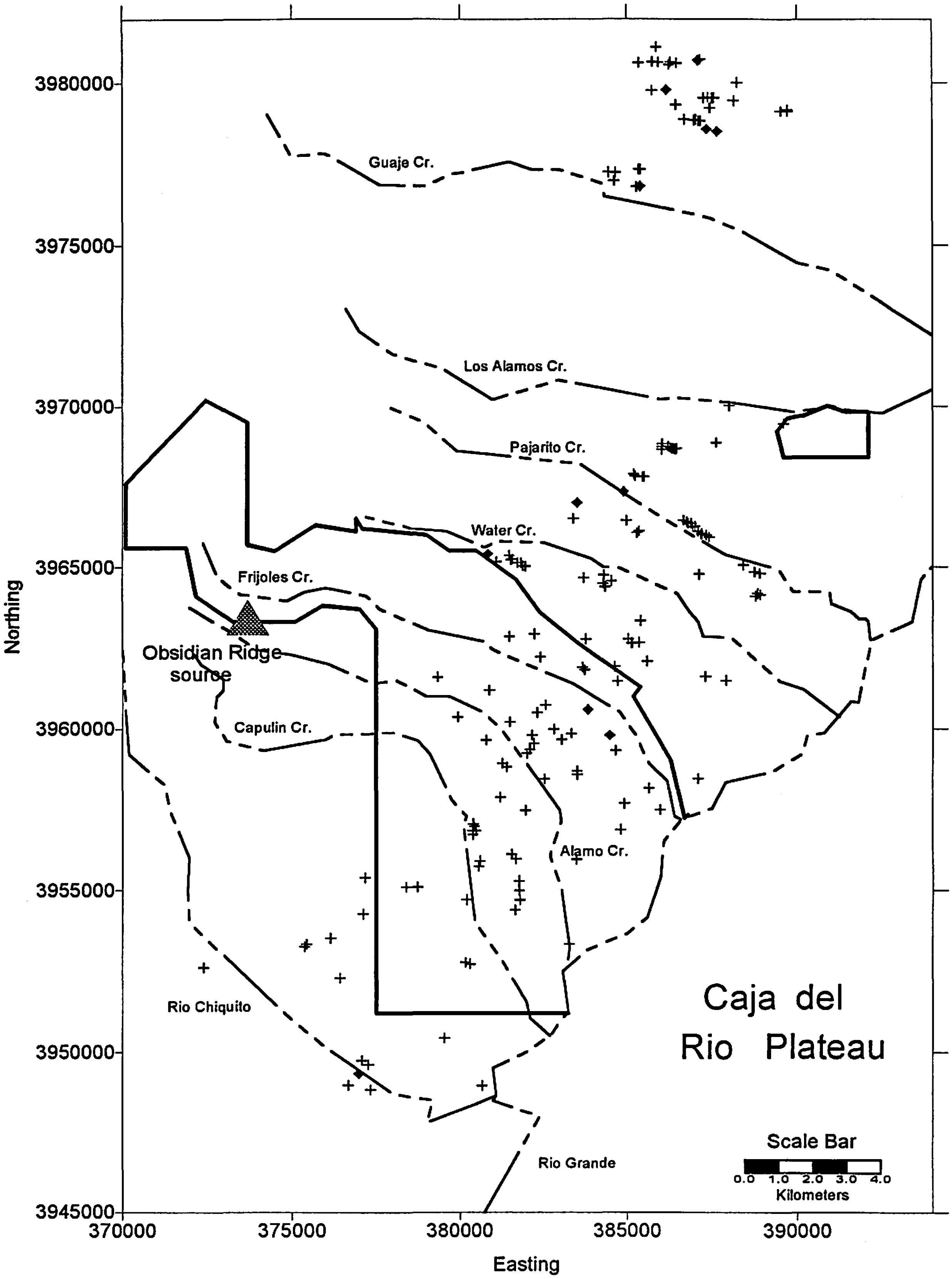

Figure 4.22. Site distribution plot for Coalition Period pueblo sites. Crosses mark sites with less than 50 percent obsidian; diamonds show sites with 50 percent or greater obsidian.

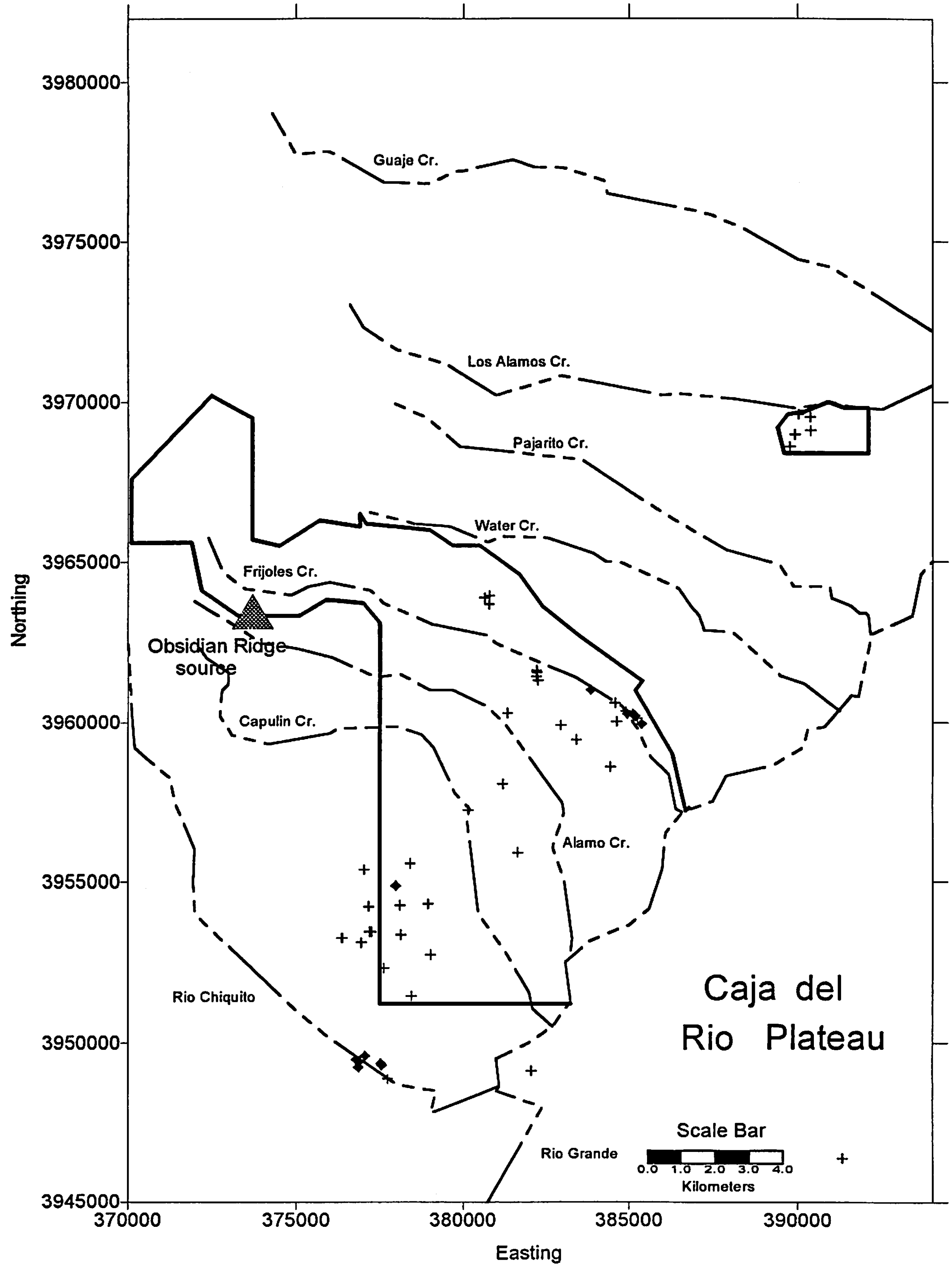

Figure 4.23. Site distribution plot for Classic Period pueblo sites. Crosses mark sites with less than 50 percent obsidian; diamonds show sites with 50 percent or greater obsidian.

and arrow point preforms broken in manufacture. These technological data were coupled with relatively high rates of obsidian bifacial flaking debris within the debitage collection (Root 1989). The presence of such pronounced indicators of biface production stood in stark contrast to the expedient lithic technologies exemplified by other sites excavated during the project. This was taken to indicate, albeit tentatively, the possibility that obsidian biface production at LA 60550 was linked to external trade (Root and Harro 1993; see also Head in press). The spatial data presented here reinforce that interpretation.

Unlike the Coalition Period, in which obsidian-rich sites were scattered across the Plateau, Classic Period obsidian procurement conducted from habitation sites was almost exclusively funnelled into Frijoles and Cochiti Canyons. There, judging from technological analyses of lithic artifacts at one of these sites (Root 1989), bifaces and arrow points were produced in amounts which probably exceeded on-site needs. The evidence for spatial organization of obsidian acquisition, coupled with the specialized technological organization of obsidian tool manufacture at LA 60550, suggests that sites within Frijoles and Cochiti Canyons functioned as production nodes in a more formal trade network than existed on the Pajarito during the Coalition Period. This network, at least in part, probably served large eastern-fringe pueblos (e.g., Pecos) which, in turn, were actively trading with Plains groups far to the east (Baugh and Nelson 1987; Baugh and Terrell 1982; Bronitsky 1982; Snow 1981; Spielmann 1983; Winter 1983).

