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Editor

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National Biological Service

and

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P.O. Box 5614
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Flagstaff, Arizona 86011

Second Biennial Conference of Research on the Colorado Plateau
Northern Arizona University
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Contents

Foreword

The papers in this volume are contributions from National Biological Service (NBS) scientists, university students, and resource managers throughout the Colorado Plateau. The focus of all studies in this volume is on providing baseline scientific information on the physical, cultural, and natural resources of the Colorado Plateau. Support for these studies came from a myriad of federal, state, and private partners concerned about the well-being of the Plateau's resources.

The rich variety of the 68 presentations given at the conference and the 16 papers included here reflects the diversity of science presently being carried out on the Colorado Plateau. I applaud the effort of the contributors who, with modest funding and a broad base of public and institutional support, have pursued important lines of work in the four states that make up this vast biogeographic region.

All across America, we face the prospect of extensive environmental changes that will continue to affect the physical, cultural, and natural resources on our federal lands. As the biological and ecological research branch of the Department of the Interior, we in the NBS are committed to providing sound scientific information that can be used by both public lands managers and private landowners to conserve and manage natural resources.

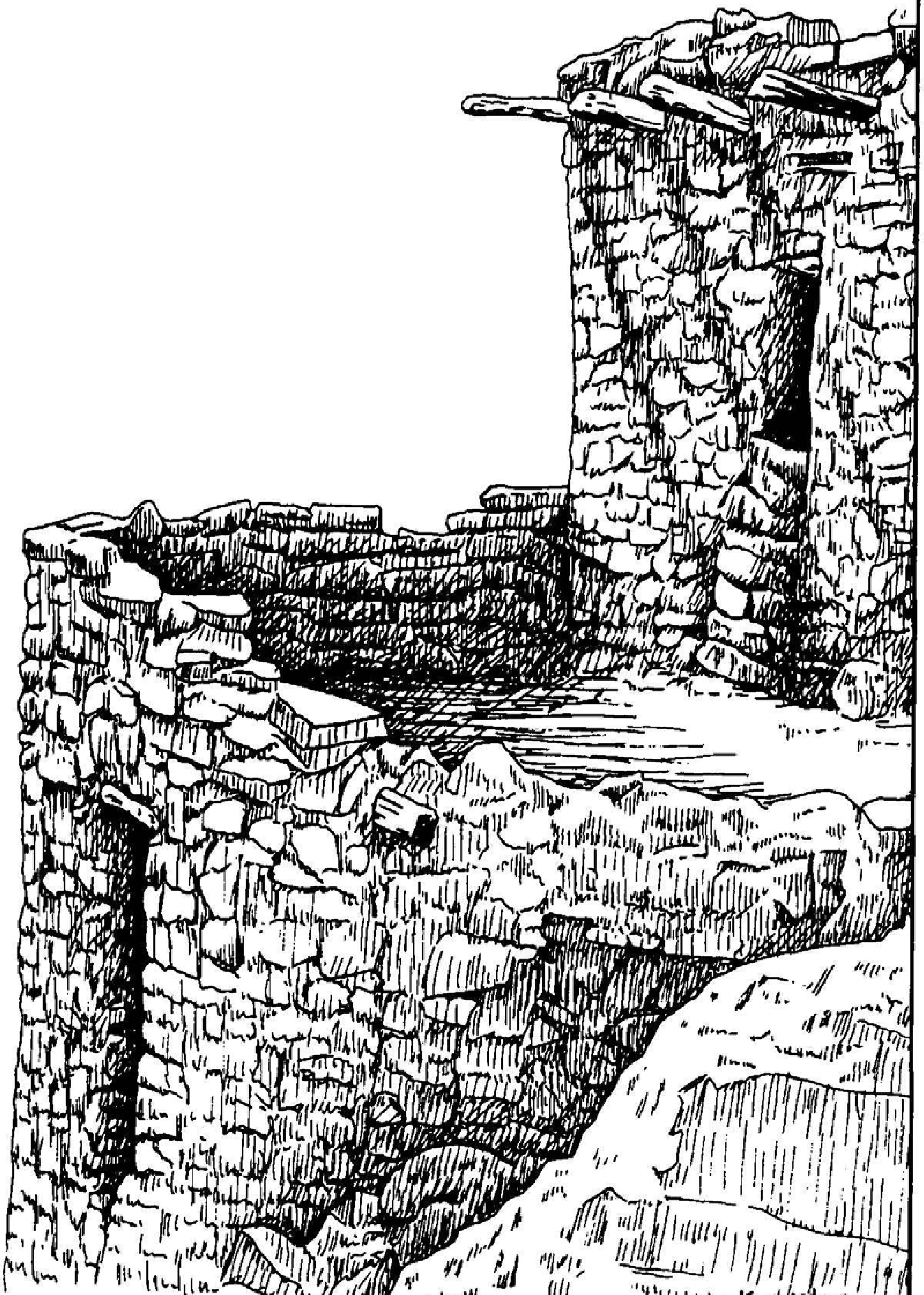
National parks represent the best remaining examples of America's natural ecosystems and, as such, are baselines for measuring future change. To protect parks and other federal lands, we must increase our efforts to inventory and monitor their biological resources, to understand the factors, both natural and human-induced, that threaten them, and to assist with the design of resource management programs that will ensure that future generations can use and enjoy them as we have.

In short, we must provide the sound science needed to conserve and manage the natural resources that sustain us, inspire us, and represent our biological and environmental heritage.

H. RONALD PULLIAM

Director
National Biological Service

Cultural Resources



Radiocarbon Record for Archaic Occupation of the Central Colorado Plateau

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Abstract. The traditional view of Archaic hunter–gatherer occupancy of the Colorado Plateau assumes population continuity and gradual evolutionary change. An alternative model contends that the Archaic period was punctuated by regional abandonments and reoccupations resulting in a succession of new lifeways and material culture. The numerous preceramic radiocarbon dates obtained from the central Colorado Plateau in the last 2 decades are tabulated and graphically summarized to provide a context for evaluating these two models. Long-term continuity in occupancy throughout the Archaic period is supported. Adaptive shifts that involved increased residential mobility and changes in settlement pattern probably account for previous gaps in the Colorado Plateau radiocarbon record, such as the 1,000-year interval during the middle Archaic (ca. 6000–5000 B.P. [before the present]). Because of the exceptional preservation of subsistence remains and perishable technology within numerous stratified dry shelters, copious paleoenvironmental data from a variety of sources, and occupation throughout the Archaic period, the central Colorado Plateau emerges as a highly productive area for studying hunter–gatherer adaptations and economic transitions, including the adoption of agriculture.

Key words: Archaic period, chronology, Glen Canyon, hunter–gatherers, Southwest prehistory.

Here I summarize the existing array of preceramic radiocarbon dates of the central Colorado Plateau (Fig. 1) to provide a context for examining two competing models of Archaic occupation. The first, regarded as the traditional concept of southwestern archaeologists, posits long-term continuity in hunter–gatherer occupancy marked by evolutionary changes and other alterations. The second model contends that hunter–gatherer occupancy was discontinuous—that the Archaic period was punctuated by a sequence of population abandonments

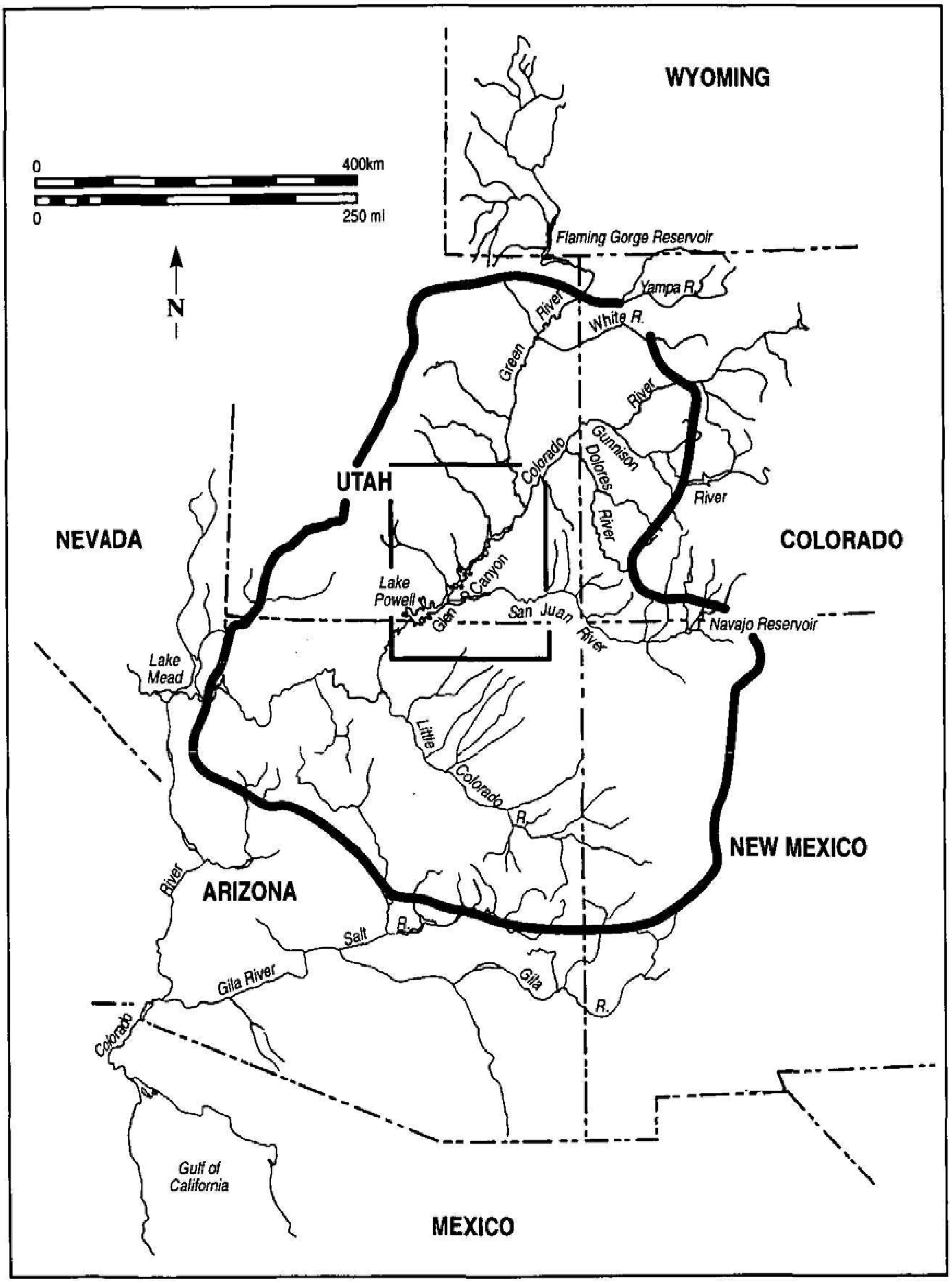

Fig. 1. Location of the central Colorado Plateau study area.

and reoccupations with new lifeways and material culture being introduced by each successive wave of hunter–gatherers (Berry and Berry 1986).

The notion of continuity in occupation during the Archaic period through the introduction of agriculture was implicit in the Pecos classification of the

1920's, which postulated that the Basketmaker II Anasazi were descendants of indigenous hunter–gatherers (Kidder 1924, 1927). This hypothetical stage of preagricultural development was designated Basketmaker I. Irwin-Williams (1967, 1973, 1979) has been the most influential recent advocate of in situ continuity in hunter–gatherer occupancy of the Colorado Plateau. Irwin-Williams (1979:35) claimed that, following abandonment by Paleo-Indians, "the northern Southwest was the focus of a long-term continuous development within the Archaic spectrum, which culminated ultimately in the formation of the central core of the relatively well-known sedentary Anasazi (Pueblo) culture." This model of continuous occupation throughout the Archaic period is so pervasive that many southwestern archaeologists consider it a fact rather than an assumption.

Few have challenged the model, but Berry and Berry (1986), with a strongly stated contrary position, are a notable exception (see Berry and Berry [1976:31–37] for the seedbed of their 1986 argument). In their opinion (Berry and Berry 1986:321),

> Its perpetuation in the literature owes more to the model's function as a self-fulfilling prophecy than it does to any consideration of empirical matters. A model that assumes continuity of occupation for millennial periods hardly fosters inquiry into the occurrence and nature of discontinuities. But continuity must be assumed if the primary research objective is "... firmly establishing and understanding an uninterrupted succession of human occupance of over a dozen millennia in the arid Southwest" (Haury 1983:159–160).

To evaluate the possibility of intermittent rather than continuous Archaic occupation, Berry and Berry (1986) analyzed the patterning of 288 radiocarbon dates before 1400 B.P. (before the present) from 119 southwestern sites. They concluded that the empirical evidence supports the contention that Archaic occupation of the Colorado Plateau was discontinuous.

The Region

The preceramic radiocarbon record we examined provides an excellent opportunity to evaluate the argument for and against continuous occupation. The 132 dates included in this study come from 64 sites scattered throughout a territory of approximately 45,000 km centered on Glen and Cataract canyons (Figs. 1 and

2). This region corresponds mostly with the Canyonlands section of the Colorado Plateau (Hunt 1974:278), a rugged area of renowned scenery—deep labyrinthian canyons bounded by colorful cliffs of mesas and plateaus and with a scattering of small mountain ranges. The region extends from the Rainbow Plateau and Monument Valley on the south to the Fremont River and Orange Cliffs on the north and from Boulder Mountain and Kaiparowits Plateau on the west to the Abajo Mountains and Comb Wash on the east. The patterning of

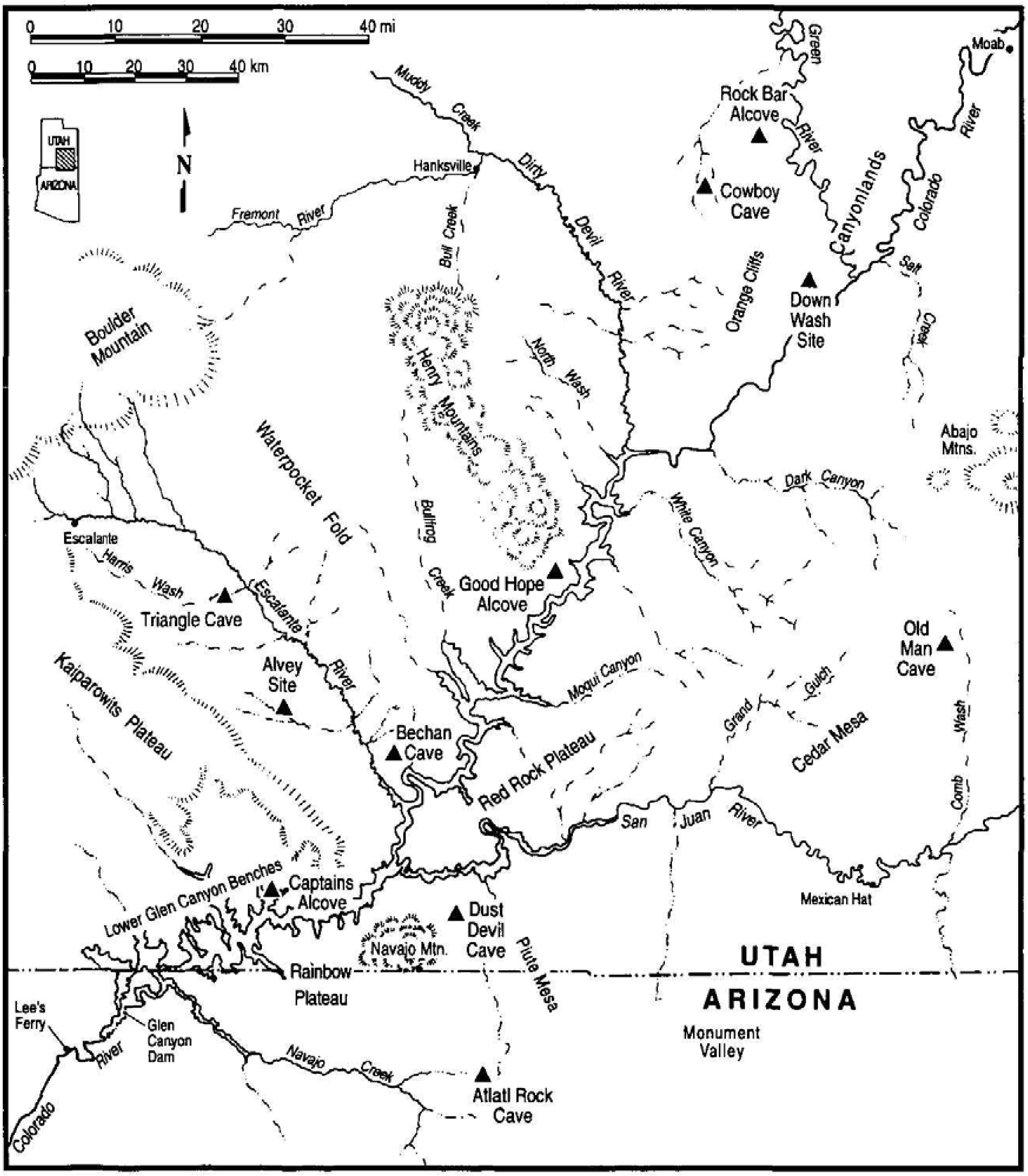

Fig. 2. The central Colorado Plateau showing the location of certain sites mentioned in the text and listed in Table 1.

radiocarbon dates analyzed here reflects human occupancy of a region considerably smaller than that examined by Berry and Berry (1986), yet the record for this central section of the Colorado Plateau should doubtless reflect the general trend on the plateau.

Key Sites

Most Archaic sites of the central Colorado Plateau have only been tested (limited excavation), so their principal contribution to this study is radiocarbon dates. These sites reveal that Archaic populations were residing throughout the region in diverse environmental settings. Two sites that help to flesh out the chronological skeleton with details of material remains and subsistence are Cowboy (north) and Dust Devil (south) caves, sites that geographically bracket the region (Fig. 2). Sandals and projectile points indicate that the Archaic groups using these two shelters had similar material culture inventories. Indeed, it is conceivable that a hunter–gatherer family group could have visited both sites, which, at 150 km apart, are within the potential long-term settlement shifts of human foragers.

Devil Cave and its nearby counterpart Sand Dune Cave[1] yielded the first conclusive evidence of Archaic culture within the central Colorado Plateau during excavations in 1961 (Lindsay et al. 1968). Sandals of previously undocumented style (open-twined) from the completely excavated Sand Dune Cave were radiocarbon dated from 8000 to 7000 B.P. (Lindsay et al. 1968), and identical sandals plus two other distinctive styles (fine warp-faced and plain-weave [coarse warp-faced]) were found during the test of Dust Devil Cave (Fig. 94 of Lindsay et al. 1968; Ambler 1994*). The subsequent total excavation of Dust Devil Cave in 1970 clarified the stratigraphic relation of the Archaic sandals and other remains, extended the range of the Archaic occupation back to almost 9000 B.P. (8830 ± 160 B.P.; Ambler 1994*), and provided much greater detail on subsistence (Van Ness 1986). Cultural deposition was relatively heavy during the early Archaic (stratum IV, ca. 8800–6700 B.P.), but a layer of essentially sterile eolian sand (stratum V) corresponding to the interval of roughly 6600–4000 B.P. reveals a significant alteration in the Archaic occu-

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[1] The archaeological significance of Sand Dune Cave is considerably less than that of Dust Devil because of excavation by arbitrary levels and the consequent mixing of materials from widely different periods (early Archaic through Pueblo).

pancy of Dust Devil Cave. Sparse late Archaic use of the site is evidenced by the recovery of Gypsum points from stratum VI (Geib and Ambler 1991).

Cowboy Cave (Jennings 1980), more than any other site, has had the most significant influence on our present understanding of Archaic culture–history and lifeways for the central Colorado Plateau. Besides being relatively rich in material remains, this site was excavated by natural rather than arbitrary levels, and the results were published in a timely manner. Furthermore, the changes in projectile point styles for the dated strata of Cowboy Cave were concordant with point style changes at Sudden Shelter (Jennings et al. 1980). On the strength of these results, Holmer (1978, 1980) outlined a chronology for Archaic point types for the northern Colorado Plateau, whereas Schroedl (1976) devised a phase system for the same region.[2] The depositional history of Cowboy Cave led Jennings to conclude that two significant occupational breaks had taken place during the Archaic use of the site—one ca. 6300–3700 B.P. and the other ca. 3200–2000 B.P. As at Dust Devil Cave, these hiatuses were represented by layers of eolian sand classified as sterile.

Two other sites deserving mention are Bechan Cave (Agenbroad et al. 1989) and Old Man Cave (Geib and Davidson 1995). Test excavations in Bechan Cave documented a single buried cultural layer without any stratigraphic separation (Agenbroad et al. 1989:338). The nine ^{14}C samples from this deposit ranged from almost 7800 to 1200 B.P., indicating mixed or poorly differentiated cultural deposition from over 6,000 years of site use. In lieu of separable cultural strata, the dates were grouped to form five cultural periods, and artifacts were assigned to each period. Whether or not the cultural periods are real, the dates are useful for this study, and their range reveals that the site holds promise for helping to understand the Archaic period.

Only a preliminary report is currently available on the recent excavations at Old Man Cave (Geib and Davidson 1995), so this site is as yet not well known. Nevertheless, the site provides an important radiocarbon record for the eastern edge of the study area, affords an excellent glimpse of early

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[2] The general applicability of Schroedl's phase system to the central Colorado Plateau is readily acknowledged, especially when contrasted with the Oshara phase system (Irwin-Williams 1973, 1979), which does not accurately represent the chronology and material remains found in and around Glen and Cataract canyons. Nevertheless, until greater detail on Archaic culture history of the study area and surrounding regions has been obtained, temporal subdivisions such as early, middle, and late Archaic provide preferred neutral alternatives for discussing portions of the long Archaic period (see Matson 1991).

Archaic subsistence based on the analysis of human feces (Hansen 1994), and has yielded open-twined sandals, among other perishable remains. As at both Cowboy and Dust Devil caves, a relatively intensive early Archaic occupation of Old Man Cave started drawing to a close during the seventh millennium B.P., terminating before 6,000 years ago. This hiatus or decline in site use ended when Basketmaker II agriculturalists began using the cave for storage and burial shortly after 2000 B.P.

Chronometric Data Base

More than 130 radiocarbon determinations from 64 sites of the central Colorado Plateau predate the use of ceramics and have clear cultural origins (Table 1). I have used 1600 B.P. as an appropriate time line cutoff for this study; it allows inclusion of the first practices of agriculture in the region (the Archaic to Formative transition) but excludes dates from the early Formative period (except perhaps for a few old wood determinations). Most of the dates listed in Table 1 were obtained in the past 10 years, so less than 15% have been included in previous summaries of Archaic radiocarbon dates (e.g., Schroedl 1976; Berry and Berry 1986). All standard dates (beta decay) are gas determinations made on wood charcoal from hearths or on perishable organics like yucca. Some of the dates on perishables are accelerator mass spectrometry (AMS) determinations, where the ratio of ^{14}C:^{12}C is directly measured. Determinations on materials subject to isotopic fractionation (Stuiver and Polach 1977) were corrected by either calculating actual ^{13}C:^{12}C ratios or using an assumed delta value.

Though all dates clearly have a cultural origin, in instances such as buried hearths exposed in arroyo cuts there is little or nothing in the way of associated artifacts. Some dates are on materials from multicomponent sites where stratigraphic context was lacking (surface artifacts) or obscured by poor excavation technique or previous disturbances. These dates are nonetheless useful for chronometric analysis because they are on materials of indisputable cultural origin, especially those on artifacts or human feces.

Dates on hearth charcoal can routinely overestimate the age of a cultural event by 200 years, with potential discrepancies of 500 years or more (Smiley 1985). This can lead to spurious conclusions about the chronology, use histories, and depositional rates—among other issues—of single sites and can be particularly confounding when attempting to trace the origin and spread of stylistic,

Table 1. Radiocarbon dates older than 1600 B.P. from the central Colorado Plateau.

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	$\delta^{13}C$[b]	Weight[c]	References and comments
Alvey Site (42KA172)	123	Beta-34942	1690 ± 80	Maize	–11.1	8.6	Geib (1993). Maize cob (FS 86) from level II (feature 31).
	116	AA-10373	1735 ± 50	Maize	(–10.0)	22.1	Maize cob (FS 124.1) from level I (feature 47).
	114	AA-10374	1755 ± 50	Maize	(–10.0)	22.1	Maize cob (FS 126.1) from level I (feature 47).
	107	AA-10375	1830 ± 50	Maize	(–10.0)	22.1	Maize cob (FS 152.3) from level I (feature 56).
	Rejected	Beta-34944	2260 ± 90	Maize	–10.8	6.8	Geib (1993). Maize cob (FS 126.2) from level I (feature 47). Rejected based on recently obtained additional maize dates from level I.
Atlatl Rock Cave	9	Beta-633306	7900 ± 60	Grass	–11.2	15.3	Grass padding (PN2.2 from open-twined sandal; PN2.1).
Beaucoup Alcove (42KA2753)	48	Beta-38342	3900 ± 60	Human fece	–20.7	15.3	One of 5 human feces collected from surface of alcove during its initial documentation. A rich site with an undoubtedly long history of occupation; this date provides the only evidence so far for a late Archaic component.
Bechan Cave (42KA2546)	93	GX-10501	2080 ± 140	Charcoal		2.8	Agenbroad et al. (1989:Appendix). Slab-lined hearth assigned to Cultural Period III.
	73	A-3516	2640 ± 50	Charcoal		22.1	Agenbroad et al. (1989:Appendix). Charcoal from auger test of cave, of uncertain context and associations. Assigned to Cultural Period III.
	42	A-3513	5500 ± 80	Charcoal		8.6	Agenbroad et al. (1989:Appendix).