Summary

The data from the three raw material distributions reveal three broad trends. First of all, through time Pedernal chert decreases over most of the Plateau. In contrast, obsidian increases over the southern Plateau and basalt becomes somewhat more prevalent on the northern Pajarito. Second, Pedernal chert is best represented at pueblo habitations, whereas obsidian was most frequent at field houses. Basalt was prevalent at field houses early, and pueblos late. And third, obsidian procurement and reduction became highly localized during the Classic Period.

In addition, a sudden break in fall-off rates of Pedernal chert and basalt was revealed at Water Canyon. Pedernal chert decreases sharply south of this canyon, whereas basalt decreases north of this point. The relationship, does not seem to be explicable by the physical proximity of sources and was, apparently, shaped largely by differing degrees of social accessibility of stone. Intriguingly, obsidian was largely excluded from this relationship. In other words, the choice of raw materials, at least within the study area, was largely between basalt and Pedernal chert, not between basalt, Pedernal chert, and obsidian. This is very surprising considering that both basalt and obsidian outcrops are physically closer than the Pedernal chert source, and that obsidian is generally considered to be the most desirable for toolmaking due to its inherent ease of knapping and extremely sharp cutting edges.

South of Water Canyon, small non-habitation sites (generally interpreted as field houses) contain large amounts of obsidian. Assuming that obsidian procurement was embedded within other activities, this implies that field house users frequently visited high mountain zones where obsidian is abundant. Interaction with low elevation basalt sources located along the Rio Grande increases with the residential permanence and size of sites. Pueblo habitations contain mostly basalt on the southern Plateau; obsidian is poorly represented at most southern Pajaritan pueblos. Unlike field houses, which are generally obsidian-rich, procurement of obsidian at southern pueblos was emphasized only within Rio Chiquito (Cochiti) and Frijoles Canyons.

On the northern Pajarito, pueblo habitations hold large amounts of Pedernal chert indicating either that regular travel to the far north where this source is located was common or, more likely, that Pedernal chert was actively traded southward (at least across the northern Pajarito). During Coalition times, field houses were associated with montane obsidian sources as they were on the southern Plateau. In the Classic, field houses located near the Rio Grande contained basalt, and field houses located near the Pedernal chert source contained mostly Pedernal chert. Put simply, in the Classic Period, northern Pajarito field houses became less associated with the mountains, and began to procure raw materials from the most accessible source.

5. SUMMARY AND CONCLUSIONS

Unlike other studies of procurement systems which commonly emphasize the acquisition (or dispersal) of a single commodity through large-scale, regional exchange networks (e.g., Findlow and Bolognese 1982; Ericson 1977; Peterson et al. 1997), this project focuses on a relatively small study area (less than 1,000 square kilometers) that contains a number of exploitable toolstones. Due to their proximity, these source fields were frequently accessed by local groups directly. Procurement systems within the study area functioned to satisfy both on-site toolstone needs in addition to supplying local and inter-regional trade networks.

Systems where raw materials were procured directly from sources are seldom studied as intensively as exchange networks per se due to their apparent organizational simplicity. The results of this study have suggested that direct procurement of toolstone is based largely, but not wholly, on site-to-source distances. Other factors that conditioned procurement behavior include physiographical impediments to travel (for example, see Figure 4.1), social barriers which controlled access to sources (see Figure 4.6), the embedding of lithic procurement within other resource extraction tasks lessening the costs of travel for the former (see chapter four's obsidian discussion), and the ease at which competing raw materials may be available through exchange (see chapter four's discussion of Pedernal chert and basalt).

At least one (and usually two) of the raw materials examined here was available within a few hours walk of any site in the study area. Within this context, the archaeological distribution of lithic raw materials on the Pajarito can be regarded largely as an epiphenomenon of other cultural activity. In other words, it was not the most important factor to consider when organizing local trade or conducting logistic travel. Unlike subsistence goods, which were spatially and temporally variable in their abundance and availability, lithic raw materials were utilitarian and ubiquitous. Most energy was probably focused on the acquisition of subsistence goods, not toolstone. As large game habitats receded into the high mountains, and agricultural villages became more dependant on exchange networks, the selection of one toolstone over another became shaped increasingly by fluctuating degrees of accessibility to sources based on embedded procurement and trade.

Obsidian and basalt sources are spatially correlated with altitude-specific resource zones on the Plateau; obsidian is found in the high mountains, whereas basalt is found along lowland canyon walls. The analysis revealed a pattern on the southern half of the Plateau where pueblos contain much more basalt than do field houses, holding location constant. Field houses, in contrast, contain much more obsidian. This pattern is reversed on the northern Pajarito but less strongly expressed. If these two toolstones were brought to sites via direct access to source area (as seems likely) then each site type was differentially associated with specific resource zones: on the southern Plateau pueblos are connected with basalt-rich lowlands containing permanent water sources, and field houses are connected with obsidian-laden montane resource zones which probably hosted the best large mammal hunting in the area, especially during later times. Again on the northern Pajarito, this pattern is reversed.

The catchment asymmetry expressed between site types is surprising considering that the small sites listed here as "field houses" have been commonly inferred to have been used in conjunction with seasonal agricultural activities. Catchments for such specialized occupations should be quite small. The greater amount of obsidian at southern Pajaritan field houses implies that these sites were additionally used as staging camps for logistical forays directed at the mountains for hunting and obsidian procurement. On the northern Pajarito, obsidian is common at field houses in the Coalition Period, and at pueblos during the Classic (Figures 4.4 and 4.5). The reason for the shift in patterns is unclear. Apparently, it reflects a shift in land use strategies that was not duplicated on the southern Plateau.

Social Boundaries

Differences between northern and southern Pajaritan groups is best expressed by the distributions of Pedernal chert and basalt across the Plateau. Based on ethnographic accounts, a territorial border separating Tewa and Keresan groups existed along the northern rim of Frijoles Canyon (Hawley Ellis 1967; Hewett 1930; Lange, Riley, and Lange 1975). The toolstone distributions showed strong evidence for such a boundary. However, instead of existing at Frijoles Canyon, the boundary is observed at the next major canyon to the north (Water Canyon). The changes in the abundance of both of these raw materials demarcated by this canyon are best explained by a semi-permeable social boundary which restricted raw material flow between northern and southern groups. An alternative explanation could be based on the changing geological abundance of toolstones in this area since Pedernal chert occurs to the north and basalt is found most abundantly to the south. However, the geologic distribution of these two materials cannot explain the abruptness of the change.

The analysis has shown that this boundary formed during or prior to the Early Coalition Period. According to current models, this was a time on the Pajarito characterized by relatively low population densities with people living in small dispersed settlements. As such there would have been less cause for conflict and competition for scarce resources such as prime agricultural land, or for control of valued exchange commodities compared with later times. The early formation of this boundary suggests: (1) that two distinct ethnic groups were occupying the Plateau prior to the initiation of aggregated settlements; (2) that competition between these groups may have existed earlier than previously thought and emerged for reasons other than those associated with increasing population densities and aggregation; and (3), that the protohistoric occupations of the Plateau known through ethnographic accounts may have had greater time depth than was previously realized.

External Obsidian Exchange

The data further revealed that through time obsidian became more widely distributed at sites on the Pajarito (Figure 4.3). Centralization of Jemez obsidian procurement for external exchange was expected to be manifest in the archaeological obsidian distributions in two ways: first, by production centers revealing themselves through greater amounts of obsidian compared with nearby sites; and second, by obsidian-rich sites clustering together over space. The first of these patterns was not apparent in the data, probably being obscured by the inclusion of field houses in those plots. Seasonally occupied field house structures may have occasionally served as short-term lithic workshops in addition to their primary function of supporting agricultural activities. However, they would not have been used as production centers for long-distance exchange networks, which probably would have included part-time knapping specialists. Craft specialization would have been based at pueblo habitations. For these reasons, field houses were filtered from the analysis and new plots were generated to show if obsidian-rich pueblos (defined as containing more that 50% obsidian) were clustered over space. Whereas clustering was not observed for basalt, Pedernal chert, or obsidian during the Coalition Period, a total of 90.9% (n=10) of all obsidian-rich pueblos from the Classic Period were clustered within Cochiti (Rio Chiquito) and Frijoles Canyons (Figure 4.23).

During the Coalition Period high densities of obsidian could be found at pueblo sites scattered across the Plateau (Figure 4.22). In the Classic Period, this pattern changed such that obsidian procurement based from pueblo habitations became focused almost exclusively within Frijoles and Cochiti Canyons. This degree of apparent reorganization and centralization of obsidian procurement and tool reduction was probably caused by the opening up of channels of trade to the east with Plains hunter-gatherers (as noted by Baugh and Terrell 1982; Baugh and Nelson 1987; Bronitsky 1982; Spielmann 1983; Winter 1983).

The data generated here refer only to differences in the relative densities of obsidian compared to other toolstones. A more complete assessment of the degree to which obsidian procurement was centralized, and tool form, technology, and production was standardized is required to fully evaluate this system. This would be best accomplished through detailed technological characterizations of lithic tool production at some of the sites found by this study to be potential components of production centers (see chapter four). The emergent pattern of obsidian procurement revealed by this investigation is provocative, but must remain tentative pending detailed technological characterizations of Classic Period obsidian tool production. The emergence of external trade relationships may have added economic and subsistence benefits for groups who could furnish distant groups with valued exchange commodities such as obsidian.

REFERENCES CITED

Acklen, John C., G. Brown, T. Crollett, W. Doering, J. Gish, R. Holloway, S. Huber, R. Kunselman, R. Lang, M. McFaul, M. Newman, P. Noyes, C. Stevenson, and M. Walsh-Anduze

1993 *Archaeological Site Testing for the Ojo Line Extension 345 kv Transmission Project in the Jemez Mountains, New Mexico.* Prepared by Mariah Associates, Inc. Submitted to The Public Service Company of New Mexico, Albuquerque.

Ammerman, Albert J.

1979 A Study of Obsidian Exchange Networks in Calabria. *World Archaeology* 11(1):95-110

Ammerman, Albert J., and William Andrefsky, Jr.

1982 Reduction Sequences and the Exchange of Obsidian in Neolithic Calabria. In *Contexts for Prehistoric Exchange*, edited by Jonathan E. Ericson and Timothy K. Earle, pp. 149-172. Academic Press, New York.

Andrefsky, William Jr.

1994a Raw-Material Availability and the Organization of Technology. *American Antiquity* 59:21-34

1994b The Geologic Occurrence of Lithic Material and Stone Tool Production Strategies. *Geoarchaeology: An International Journal* 9:375-391.

1995 Cascade Phase Lithic Technology: An Example from the Lower Snake River. *North American Archaeologist* 16:95-115.

Axelrod, Robert

1984 *The Evolution of Cooperation.* Basic Books, Inc., New York.

Bailey, R. A., and R. L. Smith

1978 Volcanic Geology of the Jemez Mountains, New Mexico. In *Guidebook to Rio Grande Rift in New Mexico and Colorado*, compiled by J. W. Hawley, pp. 184-196. New Mexico Bureau of Mines and Mineral Resources, Circular 163.

Bamforth, Douglas B.

1992 Quarries in Context: A Regional Perspective on Lithic Procurement. In *Stone Tool Procurement, Production, and Distribution in California Prehistory,* edited by Jeanne E. Arnold, pp. 131-150. Perspectives in California Archaeology, Volume 2. Institute of Archaeology, University of California, Los Angeles.

Bandelier, Adolph F.
1916 *The Delight Makers*, 2nd edition. Dodd, Mead, New York.

Baugh, Timothy G.
1984 Southern Plains Societies and Eastern Frontier Pueblo Exchange During the Protohistoric Period. In *Collected Papers in Honor of Harry L. Hadlock*, edited by Nancy L. Fox, pp.157-167. Papers of the Archaeological Society of New Mexico, No. 9, Albuquerque

Baugh, Timothy G., and Fred W. Nelson, Jr.
1987 New Mexico Obsidian Sources and Exchange on the Southern Plains. *Journal of Field Archaeology* 14:313-329.

Baugh, Timothy G., and Charles W. Terrell
1982 An Analysis of Obsidian Debitage and Protohistoric Exchange Systems in the Southern Plains as Viewed from the Edwards I Site (34BK2). *Plains Anthropologist* 95:1-15.

Benedict, Ruth
1934 *Patterns of Culture.* Houghton Mifflin, New York.

Bettinger, Robert L.
1982 Aboriginal Exchange and Territoriality in Owens Valley, California. In *Contexts for Prehistoric Exchange*, edited by Jonathan E. Ericson and Timothy K. Earle, pp.103-128. Academic Press, New York.

Binford, Lewis
1979 Organization and Formation Processes: Looking at Curated Technologies. *Journal of Anthropological Research* 35:255-273.

1982 The Archaeology of Place. *Journal of Anthropological Archaeology* 1 (1):5-31.

Braun, David P., and Stephen Plog
1982 Evolution of "Tribal" Social Networks: Theory and Prehistoric North American Evidence. *American Antiquity* 47:504-525.

Bronitsky, Gordon
1982 The Southwest and the Plains: Ecology and Economics. *Plains Anthropologist* 27:67-73.

1983 Economic Change in the Rio Grande Valley. In *Ecological Models in Economic Prehistory*, edited by G. Bronitsky, pp.168-188. Arizona State University Anthropological Research Papers, no. 29.

Brown, Gary M.

1990 Specialized Lithic Exchange and Production on Anderson Mesa. In *Technological Change in the Chavez Pass Region, North-Central Arizona,* edited by G. Brown, pp. 173-191. Anthropological Research Papers No. 41, Arizona State University, Tempe.

Bryan, Kirk

1938 Historic Quarries and Implements of Pre-Amerindian Aspect in New Mexico. *Science* 87:343-346.

1939 Stone Cultures Near Cerro Pedernal and Their Geologic Antiquity. *Bulletin of the Texas Archeological and Paleontological Society* 11:9-45.

1950 *Flint Quarries—The Sources of Tools and, at the Same Time, the Factories of the American Indians.* Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University 17(3):1-40.

Cameron, Catherine M.

1991 Chipped Stone from 29-SJ-633. In *Excavations at 29-SJ-633: the Eleventh Hour Site, Chaco Canyon, NM,* edited by Frances Joan Mathien. Reports of the Chaco Center no. 10. Division of Cultural Research, National Park Service, Santa Fe, NM.

1995 Migration and the Movement of Southwestern Peoples. *Journal of Anthropological Archaeology* 14:104-124.

Cameron, Catherine M., and Robert L. Sappington

1984 Obsidian Procurement at Chaco Canyon A.D. 500-1200. In *Recent Research on Chaco Prehistory,* edited by W. James Judge and John D. Schelberg, pp. 153-172. Reports of the Chaco Center, No. 8, Division of Cultural Research, National Park Service, Santa Fe, NM.

Carlson, Ingrid K., and Timothy A. Kohler

1990 Prolegomenon to the Study of Habitation Site Architecture During the Coalition Period on the Pajarito Plateau. In *Bandelier Archaeological Excavaion Project: Summer 1989 Excavations at Burnt Mesa Pueblo,* edited by T. A. Kohler, pp.7-26. Reports of Investigations 62. Department of Anthropology, Washington State University, Pullman.

Chapman, Richard C., and Jan V. Biella

1980 4,000 Years on the Southern Pajarito. In *Bandelier National Monument: Geology, History, Prehistory,* edited by David G. Noble, pp. 6-11. School of American Research, Santa Fe.

Church, Fermor S. and John T. Hack
1939 An Exhumed Erosion Surface in the Jemez Mountains, New Mexico. *Journal of Geology* 47(6):613-629.

Cordell, Linda S.
1995 Tracing Migration Pathways from the Receiving End. *Journal of Anthropological Archaeology* 14:203-211.

Creel, Darrell
1991 Bison Hides in Late Prehistoric Exchange in the Southern Plains. *American Antiquity* 56:40-49.

Cressie, Noel
1990 The Origins of Kriging. *Mathematical Geology* 22:239-252.

Crown, Patricia L., Janet D. Orcutt, and Timothy A. Kohler
1996 Pueblo Cultures in Transition: The Northern Rio Grande. In *The Prehistoric Pueblo World, A.D. 1150-1350*, edited by Michael A. Adler, pp. 188-201. University of Arizona Press, Tucson.

Dean, Jeffrey S.
1996 Demography, Environment, and Subsistence Stress. In *Evolving Complexity and Environmental Risk in the Prehistoric Southwest*, edited by J. A. Tainter and B.B. Tainter. pp. 25-56. Santa Fe Institute Studies in the Sciences of Complexity, Vol. XXIV, Addison-Wesley Publishing, Reading, MA.

Ericson, J. E.
1977 Egalitarian Exchange Systems in California: A Preliminary View. In *Exchange Systems in Prehistory*, edited by T. K. Earle and J. E. Ericson, pp. 109-126. Academic Press, New York.

1982 Production for exchange in California. In *Contexts for Prehistoric Exchange*, edited by Jonathan E. Ericson and Timothy K. Earle, pp. 129-148. Academic Press, New York.

Findlow, Frank J. and Marisa Bolognese
1982 Regional Modeling of Obsidian Procurement in the American Southwest. In *Contexts for Prehistoric Exchange*, edited by Jonathan E. Ericson and Timothy K. Earle, pp.53-82. Academic Press, New York.

Frison, G. C. and B. A. Bradley
1980 *Folsom Tools and Technology at the Hanson Site, Wyoming.* University of New Mexico Press, Albuquerque

Goff, Fraser, Jamie N. Gardener, and Greg Valentine

1990 *Geology of St. Peter's Dome Area, Jemez Mountains, New Mexico.* Geologic Map no. 69, New Mexico Bureau of Mines and Mineral Resources.

Golden Software Inc.

1994 *Surfer for Windows User's Guide, ver. 5.01.* Golden Software, Golden CO.

Goodyear, Albert C.

1979 *A Hypothesis for the Use of Cryptocrystalline Raw Material Among Paleo-Indian Groups of North America.* Research Manuscript Series No. 156. Institute of Archaeology and Anthropology, University of South Carolina, Columbia.