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	$\delta^{13}C$[b]	Weight[c]	References and comments
							Charcoal from auger test of cave, of uncertain context and associations. Assigned to Cultural Period II.
	27	Beta-16025	6750 ± 120	Yucca	(–25.0)[d]	3.8	Agenbroad et al. (1989:Appendix). Small fragment of open-twined sandal assigned to Cultural Period I; a whole example of this sandal type also recovered.
	17	GX-10502	7525 ± 220	Charcoal		1.1	Agenbroad et al. (1989:Appendix). Associated with a lower occupational surface near central portion of site and assigned to Cultural Period I. A "squash gourd container" is supposedly associated with the hearth and living surface (Agenbroad et al. 1989:338), but this is well out of line with current evidence for cultigen use in the Southwest. Either the date is wrong or the association is misidentified.
	10	GX-10500	7795 ± 230	Charcoal		1.0	Agenbroad et al. (1989:Appendix). Charcoal lens or perhaps a hearth (cf. Agenbroad et al. 1989:338 and Fig. 3); assigned to Cultural Period I.
Benchmark Cave (42KA433)	55	AA-10376	3355 ± 50	Yucca	(–25.0)	22.1	Plain-weave sandal (FS35.1) from feature 17 (Lipe 1960); stratum 10 of the 1962 excavation (Sharrock 1964).
Captains Alcove	76	Beta-1749	2445 ± 85	Charcoal		7.6	Tipps (1984:Table 31). Hearth 3 of

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	$\delta^{13}C$[b]	Weight[c]	References and comments
(42KA265)							occupation B, subarea 2 of shelter.
	70	Beta-1750	2720 ± 205	Charcoal		1.3	Tipps (1984:Table 31). Hearth 2 of occupation B, subarea 2 of shelter.
	69	Beta-1748	2735 ± 115	Charcoal		4.2	Tipps (1984:Table 31). Same hearth as sample 64 above; average of these two is given as 2730 ± 100 B.P. (Tipps 1984:54).
	61	UGa-3254	3145 ± 105	Small log		5.0	Tipps (1984:Table 31). Log from lowest layer of test pit 8 in subarea 2 of shelter; thought to be associated with occupation A.
	49	Beta-1232	3760 ± 75	Charcoal		9.8	Tipps (1984:Table 31). Hearth 1 of occupation A, subarea 2 of shelter.
Casa Del Fuego (42GA3132)	40	Beta-35559	5880 ± 90	Disseminated charcoal in sediment		6.8	Tipps (1992b*[e]). Associated with five unlined pits originating from an old ground surface buried by ca. 1.8 m of dune sand. Overlying sediment component has a burned pithouse dated 1550 ± 60 (Beta-20671) and 1580 ± 60 (Beta-35560); this upper component contains both Elko and Rosegate (Rose Springs) points.
Co-op Site (42KA2756)	63	GX-11339	3000 ± 145	Charcoal	–22.6	2.6	Agenbroad et al. (1989:Appendix). Site and sample provenience documented in Bungart and Geib (1987*). Hearth 2 exposed in arroyo cut. A mano fragment and several chert pressure flakes in association. Hearth is stratigraphically

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	$\delta^{13}C$[b]	Weight[c]	References and comments
							above a date of 4330 ± 80 B.P. (sample 41) and below a date of 1290 ± 75 B.P. (GX-11338; Agenbroad et al. 1989:30) and 1060 ± 80 B.P. (Beta-16274; Bungart and Geib 1987*).
	46	Beta-16276	4330 ± 80	Charcoal		8.6	Bungart and Geib (1987*). Hearth 3 stratigraphically below previous sample and buried by ca. 8 m of alluvium. Associated debitage, 2 biface fragments, a mano fragment, but no diagnostics.
Cowboy Cave (42WN420)	108	Maize cache average	1824 ± 39	Maize and grass	−12.0 −15.6		Geib and Bungart (1989:42) discuss the dating problems with the Cowboy Cave maize. Stratum of origin is unknown but presumably derived from stratum Vb or Vc and associated with Rose Spring corner-notched arrow points and other remains (see Jennings 1980).
	103	UGa-1053	1890 ± 65	Charcoal		13.1	Jennings (1980:Table 3). Obtained during original test of cave in 1973; only a probable provenience (stratum Vb) is known.
	57	SI-2495	3330 ± 80	Grass	−15.6	8.6	Jennings (1980:Table 3). Listed as unproven since recovered during 1973 testing. Presumably from unit IV. The grass (*Sporobolus cryptandrus*) is from skin bag containing various items.
	53	SI-2998	3560 ± 75	Wood		9.8	Jennings (1980:Table 3). Stratum IVd; associated with Gypsum points and split-twig figurines, among numerous other

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	$\delta^{13}C^b$	Weight[c]	References and comments
							items.
	52	SI-2715	3635 ± 55	Charcoal		18.3	Jennings (1980:Table 3). Stratum IVc; associated with Gypsum points and split-twig figurines, among numerous other items.
	34	SI-2421	6390 ± 70	Charcoal		11.3	Jennings (1980:Table 3). Loose charcoal found in sterile red sand layer, stratum IVa. Date used as upper temporal bracket for unit III instead of the date (6675 ± 75 B.P., SI-2420) from stratum IIIi. No clear associations.
	30	SI-2420	6675 ± 75	Yucca	–24.3	9.8	Jennings (1980:Table 3). Sandal fragment of unspecified construction technique from stratum IIIi. Expected to provide terminal date of occupation for unit III, but the previous sample was used for the upper temporal bracket of this unit. Associated with Northern side-notched and Elko points, plain-weave sandals, and other remains.
	25	UGa-637	6830 ± 80	Charred wood		8.6	Jennings (1980:Table 3). Listed as probable from unit III; recovered during 1973 testing. No certain associations.
	21	SI-2419	7215 ± 75	Charcoal		9.8	Jennings (1980:Table 3). Loose charcoal from midden of stratum IIId. Associated with a Northern side-notched point, open-twined and plain-weave sandals, and other remains.

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	$\delta^{13}C$[b]	Weight[c]	References and comments
	7	SI-2418	8275 ± 80	Charcoal		8.6	Jennings (1980:Table 3). Loose charcoal from first thin cultural layer in cave, stratum IIb. Associated with open-twined sandals.
Doughnut Alcove (42KA3384)	79	Beta-30568	2320 ± 80	Grass	–24.5	8.6	Geib (1990a:268). Basketmaker II cache of three wooden tools wrapped in juniper bark mat fragment and grass (*Oryzopsis hymenoides*) and placed in a pit. No other associated remains or evidence of alcove use.
Down Wash Site (42WN1666)	130	Beta-34247	1640 ± 60	Charcoal		15.3	Horn (1990*). Stratum 6, feature 2 (slab-lined hearth) upper fill. Inconsistent with a date of 1440 ± 100 B.P. from lower fill of same hearth; probably because of burning of "old wood" (cf. Horn 1990*).
	111	Beta-34260	1790 ± 100	Charcoal		5.5	Horn (1990*). Stratum 6, feature 7 (hearth). No associated diagnostics.
	102	Beta-34253	1890 ± 70	Charcoal		11.3	Horn (1990*). Stratum 7, feature 10 (hearth). No associated diagnostics.
	100	Beta-21207	1960 ± 60	Charcoal		15.3	Horn (1990*). Hearth exposed in cutbank of locus C. No associated diagnostics.
	98	Beta-34244	2010 ± 70	Charcoal		11.3	Horn (1990*). Stratum 6, feature 1 (hearth). No associated diagnostics.
	91	Beta-34254	2140 ± 70	Charcoal		11.3	Horn (1990*). Stratum 6, feature 12 (hearth). No associated diagnostics.
	87	Beta-34252	2180 ± 60	Charcoal		15.3	Horn (1990*). Stratum 8, feature 13 (hearth). No associated diagnostics.

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	$\delta^{13}C$[b]	Weight[c]	References and comments
	86	Beta-34259	2200 ± 80	Charcoal		8.6	Horn (1990*). Stratum 8, feature 15 (hearth). No associated diagnostics. [Note: Table 4–2 of Horn 1990* lists this date as 220 ± 80 B.P., clearly a typographical error given the calibrated range for the date presented in that table and the plot of the dates in Fig. 4–30 of Horn's report.]
	82	Beta-34251	2280 ± 90	Charcoal		6.8	Horn (1990*). Stratum 7, feature 9 (hearth). No associated diagnostics.
	62	Beta-34255	3110 ± 170	Charcoal		1.9	Horn (1990*). Stratum 9, feature 11 (hearth). No associated diagnostics.
	60	Beta-16667	3180 ± 140	Charcoal		2.8	Agenbroad (1987*:see Figs. 91 and 92 for provenience information). Hearth exposed in arroyo cut of locus C. No associated remains.
	54	Beta-34257	3500 ± 150	Charcoal		2.5	Horn (1990*). Loose Charcoal from stratum 11A. No associated diagnostics.
	50	Beta-34256	3750 ± 120	Charcoal		3.8	Horn (1990*). Loose charcoal from stratum 11. No associated diagnostics.
	47	Beta-34258	4070 ± 140	Charcoal		2.8	Horn (1990*). Stratum 11A, feature 14 (hearth). No associated diagnostics.
Durffeys' Kitchen (42GA3133)	44	Beta-35561	4980 ± 130	Charcoal		3.3	Tipps (1992b*). Hearth at site. No associated diagnostics.
Dust Devil Cave (NA7613)	109	TX-852	1820 ± 80	Charcoal		8.6	Lindsay et al. (1968:108). Hearth 3 of alcove outside of cave proper. No certain associations.

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	δ13C[b]	Weight[c]	References and comments
	28	TX-1261	6740 ± 110	Charcoal		4.6	Ambler (1994:Table 1) Hearth 35, top of stratum IV.
	26	AA-10379	6785 ± 60	Yucca	(–25.0)	15.3	Plain-weave sandal from top of stratum IV.
	24	TX-1260	6840 ± 130	Yucca	(–25.0)[d]	3.3	Ambler (1994:Table 1). Plain-weave sandal, top of stratum IV.
	23	AA-10378	6890 ± 60	Yucca	(–25.0)	15.3	Plain-weave sandal from top of stratum IV.
	20	TX-1264	7250 ± 110	Charcoal		4.6	Ambler (1994:Table 1). Hearth 37, middle of stratum IV.
	19	TX-1263	7340 ± 110	Charcoal		4.6	Ambler (1994:Table 1). Loose charcoal, middle of stratum IV.
	14	TX-1262	7630 ± 120	Human feces	?	3.8	Ambler (1994:Table 1). Feces from top of stratum IVb. Not corrected for isotopic fractionation; given the C4 and CAM plants consumed during the early Archaic this date could be 100–200 years older.
	3	TX-1265	8730 ±110	Charcoal		4.6	Ambler (1994:Table 1). Hearth 32, bottom of stratum IV.
	2	TX-1266	8830 ±160	Yucca	(–25.0)[d]	2.2	Ambler (1994:Table 1). feature 17 (yucca-lined pit), bottom of stratum IV. Chapter 7 of this report discusses context and associations.
Good Hope Alcove (42GA3411)	15	Beta-31191	7560 ± 130	Yucca	–21.4	3.3	Open-twined sandal fragment from buried cultural deposit exposed at front of alcove because of erosion. Other associated remains include a mano, grinding slabs, and flakes but no other diagnostics.

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	$\delta^{13}C$[b]	Weight[c]	References and comments
The Hermitage (42KA443)	41	AA-10372	5665 ± 60	Yucca	(–25.0)	15.3	Plain-weave sandal (FS 24) from an aceramic midden deposit (feature 9). Site excavated by Lipe (1960).
	37	AA-10371	5890 ± 55	Grass	–12.1	18.3	Grass padding of plain-weave sandal (FS 19.1) from an aceramic midden deposit (feature 9).
Horse Canyon Rock Shelter (42GA3138)	80	Beta-39256	2320 ± 60	Charcoal		15.3	Tipps (1992b*). Hearth, middle of stratum II. No associated shelter diagnostics. Stratum III dates 1380 ± 70 B.P. (Beta-35318) whereas stratum IV dates 770 ± 60 B.P. (Beta-20673), so date sequence is internally consistent.
	67	Beta-35319	2760 ± 100	Charcoal		5.5	Tipps (1992b*). Hearth, bottom of stratum II. No associated diagnostics.
Lone Tree Dune (42SA363)	121	Y-1350	1700 ± 80	Burned beam		8.6	Jennings (1966:34); also Berry (1982:57). Beam in fill of shallow slab-lined Basketmaker II pithouse with a slab-lined entrance (Sharrock et al. 1963:151–161).
Long Canyon Dune (42GA3122)	83	Beta-20669	2250 ± 70	Charcoal		11.3	Tipps (1992b*). Hearth at site. No associated diagnostics.
Meister Knapper (42KA2745)	125	Beta-16271	1670 ± 70	Charcoal		11.3	Bungart and Geib (1987*). Slab-lined hearth at locus B.
Murphy (42SA8500)	117	Beta-20466	1730 ± 70	Charcoal		11.3	UPAC Newsletter, Vol. 7, No. 2, Table 1, 1989.
	68	Beta-20467	2740 ± 60	Charcoal		15.3	UPAC Newsletter, Vol. 7, No. 2, Table 1, 1989.

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	$\delta^{13}C$[b]	Weight[c]	References and comments
Old Man Cave (42SA21153)	112	Beta-47741	1790 ± 90	Juniper bark		6.8	Geib and Davidson (1995; Table 1). Basketmaker II burial (feature 3) originating from level 2.
	39	Beta-47008	5890 ± 70	Rodent feces	–24.6	11.3	Geib and Davidson (1995:Table 1). *Neotoma* feces from level 4, which along with level 3 seems to represent an interval of natural deposition (cultural hiatus?). This date was not used in Figs. 3 and 4 of this report.
	36	Beta-48141	6120 ± 70	Charcoal		11.3	Geib and Davidson (1995:Table 1). Hearth (feature 5) originating within level 5. Marks the end of early Archaic occupation of the shelter.
	29	Beta-47743	6730 ± 70	Charcoal		11.3	Geib and Davidson (1995:Table 1). Hearth (feature 10) associated with level 7.
	18	Beta-40116	7440 ± 100	Yucca	–22.1	5.5	Geib and Davidson (1995:Table 1). Open-twined sandal fragment found on surface of site in looter's backdirt; south-central part of shelter. Remainder of sandal housed at Edge of the Cedars (accession ECPR 84.6).
	16	Beta-47742	7560 ± 90	Grass	–12.79	6.8	Geib and Davidson (1995:Table 1). *Sporobolus* sp. chaff from lowest midden deposits (feature 11) in south-central portion of site.
	11	Beta-47007	7790 ± 80	Charcoal		8.6	Geib and Davidson (1995:Table 1). Basin hearth (feature 12) of level 12 cut into in sterile, calcified dune sand; marks

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	$\delta^{13}C^{b}$	Weight[c]	References and comments
							the start of cultural deposition at the site.
Pantry Alcove (42GA103)	129	Beta-34936	1640 ± 80	Maize	–12.0	8.6	Geib (1993). Maize cobs (FS49.1) from fill of cist 7 (feature 3a).
Perfect Ruin (42KA2687)	33	Beta-19920	6480 ± 70	Charcoal	11.3		Eininger (1987*). Hearth encountered below a Pueblo trash deposit in a 1- × 1-m test unit; hearth separated from Pueblo trash by only 3–8 cm of sand. Hearth has two separate use episodes; this sample and sample 30.
	32	Beta-19919	6500 ± 80	Charcoal		8.6	Eininger (1987*). See above.
Pittman (GG-69-18)	122	GX-2142	1695 ± 90	Charcoal		6.8	Matson (1991:90, sidebar). Slab-lined hearth built in fill of Basketmaker II pithouse. A rerun of this sample obtained a ^{14}C age of 1759 ± 176 B.P. (Berry 1982:Table 14).
	104	GX-2074	1870 ± 100	Charcoal		5.5	Matson (1991:92, sidebar). Extramural hearth associated with pithouse. Matson rejects this date as being 200 years earlier than the other ^{14}C dates from site and the tree-ring dates.
Rock Bar Alcove (42WN1779)	6	Beta-31192	8280 ± 160	Yucca	–22.3	2.2	Open-twined sandal fragments from buried cultural deposits exposed at front of alcove because of erosion. A nearly complete open-twined sandal also recovered.
Rock Creek Alcove (42KA2661)	77	Beta-8264	2420 ± 100	Organic material	?	5.5	Nickens et al. (1988:240). Partially decomposed soft body parts of a Basketmaker II burial. Not corrected for iso-

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	$\delta^{13}C$[b]	Weight[c]	References and comments
							topic fractionation.
	4	Beta-8623	8660 ± 80	Charcoal		8.6	Nickens et al. (1988:240). Loose charcoal scattered in fill of tested area in alcove. No clear associations but probably cultural.
Salt Pocket Shelter (42SA17092)	56	Beta-21209	3340 ± 100	Charcoal		5.5	Tipps and Hewitt (1989). Basin hearth within midden deposit; encountered in a 1- × 1-m test unit. A Sand Dune side-notched point and a Barrier Canyon-style anthropomorph pictograph are present at the site but are not clearly associated with the dated hearth. [Note: On pages 92 and 137 of Tipps and Hewitt 1989, the 1σ for this date is given as 110 years. I did not notice the discrepancy until after this analysis was finished.]
Sand Dune Cave	22	A-850	7150 ± 130	Yucca	(–25.0)[d]	3.3	Lindsay et al. (1968:96). A single open-twined sandal fragment, stratum V.
	12	A-848	7740 ± 120	Grass	(–12.0)	3.8	Lindsay et al. (1968:96). Lining of open-twined sandal, stratum V. Date not corrected for isotopic fractionation in the lab. As the grass was probably *Sporobolus*, its assumed ^{13}C value is between –11 and –13; consequently, 200 years have been added to the reported date of 7540 ± 120 B.P.
	13	A-849	7700 ± 120	Yucca	(–25.0)[d]	3.8	Lindsay et al. (1968:96). Two open-twined sandal fragments, stratum V.

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	δ^{13}C[b]	Weight[c]	References and comments
Sifted Shelter (42KA2730)	81	Beta-19514	2310 ± 90	Charcoal		6.8	Agenbroad (1990*); Geib and Fairley (1986*) for site description. Sample came from a layer of burned material (sticks, twigs, and leafy material) that might be the remains of a burned brush structure largely destroyed by looters. A Gypsum point along with other remains was found in looter backdirt.
Square Cist Alcove (42KA2737)	119	Beta-31974	1720 ± 140	Basketry	–23.5	2.8	Geib (1990b:142); see Geib and Fairley (1986*) for site description. Basket fragment is close coiled, half rod and bundle stacked foundation with stitches intentionally split on both surfaces.
Sunny Beaches (42KA2751)	110	Beta-16272	1800 ± 100	Charcoal		5.5	Geib and Bungart (1989:Table 1). Basin hearth associated with Rose Spring corner-notched points.
Triangle Cave (42GA288)	132	AA-5224	1600 ± 50	Maize	–10.3	22.1	Geib (1993). Maize kernels (FS137.19) from cache of five maize ears in stratum 1.
	113	Beta-34941	1770 ± 90	Maize	–11.2	6.8	Geib (1993). Maize cob (FS161.1) from floor of structure (feature 19) in stratum 1.
Turkey Pen (42SA21153)	99	WSU-3512	1980 ± 60	Maize	(–10.0)	15.3	Date uncorrected for isotopic fractionation. 250 years have been added to the reported date of 1730 ± 60 B.P. using an assumed δ^{13}C value of ca. –10. Sample from near top of stratum A-6 in Matson's

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	δ^{13}C[b]	Weight[c]	References and comments
							(1991: Fig. 2.33, 92) stratigraphic test of site; all deposits exposed in this test are Basketmaker II and yielded various materials including cultigens.
	97	WSU-3513	2050 ± 80	Maize		8.6	Stratum C-4. Date uncorrected for isotopic fractionation. 250 years have been added to the reported date of 1800 ± 80 B.P. using an assumed δ^{13}C value of –10.
	105	WSU-2750	1860 ± 45	Charcoal		27.3	Matson (1991:Fig. 2.33). Stratum C, Basketmaker II.
	101	WSU-2751	1925 ± 55	Charcoal		18.3	Matson (1991:Fig. 2.33). Stratum A, Basketmaker II.
	96	WSU-2759	2065 ± 50	Charcoal		22.1	Matson (1991:Fig. 2.33). Stratum B, Basketmaker II.
Verres Pithouse (GG-69-1)	127	GX-2072	1655 ± 80	Charcoal		8.6	Matson (1991:92, sidebar). Burned superstructure of Basketmaker II pithouse.
Walters Cave (42WN421)	1	SI-2416	8875 ± 125	Yucca	–22.3	3.5	Jennings (1980:Table 3). Sandal of unspecified construction technique. Listed as no provenience by Jennings but field notes reveal that it is from a stratum comparable to stratum IIb of Cowboy Cave, just above a pre-occupation sand layer with oak leaves (stratum IIa).
White Crack (42SA17597)	64	Beta-24478	2990 ± 70	Charcoal		11.3	UPAC Newsletter, Vol. 7, No. 2, Table 1, 1989.
Willow Seep (42SA415)	88	Beta-20469	2160 ± 100	Charcoal		5.5	UPAC Newsletter, Vol. 7, No. 2, Table 1, 1989.

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	$\delta^{13}C$[b]	Weight[c]	References and comments
AZ C-3-2 (NAU)	90	A-3934	2140 ± 80	Charcoal		8.6	Largely deflated basin hearth of a probable Basketmaker II temporary camp.
42GA3035	128	Beta-28770	1650 ± 100	Charcoal		5.5	Bungart (1990).
42GA3048	106	Beta-16268	1850 ± 140	Charcoal		2.8	Bungart (1990).
42GA3084	66	Beta-31185	2850 ± 70	Charcoal		11.3	Bungart (1990).
42GA3086	59	Beta-32025	3230 ± 140	Charcoal		2.8	Bungart (1990).
42GA3119	89	Beta-31187	2160 ± 90	Charcoal		6.8	Bungart (1990).
42GA3202	74	Beta-31189	2530 ± 70	Charcoal		11.3	Bungart (1990).
42GA3205	71	Beta-28322	2670 ± 90	Charcoal		6.8	Bungart (1990).
	58	Beta-27897	3240 ± 60	Charcoal		15.3	Bungart (1990).
42GA3206	65	Beta-32026	2950 ± 100	Charcoal		5.5	Bungart (1990).
42KA2731	115	Beta-16587	1750 ± 90	Charcoal		6.8	Agenbroad (1990*); see Geib and Fairley (1986*) for site description and Anderson (1988:Fig. 20) for stratigraphic provenience of date. This determination comes from a thin lens of sparse charcoal buried in alluvium and is consistent with a date of 950 ± 160 B.P. from charcoal located roughly 1 m higher (see Anderson 1988:Fig. 20). No certain cultural associations.
42KA2771	43	GX-11146	5300 ± 235	Charcoal	–23.7	1.0	Agenbroad et al. (1989:Appendix); see Geib and Fairley (1986*) for site description and Anderson (1988:Fig. 21) for stratigraphic provenience of date. Sample obtained from a lens of dense charcoal-stained soil within a cultural

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	$\delta^{13}C$[b]	Weight[c]	References and comments
							stratum buried in dune sand. Flaked lithics and grinding tools in association but no diagnostics.
42KA2773	118	Beta-16277	1730 ± 70	Charcoal		11.3	Bungart and Geib (1987*); slab-lined hearth.
42SA17107	38	Beta-31790	5890 ± 70	Charcoal		11.3	Tipps and Schroedl (1990*).
	Rejected	Beta-18737	8340 ± 290	Charcoal		1.0	Tipps and Schroedl (1990*: not included in Figs. 3 or 4 because of large counting error).
42SA17141	94	Beta-21208	2080 ± 60	Charcoal		15.3	Tipps and Hewitt (1989:128). Slab-lined hearth at open site. No certain associations, but an Elko side-notched, a Pueblo I-style arrow point, and several other remains recovered from site surface; abundant materials at site.
42SA17215	5	Beta-16596	8330 ± 110	Charcoal		4.6	Agenbroad (1990*); also Tipps and Schroedl (1990*).
42SA17216	120	Beta-19284	1720 ± 80	Charcoal		8.6	Agenbroad (1990*); also Tipps and Schroedl (1990*).
	8	Beta-19285	8100 ± 220	Charcoal		1.1	Agenbroad (1990*); also Tipps and Schroedl (1990*).
42SA17790	31	Beta-18736	6580 ± 100	Charcoal		5.5	Tipps and Schroedl (1990*).
42SA20292	92	Beta-30484	2120 ± 60	Charcoal		15.3	Tipps (1992a*); also Tipps and Schroedl (1990*).
	85	Beta-30485	2220 ± 70	Charcoal		11.3	Tipps (1992a*); also Tipps and Schroedl (1990*).
42SA20256	84	Beta-30482	2220 ± 90	Charcoal		6.8	Tipps (1992a*); also Tipps and

Table 1. *Continued.*

Site	Sequence[a] no.	Lab no.	Radiocarbon age (B.P.)	Material dated	$\delta^{13}C$[b]	Weight[c]	References and comments
							Schroedl (1990*).
42SA20301	78	Beta-30487	2330 ± 90	Charcoal		6.8	Tipps (1992a*); also Tipps and Schroedl (1990*).
42SA20309	51	Beta-34978	3710 ± 230	Charcoal		1.0	Tipps and Schroedl (1990*).
42SA21091	95	Beta-31962	2070 ± 70	Charcoal		11.3	Agenbroad (1990*); also Tipps and Schroedl (1990*).
42SA21095	35	Beta-31963	6290 ± 110	Charcoal		4.6	Agenbroad (1990*); also Tipps and Schroedl (1990*).
42SA21117	124	Beta-31964	1670 ± 80	Charcoal		8.6	Agenbroad (1990*); also Tipps and Schroedl (1990*).
(No number)	45	Beta-33355	4510 ± 130	Charcoal		3.3	Agenbroad (1990*); also Tipps and Schroedl (1990*).
BC-86-1	131	Beta-15640	1600 ± 60	Charcoal		15.3	Agenbroad (1990*); see also Anderson (1988:64). Charcoal lens buried in alluvium of Bowns Canyon; no site documentation.
GG-69-20	126	GX-2143	1655 ± 85	Charcoal		7.6	Matson (1991:90, sidebar). Cist in floor of a Basketmaker II pithouse.

[a] Sequence number is the temporal order of the date from oldest to youngest within this data set.

[b] $\delta^{13}C$ values in parentheses are assumed, either by the laboratory or by this author.

[c] Product of the squared standard error of each date over the largest squared standard error (235 in this study).

[d] Sample uncorrected for isotopic fractionation but probably not a problem because all previous measurements of $\delta^{13}C$ for yucca from early Archaic contexts have obtained values between –21 and –25. For this sample it is reasonable to assume a value of –25, requiring no correction of the reported date.

[e] *Asterisk indicates unpublished material.*

technological, and biological innovations. In a regionally based examination of preceramic radiocarbon dates, age overestimation is not so critical, especially considering the millennial time spans for the Archaic subdivisions. Moreover, the suite of radiocarbon dates for the central Colorado Plateau includes many on organic remains not subject to age overestimation.

Uncalibrated dates are used to structure this discussion for two principal reasons. First, most discussion of Archaic chronology is in terms of uncalibrated dates and to continue so facilitates communication and comparison. Second, all paleoenvironment research is couched in terms of uncalibrated radiocarbon years, and until the various paleoenvironmental data sets and reconstructions are also calibrated, a calibrated Archaic archaeological record would be dislocated from its environmental context. After plotting both the calibrated and uncalibrated dates, and even though the disparity between the laboratory determination and the true age of a sample is about 700 years during the early and middle Archaic, the basic temporal pattern was unchanged. Using uncalibrated dates does not impede our understanding of prehistory until the Christian era, and then chronologies established by radiocarbon dating have to meld with high-resolution tree-ring chronologies tied to the Gregorian calendar.

Two different but complementary techniques are used to graphically summarize the radiocarbon dates (Figs. 3 and 4). The dates are arranged along the horizontal axis from oldest to youngest whereas their one-sigma values in radiocarbon years B.P. are plotted as solid lines on the vertical axis (Fig. 3). This first approach to portraying the radiocarbon record for the region provides substantial detail, but Berry and Berry (1986:284) argue that it can obscure patterning when many dates are graphed. They have developed an alternative technique that provides a relative probability bar chart that equitably accounts for a wide range of standard errors through a method of inverse weighting. The second graphic (Fig. 4) was created from the central Colorado Plateau radiocarbon record using the approach as described by Berry and Berry (1986:284), except that 50-year increments were used for the *x*-axis and a sigma value of 235 years provided the basis for calculating the weights[3] assigned to each date. This technique involves plotting each date as a scaled plus-and-minus one-sigma line (as in Fig. 3) and noting its weight. The weights within each 50-year

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[3] Weights are the product of the squared standard error of each date (from 235 to 39 years) over the largest squared standard error (235 years) and ranged from 1.0 to 36.3 in this study.