1993 Tool kit Entropy and Bipolar Reduction: A Study of Inter-assemblage Lithic Variability Among Paleo-Indian Sites in the Northeastern United States. *North American Archaeologist* 19:1-23

Gould, Richard A., and Sherry Saggers

1985 Lithic Procurement in Central Australia: A Closer Look at Binford's Idea of Embeddedness in Archaeology. *American Antiquity* 50:117-136.

Gramly, R. M.

1984 Mount Jasper: A Direct-Access Lithic Source Area in the White Mountains of New Hampshire. In *Prehistoric Quarries and Lithic Production,* edited by J. Ericson and B. Purdy, pp.11-22. Cambridge University Press, New York.

Green, Marjorie

1985 *Chipped Stone Raw Materials and the Study of Interaction on Black Mesa, Arizona.* Center for Archaeological Investigations, Occasional Paper No. 11, Southern Illinois University, Carbondale

Griggs, Roy L.

1964 Geology and Ground-water resources of the Los Alamos area, New Mexico. *U.S. Geological Survey, Water Supply Paper 1753.*

Gumerman, George J. (editor)

1994 *Themes in Southwest Prehistory.* School of American Research Press, Santa Fe.

Gumerman George J., and Murray Gell-Man (editors)

1994 *Understanding Complexity in the Prehistoric Southwest.* Santa Fe Institute Studies in the Sciences of Complexity, Vol. XXIV, Addison-Wesley Publishing, Reading, MA.

Haas, Jonathan, and Winifred Creamer

1996 The Role of Warfare in the Pueblo III Period. In *The Prehistoric Pueblo World, A.D. 1150-1350*, edited by Michael A. Adler, pp. 205-213. University of Arizona Press, Tucson.

Harry, Karen G.

1989 The Obsidian Assemblage from Homol'ovi III: Social and Economic Implications. *The Kiva* 54(3):285-296.

Hawley Ellis, Florence

1967 Where did the Pueblo People Come From? *El Palacio* 74:35-43.

Head, Genevieve N.

in press Lithic Artifacts. In *The Bandelier Archaeological Survey*, edited by R. P. Powers and J. D. Orcutt. Contribution No. 9 of the Bandelier Archaeological Survey. Division of Anthropology, National Park Service, Santa Fe.

Hewett, Edgar L.

1930 *Ancient Life in the American Southwest.* Bobbs-Merrill Publishers, Indianapolis.

1953 *Pajarito Plateau and its Ancient People.* University of New Mexico Press, Albuquerque.

Hill, James N., and Nicholas W. Trierweiler

1986 *Prehistoric Response to Food Stress on the Pajarito Plateau, New Mexico: Technical Report and Results of the Pajarito Archaeological Research Project, 1977-1985.* Final Report to the National Science Foundation for Grant no. BNS-78-08118.

Hodder, Ian

1982 Toward a Contextual Approach to Prehistoric Exchange. In *Contexts for Prehistoric Exchange*, edited by Jonathan E. Ericson and Timothy K. Earle, pp. 199-211. Academic Press, New York, New York.

Hodder, Ian and Clive Orton

1976 *Spatial Analysis in Archaeology.* Cambridge University Press, Cambridge.

Kantner, John

1996 Political Competition Among the Chaco Anasazi of the American Southwest. *Journal of Anthropological Archaeology* 15:41-105.

Kelley, Vincent C.

1978 *Geology of Española Basin, New Mexico.* Geologic Map no. 48, New Mexico Bureau of Mines and Mineral Resources.

Knapp, Bernard A.
1985 Production and Exchange in the Aegean and Eastern Mediterranean. In *Prehistoric Production and Exchange, The Aegean and Eastern Mediterranean*, edited by A. B. Knapp and T. Stech, pp. 1-11. Institute of Archaeology, Monograph XXV. University of California, Los Angeles.

Kohler, Timothy A.
1989 *Bandelier Archaeological Excavation Project: Research Design and 1988 Sampling*. Reports of Investigations 61. Department of Anthropology, Washington State University, Pullman.

1990 *Bandelier Archaeological Excavaion Project: Summer 1989 Excavations at Burnt Mesa Pueblo*. Reports of Investigations 62. Department of Anthropology, Washington State University, Pullman.

1992 Field Houses, Villages, and the Tragedy of the Commons in the Early Northern Anasazi Southwest. *American Antiquity* 57(4):617-635.

n.d. *Agent-Based Modeling of Anasazi Village Formation in the Northern American Southwest*. Ms. in possession of the author.

Kohler, Timothy A., and Angela Linse (editors)
1993 *Papers on the Early Classic Period Prehistory of the Pajarito Plateau, New Mexico*. Reports of Investigations 65. Department of Anthropology, Washington State University, Pullman.

Kohler, Timothy A., and Meredith H. Matthews
1988 Long-Term Anasazi Land Use and Forest Reduction: A Case Study From Southwest Colorado. *American Antiquity* 53 (3):537-564.

Kohler, Timothy A., and Carla R. Van West
1996 The Calculus of Self-Interest in the Development of Cooperation: Sociopolitical Development and Risk Among the Northern Anasazi. In *Evolving Complexity and Environmental Risk in the Prehistoric Southwest*, edited by J. A. Tainter and B.B. Tainter. pp. 169-196. Santa Fe Institute Studies in the Sciences of Complexity, Vol. XXIV, Addison-Wesley Publishing, Reading, MA.

Lange, Charles H., Carroll L. Riley, and Elizabeth M. Lange (editors)
1975 *The Southwestern Journals of Adolph F. Bandelier 1885-1888, vol. 3.* University of New Mexico Press, Albuquerque.

Lipe, William D.
1995 The Depopulation of the Northern San Juan: Conditions in the Turbulent 1200s. *Journal of Anthropological Archaeology* 14:143-169.

Lizee, Jonathan M., Hector Neff, and Michael D. Glascock

1995 Clay Acquisition and Vessel Distribution Patterns: Neutron Activation Analysis of Late Windsor and Shantok Tradition Ceramics from Southern New England. *American Antiquity* 60:515-530.

Luedtke, Barbara

1984 Lithic Raw Material Demand and Quarry Production. In *Prehistoric Quarries and Lithic Production*, edited by J. Ericson and B. Purdy, pp. 65-77. Cambridge University Press, New York.

MacDonald, Douglas H.

1995 Mobility and Raw Material Use at the Hunting Camp Spring Site (35WA96), Blue Mountains, Oregon. *North American Archaeologist* 16:343-361.

Matheron, G.

1963 Principles of Geostatistics. *Economic Geology* 58:1246-1266.

McBryde, Isabel

1984 Kulin Greenstone Quarries: the Social Contexts of Production and Distribution for the Mt.William Site. *World Archaeology* 16:267-285.

McKim, Rebecca, L.

1994 *Modeling Changes in the Faunal Use and Availability on the Pajarito Plateau, New Mexico.* Master's Thesis, University of Arizona, Tucson. University Microfilms International, Ann Arbor.

Minnis, Paul E.

1996 Notes on Economic Uncertainty and Human Behavior in the Prehistoric North American Southwest. In *Evolving Complexity and Environmental Risk in the Prehistoric Southwest*, edited by Joseph A. Tainter and Bonnie Bagley Tainter, pp. 57-78. Santa Fe Institute Studies in the Sciences of Complexity Proceedings Volume XXIV. Addison Wesley, Redwood City, CA.

Moore, James L.

1993 *Testing at Nine Archaeological Sites Along State Route 502 near San Ildefonso, Santa Fe County, New Mexico.* Museum of New Mexico Archaeological Publication No. 96.

Moore, Jerry D.

1989 Lithic Procurement and Prehistoric Exchange on the Santa Barbara Coast: The Role of Franciscan Chert. *North American Archaeologist* 10:79-93.

Nelson Margaret C.

1996 Technological Strategies Responsive to Subsistence Stress. In *Evolving Complexity and Environmental Risk in the Prehistoric Southwest*, edited by J. A. Tainter and B.B. Tainter. pp. 107-144. Santa Fe Institute Studies in the Sciences of Complexity, Vol. XXIV, Addison-Wesley Publishing, Reading, MA.

Newman, Jay R.

1994 The Effects of Distance on Lithic Material Reduction Technology. *Journal of Field Archaeology*, 21(4):491-501.

Orcutt, Janet D.

1993 Villages, Field Houses, and Land Use on the Southern Pajarito Plateau. In *Papers on the Early Classic Period Prehistory of the Pajarito Plateau, New Mexico*, edited by T. A. Kohler and Angela R. Linse, pp. 87-104. Reports of Investigations 65. Department of Anthropology, Washington State University, Pullman.

in press Demography, Settlement, and Agriculture. In *The Bandelier Archaeological Survey*, edited by R. P. Powers and J. D. Orcutt. Contribution No. 9 of the Bandelier Archaeological Survey. Division of Anthropology, National Park Service, Santa Fe.

Orcutt, Janet D., Eric Blinman, and Timothy A. Kohler

1990 Explanations of Population Aggregation in the Mesa Verde Region Prior to A.D. 900. In *Perspectives on Southwestern Prehistory*, edited by P. Minnis and C. Redman, pp.196-212. Westview Press, Boulder

Peterson, Jane, Douglas Mitchell, and M. Steven Shackley

1997 The Social and Economic Contexts of Lithic Procurement: Obsidian from Classic-Period Hohokam Sites. *American Antiquity* 62:231-259.

Portugali, Yuval, and A. Bernard Knapp

1985 Cyprus and the Aegean: A Spatial Analysis of Interaction in the 17th-14th Centuries B.C. In *Prehistoric Production and Exchange, The Aegean and Eastern Mediterranean*, edited by A. B. Knapp and T. Stech, pp.44-69. Institute of Archaeology, Monograph XXV. University of California, Los Angeles.

Powers, Robert P.

1988 *Final Archaeological Research Design for a Sample Inventory Survey of Bandelier National Monument.* Branch of Cultural Research, National Park Service, P.O. Box 728, Santa Fe.

Powers, Robert P., and Janet D. Orcutt (editors)
in press *The Bandelier Archaeological Survey.* Contribution No. 9 of the Bandelier Archaeological Survey. Division of Anthropology, National Park Service, Santa Fe.

Preucel, Robert W.
1987 Settlement Succession on the Pajarito Plateau, New Mexico. *The Kiva* 53(1):3-33.

Rautman, Alison E.
1993 Resource Variability, Risk and the Structure of Social Networks: An Example form the Prehistoric Southwest. *American Antiquity* 58:403-424.

1996 Risk, Reciprocity, and the Operation of Social Networks. In *Evolving Complexity and Environmental Risk in the Prehistoric Southwest*, edited by J. A. Tainter and B.B. Tainter. pp. 197-222. Santa Fe Institute Studies in the Sciences of Complexity, Vol. XXIV, Addison-Wesley Publishing, Reading, MA.

Renfrew, Colin
1977 Alternate Models for Exchange and Spatial Distributions. In *Exchange Systems in Prehistory*, edited by Timothy K. Earle and Jonathan E. Ericson, pp. 71-90. Academic Press, New York.

1984 Trade as Action at a Distance. In *Approaches to Social Archaeology*, pp. 86-134. Harvard University Press, Cambridge.

Renfrew, Colin, and Eric V. Level
1984 Exploring Dominance: Predicting Polities from Centers. In *Approaches to Social Archaeology*, pp. 54-77. Harvard University Press, Cambridge.

Root, Matthew J.
1989 Stone Artifacts. In *Bandelier Archaeological Excavation Project: Research Design and 1988 Sampling*, edited by T. A. Kohler, pp. 69-84. Reports of Investigations 61. Department of Anthropology, Washington State University, Pullman.

Root, Matthew J., and Stanley A. Ahler
1993 Research Design. In *Site 32DU955A: Folsom Occupation of the Knife River Flint Primary Source Area*, edited by M. Root, pp. 13-22. Prepared by Center for Northwest Anthropology, Department of Anthropology, Washington State University, Pullman. Submitted to U.S. Fish and Wildlife Service, Denver Colorado, and GEI Consultants, Inc., Englewood CO. Contract No. 14-16-0010-90-0003.

Root Matthew, J., and Douglas R. Harro

1992 Stone Artifacts from Casa del Rito and Burnt Mesa Pueblo. In *Bandelier Archaeological Excavation Project: Summer 1990 Excavations at Burnt Mesa Pueblo and Casa del Rito*. Reports of Investigations 64. Department of Anthropology, Washington State University, Pullman.

1993 Stone Artifacts. In *Papers on the Early Classic Period Prehistory of the Pajarito Plateau, New Mexico*, edited by T. A. Kohler and Angela R. Linse, pp. 43-60. Reports of Investigations 65. Department of Anthropology, Washington State University, Pullman.

Schiffer, Michael B.

1972 Archaeological Context and Systemic Context. *American Antiquity* 37:156-165.

1996 Some Relationships between Behavioral and Evolutionary Archaeologies. *American Antiquity* 61:643-662.

Sidrys, Raymond

1977 Mass-Distance Measures for the Maya Obsidian Trade. In *Exchange Systems in Prehistory*, edited by T. K. Earle and J. E. Ericson, pp. 91-108. Academic Press, New York.

Singer, Clay A.

1986 The Prehistory of Fused Shale in Southern California. Paper presented at the World Archaeological Congress, London.

Smith, Harold T. U.

1938 Tertiary Geology of the Abiquiu Quadrangle, New Mexico. *Journal of Geology* 46(6):933-965.

Snow, David H.

1981 Protohistoric Rio Grande Pueblo Economics: A Review of Trends. In *The Protohistoric Period in the North American Southwest, AD 1450-1700*, edited by David R. Wilcox and Bruce Masse, pp.354-377. Anthropological Research Papers 24, Dept. of Anthropology, Arizona State University, Tempe.

1991 Upland Prehistoric Maize Agriculture in the Eastern Rio Grande and Its Peripheries. In *Farmers, Hunters, and Colonists*, edited by K. Spielmann, pp. 71-88. University of Arizona Press, Tucson.

Speth, John D.

1991 Some Unexplored Aspects of Mutualistic Plains-Pueblo Food Exchange. In *Farmers, Hunters, and Colonists*, edited by K. Spielmann, pp. 18-35. University of Arizona Press, Tucson.

Spielmann, Katherine A

1983 Late Prehistoric Exchange Between the Southwest and Southern Plains. *Plains Anthropologist* 28:257-271.

1991a Interaction Among Nonhierarchical Societies. In *Farmers, Hunters, and Colonists*, edited by K. Spielmann, pp. 1-17. University of Arizona Press, Tucson.

1991b Coercion or Cooperation? Plains-Pueblo Interaction in the Protohistoric Period. In *Farmers, Hunters, and Colonists*, edited by K. Spielmann, pp. 36-50. University of Arizona Press, Tucson.

Tainter, Joseph A., and B. B. Tainter (editors)

1996 *Evolving Complexity and Environmental Risk in the Prehistoric Southwest.* Santa Fe Institute Studies in the Sciences of Complexity Proceedings Volume XXIV. Addison Wesley, Redwood City, CA.

Torrence, Robin

1986 *Production and Exchange of Stone Tools.* Cambridge University Press, New York.

Trierweiler, W. Nicholas

1989 Identification and Analysis of Faunal Specimens. In *Bandelier Archaeological Excavation Project: Research Design and 1988 Sampling*, edited by T. A. Kohler, pp. 85-92. Reports of Investigations 61. Department of Anthropology, Washington State University, Pullman.

Upham, Steadman

1982 *Polities and Power: An Economic and Political History of the Western Pueblo.* Academic Press, New York

Upham, Steadman, and Fred Plog

1986 The Interpretation of Prehistoric Political Complexity in the Central and Northern Southwest: Toward a Mending of the Models. *Journal of Field Archaeology* 13:223-238.

Vint, James M.

1993 Sherds and the Social Milieu of Bandelier National Monument During the Coalition Period in the Northern Rio Grande Region. Paper Presented at the 58th Annual Meeting of the Society of American Archaeology, St. Louis.

Van Zant, Tineke

1993 Houses Made of Tuff: Anasazi Architecture at Bandelier National Monument. Paper Presented at the 58th Annual Meeting of the Society for American Archaeology, St. Louis.

Wandsnider, Luann and Eileen Camilli
1992 The Character of Surface Archaeological Deposits and its Influence on Survey Accuracy. *Journal of Field Archaeology* 19(2):169-188.

Warren, A. H.
1979 Geological and Mineral Resources of the Cochiti Reservoir Area. In *Archaeological Investigations in the Cochiti Reservoir, New Mexico, Volume 4: Adaptive Change in the Northern Rio Grande Valley*, edited by Jan V. Biella and R. C. Chapman, pp.46-58. Office of Contract Archaeology, University of New Mexico, Albuquerque.

Wilcox, David R.
1984 Multi-Ethnic Division of Labor in the Protohistoric Southwest. In *Collected Papers in Honor of Harry L. Hadlock*, edited by Nancy L. Fox, pp.157-167. Papers of the Archaeological Society of New Mexico, No. 9, Albuquerque

1991 Changing Contexts of Pueblo Adaptations, A.D. 1250-1600. In *Farmers, Hunters, and Colonists*, edited by K. Spielmann, pp. 128-154. University of Arizona Press, Tucson.

Wilcox, David R., and Jonathan Haas
1994 Scream of the Butterfly, Competition and Conflict in the Prehistoric Southwest. In Themes in Southwest Prehistory, edited by G. Gumerman, pp. 211-238. School of American Research Press, Santa Fe.

Winter, Joseph C.
1983 Jemez Mountain Obsidian Exchange—A View from Redondo Valley. In *Cultural Resource Management--High Altitude Adaptations in the Southwest*, edited by Joseph C. Winter, pp.91-114, Report 91-107. USDA Forest Service, Albuquerque.

APPENDIX A

Table A.1. Project data base listed by Lab of Anthropology (LA) site number, survey project affiliation, archaeological period, site type, and percentages of Pedernal chert, basalt, obsidian, and local non-Pedernal chert. Note: sites recorded by the PARP do not list local chert percentages.