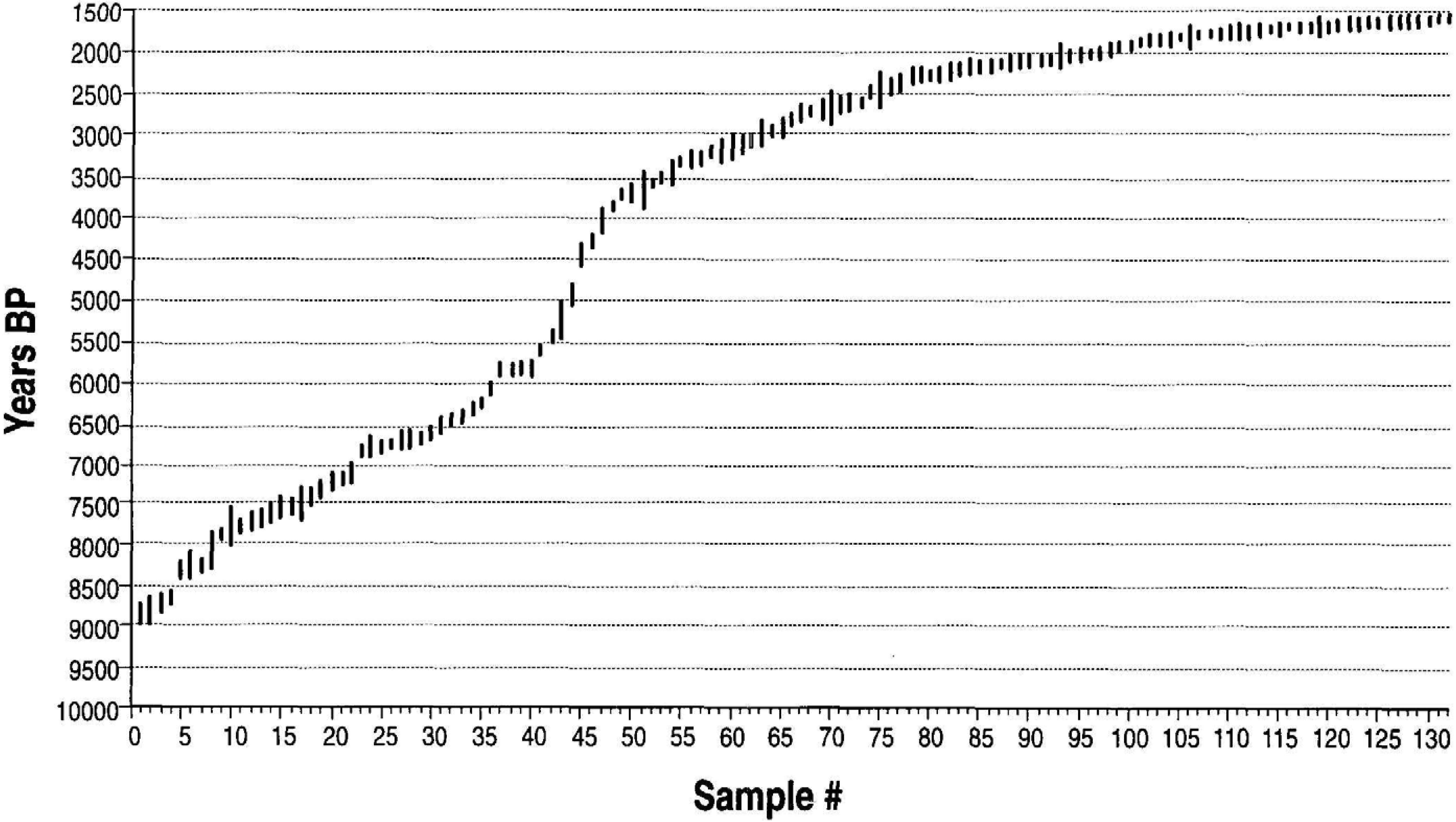

Fig. 3. Array of preceramic (pre-1600 B.P.) radiocarbon dates from the central Colorado Plateau; refer to Table 1.

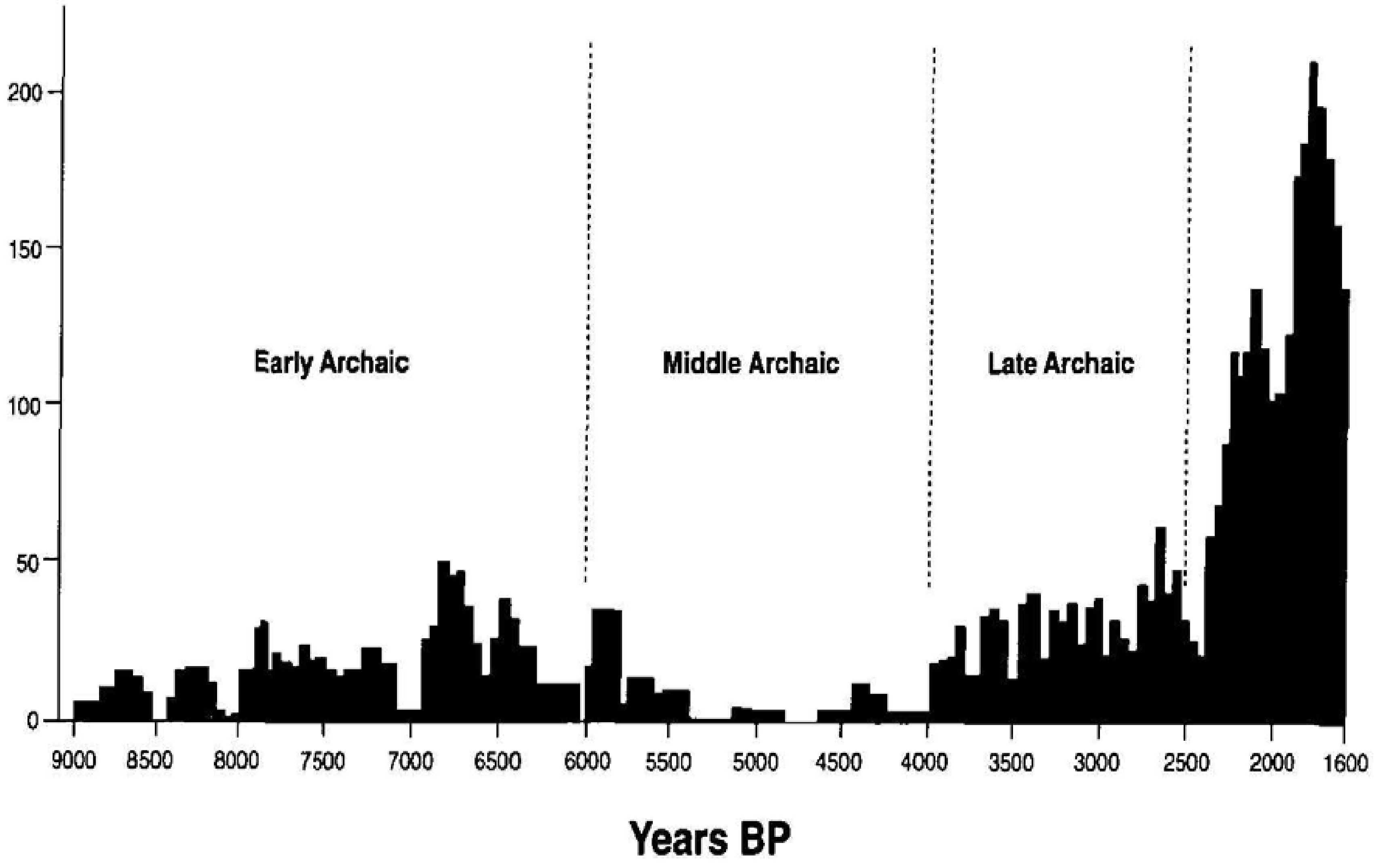

Fig. 4. Weighted preceramic radiocarbon bar chart for the central Colorado Plateau produced according to the method developed by Berry and Berry (1986:284); 50-year intervals for the *x*-axis.

increment are then summed to provide the ordinate value for that period. Included in Fig. 4 are three approximate cut points of the long Archaic sequence that seem to have adaptive significance.

Results

Because radiocarbon dates represent human activity at points in time and the number of dates may be related to the "magnitude of occupation... it is possible to assess and compare, in a relative fashion, the occupation histories within and between regions" (Rick 1987:55). The radiocarbon record for the central Colorado Plateau (Fig. 4) starts abruptly at 9,000 years ago; no radiocarbon dates are yet available for Paleo-Indian remains of the region. During the ensuing 3,000 years, the record is filled in except for a short gap around 8500 B.P. and two dips in the record about 8050 and 7000 B.P. A significant decline exists in dates between 6,000 and 4,000 years ago, as well as a small gap between 4850 and 4650 B.P. After 4000 B.P. the frequency of dates increases and remains fairly high but fluctuating until about 2500 B.P., at which point there is a short dip and then a dramatic increase to an all-time high. The record is arbitrarily cut off at 1600 B.P., and the short dip just before this is the result of edge effect.

At this point, it is worthwhile to consider the degree to which the patterning of Fig. 4 results from differential preservation related to such postdepositional biases as erosion and burial by recent sediment. First, most early and middle Archaic dates are from natural shelters (caves, alcoves, and rock shelters) that have served to preserve the remains from this early time. A few dates are from deeply buried open sites, but none come from sites exposed on the surface. Surface lithic scatters earlier than about 4,000 years ago may exist, but such sites have been so severely eroded that datable organic material is often absent. Thus, the early portion of the radiocarbon record is the byproduct of both costly excavation of deeply stratified shelters and chance finds of buried hearths or organic remains exposed by erosion.

In contrast, about one-third of the late Archaic dates are from surface hearths at open sites. Sampling these features (Bungart 1990; Tipps and Schroedl 1990*[4]) has increased the frequency of late Archaic dates over preceding periods. These features were not sampled to provide a detailed late Archaic chronology, but this has been the outcome (see Bungart 1990:55). Natural factors have resulted in a greater accumulation of late Archaic dates because sites of this period are more visible (less buried or eroded) and, as hearths are still preserved, they have a greater likelihood to contain datable remains. In short, sites exposed on the surface are more likely to be discovered, and such sites have a greater likelihood to date to the late Archaic period or more recently.

What about the reduction in dates between 6,000 and 4,000 years ago? Could this be a consequence of postdepositional bias? The same sheltered sites that produced numerous early Archaic dates yielded few if any middle Archaic dates, suggesting that differential preservation may not be evoked in this instance. Something apparently happened that prompted humans to abandon or seldom use shelters that were previously important residential bases. Although preservation bias may not be a significant factor in the middle Archaic decline in radiocarbon dates, sampling bias could well play a role. Thus, middle Archaic sites may be located in areas heretofore inadequately investigated.

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[4] Asterisk indicates unpublished material.

Discounting preservation bias, the low frequency of middle Archaic dates may be the result of sampling bias related to another visibility problem. The archaeological record produced by foragers with a high degree of residential mobility and variable annual rounds might be so dispersed as to be largely invisible, and thus rarely subject to archaeological treatment. Wills (1988:65) argues that logistically organized hunter–gatherers produce more visible archaeological traces than mobile foragers and consequently their remains are more likely to contribute to regional chronologies. "Interregional variation in radiocarbon chronologies may well be the product of shifts in economic organization and mobility. . . " and consequently ". . . should not be taken as a direct indicator of prehistoric demographics" (Wills 1988:65). Thus, changes in mobility and subsistence–settlement strategies during the Archaic may be partially responsible for some patterning in the radiocarbon chronology.

Before proceeding, a brief digression about sandals is in order. Many of the Archaic dates listed in Table 1 are on sandals made of yucca leaves. Three different sandal types were produced during the Archaic: open-twined, fine warp-faced, and plain-weave (or coarse warp-faced). Each of these was first described by J. Richard Ambler from his excavations at Dust Devil and Sand Dune caves. He (Lindsay et al. 1968:95–97, 120–121) identified open-twined sandals as a key diagnostic trait of the early Archaic Desha complex northeast of Navajo Mountain. Excavations at Cowboy Cave, however, produced this sandal type from cultural units IV and V (Table 12 of Hewitt 1980) dated about 3700–3300 and 1900–1500 B.P., respectively. Ambler (1984*) suggested that these were present in more recent strata at Cowboy Cave as a result of disturbance of early deposits by later occupants. Berry and Berry (1986:309–310) gave a similar argument to account for the presence of Gypsum points and split-twig figurines in unit V at this cave. Since Ambler's contention, open-twined sandals from five separate sites of the central Colorado Plateau were directly dated, and all are within the early Archaic period: Atlatl Rock Cave at 7900 B.P., Bechan Cave at 6750 B.P., Good Hope Alcove at 7560 B.P., Old Man Cave at 7440 B.P., and Rock Bar Alcove at 8280 B.P. (Table 1). Ambler is therefore probably correct about the upward displacement of open-twined sandals in the deposits of Cowboy Cave into later cultural units. At this juncture there is sufficient justification to state that this type of footwear is restricted to the early Archaic and may be expected anytime after 9000 B.P. but before 6000 B.P.; direct dates confirm that sandals of this type occurred during the interval 8300–6700 B.P. (or 8600–6500 B.P. based on the two-sigma deviations).

Based on current radiocarbon dates, it is evident that plain-weave sandals were initially manufactured during the end of the early Archaic; both plain-weave and open-twined styles overlapped during the first half of the seventh millennium B.P. but open-twined sandals predate plain-weave sandals by at least 1,500 years. Plain-weave sandals continued to be manufactured through the middle Archaic, apparently extending into the late Archaic, up to 3,000 years ago. A sandal technology that began during the end of the early Archaic and persisted into the late Archaic provides convincing circumstantial evidence in itself for cultural continuity over more than 3,000 years of significant paleoenvironmental change and alterations in settlement pattern. Temporal placement of fine warp-faced sandals is not certain because few have been recovered (all extant examples come from Dust Devil Cave), and none have been directly dated; they are probably restricted to the early Archaic.

Archaic Origins

No apparent local antecedents exist for the early Archaic remains of the central Colorado Plateau. It seems doubtful that the point types (Elko Corner Side-notched, Northern Side-notched, Pinto), sandals, close-coiled basketry, and generalist subsistence remains (diverse small seeds, cactus pads, and small mammal bone) that characterize the earliest cultural deposits from sites such as Dust Devil and Cowboy caves were the cultural residue of local Paleo-Indians turned foragers. Though the region apparently had a low-level late Paleo-Indian occupation (Schroedl 1991; Geib 1994), a break in occupation probably occurred before about 9000 B.P., and Archaic hunter–gatherers soon resettled the abandoned rugged canyon landscape. This assumes, of course, that hunter–gatherers would not make an abrupt change in adaptive strategy and that if such a change is evident it represents population replacement. Regarding the first issue, a body of theory exists supporting the notion that change among hunter–gatherers is mainly a conservative process (see Wills 1988:36 for summary of this opinion with regard to hunter–gatherer adoption of agriculture). Regarding the second issue, little is known of the late Paleo-Indian occupation, so the degree to which early Archaic subsistence patterns and material culture vary from earlier patterns and remains is largely conjectural.

Early Archaic

That the Archaic period began almost 9,000 years ago is evidenced by 8800 B.P. dates on yucca leaves from caves in both northern and southern portions of the central Colorado Plateau. The oldest of these dates is on a sandal from the lowest cultural deposit of Walters Cave (Jennings 1980), which is adjacent to Cowboy Cave. Because other organic remains were found near the sandal, additional radiocarbon dates can eventually verify this early determination. Unfortunately, the manufacturing technique for the sandal apparently was not recorded before its destruction. The second early date comes from the lowest portion of stratum IV in Dust Devil Cave (Ambler 1994*). As with the early date from Walters Cave, this one is also on yucca—in this instance leaves lining a storage pit.

Six other dates for the region fall within the ninth millennium B.P., but only one of these is on material that will not result in age overestimation. This is the date of 8280 B.P. on open-twined sandal fragments from Rock Bar Alcove on the Spur, just 14 km northeast of Cowboy Cave (Table 1). The other five dates are on charcoal and provide equivocal evidence for occupation before 8000 B.P. The bulk of early Archaic radiocarbon dates fall within the eighth and seventh millennia B.P., including numerous dates on yucca leaves or other materials not subject to age overestimation.

The end of the early Archaic is problematic but placed sometime during the latter half of the seventh millennium B.P. No clear break exists in the radiocarbon record—just a reduction in the number of dates from 7,000 to 6,000 years ago. Besides fewer dates, a principal reason for identifying an end to the early Archaic is that cultural activity at Cowboy, Dust Devil, and Old Man caves ceased (or was greatly diminished) during the seventh millennium, and over the next several thousand years the sites were seldom if ever used (Jennings 1980:17–26; Ambler 1994*; Geib and Davidson 1995). Several hundred years of apparent gradual change in hunter–gatherer adaptation during the seventh millennium B.P. marks the transition from early to middle Archaic.

Middle Archaic

The middle Archaic is characterized by a significant reduction in radiocarbon dates. This period began during the latter half of the seventh millennium B.P. and lasted over 2,000 years until around 4000 B.P., when there is a marked increase in dates. The beginning of this interval is not fixed in time, a reflection of the extended transition from the early Archaic as mentioned above. Besides fewer dates, a principal reason for identifying the onset of the middle Archaic is that sites that were once key nodes in an annual subsistence round lost their former significance and were rarely used. This is well exemplified by Cowboy, Dust Devil, and Old Man caves, each of which ceased to function as a residential base during the middle Archaic. This change in site use at both Cowboy and Dust Devil caves is represented by essentially sterile dune sand that accumulated within the caves (strata IVa and IVb at Cowboy Cave and stratum V at Dust Devil Cave; Jennings 1980:20–26; Ambler 1994*). At Old Man Cave, the temporally comparable hiatus deposit consists of small roof spalls, dust, and rat dung, with very little addition of cultural material (Geib and Davidson 1995).

Changes in site use at the onset of the middle Archaic are also exemplified by Rock Bar and Goodhope alcoves and Atlatl Rock Cave. At the former two sites, trashy early Archaic deposits are buried beneath apparently sterile eolian sand layers similar to those reported at Cowboy and Dust Devil caves. The strata are exposed in profile at the front of each alcove because of downslope movement of talus and sediment from drip-line erosion. Goodhope Alcove was reoccupied during the Formative period, but at Rock Bar Alcove the only evidence of occupation is the early Archaic deposit. Atlatl Rock Cave was recently investigated in the wake of serious looting, so dating results are not yet available. Nevertheless, it is clear from extensive stratigraphic exposures that a layer of culturally sterile ceiling rock spalls up to 70 cm thick separates early Archaic deposits from those of Basketmaker II.

The middle Archaic period includes the apparent 1,000-year gap in radiocarbon dates for the northern Colorado Plateau noted by Schroedl (1976: 13–29 and Figs. 2 and 4) and Berry and Berry (1986:Fig. 14). As is evident from Figs. 3 and 4, dates from the central Colorado Plateau are beginning to fill this gap, as are dates from further north along the Colorado River (Barnes 1985). Schroedl's (1976:64) suggestion that population declined to an all-time low relative to other periods may be right, but with the partial filling of the middle Archaic gap in the radiocarbon record, there is good reason to doubt that hunter–gatherers completely abandoned the region 6,000 years ago as Berry and Berry (1986:315) suggested. The small middle Archaic break in the central Colorado Plateau radiocarbon record seems more likely attributable to sampling problems than to a lack of occupation.

Sites interpreted as having been abandoned during the middle Archaic provide some of the most compelling evidence for an overall break in occupation. Nevertheless, there is reason to believe that sites such as Dust Devil and Cowboy caves were used at least on occasion during this interval. An analysis of lithics from Dust Devil Cave showed that almost as many projectile points were recovered from the apparently sterile middle Archaic stratum V as from the early Archaic stratum IV (Geib 1984*). Despite the quantity of projectile points, flake density was reduced, as was the amount of most other debris. Instead of a hiatus, it seems plausible that there was a significant change in cave use: after about 7000 B.P., the cave was used less and less frequently as a base camp and ultimately became a seldom-used way station for small groups of highly mobile hunters who added little debris to the eolian sand accumulating within the cavern (Ambler 1994*). A similar argument might be extended to the middle Archaic hiatus layers of Cowboy Cave (strata IVa and b), which, though supposedly representing an approximate 2,000-year interruption in human use, contained more flaked lithic tools and debitage than any of the early Archaic strata of unit III (Weder 1980:Table 7). Jennings (1980:26) attributes artifacts in the nonoccupation sand layers of Cowboy Cave to intrusion from overlying cultural layers, "varyingly, artifacts were pushed down into the loose upper sand zones by foot traffic when occupancy of the cave was renewed." This would mean that fully 35% of the debitage and 25% of the flaked lithic tools from the stratum of renewed occupation (IVc) were intruded down into the sand of strata IVa and IVb.

The apparent middle Archaic population decline and the abandonment, or drastic reduction in use, of previously inhabited shelters likely results from regional climatic change. Perhaps not by coincidence, the middle Archaic occurs during the period that Antevs (1955) characterized as being warm and dry, his Altithermal drought. This drought episode continues to be a controversial subject (e.g., Martin 1963; Mehringer 1967; Peterson 1981; Davis 1984; Hall 1985; Barnosky et al. 1987; Van Devender et al. 1987), perhaps because the Altithermal episode "was far more variable across space and through time than Antevs ever imagined" (Meltzer 1991:236). Current evidence suggests that the central Colorado Plateau, like certain other places of the western United States, was characterized by a middle Holocene drought (Scott 1980*; Cole 1981; Hall 1985; Karlstrom and Karlstrom 1986; Anderson 1988:98; Karlstrom 1988:69; Withers 1989).

As the climate warmed and dried during the early to middle Archaic transition, hunter–gatherers might have made several adaptive responses. The most extreme response would have been wholesale population movement over long distances to more favorable environments—the Altithermal refuge model. This is what Berry and Berry (1986) advocate. The Colorado Rockies, which have numerous middle Archaic sites, could have served as an Altithermal refuge as Benedict (1979) proposed. The Berrys (1986:317) concur with Benedict's argument but conclude that the eastern Great Basin, with its resource-rich lake margins, could have absorbed many more middle Archaic hunter–gatherers (Berry and Berry 1986:319).

With the recent accumulation of about a dozen radiocarbon dates during the purported middle Archaic date gap, total emigration of hunter–gatherers is not credible. Without completely discounting long-distance movement of some populace, it is more likely that hunter–gatherers made localized adaptive adjustments in settlement–subsistence strategies in response to increasing aridity. One probable adjustment could have been a relocation of base camps to secure water sources. Meltzer (1991:259) relates that "a lack of water, and not food resources or foraging efficiency, is the limiting factor in arid settings." Settlement patterns may have shifted as sites situated at a distance from reliable (i.e., drought-resistant) water sources became less desirable for residential bases. Two of the sites dated to the middle Archaic are within Bowns Canyon, which has a permanent stream fed from numerous springs. Even during a protracted drought, the Navajo sandstone aquifer of this canyon probably would have maintained its viability.

Even in the worst conditions, the Colorado, San Juan, Escalante, and Dirty Devil rivers would have provided resident hunter–gatherers with a plentiful water supply. Further north along the Colorado River, sites such as DeBeque Rockshelter (Reed and Nickens 1980*) have middle Archaic cultural deposits. Reed and Nickens postulate that this site's proximity to the Colorado River may have made it a more suitable residence relative to other areas of the Colorado Plateau during a time of deteriorating environmental conditions. To investigate this possibility for the central Colorado Plateau, portions of plain-weave sandals from two shelters beside the Colorado River of lower Glen Canyon (The Hermitage and Benchmark Cave; Lipe 1960) were recently submitted for AMS radiocarbon analysis. The dates on these artifacts, a few of which were available in time to include in this analysis (Table 1), confirm that the shelters had previously unsuspected middle Archaic occupations and support the proposition that Archaic populations shifted some residential bases to river corridors.

Besides shifting residential camps to more water-rich lowland settings, some camps could have been moved to the several higher-elevation settings—those above 2,438 m—in and adjacent to the central Colorado Plateau. These include Navajo Mountain in the southern part of the region, the Henry Mountains near the central portion, the Abajo Mountains and associated high mesas (e.g., Elk Ridge) to the east, the Aquarius Plateau (Boulder Mountain) to the west, and the La Sal Mountains to the northeast. The benefit of the high-elevation settings during a protracted drought would have been their greater biotic productivity and faster regeneration rates for foraged resources relative to the lower-elevation benchlands and canyons. The presence of so many high elevation settings, especially those of great areal extent such as the extensive Aquarius Plateau (ca. 2,600 km^2 above 2,750 m), might have been an important factor in the apparent continual hunter–gatherer occupation of the central Colorado Plateau during the middle Archaic.

In addition to changes in the location of residential camps, middle Archaic populations could have increased the frequency of residential moves, expanded the territory of seasonal rounds, and decreased the periodicity of residential reuses. All of these factors could have led to a substantially diminished and more diffuse archaeological record. In essence, middle Archaic remains might be far more dispersed than those of the early Archaic, and thus less subject to archaeological discovery and investigation. This might sound contrary to the notion of becoming tethered to water sources, which could result in more concentrated accumulations of debris. Nevertheless, if the truly reliable middle Archaic water sources of the central Colorado Plateau were the linear oases of rivers, there would be less chance for point-specific concentrations. Along rivers, hunter–gatherers could have had the option to move camps frequently in response to lowered foraging return rates without having to worry about not finding water elsewhere. Moreover, despite being tethered to secure water sources, expanded foraging territories, shorter stays at residential bases, and longer lapses between residential reuse still would have resulted in a diffuse archaeological record.

Late Archaic

The late Archaic began about 4,000 years ago with a noticeable increase in radiocarbon dates and is temporally correlated with an increase in effective moisture during what has been termed the sub-boreal interval (Berry and Berry 1986:316–317). The middle–late Archaic transition may have happened at a quicker pace than the early–middle Archaic transition, though this is just an impression. The increase in radiocarbon dates may be partially the result of population growth; in addition, settlement and subsistence strategies might have changed, thereby greatly increasing the archaeological visibility of late Archaic hunter–gatherers. This is basically the reverse of the scenario proffered for the early–middle Archaic transition, though the specifics of late Archaic subsistence and settlement may have varied from earlier patterns owing to the expanded range of the pinyon pine (*Pinus edulis*; see Bungart 1990) and other factors. Moreover, as discussed earlier, late Archaic sites have a greater chance of contributing to the radiocarbon record because of preservation biases with earlier periods.

Berry and Berry (1986:318) hypothesized that a major exodus was responsible for the apparent late Archaic population increase and suggested the Mexican highlands as one possible source region based on similarities between Gypsum points of the Southwest and the earlier constricting stem points of Mexico. Appearing sometime after about 4500 B.P. (Holmer 1986:105), Gypsum points are among the most common temporally sensitive dart-sized point type found over much of the region. The frequency and distribution of Gypsum points alone indicates a rather significant late Archaic occupation of the central Colorado Plateau. Nevertheless, it has yet to be demonstrated that a point style equals a people, and there are many examples of point styles spreading rapidly between different cultural groups.

Starting about 3700 B.P., Cowboy Cave again became an important settlement nexus, but cave sites south and east of the Colorado River in the southern portion of the region continued to be little used. Several Gypsum points are present in stratum VI of Dust Devil Cave (Geib and Ambler 1991), but this layer seems to be predominantly of Basketmaker origin. A few Gypsum points were recovered from Sand Dune Cave (Fig. 23w of Lindsay et al. 1968), but the lack of stratigraphically controlled excavation precludes an accurate assessment of how extensively this site was used during the late Archaic. At Old Man Cave, there is as yet no evidence of a late Archaic presence, though the strata that correspond to this interval were largely disturbed by vandals and have yet to be adequately sampled. Gypsum points are even more rare immediately south of Glen Canyon, with few examples known from the Kayenta region.

The introduction of agriculture marks the end of the late Archaic, a process that on the central Colorado Plateau occurred less than 2,500 years ago. As Berry and Berry (1986:319) observe, "the agricultural influx drastically changed the character of southwestern subsistence systems and altered profoundly the trajectory of evolutionary development. . . . Hence, for all intents and purposes, the Archaic came to a close." Direct dating of maize, cucurbita, and beans from the study region has yet to produce a reliable date before 2,000 years ago. A maize cob from the Alvey Site produced a radiocarbon age of 2260 B.P. (Geib 1993), but additional dating of maize from this site demonstrated that this early date is probably in error (Geib 1994). Cultigens have considerably greater antiquity immediately south of the region (Smiley 1993, 1994).