Key:

PARP: Pajario Archaeological Research Project	CS: Classic Period
BASP: Bandelier Archaeological Survey Project	PB: Pueblo Structure
CO: Coalition Period	SS: Field House Structure

LA No.	Dbase	Period	Sitetype	Pedernal Chert %	Obsidian %	Basalt %	Local chert %
5	PARP	CS	SS	30	15	50	
42	BASP	CS	PB	83.87	11.29	0	1.61
78	BASP	CS	PB	12.22	10	76.67	0
82	BASP	CS	PB	9.84	34.43	52.46	0
211	BASP	CS	PB	59.57	27.83	2.61	6.96
250	BASP	CS	PB	12.21	30.53	54.2	1.27
350	PARP	CO	PB	70	5	20	
351	PARP	CO	PB	70	5	20	
370	BASP	CS	PB	12.93	27.89	46.26	2.72
3752	BASP	CO	PB	3.33	56.67	40	0
3752	BASP	CO	PB	6.45	41.94	51.61	0
3755	BASP	CO	PB	6.67	16.67	76.67	0
3760	BASP	CO	PB	30	23.33	46.67	0
3766	BASP	CS	PB	12.5	15.63	71.87	0
3768	BASP	CS	PB	15.15	6.06	69.7	3.03
3769	BASP	CS	PB	6.67	26.67	66.67	0
3770	BASP	CS	PB	0	22.58	77.42	0
3771	BASP	CO	PB	3.33	30	63.33	3.33
3771	BASP	CS	SS	3.03	63.64	33.33	0
3772	BASP	CS	SS	3.23	83.87	12.9	0
3782	BASP	CS	PB	23.33	0	73.33	0
3783	BASP	CS	PB	22.86	0	74.29	0
3790	BASP	CO	PB	3.33	6.67	90	0
3793	BASP	CS	SS	0	81.82	15.15	0
3799	BASP	CO	SS	20	26.67	50	0
3801	BASP	CS	SS	6.67	63.33	30	0
3811	BASP	CO	SS	0	65.62	34.38	0
3812	BASP	CS	PB	22.86	11.43	65.71	0
3813	BASP	CS	SS	18.75	21.87	56.25	0
3814	BASP	CO	PB	10	20	60	0
3821	BASP	CO	PB	10.53	45.61	42.11	0
3826	BASP	CS	SS	3.12	34.38	62.5	0
3827	BASP	CS	SS	6.06	45.45	39.39	0
3834	BASP	CS	SS	12.9	9.68	67.74	3.23
3838	BASP	CS	PB	6.45	35.48	54.84	3.23
3840	BASP	CS	PB	16	42.67	38.67	0
3842	BASP	CO	PB	16.67	3.33	73.33	3.33
3848	BASP	CO	PB	15.15	12.12	66.67	0
3851	BASP	CO	PB	9.38	18.75	68.75	0
3852	BASP	CO	PB	12.5	9.38	68.75	0
3858	BASP	CO	PB	15.15	3.03	81.82	0
4602	PARP	CO	PB	97	.5	2	
4604	PARP	CO	PB	93	5	1	
4605	PARP	CO	PB	98	1	1	
4606	PARP	CO	PB	98	1	1	
4607	PARP	CO	PB	75	5	18	
4607	PARP	CO	PB	75	5	20	

LA No.	Dbase	Period	Sitetype	Pedernal Chert %	Obsidian %	Basalt %	Local chert %
4608	PARP	CO	PB	78	15	5	
4609	PARP	CO	PB	80	10	10	
4616	PARP	CO	PB	40	20	40	
4618	PARP	CO	PB	50	10	40	
4619	PARP	CO	PB	60	5	35	
4620	PARP	CO	PB	45	10	44	
4621	PARP	CO	PB	50	10	40	
4622	PARP	CO	PB	45	10	45	
4623	PARP	CO	PB	65	4	30	
4624	PARP	CO	PB	50	10	35	
4639	PARP	CO	SS	85	5	10	
4688	PARP	CO	PB	50	25	25	
4690	PARP	CO	PB	50	25	25	
4693	PARP	CO	PB	35	4	60	
4708	PARP	CO	PB	50	1	49	
5137	PARP	CS	PB	3	7	90	
9781	PARP	CO	PB	28	10	60	
9787	PARP	CS	SS	5	5	90	
9791	PARP	CS	SS	25	20	55	
9821	PARP	CS	PB	30	60	10	
9842	PARP	CO	PB	10	40	40	
9843	PARP	CS	SS	0	5	94	
9845	PARP	CO	PB	20	10	70	
9849	PARP	CS	PB	15	75	10	
9850	PARP	CS	PB	15	65	10	
9851	PARP	CS	PB	40	50	10	
9853	PARP	CS	SS	25	5	70	
9856	PARP	CS	PB	0	99	1	
9863	PARP	CO	PB	10	10	80	
9870	PARP	CO	SS	15	15	60	
9904	PARP	CO	SS	0	10	90	
9908	PARP	CS	SS	2	25	70	
10942	BASP	CS	PB	2.78	63.89	33.33	0
12119	BASP	CO	PB	12.07	6.9	79.31	0
12125	BASP	CS	SS	0	0	100	0
12198	PARP	CS	SS	10	30	60	
12211	PARP	CO	PB	30	15	30	
12215	PARP	CS	SS	20	10	70	
12247	PARP	CS	PB	25	25	45	
12259	PARP	CO	SS	30	30	40	
12609	PARP	CO	PB	95	2	3	
12641	PARP	CO	PB	18	80	2	
12641	PARP	CO	PB	50	35	15	
12641	PARP	CO	SS	0	95	5	
12664	PARP	CO	PB	40	30	30	
12664	PARP	CO	SS	30	35	35	
12668	PARP	CO	SS	0	0	100	
12668	PARP	CO	SS	0	0	100	
12668	PARP	CO	SS	10	0	90	
12685	PARP	CO	PB	20	20	60	
12702	PARP	CO	PB	50	10	40	
13660	BASP	CS	SS	6.45	16.13	70.97	3.23
15865	PARP	CO	PB	0	60	40	
16036	BASP	CO	PB	3.23	0	96.77	0
16036	BASP	CO	PB	15.63	3.12	78.12	0

LA No.	Dbase	Period	Sitetype	Pedernal Chert %	Obsidian %	Basalt %	Local chert %
16048	BASP	CS	SS	0	32.35	67.65	0
16062	BASP	CO	PB	3.33	3.33	93.33	0
16062	BASP	CO	PB	9.68	6.45	80.65	0
16062	BASP	CO	PB	18.75	15.63	62.5	0
16066	BASP	CO	SS	3.23	16.13	77.42	0
16071	BASP	CO	PB	22.58	29.03	48.39	0
16075	BASP	CO	SS	3.33	50	46.67	0
16800	PARP	CO	PB	49	2	49	
21285	PARP	CO	PB	45	10	40	
21291	PARP	CO	PB	65	10	25	
21307	PARP	CO	PB	80	5	14	
21312	PARP	CO	PB	55	5	40	
21313	PARP	CO	PB	10	5	85	
21321	PARP	CO	SS	0	40	60	
21328	PARP	CO	PB	45	10	45	
21329	PARP	CO	PB	70	10	20	
21343	PARP	CO	PB	29	10	60	
21345	PARP	CO	PB	40	1	59	
21346	PARP	CO	PB	85	7	7	
21348	PARP	CO	PB	25	25	49	
21351	PARP	CO	PB	33	33	34	
21353	PARP	CO	SS	35	40	25	
21356	PARP	CO	PB	81	8	10	
21360	PARP	CO	PB	30	9	70	
21366	PARP	CO	PB	75	1	24	
21378	PARP	CO	PB	15	75	10	
21381	PARP	CO	SS	40	30	30	
21389	PARP	CO	PB	74	5	20	
21396	PARP	CO	PB	15	5	80	
21398	PARP	CO	PB	60	9	30	
21400	PARP	CO	PB	45	15	40	
21402	PARP	CS	SS	25	25	50	
21403	PARP	CO	SS	35	20	45	
21408	PARP	CO	PB	15	45	40	
21466	PARP	CO	PB	90	5	5	
21467	PARP	CO	SS	0	100	0	
21468	PARP	CO	SS	50	0	50	
21469	PARP	CO	PB	30	60	5	
21472	PARP	CO	SS	90	7	3	
21474	PARP	CO	PB	70	5	20	
21475	PARP	CO	PB	68	10	20	
21476	PARP	CO	SS	60	30	10	
21478	PARP	CO	PB	68	2	30	
21485	PARP	CO	SS	75	20	5	
21489	PARP	CO	PB	80	15	5	
21490	PARP	CO	PB	100	0	0	
21491	PARP	CO	SS	0	100	0	
21493	PARP	CS	SS	100	0	0	
21495	PARP	CS	SS	0	0	0	
21496	PARP	CO	SS	100	0	0	
21498	PARP	CO	PB	33	66	0	
21501	PARP	CO	PB	70	25	0	
21603	PARP	CO	SS	70	30	0	
21604	PARP	CO	PB	85	7	6	
21674	PARP	CO	PB	85	8	7	