The end of the late Archaic is coincident with a reduction in the frequency of radiocarbon dates for the central Colorado Plateau. A similar break or dip in the Colorado Plateau radiocarbon record between roughly 3000 and 2500 B.P. was highlighted by Schroedl (1976:Fig. 4) and Berry and Berry (1986:Fig. 14). Despite the apparent break in his plot of radiocarbon dates from about 3000 to 2500 B.P., Schroedl (1976:68–73) saw strong evidence for cultural continuity in points, basketry, and other material remains from dated contexts both sides of this 500-year gap. Thus, he defined the Dirty Devil phase as spanning the possible hiatus. Berry and Berry (1986:309) took issue with his reasoning, characterizing it as "a typical case of phase-stacking to achieve the illusion of continuity." Alternatively, they see significant depopulation because of drought as the reason for the drastic reduction in radiocarbon dates between 3000 and 2500 B.P. and conclude that Archaic hunter–gatherers were subsequently displaced by San Pedro Basketmaker II agriculturalists from some southern source area (Berry and Berry 1986:318–319). Rather than cultural continuity from the Archaic to Formative periods, as maintained by Schroedl (1976:77), Berry and Berry see cultural replacement (see Matson 1991 for a detailed discussion on this issue). Some stratified shelters in and near the region still reveal a break in occupation between about 3000 and 2000 B.P. (e.g., Horn 1990:85*; Janetski et al. 1991:Table 1), but dates on hearth charcoal from open sites throughout the central Colorado Plateau indicate a lack of wholesale abandonment at the end of the late Archaic. The basis for concluding that there was an occupational discontinuity about 3000 B.P. is not, therefore, evident in the chronometric data.

A major point in Berry and Berry's (1986:309–310) argument for a lack of continuity during the late Archaic–Formative transition is placing an upper temporal limit on the production of Gypsum points and split-twig figurines. The crucial evidence that Berry and Berry must refute comes from Cowboy Cave, where these twin late Archaic diagnostics were recovered from unit V, dated roughly 1900–1500 B.P. Berry and Berry may be right about the displacement of late Archaic artifacts upward from unit IV into unit V at Cowboy Cave and that Gypsum points and split-twig figurines were not produced much after about 3000 B.P., but their argument cannot account for the basketry sequence at the site, which mirrors the developmental sequence in Utah from Archaic to Fremont (Hewitt 1980:57). Preformative basketry from the Escalante River basin also represents a continuation and elaboration of Archaic basketry technology for Utah and supports the idea of cultural continuity during the agricultural transition north of the Colorado River (Geib 1990b). As Matson (1991) has detailed, the instance south of the Colorado River is substantially different and seems to support the notion of an intrusive agricultural population.

Discussion

Berry and Berry (1986) identified three temporally discrete occupations separated by abandonments for the Archaic occupation of the entire Colorado Plateau. These discrete occupations are not apparent in the central Colorado Plateau radiocarbon record. The purported 1,000-year middle Archaic gap in the Colorado Plateau radiocarbon record is not evident in the record for the central portion of the plateau. Significantly fewer dates exist between 6,000 and 4,000 years ago than either previously or subsequently, but there is good reason to suggest that the central Colorado Plateau was not completely abandoned about 6000 B.P., as Berry and Berry (1986:315) suggested happened for the plateau as a whole. The small middle Archaic gap remaining in the radiocarbon record examined here seems more likely because of sampling problems than to a lack of occupation. The apparent abandonment of previously well used sites provides the most compelling evidence for an occupational hiatus, but this probably reflects a change in settlement pattern, with residential bases relocated close to secure water sources such as rivers and perhaps to the several high-elevation settings near the canyon lowlands. In addition, middle Archaic populations could have increased the frequency of residential moves, expanded the territory of their seasonal round, and decreased the periodicity of residential reuse. These factors would have led to a substantially diminished archaeological record.

In essence, middle Archaic remains might be far more dispersed than those of the early Archaic and thus less subject to archaeological discovery and investigation.

Recall Schroedl's (1976:63) point about the possibility that archaeologists have missed the evidence corresponding to this interval (which he calls the Castle Valley phase) by incorporating middle Archaic remains with those of earlier or later occupations. Based on the Sudden Shelter sequence, he reasoned that greatly reduced depositional rates resulted in thin middle Archaic deposits and that "unless very fine-grained distinctions with tight controls are utilized during excavation of Archaic sites, the occupations associated with this phase [Castle Valley or the middle Archaic] might be completely missed" (Schroedl 1976:64).

The other occupational hiatus recognized by Berry and Berry corresponds to the 500-year interval between 3,000 and 2,500 years ago, just before the introduction of agriculture. This was also the hiatus identified by Madsen and Berry (1975) as evidence for lack of continuity between Archaic and Fremont populations in Utah. In the central Colorado Plateau radiocarbon record, no hiatus is apparent. The date frequency has an obvious dip, but the region was apparently not void of human occupants. Again, certain key sites such as Cowboy Cave and the Down Wash site were apparently abandoned, but dates from open sites throughout the central Colorado Plateau indicate a continued human presence during the Archaic to Formative transition. The occupational records of a few key sites can never vouch for that of a region, no matter how unequivocal the evidence. As Wills (1988:155) put it, "We need to consider individual sites and artifacts as participants in and products of socioeconomic systems, not models for such systems."

At this point, I wonder whether the tripart temporal subdivision of the Archaic period is not too coarse for future research goals? The seven-part framework presented in Table 2 is tentatively advanced as a potentially useful partitioning of the roughly 6,500 years of hunter–gatherer occupation of the central Colorado Plateau to better describe change.[5] These seven temporal subdivisions of the Archaic period should not be viewed as cultural phases in

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[5] In Table 2, the breaks between the seven temporal subdivisions are also listed in calibrated years B.C. This reveals that some of these intervals are relatively longer than indicated by the radiocarbon dates, while a few are slightly shorter. For example, the 1,600-year middle Archaic period actually spanned almost 1,900 years.

Table 2. Synopsis of the Archaic period for the central Colorado Plateau according to seven temporal subdivisions.

^{14}C years (B.P.)	Archaic period subdivisions	Descriptive characterization	Important sites and components	Diagnostic projectile points	Diagnostic perishable artifacts	Calibrated years B.C.
2500	Terminal Archaic	Apparent population decline but without an occupational hiatus of entire region. Perhaps an abbreviated version of the middle Archaic period. Introduction of agriculture during end of this period profoundly affects cultural systems. Hunting and gathering was still important, but horticulture became the predominant subsistence mode well before introduction of ceramics.	Hiatus layer at Cowboy Cave (stratum Va), open sites of the Orange Cliffs	Gypsum points (?), Elko points	Perhaps same as previously?	670
3000	Late Archaic	Perhaps greatest population during the entire Archaic period; thick trash accumulations in certain natural shelters and numerous open sites with slab-lined and basin hearths and dense artifact scatters.	Cowboy Cave (unit IV), sparse use of Dust Devil Cave (stratum VI), Bechan Cave, and other sites in same canyon	Gypsum points, Elko Eared, McKean Lanceolate	Split-twig figurines, Morss's problematical objects, plain-weave sandals	1265
3800	Middle–late transition	Apparent population increase or at least greater archaeological visibility over previous period, temporally correlated with climatic amelioration and expansion of pinyon into or beyond current elevational and geographical range.	Down Wash site, Co-op site, and nearby sites in same canyon: Beaucoup Alcove and Beaver Shelter	Replacement of earlier side-notched types by San Rafael side-notched; appearance of McKean Lanceolate	Appearance of split-twig figurines, plain-weave sandals	2235
4400	Middle Archaic	Apparently corresponds to a drought interval; significantly warmer and drier than before or since. Drastic reduction in population but not total abandonment. Fewer people per square kilometer than during previous Archaic periods owing to greatly expanded territories and perhaps some migration. Residential bases perhaps relocated to well watered settings such as along rivers. Local high-elevation settings such as the Aquarius Plateau could have served as additional altithermal refugia. Low archaeological visibility.	Hiatus layers at Cowboy (stratum IVa), Dust Devil (stratum V), and Old Man (levels 3 and 4) caves; occupation of Bechan Cave and site 42KA2771 in same canyon; Benchmark Cave and The Hermitage	Apparent continuation of Sudden side-notched and Hawken side-notched	Continuation of plain-weave sandals as evidenced by recent direct dating of specimens from lower Glen Canyon	3035

Table 2. *Continued.*

^{14}C years (B.P.)	Archaic period subdivisions	Descriptive characterization	Important sites and components	Diagnostic projectile points	Diagnostic perishable artifacts	Calibrated years B.C.
6000	Early–middle transition	Apparent population decline, perhaps because of expanded territories and some movement to other regions. Change in settlement patterns and perhaps an increase in residential mobility brought about a decreased use of certain previously well used sites. Overall decline in archaeological visibility over previous period.	Sites previously used rather intensively and frequently were rarely used and some may have been virtually abandoned. All sites previously mentioned contain little evidence of occupation corresponding to this interval.	Replacement of early Archaic point types with various side-notched forms: Sudden (including Rocker) and Hawken	Plain-weave sandals and perhaps a continuation of open-twined sandals	4925
6800	Early Archaic	Increased population from preceding period. Thick trash accumulations in preserved sites indicates frequent reoccupations of favored locales; perhaps relatively low residential mobility.	Cowboy and Walters caves (Unit III), Dust Devil Cave (stratum IV), Sand Dune Cave (lower stratum V), Old Man Cave (levels 7–12), Good Hope Alcove, Rock Bar Alcove (?), and Bechan Cave	Elko Corner side-notched, Northern side-notched, Pinto, and perhaps Sand Dune side-notched	Open-twined sandals and plain-weave sandals (coarse warp-faced)	5645
7800	Initial Archaic	Start of Archaic occupation in the region; sort of a "settling in" period with sparse population. Apparently no continuity with local late Paleo-Indians; rather, Archaic populations intrusive from eastern Great Basin.	Cowboy and Walters caves (Unit II), Dust Devil Cave (lower stratum III), Rock Bar Alcove, and perhaps Sand Dune Cave (stratum III)	Pinto, Elko Corner side-notched, perhaps Sand Dune side-notched	Open-twined sandals, fine warp-faced sandals	6610
9000						8050

the traditional sense, although they do seem to correspond to intervals wherein cultural patterns were relatively similar yet sufficiently different from earlier and later patterns. These intervals also correspond to some degree with the extent of current knowledge. For example, on a scale from 0 to 10, where 10 denotes detailed knowledge, the empirical underpinning for each of the seven subdivisions might be ranked as follows: 5 for the early and late Archaic, 1 for the two transitions and the initial Archaic, 0.5 for the terminal Archaic, and 0.1 for the middle Archaic. Once we have comparable amounts of information for the entire Archaic sequence, more useful temporal partitions might become obvious. If for no other reason, the seven subdivisions serve to emphasize which portions of the Archaic sequence should receive concerted investigation.

Conclusion

Having reviewed the available chronometric dates, I find that the data support the model of long-term continuity in Archaic occupation of the central Colorado Plateau. The radiocarbon record is sufficient to cast doubt on interpreting the Archaic period as a sequence of major population abandonments and intrusions on a pan-regional scale. Despite arguing for occupational continuity, I am unwilling to discount population immigration as a reason for some apparent changes during the Archaic. Migration still has something to offer archaeologists for understanding prehistory (see Anthony 1990) but not to the extent that Berry and Berry (1986:321) believe when they suggest that major population replacement "is the key to understanding Archaic prehistory in the Desert West." Current knowledge of the Archaic period is still so limited and spotty that we cannot yet critically evaluate the issue of migration during this early interval. I see no necessary linkage between long-term occupational continuity and gradualism (Berry 1982; Berry and Berry 1986:255) but find little evidence for sudden change during the Archaic. Even by examining change during seven temporal subdivisions instead of three, it is difficult to make an argument for anything happening rapidly because the smallest time interval is of 500-year duration—about 20 biological generations.

Future research on the Archaic period of the central Colorado Plateau must attempt to muster evidence for those portions of the Archaic sequence that are still poorly documented. Only by such an effort can we adequately describe the economic and cultural transitions during the roughly 6,500 years and thereby disentangle the various historical and evolutionary processes that might be involved in culture change. Even for those portions of the Archaic sequence that are more completely understood, the information is derived from a paltry site sample with primary reliance on two sites in largely similar environmental settings—Cowboy and Dust Devil caves. The excavated sample of high-information sheltered sites needs to be expanded to cover a diversity of environmental settings, with particular emphasis placed on well-watered canyon lowlands and on high-elevation settings (ca. 2,625 m). Open sites need to be investigated also, but it seems evident that the sample of absolutely-dated early and middle Archaic open sites available for study is limited. Open sites are potentially assignable to these early periods based on point types, but even if such assignments are correct, the sites are often so deflated and otherwise affected by postdepositional processes that our ability to use them for interpretive purposes is limited.

The central Colorado Plateau emerges as a region of the Southwest with significant evidence of Archaic culture. Indeed, the earliest documented expression of an Archaic lifeway anywhere on the Colorado Plateau is found here. Exceptionally preserved subsistence remains and perishable technology are present within numerous stratified dry shelters. Paleoenvironmental data are rife from a variety of sources (alluvial stratigraphy, packrat middens, cave sediments, etc.) and should eventually enable detailed climatic and biogeographic reconstructions for the entire Holocene. As such, the central Colorado Plateau is one of the highly productive areas for studying Archaic hunter–gatherer adaptations and economic transitions, including the adoption of agriculture. Our understanding of this period is not limited by a lack of potential data sources, though the best of these are in serious danger of being lost to illicit digging. To gain the most benefit from the still-rich archaeological data base, a long-term, regionwide research program is needed, designed to document not just the common lifeway patterns that form the basis of culture–history but also the variability that informs us about the organization of hunter–gatherer societies and how they change.

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Compositional Analysis of Temper in Emery Gray Ceramics From Central Utah

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Abstract. Emery Gray ceramics of the Fremont culture are characterized by crushed igneous rock temper. Several temper types that appear distinct under the binocular microscope are included in this ceramic type, and the relation of these temper types and the sources of the rocks have been debated. Emery Gray sherds from a site in central Utah were used to address this research question. Analysis with the petrographic microscope and electron microprobe indicates that the composition of feldspars in two distinct temper types is similar. Samples of potential source rocks collected near the site also were analyzed and compared with the temper samples. The feldspar composition of the rocks and the Emery Gray sherd temper are comparable and the mineral assemblages also are similar. Combining the compositional data with the distribution of the several rock types revealed patterns that can be used to determine the location of production and patterns of distribution of Emery Gray ceramics. These patterns provide information on resource use by Fremont peoples. The data may also be useful in refining the classification system for Fremont ceramics.

Key words: Ceramic production, Fremont, Utah prehistory.

Studies of Fremont ceramics have followed the pattern of development that characterizes archaeological analysis of ceramics in most of the New World. Subsumed under Desert Gray Ware (Rudy 1953), several ceramic types have been named, described, and used in the identification of regional variants of the Fremont culture. Recently, however, more intensive analysis revealed problems with the traditional taxonomy, and revisions may be necessary to accurately characterize excavated Fremont ceramic assemblages.

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One potential problem with the classification system is that temper type is heavily emphasized as an attribute, even though few petrographic or compositional analyses of Fremont ceramics have been conducted. This has led to confusion and difficulty in applying the classification, even by analysts familiar with Fremont ceramics. For example, Madsen (1977) described Emery Gray temper as fine gray basalt and Sevier Gray temper as coarser black basalt. Compositional analysis revealed, however, that the temper material in these ceramics is not basalt (Spurr 1993); it was identified as such because of its dark color. Furthermore, Emery Gray has a range of temper color, possibly dependent on where the ceramics were produced (Geib and Lyneis 1993). The difficulty with defining ceramic types based on temper type is compounded by the complexity of the geology of central and southern Utah. A great number and variety of igneous—mainly volcanic—formations crop out in this area. The temper material of Fremont ceramics in this region is mainly igneous rock, and the potential for identifying production locations is great but must be approached with caution.

Perhaps the greatest problem with the current classification of Fremont ceramics is the inaccurate and inconsistent temper designations (Geib and Lyneis 1992*[2]). The nonspecific nature of most temper descriptions makes their application difficult. The problem is exacerbated by the difficulty with correlating small pieces of rock, such as temper, with hand samples of rock. This step, however, is necessary to identify temper sources. The use of nonspecific terms such as *black basalt* and *gray basalt* to indicate two distinct ceramic types invites inconsistent identification. This is exactly the situation faced by analysts of Sevier Gray and Emery Gray ceramics.

The need for a revision of the Fremont ceramic typology has become evident. The system is not failing; the modification of classification systems as new information becomes available is a normal part of scientific endeavor. In 1992, I completed compositional analyses of Emery Gray sherds from a Fremont site in central Utah. The research project, undertaken at Northern Arizona University, had several goals:

1. to define the variability of temper in sherds from one site;
2. to determine the chemical composition of the temper material in the sherds;

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[2] Asterisk indicates unpublished material.

3. to determine the chemical composition of rocks from the local area;
4. to compare the compositions of the temper and rock to determine a possible source of the temper; and
5. to compare the variability of the sherds to the current type description of Emery Gray.

Although my research focused on both Emery Gray and Sevier Gray ceramics, this paper will concentrate on Emery Gray ceramics. In addition to providing confirmation of local ceramic production, compositional analyses revealed that a single ceramic type cannot adequately describe the variety of temper in Emery Gray.

Round Spring Site and Ceramic Assemblage

The research area is in the San Rafael region of the Fremont culture area, which extends from the east side of the Wasatch Mountains of Utah eastward to the Uncompahgre Plateau in Colorado and from the southern edge of the Uinta Mountains south to the Colorado River in Utah (Fig. 1). In this geographic area, along the tributaries of the Fremont River, Morss (1931) recorded the sites and artifact assemblages that defined the Fremont culture. Gunnerson (1957, 1969) and Rudy (1953) carried out further survey and test excavations of several Fremont sites in a wide area in Utah and helped refine the definition of the Fremont culture. One of the sites that Gunnerson located and tested was the Round Spring site (42SV23), the focus of this project (Gunnerson 1957:102–105).

The Round Spring site is a large San Rafael Fremont pit house village at the confluence of the Round Spring Draw and Last Chance Creek (Fig. 2) on the eastern edge of the Wasatch Plateau. At an elevation of 2,278 m, the site is surrounded by pinyon–juniper forest and sagebrush grassland. The site is on an aggrading colluvial fan deposit that slopes gently to the southeast; the Fremont component of the site is buried by as much as 1.5 m of sediment (Metcalf 1993a). During a survey before the realignment and upgrading of State Highway 72, archaeologists from Brigham Young University evaluated the Round Spring site as eligible for nomination to the National Register of Historic Places (Nielson and Hall 1985). In 1987, Metcalf Archaeological Consultants, Inc. (MAC), conducted excavations to mitigate destruction of the central portion of the site by road construction.

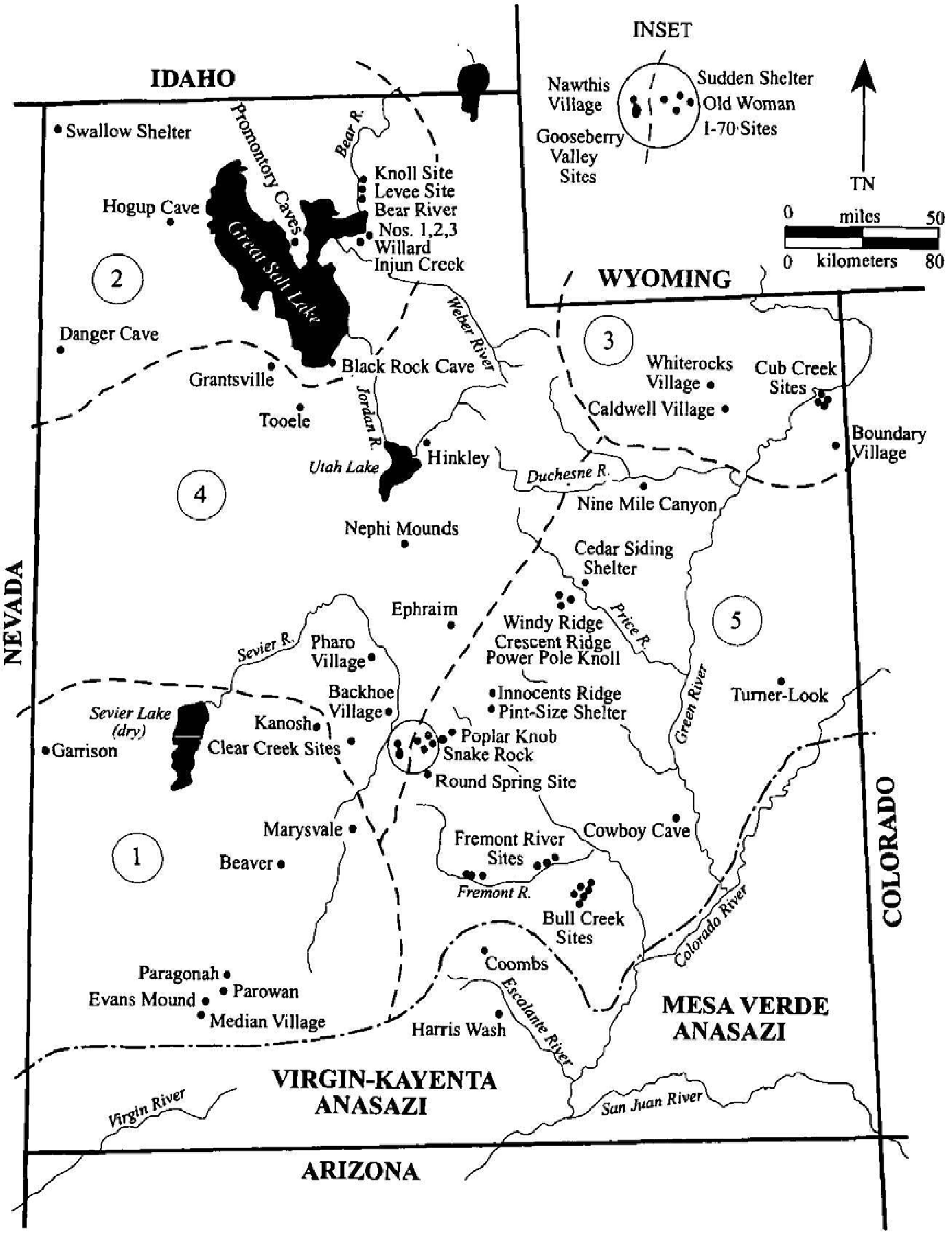

Fig. 1. Map of selected Fremont sites and Fremont regional variants: *1*. Parowan Fremont; *2*. Great Salt Lake Fremont; *3*. Uinta Fremont; *4*. Sevier Fremont; and *5*. San Rafael Fremont. Redrawn after Marwitt (1970:Figure 84). Courtesy of the University of Utah Press.

The highway corridor, 300 m long and 50 m wide, transects the site. Crews from MAC conducted excavations along this corridor and in an additional 20- × 20-m block along the two-track road that leads to Round Spring. In

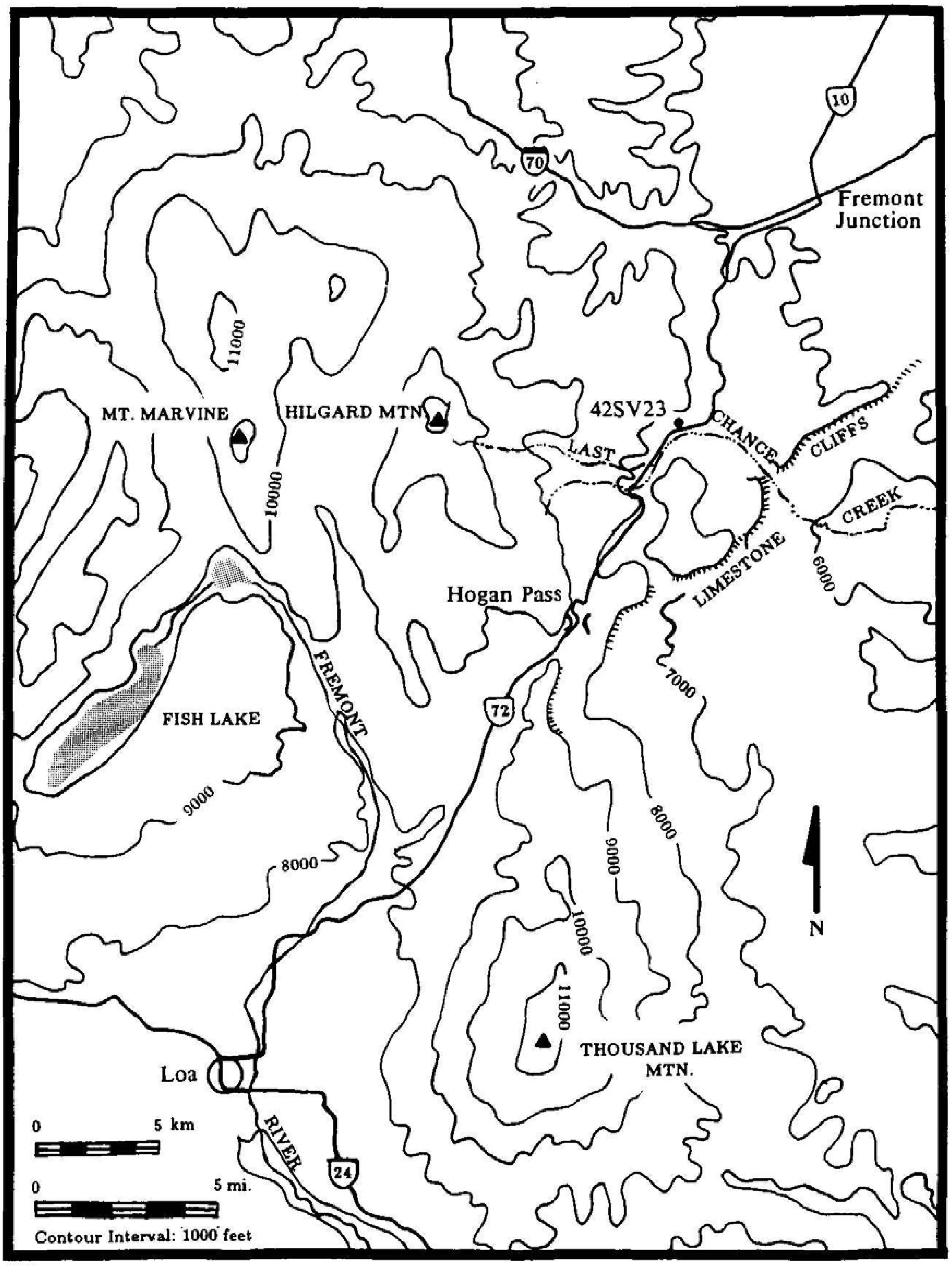

Fig. 2. Map of the project area, showing the location of 42SV23, the Round Spring site. Redrawn after Rood et al. (1988:Fig. 1).

addition to the 2 structures that Gunnerson (1957:102–105) excavated, MAC crews excavated 6 complete and 4 partial structures (mainly pit houses), 1 puddled adobe surface storage unit, a possible jacal structure, at least 3 outdoor activity areas, and more than 20 hearths (Metcalf 1993a). Several features outside the highway right-of-way were not excavated by MAC. The number of structures on the site probably exceeds 20 and makes the Round Spring site one of the larger Fremont sites in the vicinity. Architecture and artifact assemblages are similar to those of other San Rafael Fremont sites in the area.