LA No.	Dbase	Period	Sitetype	Pedernal Chert %	Obsidian %	Basalt %	Local chert %
21676	PARP	CO	PB	60	20	20	
21677	PARP	CO	PB	100	0	0	
21678	PARP	CO	SS	90	6	2	
21679	PARP	CO	PB	60	25	13	
21680	PARP	CO	PB	78	5	5	
21681	PARP	CO	SS	33	33	33	
21688	PARP	CO	PB	50	30	30	
21689	PARP	CO	PB	60	20	20	
21690	PARP	CO	PB	60	20	20	
29624	PARP	CS	SS	20	5	75	
29626	PARP	CS	SS	27	3	70	
29627	PARP	CS	SS	20	20	60	
29653	PARP	CS	SS	15	0	85	
29659	PARP	CS	PB	40	10	50	
29666	PARP	CS	SS	10	10	80	
29672	PARP	CO	PB	5	5	90	
29673	PARP	CS	SS	10	15	0	
29674	PARP	CO	SS	0	45	45	
29677	PARP	CS	SS	4	1	95	
29678	PARP	CS	SS	7	3	90	
29679	PARP	CS	SS	5	20	75	
29682	PARP	CO	PB	50	10	40	
29683	PARP	CO	PB	7	3	90	
29687	PARP	CS	SS	10	39	50	
29689	PARP	CS	SS	10	50	40	
29690	PARP	CS	SS	5	55	40	
29691	PARP	CO	PB	95	1	3	
29692	PARP	CO	PB	88	10	0	
29697	PARP	CO	SS	50	20	0	
29700	PARP	CO	PB	95	0	5	
29701	PARP	CO	PB	95	5	0	
29707	PARP	CO	PB	90	10	0	
29708	PARP	CO	PB	80	10	5	
29709	PARP	CO	PB	80	10	5	
29710	PARP	CO	PB	85	10	0	
29711	PARP	CO	PB	100	0	0	
29712	PARP	CO	PB	80	5	15	
29719	PARP	CO	PB	50	50	0	
29720	PARP	CO	PB	40	55	5	
29722	PARP	CO	SS	55	5	40	
29728	PARP	CO	SS	30	20	50	
29734	PARP	CS	SS	100	0	0	
29738	PARP	CO	PB	97	2	1	
29738	PARP	CO	PB	100	0	0	
29739	PARP	CO	SS	95	5	0	
29740	PARP	CO	PB	98	1	1	
29741	PARP	CO	SS	60	35	0	
29743	PARP	CO	PB	75	23	2	
29744	PARP	CO	PB	90	10	0	
29745	PARP	CO	PB	100	0	0	
29746	PARP	CO	PB	90	9	1	
29747	PARP	CO	PB	50	50	0	
29750	PARP	CO	SS	88	5	2	
29751	PARP	CO	PB	60	38	2	
29753	PARP	CO	SS	100	0	0	

LA No.	Dbase	Period	Sitetype	Pedernal Chert %	Obsidian %	Basalt %	Local chert %
29756	PARP	CO	PB	35	10	35	
29763	PARP	CO	SS	80	5	10	
29764	PARP	CO	PB	70	10	10	
29765	PARP	CO	PB	80	5	10	
29766	PARP	CO	PB	70	10	20	
29767	PARP	CO	PB	75	5	10	
29769	PARP	CO	PB	75	5	10	
29774	PARP	CO	PB	89	10	0	
29777	PARP	CO	PB	40	18	40	
29779	PARP	CO	SS	0	0	100	
29783	PARP	CO	PB	75	15	5	
29784	PARP	CO	PB	80	1	18	
29785	PARP	CO	PB	90	5	4	
29786	PARP	CO	SS	40	30	5	
29789	PARP	CO	PB	28	2	70	
29795	PARP	CO	PB	35	3	60	
29800	PARP	CO	SS	15	15	70	
29803	PARP	CS	SS	20	10	70	
29806	PARP	CS	SS	10	15	75	
29807	PARP	CS	SS	25	25	50	
29814	PARP	CO	PB	45	10	45	
29816	PARP	CO	SS	10	10	80	
29819	PARP	CO	PB	45	10	45	
29822	PARP	CO	SS	15	5	80	
29823	PARP	CO	PB	25	15	60	
29824	PARP	CS	PB	20	10	70	
29825	PARP	CO	SS	30	10	60	
29829	PARP	CO	SS	20	10	70	
29833	PARP	CS	SS	30	18	50	
29834	PARP	CS	PB	30	10	60	
29835	PARP	CS	PB	35	35	30	
29837	PARP	CS	SS	30	10	60	
29839	PARP	CS	SS	5	10	85	
29840	PARP	CO	PB	45	9	45	
29841	PARP	CS	PB	20	10	70	
29845	PARP	CS	SS	0	10	80	
29846	PARP	CS	SS	5	14	80	
29847	PARP	CS	SS	0	20	80	
29849	PARP	CS	PB	5	15	80	
29850	PARP	CO	SS	15	3	81	
29851	PARP	CS	SS	20	5	75	
29852	PARP	CS	SS	5	15	80	
29853	PARP	CS	PB	60	15	20	
29854	PARP	CS	SS	10	30	60	
29855	PARP	CS	SS	30	10	50	
29858	PARP	CS	SS	5	25	70	
29859	PARP	CS	SS	10	80	10	
29862	PARP	CS	SS	5	65	25	
29863	PARP	CO	SS	30	20	50	
29864	PARP	CS	SS	10	60	20	
29867	PARP	CO	PB	10	65	25	
29869	PARP	CS	PB	0	80	20	
29871	PARP	CS	SS	10	10	80	
29873	PARP	CO	PB	10	10	80	
29880	PARP	CS	SS	28	30	40	

LA No.	Dbase	Period	Sitetype	Pedernal Chert %	Obsidian %	Basalt %	Local chert %
29883	PARP	CS	SS	40	20	40	
50918	BASP	CO	SS	9.68	6.45	38.71	38.71
50932	BASP	CS	SS	0	53.33	46.67	0
50942	BASP	CO	SS	0	70.59	29.41	0
50943	BASP	CO	SS	5.8	43.48	49.28	1.45
50953	BASP	CO	PB	20.49	11.48	64.75	.82
50954	BASP	CS	SS	6.67	36.67	50	0
50955	BASP	CO	PB	19.35	16.13	64.52	0
50956	BASP	CS	SS	13.33	20	60	0
50970	BASP	CS	PB	14.74	47.37	36.84	0
50971	BASP	CS	PB	6.25	40.63	46.88	0
50974	BASP	CS	PB	9.52	31.75	34.92	1.59
50995	BASP	CS	SS	11.43	37.14	51.43	0
50999	BASP	CS	SS	2.44	31.71	65.85	0
51000	BASP	CS	SS	6.67	36.67	56.67	0
53154	BASP	CS	SS	6.45	6.45	83.87	0
53155	BASP	CS	SS	0	72.5	27.5	0
53163	BASP	CO	PB	13.79	8.05	75.86	0
53181	BASP	CO	PB	43.33	0	50	3.33
53195	BASP	CS	SS	3.33	13.33	83.33	0
60056	BASP	CO	SS	0	90.32	6.45	0
60060	BASP	CS	SS	3.33	66.67	30	0
60065	BASP	CO	PB	13.46	7.69	75	3.85
60070	BASP	CS	PB	16.67	10	73.33	0
60078	BASP	CS	SS	0	35.48	64.52	0
60094	BASP	CO	SS	3.09	61.86	35.05	0
60096	BASP	CS	SS	5.88	61.76	29.41	0
60099	BASP	CS	SS	0	38.24	61.76	0
60104	BASP	CS	PB	10	6.67	83.33	0
60109	BASP	CS	SS	3.33	73.33	20	3.33
60131	BASP	CS	SS	0	70.97	29.03	0
60149	BASP	CS	SS	5.88	20.59	58.82	0
60189	BASP	CS	SS	3.33	6.67	83.33	0
60196	BASP	CS	SS	9.38	15.63	43.75	0
60199	BASP	CS	SS	8.57	0	62.86	0
60202	BASP	CS	SS	13.33	6.67	46.67	0
60216	BASP	CS	SS	12.5	28.12	43.75	0
60217	BASP	CS	SS	6.06	6.06	69.7	0
60218	BASP	CS	SS	3.33	6.67	66.67	3.33
60229	BASP	CS	PB	13.33	13.33	40	0
60235	BASP	CS	SS	10	3.33	56.67	3.33
60254	BASP	CS	SS	13.33	6.67	60	0
60255	BASP	CS	PB	10.26	5.13	74.36	2.56
60258	BASP	CS	PB	23.33	0	70	0
60260	BASP	CO	PB	10	86.67	3.33	0
60270	BASP	CS	SS	2.7	8.11	89.19	0
60272	BASP	CS	SS	0	37.5	62.5	0
60276	BASP	CO	SS	0	70.59	29.41	0
60280	BASP	CS	SS	0	73.33	26.67	0
60281	BASP	CS	SS	0	39.39	60.61	0
60282	BASP	CS	PB	16.67	6.67	76.67	0
60293	BASP	CS	SS	13.51	5.41	81.08	0
60301	BASP	CO	SS	0	36.67	63.33	0
60333	BASP	CO	PB	6.67	33.33	50	3.33
60351	BASP	CO	SS	8.57	2.86	88.57	0