Twenty-two radiocarbon dates from the main area of the site range from 1520 ± 80 B.P. to 150 ± 50 B.P. Radiocarbon dates, diagnostic projectile point styles, and ceramic trade wares indicate occupation from about A.D. 650 to 1300. Although the occupation may have been continuous, different areas of the site were used during shorter periods. The period from A.D. 650 to 900 is associated with features from several areas across the site. The second period, A.D. 900–1050, is mainly represented by features in the central section of the site. The third period, A.D. 1050–1150, saw the most intensive use of the site, mainly concentrated in the western area. The final period, represented by only one structure at the southeastern edge of the site, was from A.D. 1150 to 1300. Two late dates—590 ± 5 and 150 ± 50 B.P.—from features in the eastern section of the site are probably associated with subsequent Numic use of the area (Metcalf 1993b).

Basic ceramic analysis, including classification by ceramic type, was completed on the ceramic assemblage of nearly 30,000 sherds that MAC recovered (Morris et al. 1993). Fremont ceramic types make up more than 99% of the ceramic assemblage from the site, a pattern that is typical in this region. Most Fremont ceramics (89.4%) were classified as Emery Gray. The next most common types at the site were Sevier Gray (3.9%) and Ivie Creek Black-on-white (3.9%). Small quantities of the Snake Valley series (1.7%), a few sherds of Great Salt Lake Gray, and one sherd of Paragonah Coiled also were recovered (Morris et al. 1993:Table 1).

Non-Fremont trade wares composed only 0.2% of the assemblage and included Kayenta Anasazi types such as Tusayan Black-on-red, Tusayan Polychrome, and Dogoszhi Black-on-white and Mesa Verde types such as McElmo–Mesa Verde Black-on-white, Cortez Black-on-white, and Mesa Verde Corrugated. Twelve pieces of brownware also were noted in the collection. These sherds may be Alameda Brown Ware, a Sinagua ceramic type produced in north-central Arizona (Colton and Hargrave 1937).

Ceramic Analysis

Because ceramics are formed from natural materials, ceramic vessels are compositionally linked to the environment in which they are produced. This fact forms the basis of compositional studies of ceramic provenience, production, and distribution. Ceramic composition relates not only to the cultural realm (social and individual patterns of material procurement and preparation), but also to the natural realm (source rocks, weathering, and transportation). Binocular and petrographic microscope analyses allow the archaeologist to address both aspects quickly and inexpensively. Information regarding locations of ceramic production and patterns of distribution can be gained by identifying materials present in the ceramic paste, determining which were added and which were natural inclusions, and then comparing the materials to geologic resources. Provenience studies are the most common use of petrographic analysis in archaeology and have proven to be reliable and useful.

Analysis Methods

I used three successively more detailed methods of compositional analysis to characterize the temper in ceramics from the Round Spring site. For this study, temper is defined as nonplastic material that is deliberately added to clay by the potter (Shepard 1985:24; Rice 1987:406). This distinction is usually made on the basis of particle shape, size range, and frequency (Maggetti 1982:131; Rice 1987:409–411).

I analyzed temper in plain and surface-manipulated graywares, the most common types in the Fremont region; painted ceramics were not included. The majority of the ceramics in the sample were Emery Gray, usually associated with the San Rafael Fremont (Madsen 1970). This ceramic type was originally defined by Wormington (1955; called Turner Gray—variety II), and later revised by Lister (1960; called Turner Gray—Emery variety) and Gunnerson (1960*, 1969). Most recently, R. Madsen (1977:31) characterized the temper as "... angular crushed fragments of gray basalt (20–40%) and quartz (10–25%); some mica occasionally present. Inclusions range from 0.1–1.5 mm in size...." Most analysts working in the area agree that there is more variation in the temper than is recognized by the current type description, but systematic studies are needed to quantify the variation.

Because of the large amount of ceramic material recovered from the Round Spring site during MAC's excavation, only a small percentage of the total could be analyzed for this study. I tried to avoid analyzing more than one sherd from a single vessel in order to represent the range of variation in the assemblage as completely as possible. I believed that a simple random sample of the sherds could increase the chances of including more than one sherd from a single vessel (as well as unsuitable sherds), and so I used a more rigorous sampling design.

The sample was limited to rim sherds, which allowed the vessel type to be determined because correlations between specific temper materials and specific types of vessels were considered in the analysis. Sherds smaller than a quarter were not included because of a minimum size limit for petrographic thin sections as well as a concern about accurate temper identification in extremely small sherds. Each structure and activity area in the site was divided into horizontal units based on the cultural stratigraphy. From the total rim sherd collection I selected those from well documented, well controlled contexts, especially from proveniences inside structures under roof fall (floor fill and floor contact). Two hundred seventy-two bags of sherds met all the criteria, and one sherd was chosen randomly from each bag. A fresh break on each sherd was examined under a low power (×30–40) binocular microscope. The types of inclusions were recorded and identified as temper or natural inclusions. Temper in the Emery Gray sherds was divided into three categories: type A, type C, and a combination of both types.

Petrographic microscope analysis was used to identify more specifically the minerals present in temper particles of sherds analyzed with the binocular microscope. Thirty-two sherds of Emery Gray were included in the petrographic analysis—26 of type C, one of type A, and five with both temper types. This sample reflects the frequency distribution of temper types in the binocular microscope sample. Sherds were chosen from the larger sample using a random number generator and were then inspected for suitability. Those that had a pronounced curve to them were not used in an effort to avoid excessively small thin sections and to ensure a representative sample of temper. Friable sherds were not used because of the large amount of epoxy impregnation required for these specimens, and burned specimens were rejected because of the difficulty in studying dark thin sections.

At each of 300 points on each sherd, the material under the microscope cross-hairs was recorded. This type of point counting, termed *multiple intercept*, is common in geologic studies and has been determined to be satisfactory for ceramics studies (Middleton et al. 1985). *Multiple intercept* indicates that if a single grain appears under the crosshairs at more than one point, it is counted more than once. The result is actually a measure of the relative area or volume of each type of material in the thin section rather than the number of each grain type.

The third phase of analysis used an electron microprobe. The microprobe is useful for archaeological studies because it is nondestructive; a single sample can be used for repeated analyses and the sample, a thin section, can be curated for future studies. Furthermore, the small size of the thin sections used by the microprobe makes it possible to analyze small pieces of vessels or sherds. The main advantage of the microprobe over X-ray fluorescence, to which it is similar, is that the electron beam can be focused to include only a few cubic micrometers (μm) of material in the analysis. This permits analysis of small portions of the artifact, such as ceramic temper, which would be difficult to mechanically separate from the sample.

The microprobe produces a beam of electrons that, after passing through a series of magnetic lenses, strike the target specimen and interact with the atoms in the specimen. Inner-shell electrons in the atoms are knocked out of their orbits by the impact of the electrons, and as the resulting ion returns to its normal stable energy state it gives off energy in the form of an X-ray characteristic of the element. The X-rays emitted by this process can be detected by either wavelength or energy spectrometers and analyzed. Wavelength dispersive spectrometry, used in this analysis, counts the X-rays emitted by specific elements and provides a quantitative analysis of those elements in the sample. Birks (1963) and Fitzgerald (1973) provide more detailed descriptions of the mechanical aspects of the microprobe. Microprobe analysis operating conditions and detection limits for this analysis are described by Spurr (1993:81–85).

Sherds to be analyzed with the electron microprobe were chosen based on the petrographic microscope analysis and included one sherd with temper type A, five with temper type C, and two with both temper types. Two sherds of Sevier Gray were also included in the microprobe analysis. The goal of the microprobe work was a quantitative compositional analysis of feldspar in the temper in the sherds. Elements analyzed with the microprobe were Na (sodium), Al (aluminum), Si (silica), K (potassium), Ca (calcium), Ba (barium), and Fe (iron). These elements, reported as oxide weight percents of Na_2O, Al_2O_3, SiO_2, K_2O, CaO, BaO, and Fe_2O_3, represent the major constituents of the feldspar group.

Feldspars are the most common rock-forming minerals in the earth's crust and are a major constituent of igneous rocks; the types and associations of feldspars are one of the attributes used to classify rocks (Moorhouse 1959; Deer et al. 1971). The feldspars, which are framework silicates, form two solid solution series in which the chemical composition varies between finite limits whereas the crystalline form remains essentially the same. The standard classification of feldspars approximates a ternary system and is divided into two series, alkali feldspar and plagioclase (Fig. 3). End members of the feldspar system are orthoclase (Or), albite (Ab), and anorthite (An). Rare celsian (Cs) feldspars, in which barium replaces all or most Ca, can exist in the place of anorthite in the system.

Orthoclase ($KAlSi_3O_8$) and albite ($NaAlSi_3O_8$) form the end members of the alkali feldspar group, in which anorthite ($CaAl_2Si_2O_8$) is absent or a minor constituent. Minerals in this group are monoclinic or triclinic. Alkali feldspars are mainly present in felsic igneous rocks such as syenite and granite and their volcanic equivalents. Albite and anorthite are the end members of the plagioclase series, in which orthoclase represents less than 10% of the composition.

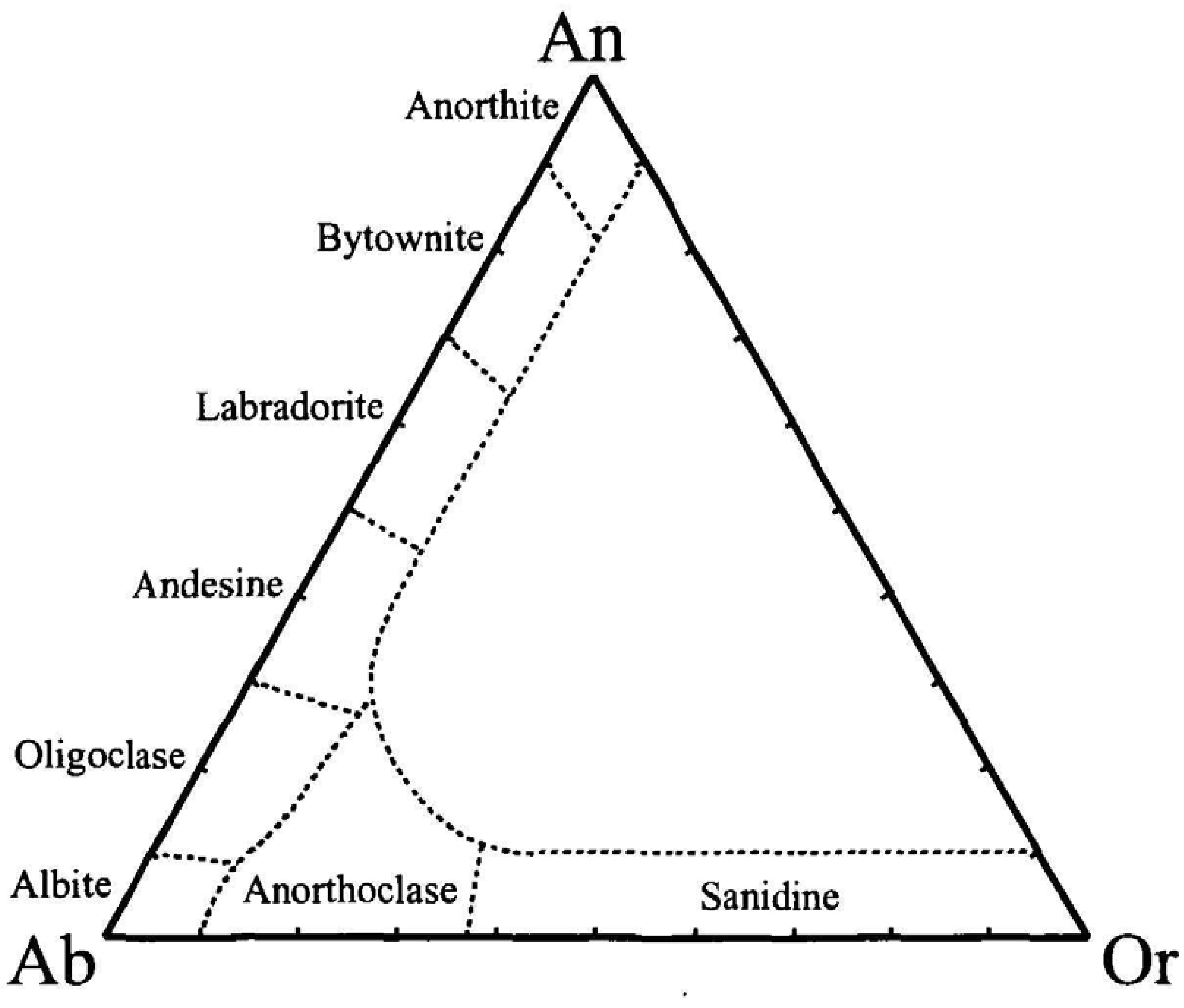

Fig. 3. Ternary diagram of the feldspar system, with conventional nomenclature.

Plagioclase minerals are triclinic. These minerals are found in intermediate and mafic igneous rocks such as andesite and basalt. Plagioclase may comprise both phenocrysts and groundmass of these rocks, and several types of plagioclase are commonly found in a single rock.

The feldspar system is essentially a continuous reaction series involving a gradual change in composition caused by continuous substitution of Na for Ca or K for Na. The crystal structure remains essentially unchanged by these compositional changes. The composition of feldspars represents a closed system, and the elements composing different feldspars are not independent variables. For instance, the amount of Ca is directly proportional to the amount of Na and Al and to a lesser extent K. Because of the closed nature of the feldspar system, statistical methods that treat one or more variables as independent, such as Principle Components Analysis, are not appropriate for modeling the feldspar system. The standard method of presentation is on a ternary diagram, where feldspar composition is presented as a percentage of the end members. For example, $An_{66.0}Or_{0.7}Ab_{33.1}Cs_{0.2}$ represents a feldspar with 66.0% anorthite component, 0.7% orthoclase component, 33.1% albite component, and 0.2% celsian component.

Analysis Results

Binocular microscope analysis of 272 sherds indicated that two types of igneous rock were used as both primary and secondary temper in the Emery Gray ceramics from the Round Spring site. Primary temper is the most abundant type, and secondary temper is a relatively less abundant type. Because the temper particles in each sherd are generally of roughly equal size, the primary–secondary distinction is based on both the number of grains and the volume of each type.

The two temper materials identified with the binocular microscope correspond to types previously identified by Geib and Lyneis (1993) in Fremont sherds. In the interest of consistency, I have continued the designation system used by Geib and Lyneis (1993) in their research. Under the microscope, temper type A is black to dark gray with a glassy groundmass and abundant phenocrysts of plagioclase and dark green to black pyroxene. Based on petrographic analysis, this material was identified by Geib and Lyneis (1993) as basaltic andesite. Temper type C is a microcrystalline intermediate igneous material, light to medium gray in color, with abundant phenocrysts of dark green to black pyroxene and black magnetite. This temper type is generally considered to be the classic Emery Gray temper. This material was also noted by Geib and Lyneis (1993) and was identified as a possible variation of the basaltic andesite that is type A.

Temper types A and C make up the majority of the ceramic temper at the Round Spring site. In the binocular microscope analysis, temper type A represents 1.8% of the total sample, type C makes up 73.9%, and sherds with both temper types represent 12.9% of the assemblage; only 11.4% of the sherds do not have one or both of these temper types. Crosstabulations indicate that there is no correlation between temper type and vessel form or surface treatment. When temper types A and C are present in the same sherd, it is often difficult to distinguish between them based on mineralogy, lending credence to the possibility that the raw material that produces these two temper types is a gradation of a single igneous formation.

During point counting with the petrographic microscope, each grain was identified as sherd paste, epoxy, feldspar, pyroxene (clinopyroxene or orthopyroxene), opaque minerals (such as magnetite), biotite, olivine, volcanic glass, or rock fragment. Rock fragments are pieces of the source rock groundmass, characterized by very small, tightly bonded crystals of feldspar, pyroxene and some volcanic glass as well as small to large phenocrysts of various minerals. Phenocrysts were recorded as a mineral when they were loose in the sherd paste but as rock fragments when they were within groundmass. This distinction may be an indication of the level of processing of temper in the sherds or of the nature of the raw temper material (e.g., dense vs. porous or fresh vs. weathered). Differences noted in the ratio of feldspar to pyroxene in the groundmass of the rock fragments may correspond to macroscopic differences in temper sources, as discussed below. Petrographic analysis revealed that temper types A and C have similar amounts of feldspars, pyroxenes, and opaque minerals indicating that temper types A and C could be derived from the same rock source. Statistical tests of the frequency of minerals present revealed that temper types A and C are mineralogically similar but are significantly different from temper in Sevier Gray ceramics from the site.

The petrographic point count data were analyzed by cluster analysis using Euclidean distance and the complete linkage (farthest neighbor) method. The cluster analysis yielded three distinct groups, which correspond to the temper types (Table 1; temper type E represents Sevier Gray ceramics). The clusters are differentiated mainly by the amount of volcanic glass, pyroxene, and rock fragments in the temper and to a lesser degree by the amount of opaque minerals (such as magnetite) and feldspar (Table 2). It is plausible that temper types A

Table 1. Distribution of temper groups by cluster for sherd petrographic microscope analysis.

	Cluster			
Temper type	1	2	3	Total
A	1[a]	—	—	1
	2.8[b]			2.8
A & C	5	—	—	5
	13.9			13.9
C	19	—	7	26
	52.8		19.4	72.2
E[c]	—	4	—	4
		11.1		11.1
Total	25	4	7	36
	69.4	11.1	19.4	100.0

[a] Frequency.
[b] Percent.
[c] Temper in Sevier Gray ceramics.

and C are derived from the same rock source, as the frequencies of mineral inclusions in clusters 1 and 3 are similar (Table 2). The presence of both temper types A and C in cluster 1 indicates that these temper types are not mineralogically distinct. The main difference between clusters 1 and 3 is the ratio of rock fragments to paste, which only indicates that the sherds in cluster 3 contain more temper than those in cluster 1.

Roughly 20 points were analyzed on each of the 10 sherds selected for electron microprobe analysis. The relative proportions of each analyzed element were used to plot the electron microprobe data on ternary diagrams. Figures 4–11 show the analysis results of the Emery Gray sherds and indicate that the feldspar in all the sherds is similar. The feldspar in temper types A and C straddles the boundary between andesine and labradorite and ranges in composition from $An_{35.9}Or_{6.2}Ab_{55.3}Cs_{0.3}$ to $An_{68.6}Or_{1.4}Ab_{29.9}Cs_{0.1}$ (Figs. 4–11). Microprobe analysis data from the sherds indicates that the feldspar in temper types A and C is similar (Fig. 12) but is clearly different from feldspar in sherds with other temper types (Fig. 13). Chemical differences between the feldspars are most apparent in the amount of Fe_2O_3 and BaO. Sherds with temper types A and C contain similar amounts of these oxides (Fig. 14) but differ from sherds with other temper types (Fig. 15).

Table 2. Distribution of minerals by cluster for sherd petrographic microscope analysis.

Cluster	Sherd paste	Feldspar	Volcanic glass	Pyroxene	Opaque	Biotite	Rock frag.	Epoxy
1	140–209[a]	9–53	0–2	2–18	0–12	0–2	53–103	0–14
n = 25	171.8/170[b]	32.1/33	0.12/0	8.9/7	4.6/5	0.2/0	76.7/74	5.4/5
	19.5[c]	12.5	0.4	4.6	3.2	0.5	14.6	3.6
2	130–189	13–35	52–106	0–2	0–6	2–7	0–7	11–21
n = 4	172.5/185.5	24.3/24.5	75.0/71	0.8/0.5	2.3/1.5	4.8/5	2.5/1.5	15.0/14
	28.5	9.2	22.8	1.0	2.6	2.6	3.3	4.2
3	119–156	15–46	0–0	3–10	0–5	0–0	106–142	0–24
n = 7	139.0/143	25.9/25	0.0/0	6.7/6	2.4/3	0.0/0	120.4/116	5.6/1
	13.5	10.3	0.0	3.3	2.1	0.0	11.8	8.6

[a] Frequency range.
[b] Mean/median.
[c] Standard deviation.

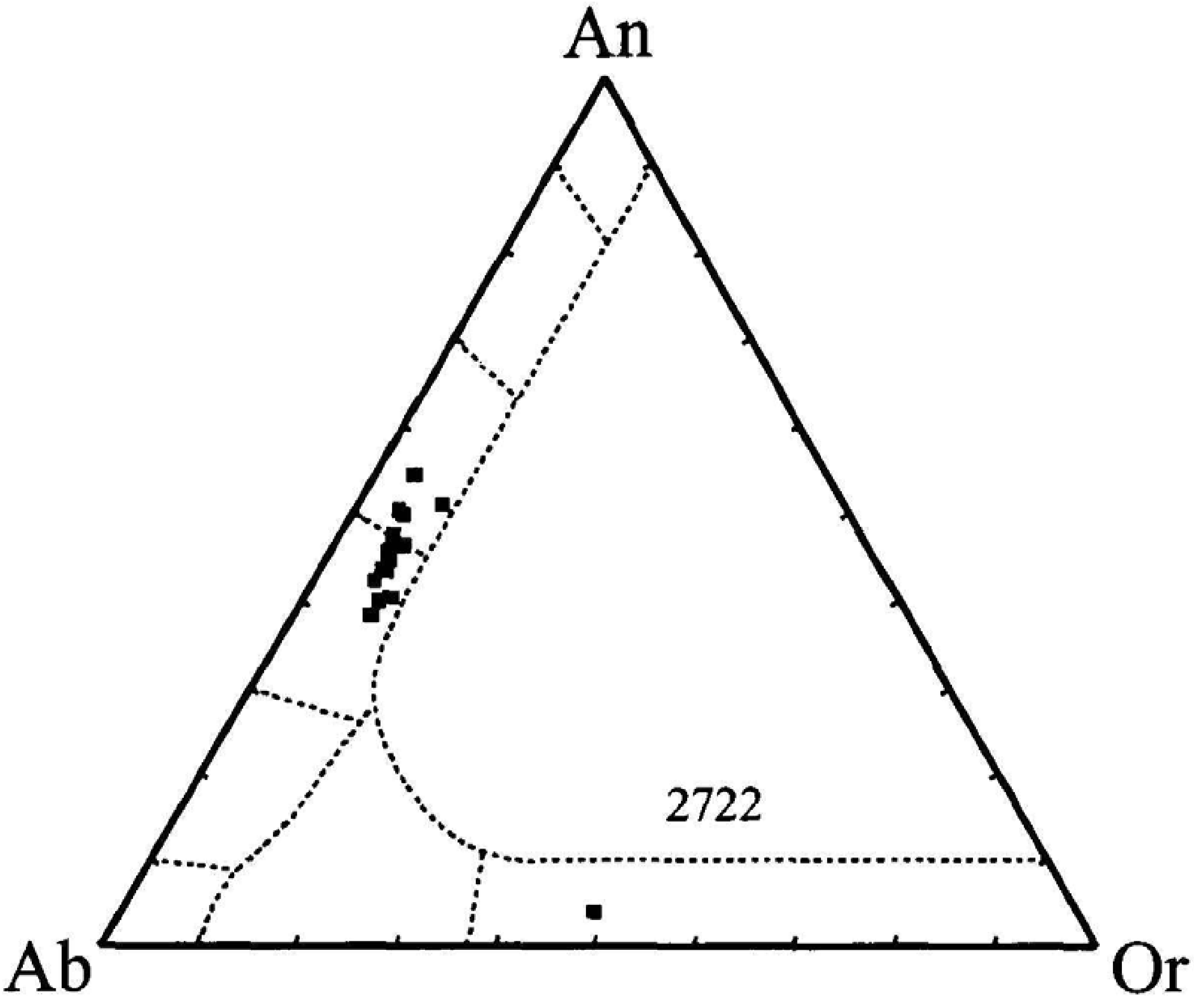

Fig. 4. Results of electron microprobe analysis of sherd 2722.

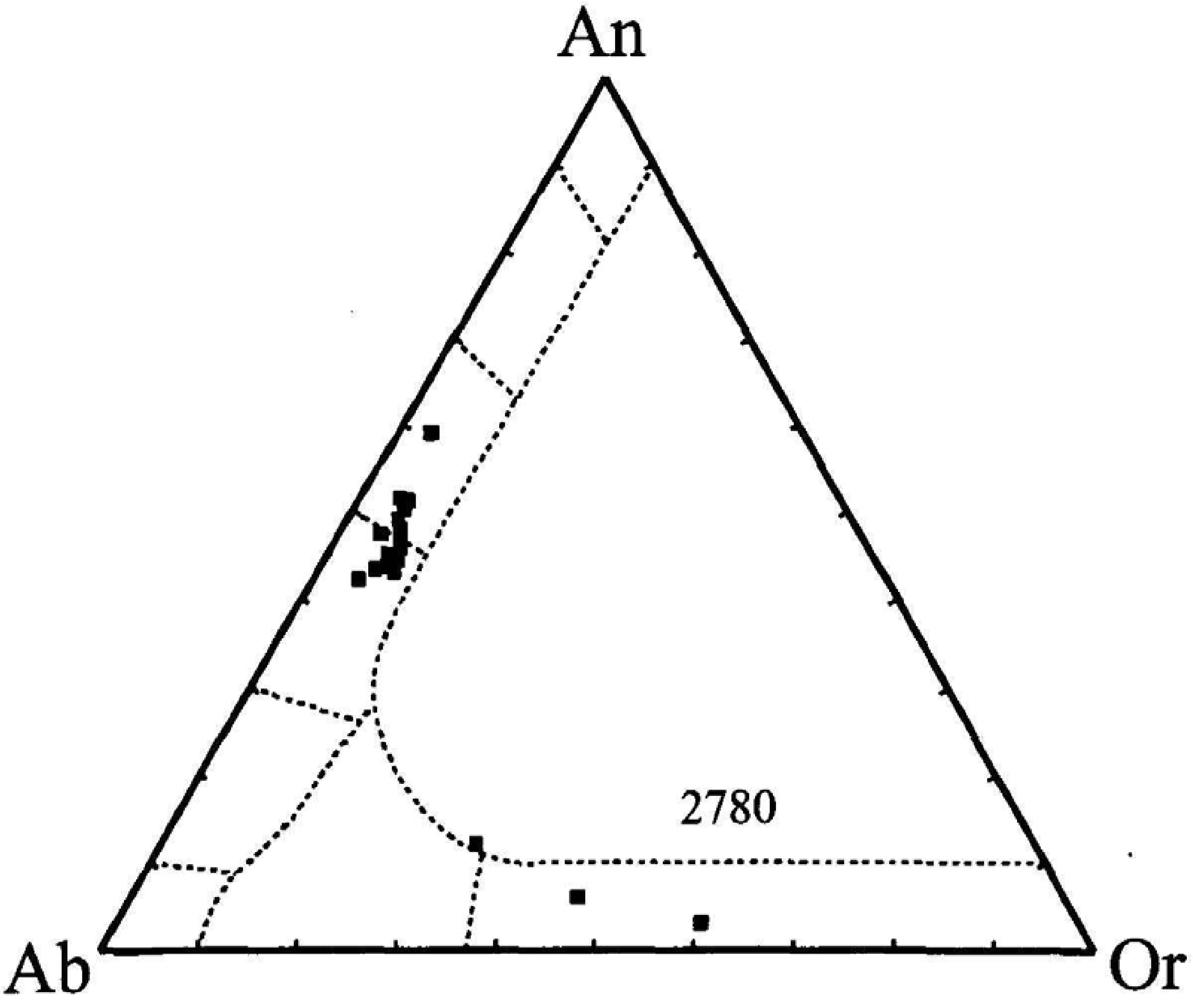

Fig. 5. Results of electron microprobe analysis of sherd 2780.

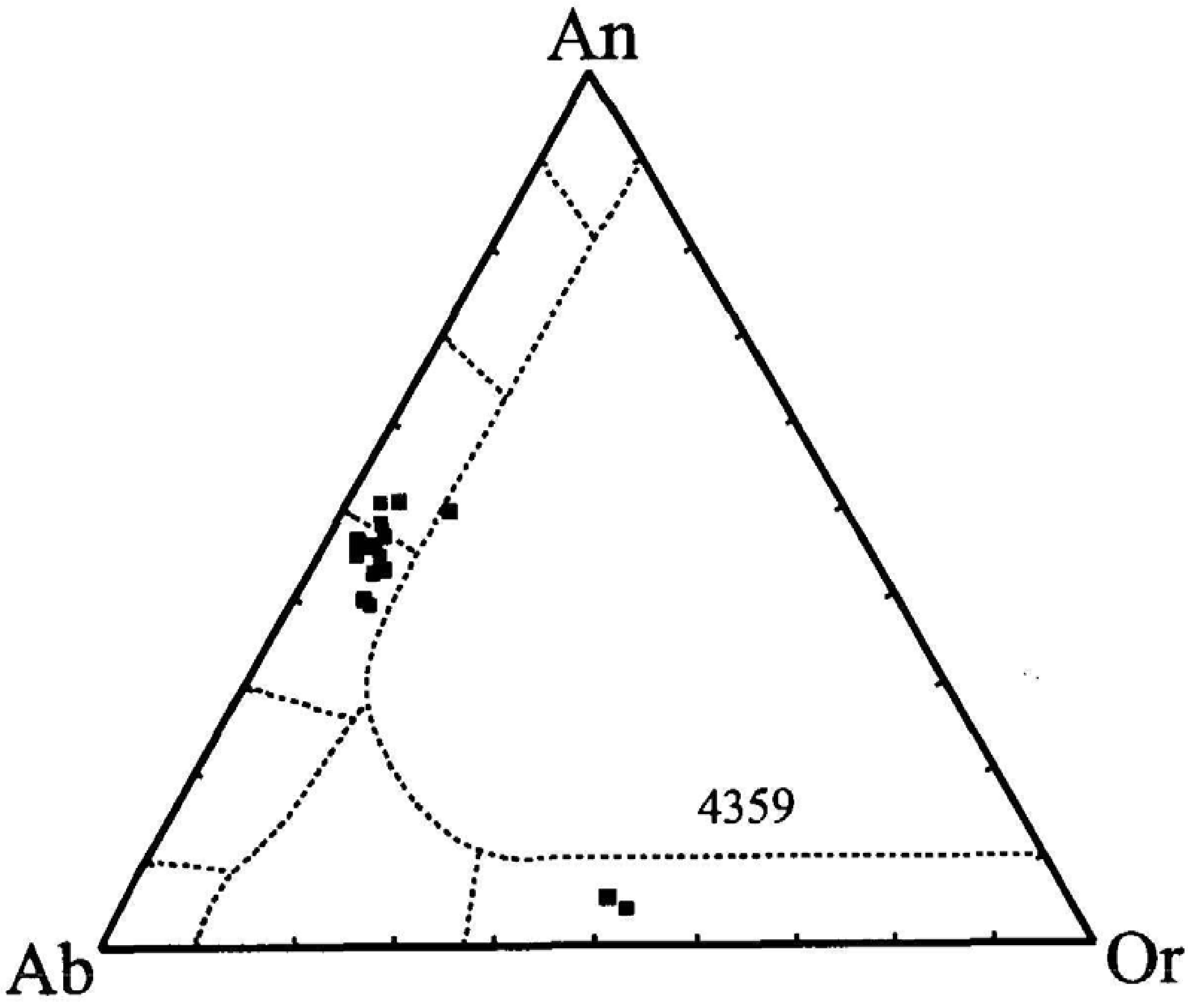

Fig. 6. Results of electron microprobe analysis of sherd 4359.

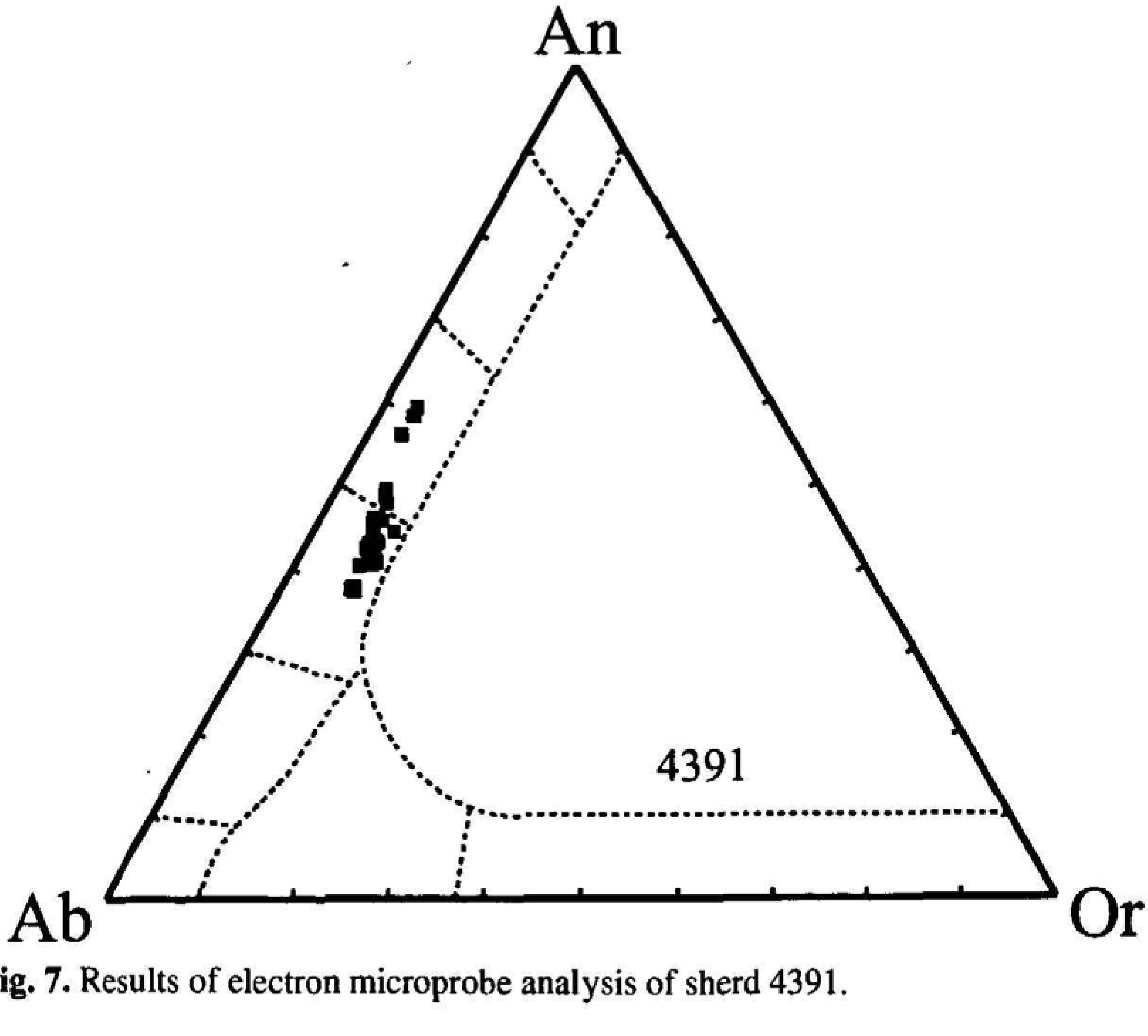

Fig. 7. Results of electron microprobe analysis of sherd 4391.

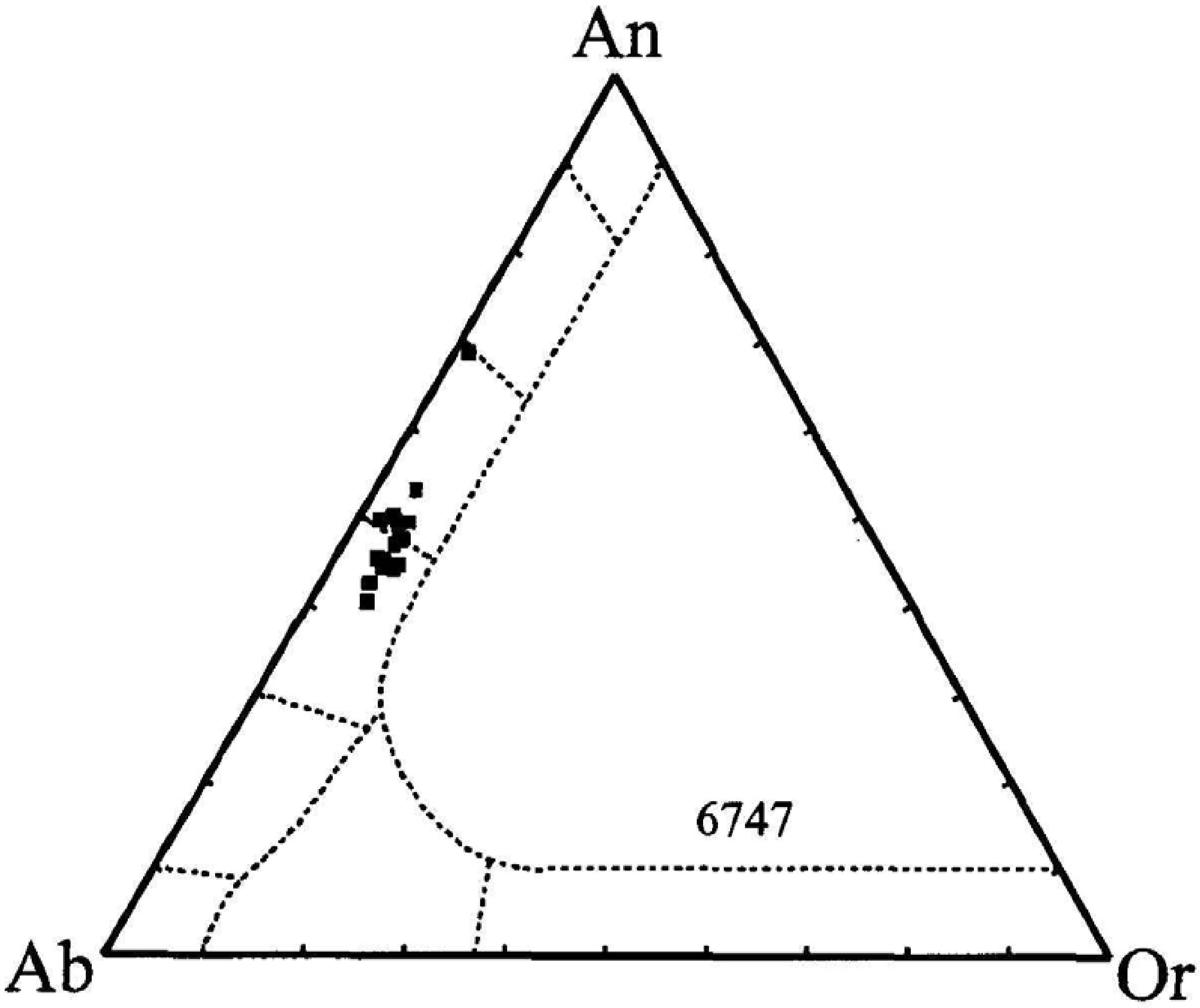

Fig. 8. Results of electron microprobe analysis of sherd 6747.

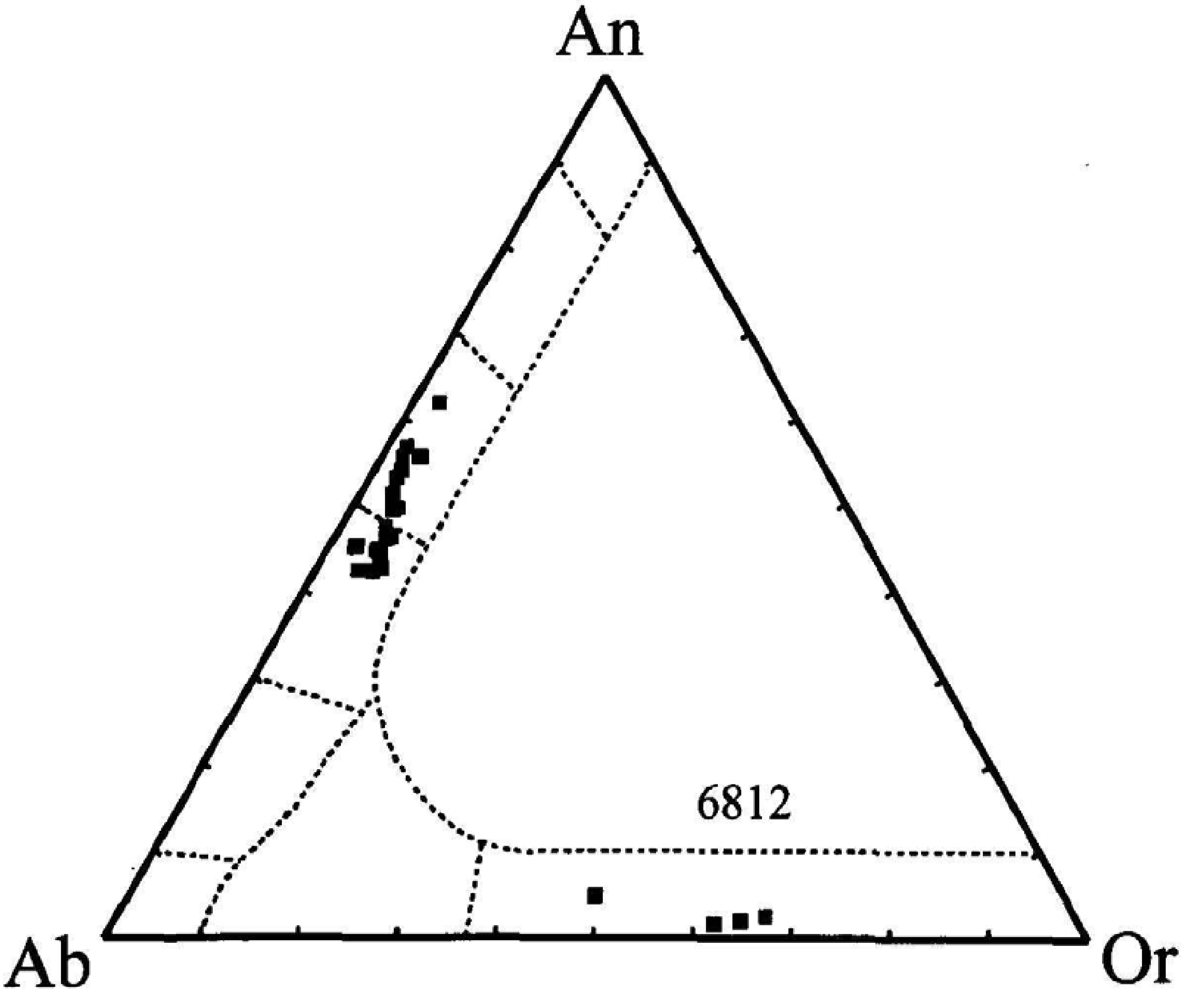

Fig. 9. Results of electron microprobe analysis of sherd 6812.

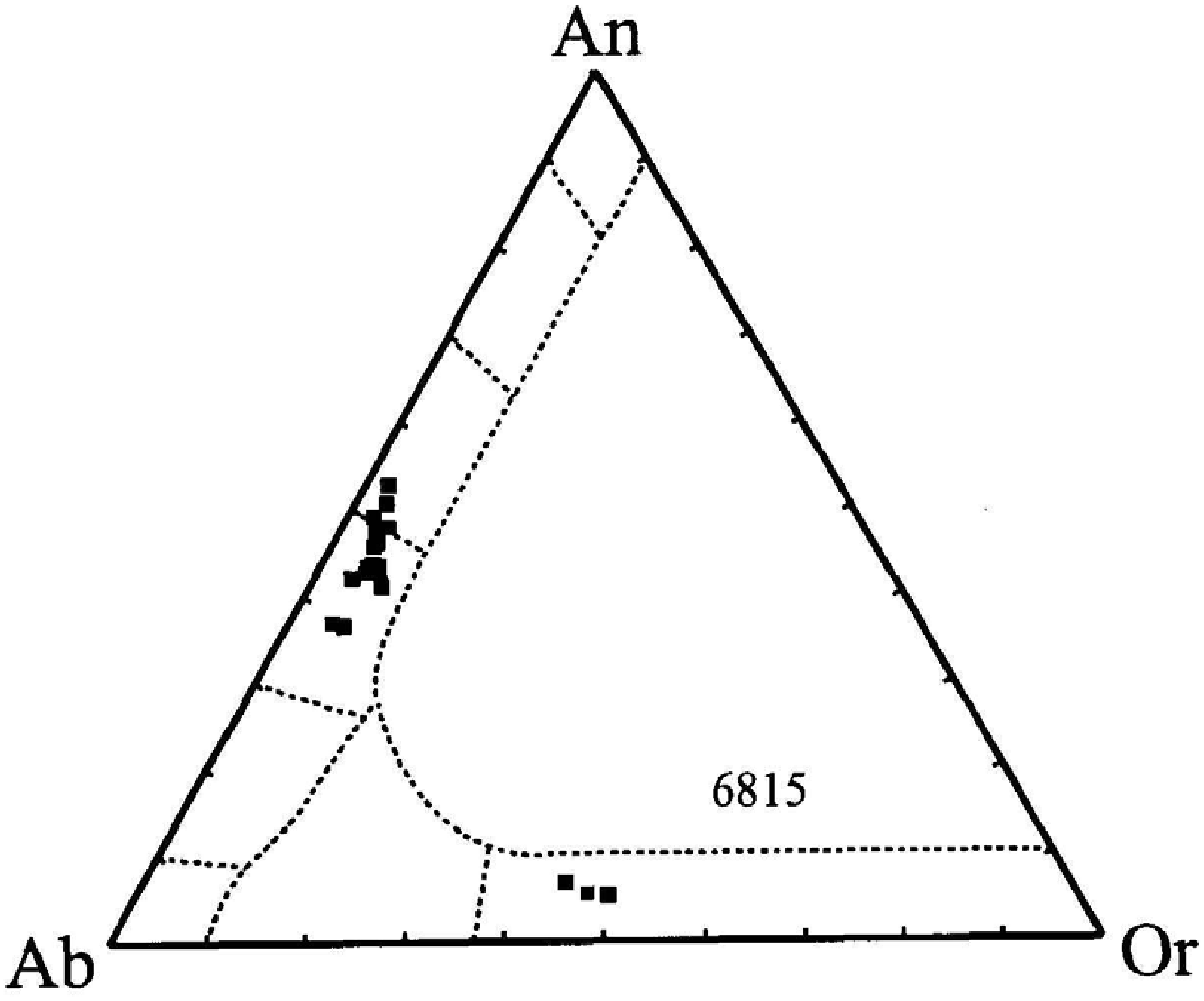

Fig. 10. Results of electron microprobe analysis of sherd 6815.

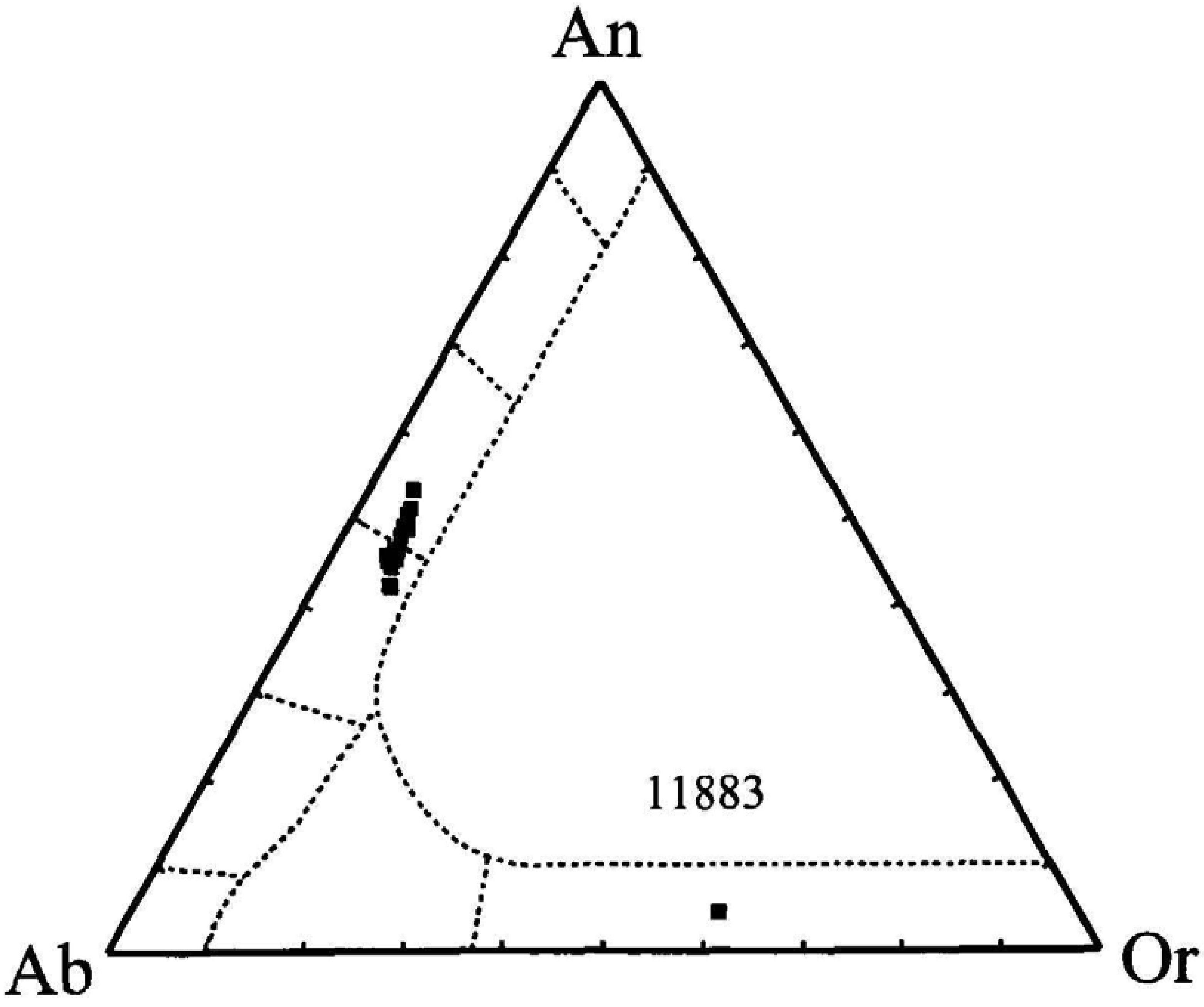

Fig. 11. Results of electron microprobe analysis of sherd 11883.

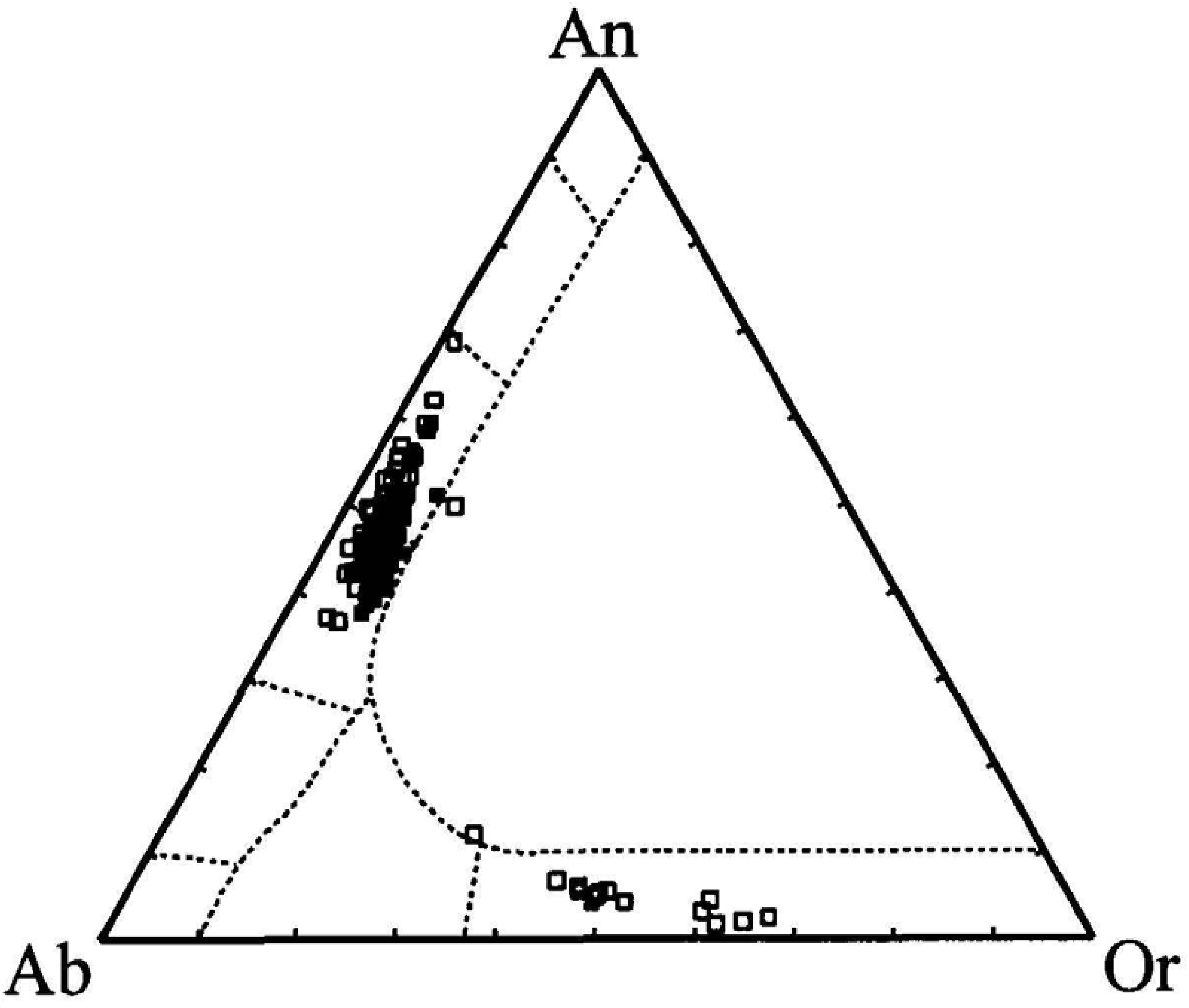

Fig. 12. Comparison of feldspar composition in sherds with temper type A (■) versus temper type C (□).