LA No.	Dbase	Period	Sitetype	Pedernal Chert %	Obsidian %	Basalt %	Local chert %
60353	BASP	CO	PB	6.67	10	83.33	0
60372	BASP	CO	PB	38.89	2.78	50	2.78
60415	BASP	CS	PB	3.23	3.23	93.55	0
60419	BASP	CS	SS	3.33	0	96.67	0
60447	BASP	CS	SS	3.12	28.12	65.62	0
60462	BASP	CS	SS	2.33	59.3	33.72	0
60476	BASP	CO	SS	2.86	60	31.43	0
60481	BASP	CO	PB	28.21	4.27	64.96	0
60490	BASP	CS	SS	3.57	17.86	76.79	0
60492	BASP	CS	SS	26.67	36.67	23.33	6.67
60543	BASP	CS	PB	3.33	3.33	70	23.33
60550	BASP	CS	PB	10	76.67	13.33	0
61049	BASP	CS	PB	66.67	13.33	13.33	3.33
65593	BASP	CS	SS	2.7	18.92	27.03	48.65
65608	BASP	CS	SS	8.57	20	62.86	5.71
65615	BASP	CO	PB	16.67	10	63.33	10
65627	BASP	CS	SS	16.67	13.33	60	3.33
65630	BASP	CS	SS	0	87.76	12.24	0
65645	BASP	CS	SS	0	20	50	3.33
65649	BASP	CS	SS	0	10	80	6.67
65657	BASP	CS	PB	70	6.67	6.67	10
65692	BASP	CS	SS	0	75	21.87	0
65702	BASP	CO	PB	75	15	8.33	0
65705	BASP	CS	SS	13.33	30	56.67	0
65712	BASP	CS	SS	76.67	3.33	16.67	0
65731	BASP	CO	PB	13.79	19.54	66.67	0
65733	BASP	CS	SS	0	76.67	23.33	0
65735	BASP	CS	SS	8.33	52.78	36.11	0
65736	BASP	CS	SS	0	46.88	43.75	0
65737	BASP	CS	SS	10	50	40	0
65748	BASP	CS	PB	73.33	6.67	10	6.67
65762	BASP	CS	SS	0	56.25	43.75	0
65768	BASP	CS	SS	8.11	40.54	51.35	0
65774	BASP	CO	SS	20.31	7.81	67.19	0
65775	BASP	CO	PB	31.25	6.25	56.25	3.12
65776	BASP	CO	PB	46.74	5.43	41.3	0
65786	BASP	CS	SS	12.12	21.21	60.61	3.03
65788	BASP	CO	PB	21.59	27.27	51.14	0
65789	BASP	CO	PB	27.96	12.9	55.91	1.08
65792	BASP	CO	PB	38.71	12.9	48.39	0
65794	BASP	CS	SS	31.25	21.87	46.88	0
65809	BASP	CO	PB	36.67	16.67	46.67	0
65818	BASP	CS	SS	3.23	70.97	25.81	0
65826	BASP	CO	SS	13.33	33.33	53.33	0
65832	BASP	CS	SS	0	75.76	24.24	0
65850	BASP	CO	SS	3.33	36.67	46.67	0
70764	BASP	CS	SS	3.33	96.67	0	0
70766	BASP	CS	SS	3.33	20	76.67	0
70770	BASP	CS	SS	12.9	9.68	67.74	3.23
70775	BASP	CO	SS	2.86	82.86	11.43	0
70781	BASP	CS	SS	0	86.67	13.33	0
70782	BASP	CO	SS	0	20	73.33	3.33
70787	BASP	CO	PB	3.39	5.08	89.83	1.69
70789	BASP	CS	SS	0	28.95	71.05	0
70794	BASP	CS	SS	3.33	36.67	60	0

LA No.	Dbase	Period	Sitetype	Pedernal Chert %	Obsidian %	Basalt %	Local chert %
70796	BASP	CO	PB	22.86	5.71	71.43	0
70808	BASP	CS	SS	3.12	37.5	59.38	0
70817	BASP	CS	SS	8.33	27.78	58.33	0
70825	BASP	CS	SS	6.45	41.94	51.61	0
70829	BASP	CS	SS	12.9	25.81	54.84	3.23
70840	BASP	CO	PB	9.38	3.12	87.5	0
70841	BASP	CS	SS	6.67	60	26.67	3.33
70844	BASP	CS	SS	2.94	55.88	41.18	0
70849	BASP	CO	SS	16.67	3.33	80	0
70859	BASP	CO	SS	24.32	2.7	70.27	0
70862	BASP	CS	SS	10	20	56.67	13.33
70867	BASP	CO	PB	32.26	9.68	58.06	0
70869	BASP	CO	PB	30	3.33	63.33	3.33
70886	BASP	CO	PB	30.3	3.03	60.61	0
70889	BASP	CO	PB	18.75	25	43.75	3.12
70890	BASP	CO	PB	11.11	8.33	69.44	0
70890	BASP	CO	PB	11.43	0	77.14	0
70892	BASP	CS	SS	7.5	35	35	7.5
70913	BASP	CO	PB	32.76	10.34	32.76	6.9
70914	BASP	CS	SS	0	16.13	64.52	0
70924	BASP	CS	SS	3.33	16.67	53.33	6.67
70924	BASP	CS	SS	18.18	15.15	48.48	6.06
70946	BASP	CO	SS	30	10	48.33	3.33
70960	BASP	CS	SS	53.33	33.33	10	0
70963	BASP	CS	PB	3.33	53.33	13.33	6.67
70970	BASP	CS	SS	35.48	58.06	3.23	3.23
70995	BASP	CO	PB	20	10	66.67	0
71000	BASP	CS	PB	20.69	6.9	70.11	0
71003	BASP	CS	SS	3.33	30	66.67	0
71015	BASP	CS	SS	16.67	30	53.33	0
71030	BASP	CS	SS	21.21	9.09	57.58	0
71038	BASP	CO	PB	35.14	2.7	59.46	0
71038	BASP	CO	SS	23.08	2.56	71.79	0
71041	BASP	CO	PB	25.95	9.16	64.12	0
71045	BASP	CS	SS	12.5	55	27.5	2.5
71049	BASP	CS	SS	3.33	33.33	63.33	0
71057	BASP	CS	PB	20	8.57	62.86	8.57
71065	BASP	CS	SS	14.71	35.29	32.35	8.82
71067	BASP	CS	SS	20	13.33	66.67	0
71072	BASP	CS	SS	0	63.89	36.11	0
71083	BASP	CS	SS	6.25	6.25	78.12	0
71103	BASP	CS	SS	3.33	6.67	90	0
71137	BASP	CS	SS	13.33	30	36.67	20
71140	BASP	CS	SS	0	100	0	0
71141	BASP	CS	SS	0	40	46.67	6.67
71157	BASP	CS	SS	0	2.94	97.06	0
77577	BASP	CO	SS	5.56	5.56	83.33	0
77580	BASP	CS	SS	9.68	32.26	54.84	0
77596	BASP	CO	PB	5.88	8.82	79.41	0
77597	BASP	CO	PB	6.67	13.33	80	0
77606	BASP	CS	SS	3.23	93.55	3.23	0
77619	BASP	CS	SS	6.67	40	53.33	0
77621	BASP	CO	PB	41.94	12.9	38.71	0
77624	BASP	CS	SS	0	50	47.37	0
77629	BASP	CS	SS	5.56	36.11	58.33	0

LA No.	Dbase	Period	Sitetype	Pedernal Chert %	Obsidian %	Basalt %	Local chert %
77645	BASP	CS	SS	0	18.75	81.25	0
77647	BASP	CO	PB	10.94	3.12	82.81	1.56
77651	BASP	CO	PB	12.12	30.3	57.58	0
77661	BASP	CS	SS	0	78.95	21.05	0
77684	BASP	CO	PB	12.62	20.39	66.99	0
77691	BASP	CS	PB	27.12	45.76	25.42	0
77695	BASP	CS	SS	0	16.67	83.33	0
77716	BASP	CS	PB	3.33	56.67	40	0
77718	BASP	CS	SS	0	0	100	0
77742	BASP	CS	SS	2.56	20.51	69.23	0
77744	BASP	CO	PB	6.67	3.33	86.67	0
77748	BASP	CS	SS	0	67.74	32.26	0
77751	BASP	CO	PB	10	25	60	0
77753	BASP	CO	SS	0	96.87	0	0
77755	BASP	CO	SS	0	13.33	80	0
77767	BASP	CO	SS	6.45	19.35	70.97	0
77770	BASP	CO	SS	0	68.75	31.25	0
77771	BASP	CS	SS	3.12	3.12	93.75	0
77772	BASP	CO	SS	18.42	0	81.58	0
77774	BASP	CS	SS	0	13.33	76.67	0
77812	BASP	CS	SS	0	35.48	64.52	0
77828	BASP	CS	SS	0	56.67	43.33	0
77842	BASP	CS	SS	0	96.77	3.23	0
84004	BASP	CS	SS	3.33	33.33	50	6.67
84028	BASP	CS	SS	0	96.67	3.33	0
84035	BASP	CS	SS	0	4.65	93.02	0
84042	BASP	CS	SS	0	25	75	0
84060	BASP	CO	PB	13.33	0	80	0
84064	BASP	CS	SS	0	10	90	0
84103	BASP	CO	SS	50	13.16	28.95	0
84110	BASP	CS	SS	12.12	21.21	66.67	0
84146	BASP	CS	PB	5.26	57.89	36.84	0