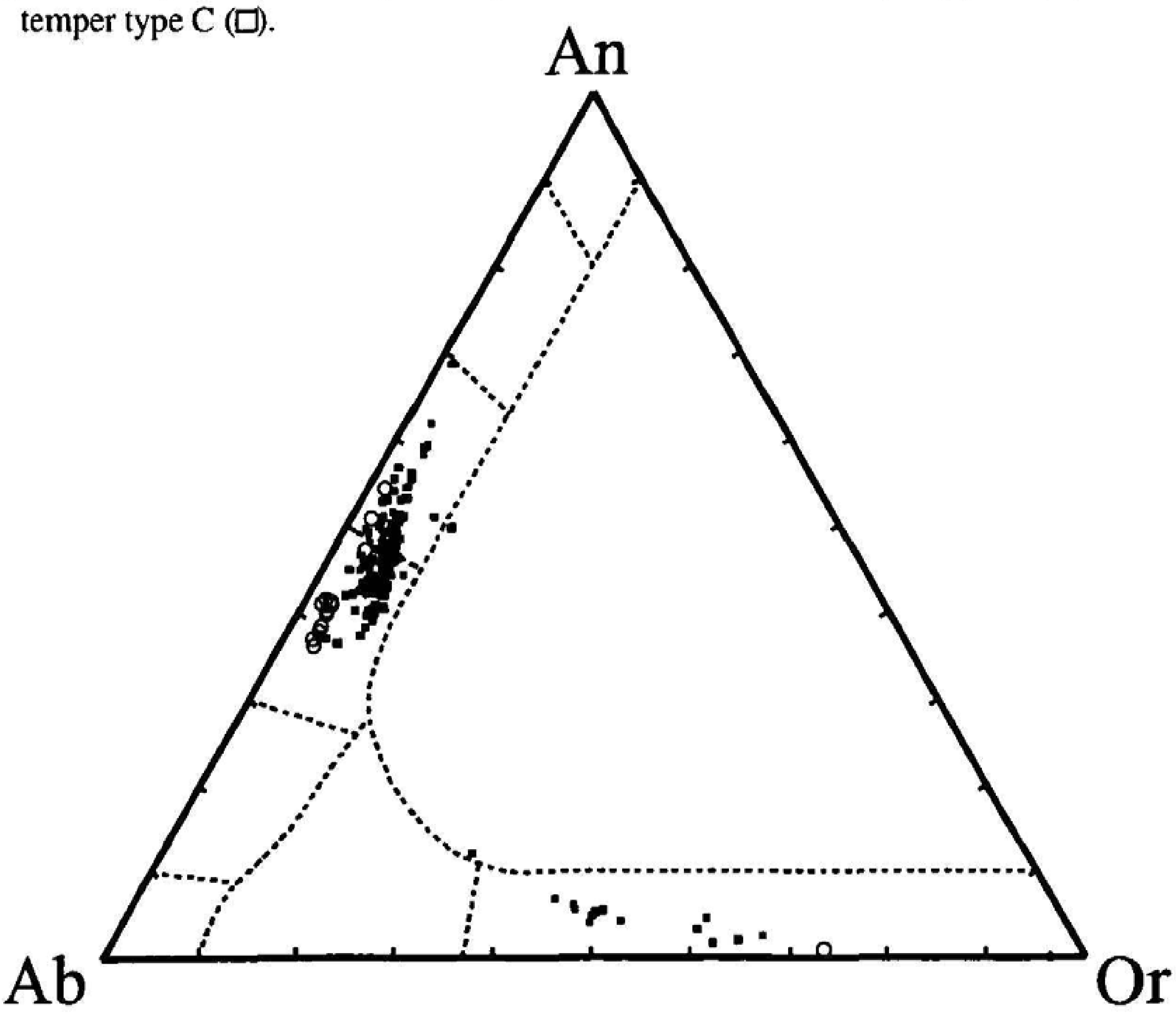

Fig. 13. Comparison of feldspar composition in sherds with temper type E (○) versus temper types A and C (■).

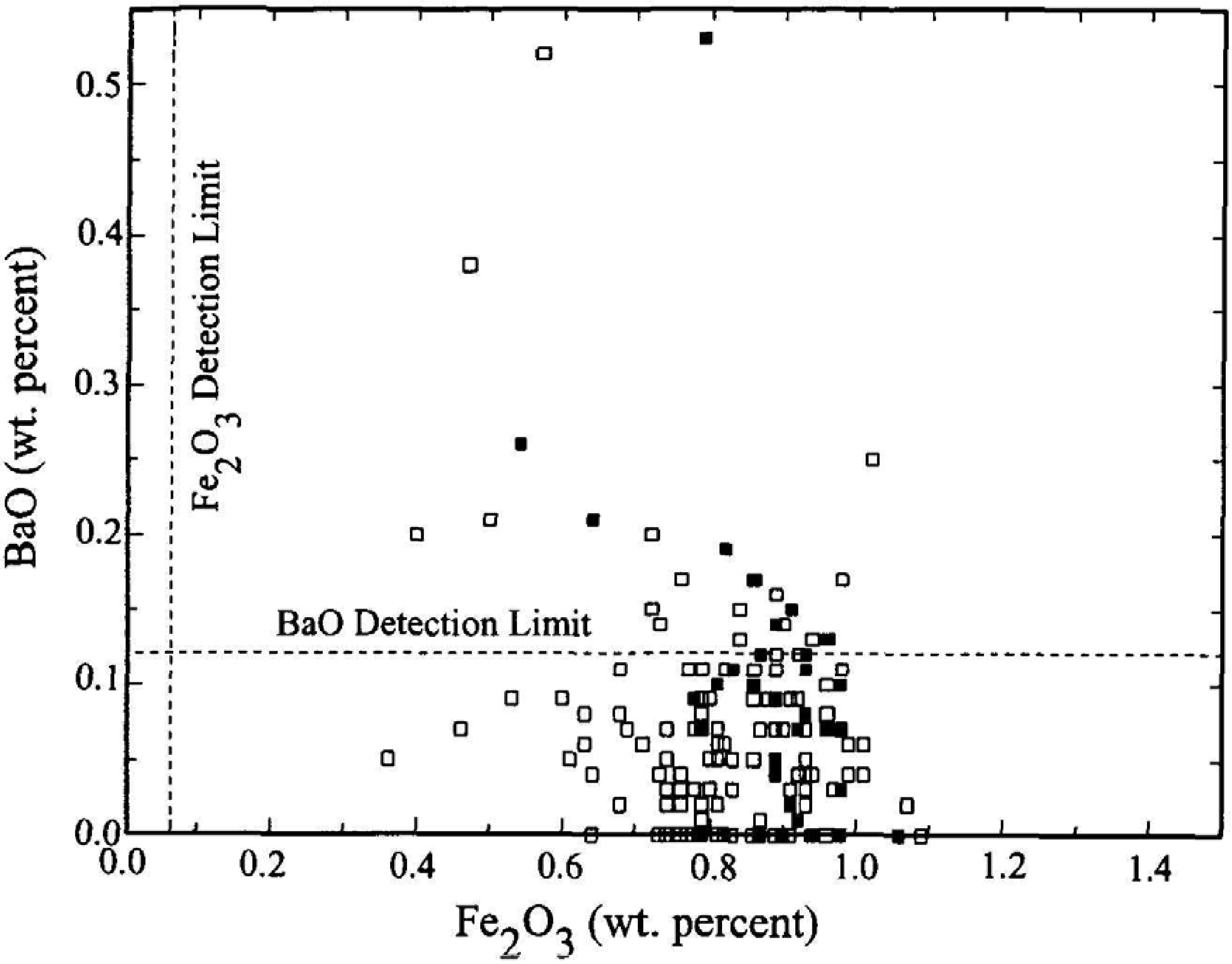

Fig. 14. Plot of Fe_2O_3 versus BaO content in sherds with temper type A (■) versus temper type C (□).

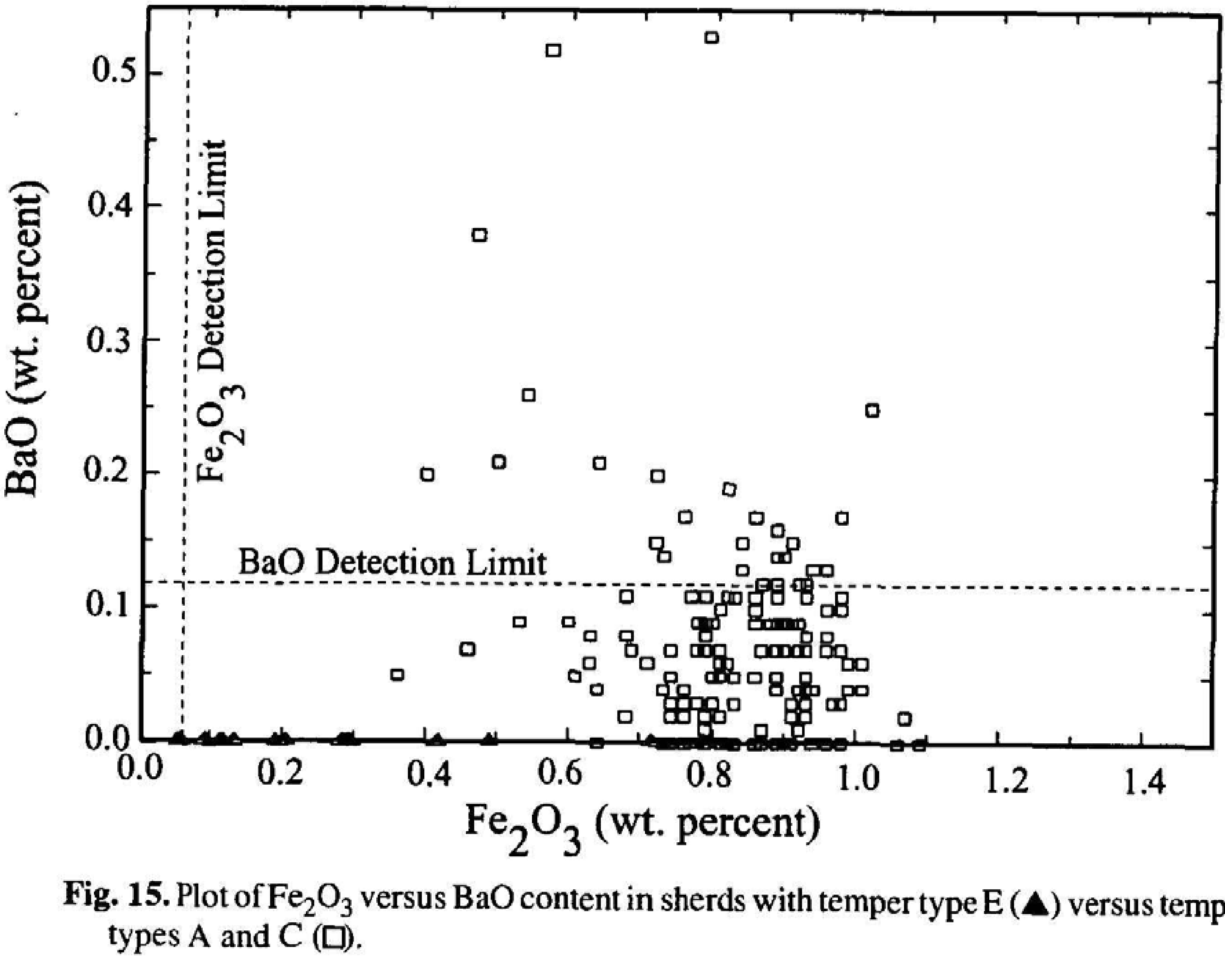

Fig. 15. Plot of Fe_2O_3 versus BaO content in sherds with temper type E (▲) versus temper types A and C (□).

In addition to the feldspar, the mineral assemblages of the temper in sherds with temper types A and C are similar. The microprobe analysis revealed titano-magnetite, ilmenite, and two forms of pyroxene—diopside (or augite) and hypersthene—in all sherds with temper types A or C. Alkali feldspar was also noted in most sherds during the microprobe analysis and may have been residual in the clay (Spurr 1993:124–125).

Geologic Analysis

As additional research on the ceramics at the Round Spring site, rock samples were collected from the vicinity of the site to compare the composition of the temper in the sherds to the geology of the site location and to determine which temper types were local and which were not. Geologic formations surrounding the project area include mainly sedimentary rocks to the east and a combination of sedimentary and igneous rocks to the west. The igneous rocks are of various intermediate types except for the most recent, which are basaltic (Eardley 1963:27; Proctor and Bullock 1963; Williams and Hackman 1983).

Although the hillsides and old terraces upstream from the site are covered with boulders and cobbles from igneous formations that have eroded away, there is little igneous material cropping out in the drainage basin of upper Last Chance Creek. Prehistoric people probably obtained their ceramic temper material from the terraces and the streams. The extreme hardness of the material at outcrops also argues against collection of material from these sources. After transportation down the streams and weathering on the terrace surfaces, the cobbles are smaller, more friable, and more easily broken.

Methods

Samples of possible temper materials, in the form of alluvial cobbles from stream beds and old terraces, were collected from drainages near the Round Spring site. These samples were compared macroscopically and microscopically to temper materials in the ceramics from the site to relate the ceramic temper to the local geology. Geib and Lyneis (1993) were successful in similar efforts to match rock samples with temper in sherds from other Fremont sites.

The collection of the geologic materials used a modified version of the line intercept (or belt intercept) method developed by biologists for sampling plant species (Brown 1954:20–21, 63–71). Transects (1 × 10 m) were placed in drainage channels and on terraces along the main tributaries of Last Chance Creek to examine the range of igneous materials available and the variation in resource distribution around the site. Transects were placed so all tributaries that contribute material to Last Chance Creek were sampled. Figure 16 shows the location of the transects in relation to the Round Spring site.

Extrapolating from models generated by ethnographic research (Browman 1976:469–471; Arnold 1985:45–46, 51–52), sources of temper used in the manufacture of ceramics at the Round Spring site were expected to be located within 9 km of the site. A representative sample of rocks found within 9 km of the site was collected, crushed, and sieved, and the various size fractions were studied under the binocular microscope. Seven rock samples were analyzed with the petrographic microscope. These included rocks from both macroscopic groups (see next paragraph) as well as intermediate samples. Petrographic thin sections were analyzed in the same manner as the ceramic thin sections. Finally, feldspar in four of the rock samples was analyzed with the electron microprobe for the same elements as the feldspar in the sherds. Methods and operating conditions for the microprobe analysis were the same as for the sherd analysis.

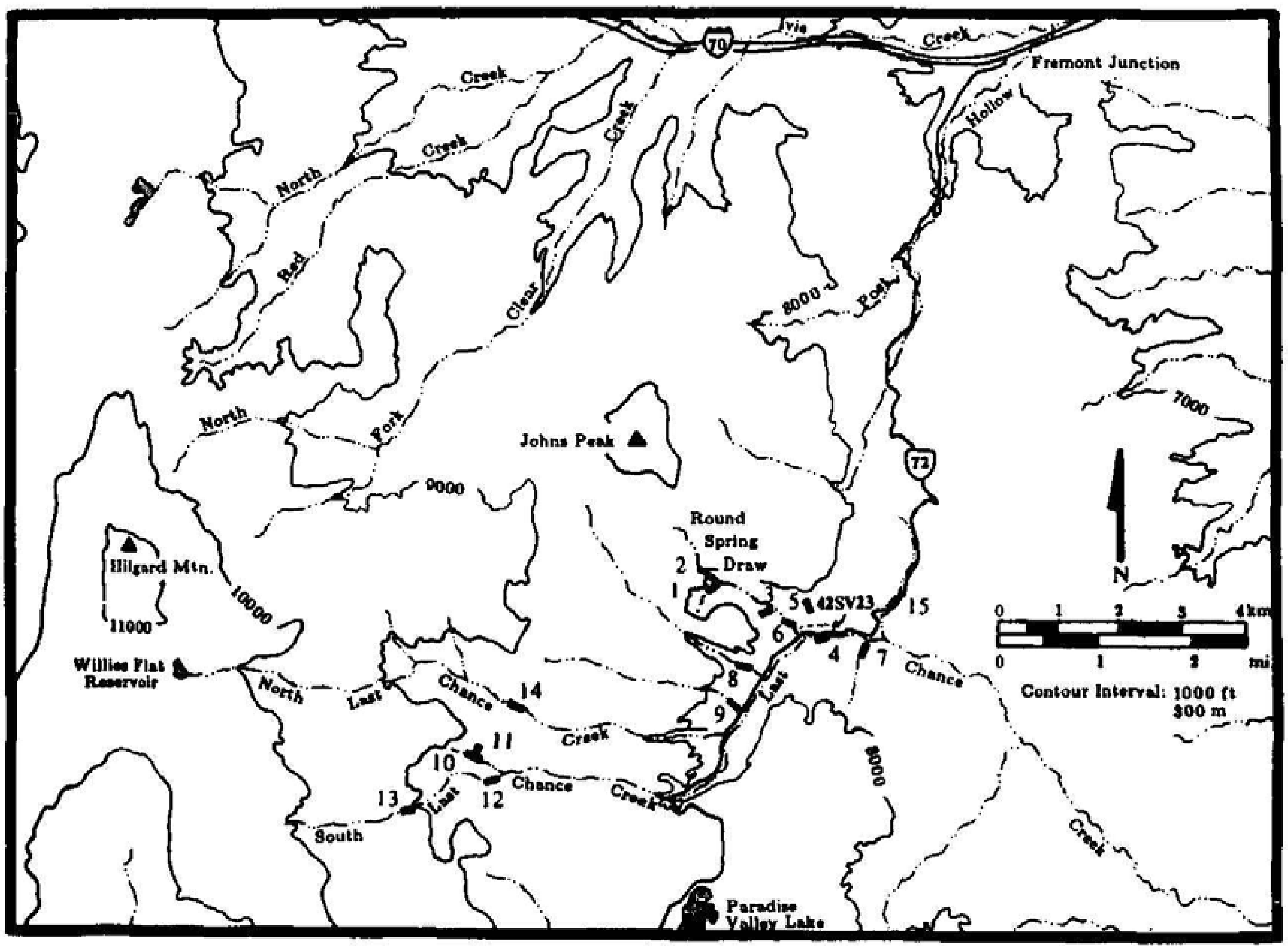

Fig. 16. Location of geologic sampling transects. Base map is Salina, Utah—1:100,000 (1990).

Results

Macroscopic inspection of the rock samples indicates two groups. Rocks in the first group are dense and hard. These rocks have a fine-grained holocrystalline groundmass of feldspar and pyroxene crystals of various sizes. They are generally light gray because of their high feldspar content. Feldspar and pyroxene phenocrysts are abundant. When crushed, the rocks produce a large amount of fine dust and small angular particles. Large pieces of this material are difficult to crush because of their hardness, but smaller pieces are more easily reduced.

Rocks in the second group are vesicular, and relatively large feldspar and pyroxene phenocrysts are common in the glassy to microcrystalline groundmass. These rocks are generally dark gray to black, although they sometimes exhibit a dark red weathering rind. When crushed, they produce rough, angular pieces and loose crystals and less fine dust than rocks in the first group. Because of the vesicular nature of the rocks, it is much easier to crush these rocks than those in the first group. This rock matches that identified by Geib and Lyneis (1993) as the basaltic andesite that is the source of temper type A.

Aside from the dense versus vesicular texture and the variation in color, rocks in the two groups appear to be mineralogically similar and contain similar phenocrysts. Also, several rock samples are intermediate in texture and color. When weathering rinds cover the rocks or when they are wet, it is difficult to differentiate between the two groups. The texture of igneous rocks is largely dependent on the viscosity of the magma and the rate of cooling rather than the composition of the magma. Geologic maps (i.e., Williams and Hackman 1983) and previous research indicate that the rock samples may be part of a discontinuous volcanic formation, Tertiary basaltic andesite (Tba), that is identifiable from the Escalante River drainage to the Ivie Creek drainage (Geib and Lyneis 1993) and from the project area at least to Clear Creek Canyon west of the Sevier Valley (Lane Richens, Brigham Young University, Provo, Utah, personal communication).

Petrographic microscope analysis revealed that the groundmass of all rock samples is composed of fine to microcrystalline feldspar and pyroxene. Even in vesicular samples the groundmass is compact. Phenocrysts of feldspar, pyroxene, and opaque minerals are present in all the samples, although the sizes of the phenocrysts vary greatly. Biotite and altered olivine crystals are present in some samples as well. Cluster analysis indicates that all seven samples are similar (Table 3), and cluster membership crosscuts the macroscopic divisions of the rock samples.

Although the same mineral assemblages are present in all the rock samples, some differences are apparent. The relative frequency of feldspar and pyroxene crystals in the groundmass differs and, consequently, the groundmass ranges in color from dark to light gray. This variation was observed in both the hand specimens and the petrographic samples and may provide an expedient way to correlate temper with raw material source. In general, designation of temper as dark or light correlates with temper types A and C, respectively.

Another difference among the rock samples is the presence or absence of biotite. The presence of this mineral is often considered an indicator of specific compositions and formation conditions (Moorhouse 1959). Biotite contains relatively large amounts of K and Fe and is generally present in rocks with high K content. The presence of biotite in some of the samples and its absence in others could indicate that the samples are from different formations. The presence of biotite does not seem to be associated with any other characteristics of the samples, however, as biotite is present in samples from both macroscopic groups of rocks. Either the presence of biotite is linked to some variable that has not been considered here or its presence is not significant in the rocks involved in this study. Bulk compositional analysis would be of help in assessing the similarity of the rocks, but this analysis has not yet been completed.

Results of the electron microprobe analysis for the rock samples are shown in Figs. 17–20. Plagioclase compositions in all rock samples range from $An_{40.4}Or_{7.4}Ab_{50.1}Cs_{0.3}$ to $An_{66.4}Or_{2.7}Ab_{30.9}Cs_{0.0}$, intermediate between andesine and labradorite. The similarity of the plagioclase in the rock samples supports the hypothesis that the two rock groups are not chemically distinct, at least as regards feldspar composition.

Discussion

In all phases of analysis, Emery Gray temper types A and C are similar, and in the petrographic and microprobe analyses it can be difficult to distinguish between them. With the binocular microscope they can be separated by texture and the types of associated inclusions, such as pyroxene. Mineralogy and elemental composition show strong similarities, however, indicating that the two temper types may be derived from the same or very similar geologic sources.

Table 3. Distribution of minerals by cluster for petrographic microscope analysis of geologic samples.

Cluster	Groundmass	Feldspar	Pyroxene	Opaque	Biotite	Other	Epoxy
1 $n = 2$	140–141[a]	67–87	34–54	11–18	0	0	20–28
2 $n = 3$	139–146	106–133	26–31	5–12	5–10	0–1	3–21
3 $n = 2$	104–121	103–135	28–33	6–13	2	0–1	7

[a] Frequency range.

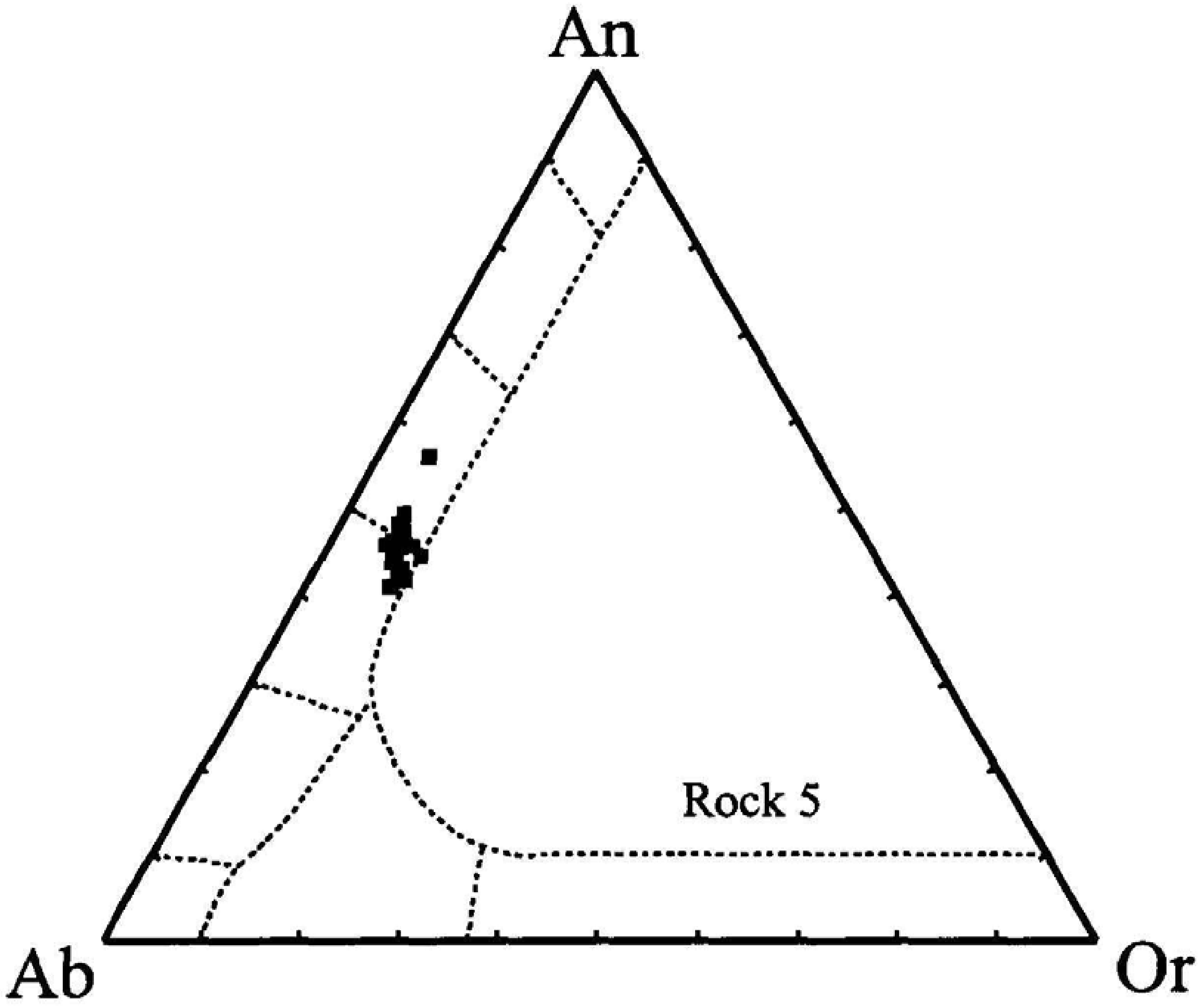

Fig. 17. Results of electron microprobe analysis of geologic sample 5.

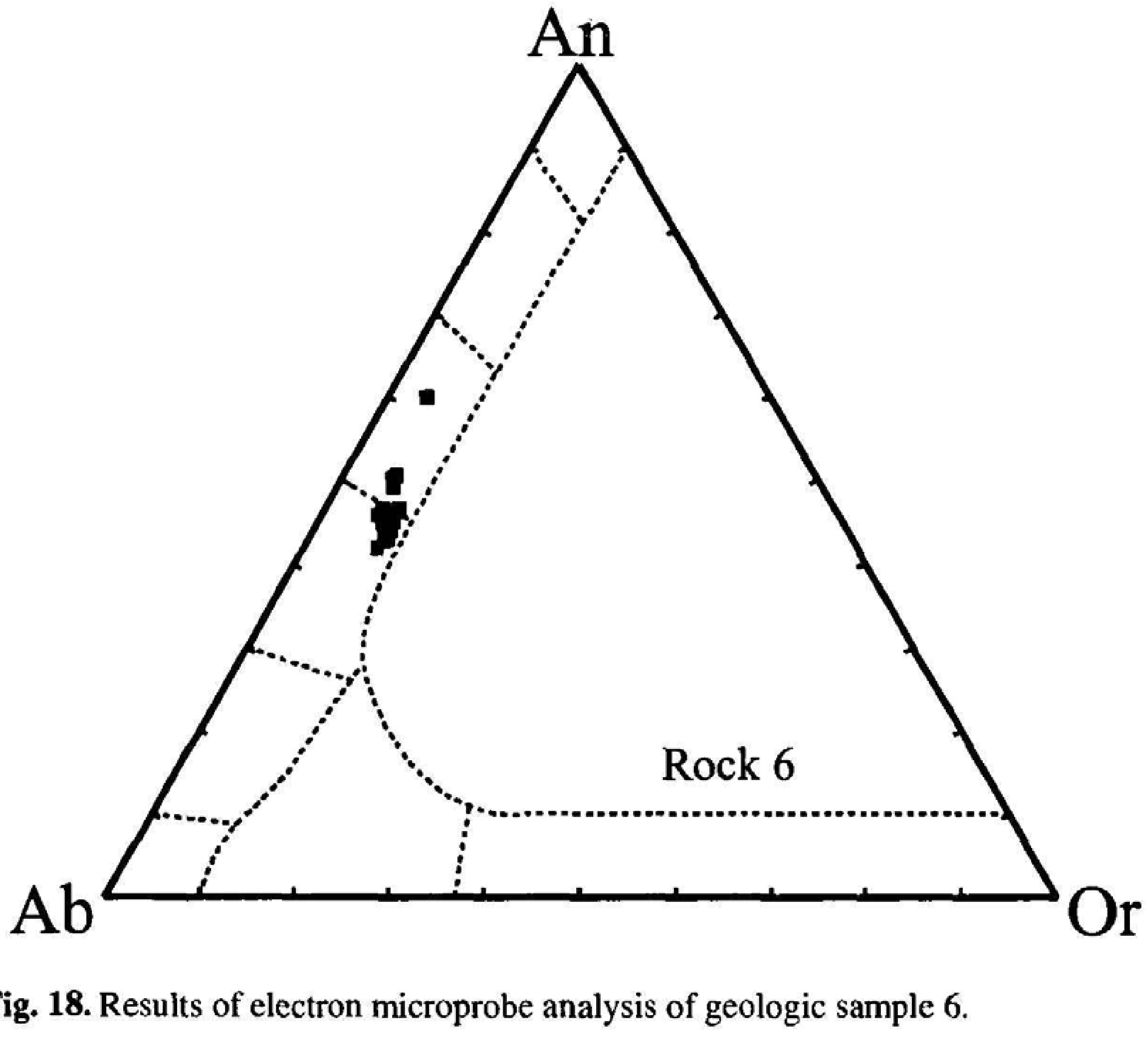

Fig. 18. Results of electron microprobe analysis of geologic sample 6.

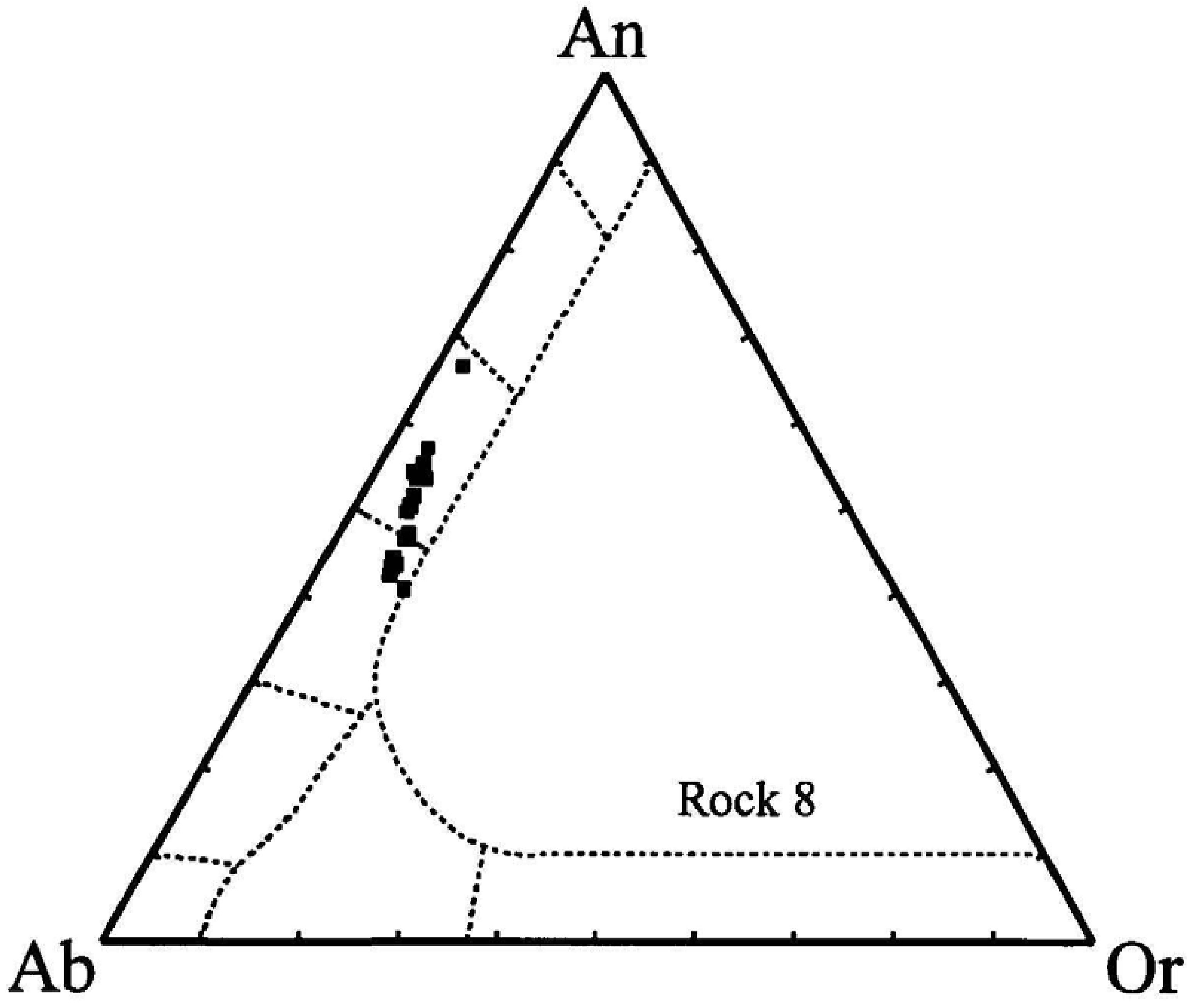

Fig. 19. Results of electron microprobe analysis of geologic sample 8.

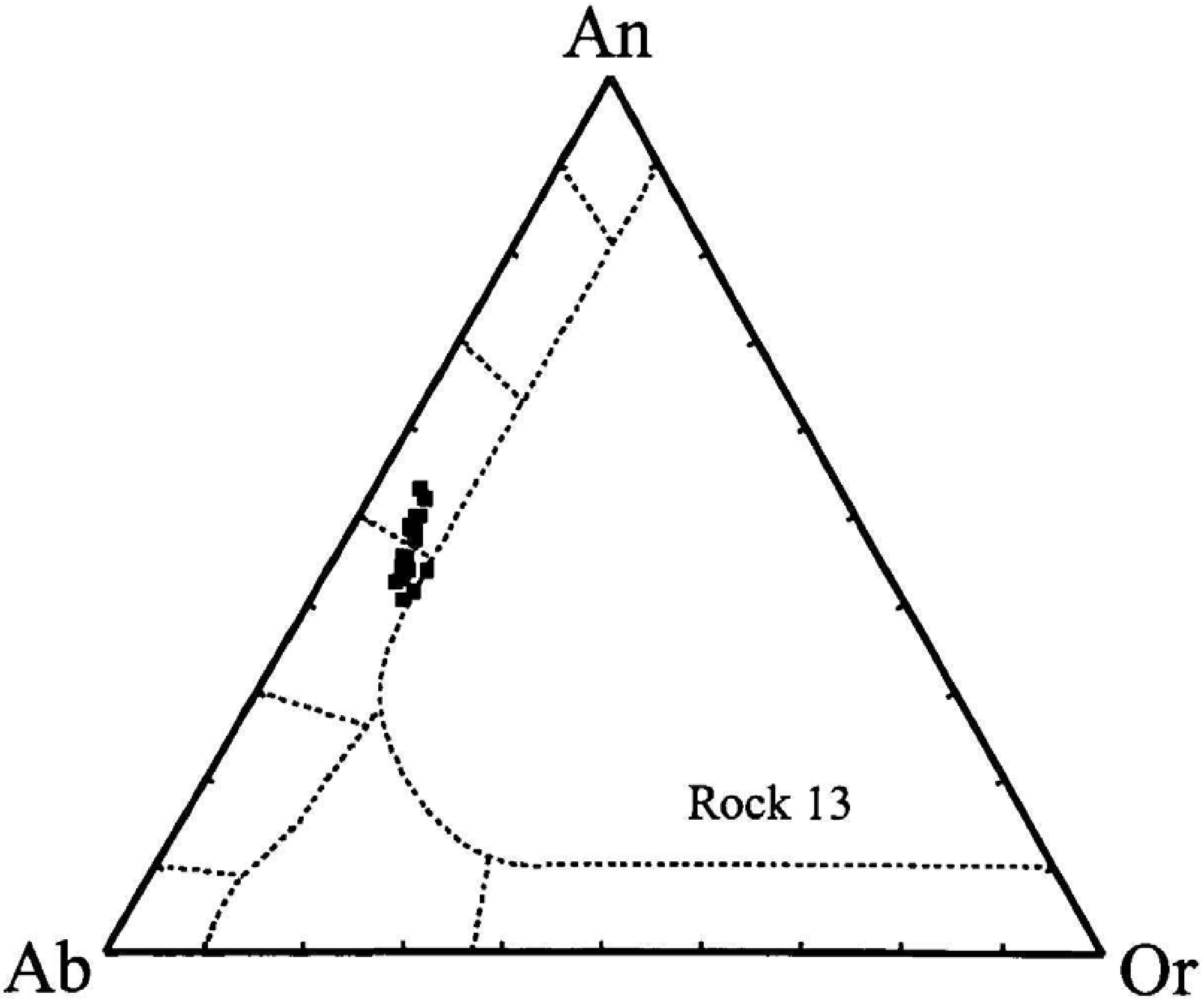

Fig. 20. Results of electron microprobe analysis of geologic sample 13.

Analysis of other minerals in the material—the pyroxenes, for example—is necessary to verify this possibility.

Analysis results of the geologic samples indicate that, despite macroscopic differences in texture, density, and color, all the rocks collected are similar. The major differences among the samples are the amount of biotite and feldspar present as phenocrysts and the absolute frequency of phenocrysts (Table 3). Although it is difficult to prove that several rock samples are the same material based on the analysis of only one mineral, it is plausible that the two rocks, macroscopically different, are related compositionally. The similarity of the rocks in every level of analysis supports the conclusion that both rock groups are basaltic andesite.

Plotting the microprobe analyses of the rock samples and of the sherds with temper types A and C reveals that all contain similar plagioclase (Fig. 21). The plagioclase in the sherds contains slightly less K_2O than plagioclase in the rocks, although the two fields overlap substantially. The amount of Fe_2O_3 and BaO in the rocks also is similar to the amount of these compounds in the temper

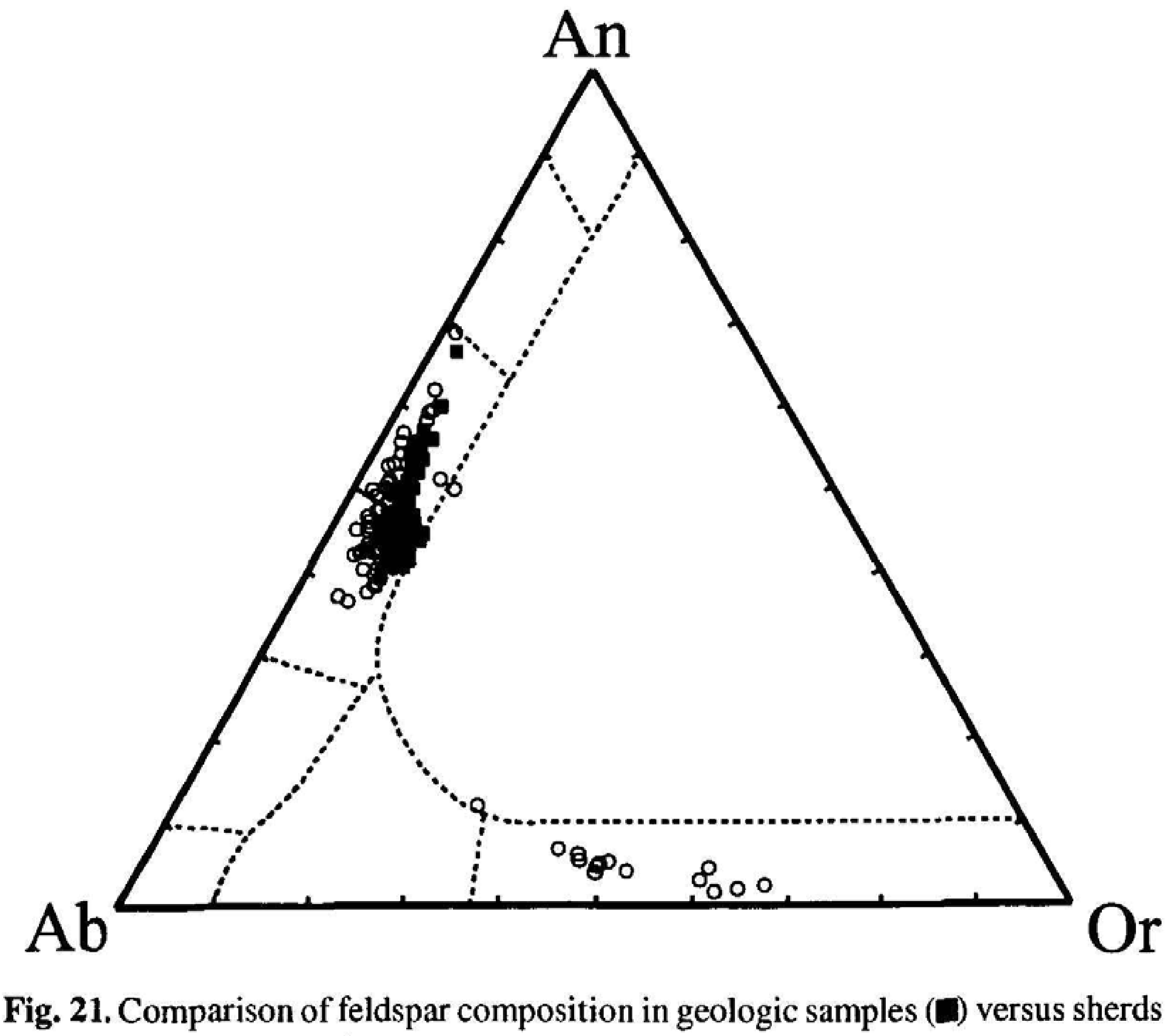

Fig. 21. Comparison of feldspar composition in geologic samples (■) versus sherds with temper types A and C (○).

(Fig. 22). These data indicate that the rocks near the Round Spring site may be the source of temper types A and C. The difference in K_2O content is problematic and needs to be further examined before the rocks can be considered the source of the temper. The process of firing ceramics may affect the K_2O content of the plagioclase.

The rock samples also contain pyroxenes—hypersthene and diopside or augite—that are the same as the pyroxenes in the sherds. Titano–magnetite and possibly ilmenite, noted in the sherds, are present as phenocrysts in the rocks. In the future, pyroxenes and opaque minerals may be analyzed with the microprobe, because they may increase the certainty that temper types A and C are from similar rock sources. Examination of the same minerals in the rock samples would help determine whether these rocks are the sources of the temper.

Although the amount of igneous material in the vicinity of the Round Spring site is large, the variety is limited. The rocks collected for this study are the only types available in any appreciable amount near the site. The frequency of the rock types in the sampling transects is homogeneous, and there is no

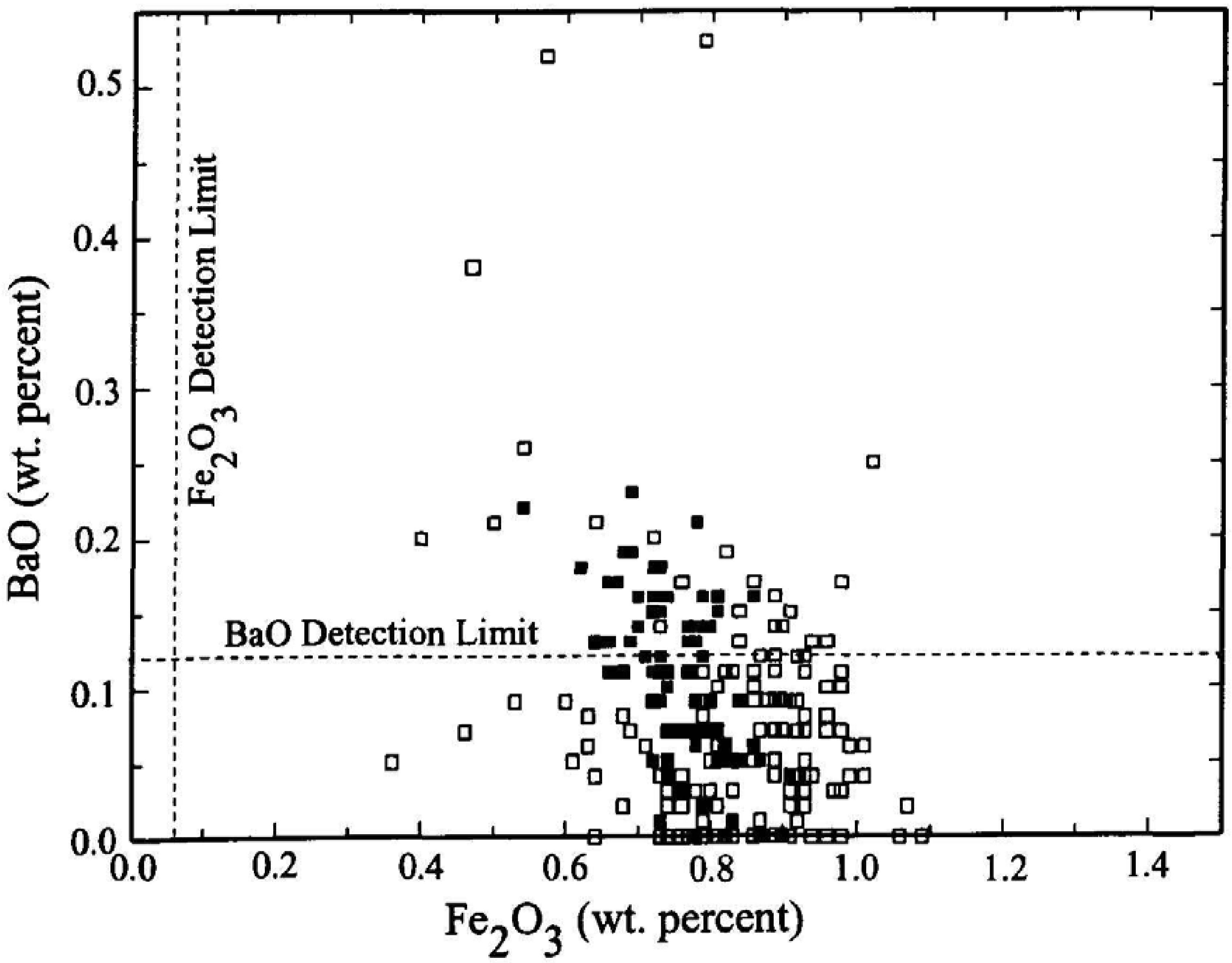

Fig. 22. Plot of Fe_2O_3 versus BaO content in geologic samples (■) and sherds with temper types A and C (□).

indication that these frequencies change systematically in any direction from the site. Igneous material exists in every drainage near the site, and residents of the Round Spring site evidently obtained igneous rock for ceramic temper from the immediate vicinity of the site. Rocks from both macroscopic groups, which seem to be the same or very similar rock, were probably used interchangeably. Several of the rock samples are identical to rocks previously noted by Geib and Lyneis (1992*, 1993) as sources of Emery Gray temper.

The distinctive nature of the temper types under low-power magnification suggests that heavy reliance on temper type is not necessarily a major problem in Fremont ceramic analysis. Instead, accurate and consistent identification of the temper types seems to be a bigger problem. The presence of distinct temper may be the reason that temper became a major criterion of classification in the first place; early researchers may have realized that temper was the only consistent difference among the types, which are mainly graywares with plain or textured surfaces. Unfortunately, few archaeologists have considered the relation of local geology to the distribution of temper types. Assuming local ceramic production, the abundance of igneous rocks in southern and central Utah requires that ceramic types based on igneous temper type have a large amount of variation in the type definitions or a large number of types. This situation is not reflected in the Fremont ceramic typology, and the result is a typology that is difficult to apply.

This is true with regard to Emery Gray ceramics. Temper type C can be considered classic Emery Gray temper and would be easily classified by most analysts. Sherds containing temper type A, however, would not be classified as Emery Gray by some analysts because the temper particles are too dark to be the gray basalt described by Madsen (1977:31). The similar composition of these temper types and their pattern of distribution as noted by Geib and Lyneis (1993) suggest that both belong to the ceramic tradition of the San Rafael Fremont. The Fremont ceramic classification system is in need of revision and, following Geib and Lyneis (1992*), two possibilities present themselves. The first is that a wider range of variation in Emery Gray, including types A and C, be included in the system. Perhaps establishing varieties of Emery Gray, based on temper type, would illustrate distribution patterns of the different tempers. These distribution patterns should reflect production areas of the ceramics. The second possibility is that temper type C defines Emery Gray, and a separate type designation be given to ceramics containing temper type A. As Geib and Lyneis (1992*) noted, however, the addition of new ceramic types is not what Fremont archaeology needs. Perhaps for now, more careful and consistent descriptions of temper and better correlations of temper with geologic units are the most constructive tasks for Fremont ceramic analysts. As more research is completed on the types and distributions of temper, the Fremont ceramic taxonomy can be refined to provide a more useful and accurate system.

Acknowledgments

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A Model to Study Fire Effects on Cultural Resource Studies of Mesa Verde

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Abstract. On 8 July 1989, lightning struck the dry terrain of Long Mesa in Mesa Verde National Park and ignited a 2-week burn that scorched 1,200 ha. As a result, park management initiated studies of the effects of high-intensity fire on cultural resources. Mesa Verde National Park was established to protect works of prehistoric humans including pit-houses and cliff dwellings of the Anasazi. Later, park management was charged with the preservation of historic buildings and wood structures of 20th-century Americans. Our research will provide the necessary background information to predict specific fire effects on cultural sites. We mapped the vegetation communities, reconstructed the prehistoric fire history of half of Mesa Verde, and will document postfire succession. These data sets, incorporated into spatially explicit layers in the park's Geographic Information System, will be used to model the risk and specific effects of fire as related to particular classes of cultural resources.

Key words: Anasazi, postfire succession, vegetation mapping.

Mesa Verde is a series of north–south mesas in sandstone and shale substrates. Mancos Shale of marine origin is topped by Point Lookout Sandstone, then covered in parts of Mesa Verde National Park by the diverse Menifee Shale. The Cliffhouse Sandstone is exposed above these formations, and it is in this final layer that the most impressive cliff dwellings were built (Griffiths 1990). Water is ephemeral throughout the Mesa system—seeps and springs are infrequently encountered. The Mancos River forms the eastern boundary of the park and provides the only perennial water source.

We focused our postfire succession study on Long Mesa, the site of the 1989 fire that burned 1,200 ha. Long Mesa, one of the western mesas, ranges in elevation from 2,180 m in the south to 2,517 m at the north end. Long Canyon floor is 2,133 m. The vegetation on Long Mesa is a mosaic of mature piñon–juniper woodlands and mountain shrub associations. Shrub associations range from oak (*Quercus gambelii*) and serviceberry (*Amelanchier utahensis*) to sagebrush (*Artemisia nova*) and bitterbrush (*Purshia tridentata*).

Piñon (*Pinus edulis*) and juniper (*Juniperus osteosperma*) woodlands dominate the lower, southern ends of the mesas, whereas mountain shrub communities dominate on the northern ends. Differential fire frequency is hypothesized to be the major factor controlling this pattern (e.g., Erdman 1970). Douglas-fir (*Pseudotsuga menziesii*) forms dense stands on the north escarpment or on steep north-facing slopes. Ponderosa pine (*Pinus ponderosa*) is found in a few limited stands in Morefield and Prater canyons and in isolated pockets elsewhere. Scattered, small deciduous forest communities include aspen (*Populus tremuloides*) and maple (*Acer* sp.).

Methods and Preliminary Results

Mapping of Vegetation and Woody Fuels

The first step in modeling the effects of fire on cultural resources was to compile a digital map to define the vegetation of Mesa Verde to accurately predict the fire potential of each plant community. Landsat TM and SPOT panchromatic scenes from May and June 1990 were used as a spatial and spectral base. An unsupervised classification of the image and initial field surveys showed that 17% of the image was in shadow and that important vegetation characteristics were obscured. To mitigate the topographic effects in the image data, a transformation was used to separate the spectral and illumination information (Pouch and Campagna 1990). The transformed image was then reclassified. Ground-truth efforts guided by this reclassification were made with relevé stand analyses (Mueller-Dombois and Ellenburg 1974) of more than 300 sites, each located with a Trible Basic Pathfinder Global Positioning System (GPS). Species cover and abundance ratings were clustered with TWINSPAN, a multivariate clustering program (Gauch 1982). This ordination was used to guide the final supervised classification of the image data with training signatures from the mean spectral signatures of the clustered sample points. In this way, the spectral and field information were related to one another.

Woody fuels were assessed in a subsample of the sampling points ($n = 26$). Canopy fuels—dead snags and woody fuels in live trees and shrubs—were measured (Meeuwig and Budy 1981). Downed fuels were sampled on transects with the plane–intercept method (Brown 1974). These data will be used in the fire behavior model BEHAVE (Burgan and Rothermel 1984) to predict the fire potential within the major vegetation communities in Mesa Verde National Park.

Fire History and Fire Effects

Our study of fire history and fire effects at Mesa Verde Park had two objectives (Floyd-Hanna and Romme 1993*[1]). First was to document the postfire succession patterns following the 1989 fire on Long Mesa. This large fire affected at least three different vegetation types—piñon–juniper, mountain shrub, and Douglas-fir. Three permanent sampling grids containing 291 sampling points were established to document postfire patterns. Percent cover of plants, litter, or bare substrates was recorded in 1991, 1992, and 1994.

The second objective was to develop and apply a method of dating past fires in Mesa Verde (for background see Arno and Sneck 1977; Romme 1982). Because few fire-scarred trees are in Mesa Verde National Park and no unequivocal fire scars were located, we developed a method to age shrubs, which resprout vigorously after fires, using annual ring counts to determine their time of origin. All dominant shrub species were sampled and aged in the historically documented 1934, 1959, 1972, and 1989 burns. Although there is some variability within an individual plant as to the date of shoot emergence, we determined that by selecting the centermost shoot and restricting ourselves to the species *Quercus gambelii* we could determine reliably the known fire date. In

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[1] Asterisk indicates unpublished material.

1992 and 1994, we applied this method to sample areas of unknown fire history in the northern portion of Mesa Verde National Park.

Results of the postfire succession sampling indicate that perennial resprouting has returned the cover of the northern sector of the burn to a shrub-dominated community much like the prefire community, whereas the southern burned areas (formerly piñon–juniper) are proceeding through a herbaceous phase of succession. The effects of prefire vegetation have been significant, and previous fire history has also affected the postfire successional patterns since the 1989 fire. Noxious weed invasion of the southern end of the fire is becoming an increasing problem.

Using the technique to age shrubs, we successfully identified and mapped prehistoric fires that occurred between 1850 and the 1920's. The median fire return interval varied from 55 years in the west to greater than 130 years in the eastern portion of the sampling area.

Discussion

Effects of Fire on Cultural Resources

These data will allow us to predict the probability of occurrence and the effect that a fire might have on a given type of archaeological site, depending on its location in the landscape. Data layers, each spatially defined for points or extrapolated to areas, will be as follows (Figure):

1. Median fire interval—expressed as a probability of occurrence: high = 0.02 (from a 50-year fire return interval), medium = 0.01 (from a 100-year fire return interval), and low < 0.01 (for fire return intervals greater than 100 years).
2. Vegetation—fuels and fire intensity potential—expressed as high, medium, or low intensity. High potential occurs in Douglas-fir forests or piñon–juniper woodlands, medium potential occurs in sparse piñon–juniper woodlands, and low potential occurs in mountain shrublands and meadows.
3. Significant and vulnerable cultural resources—Although all cultural resources at Mesa Verde have intrinsic value, some are more vulnerable to fires than other. The following classification was

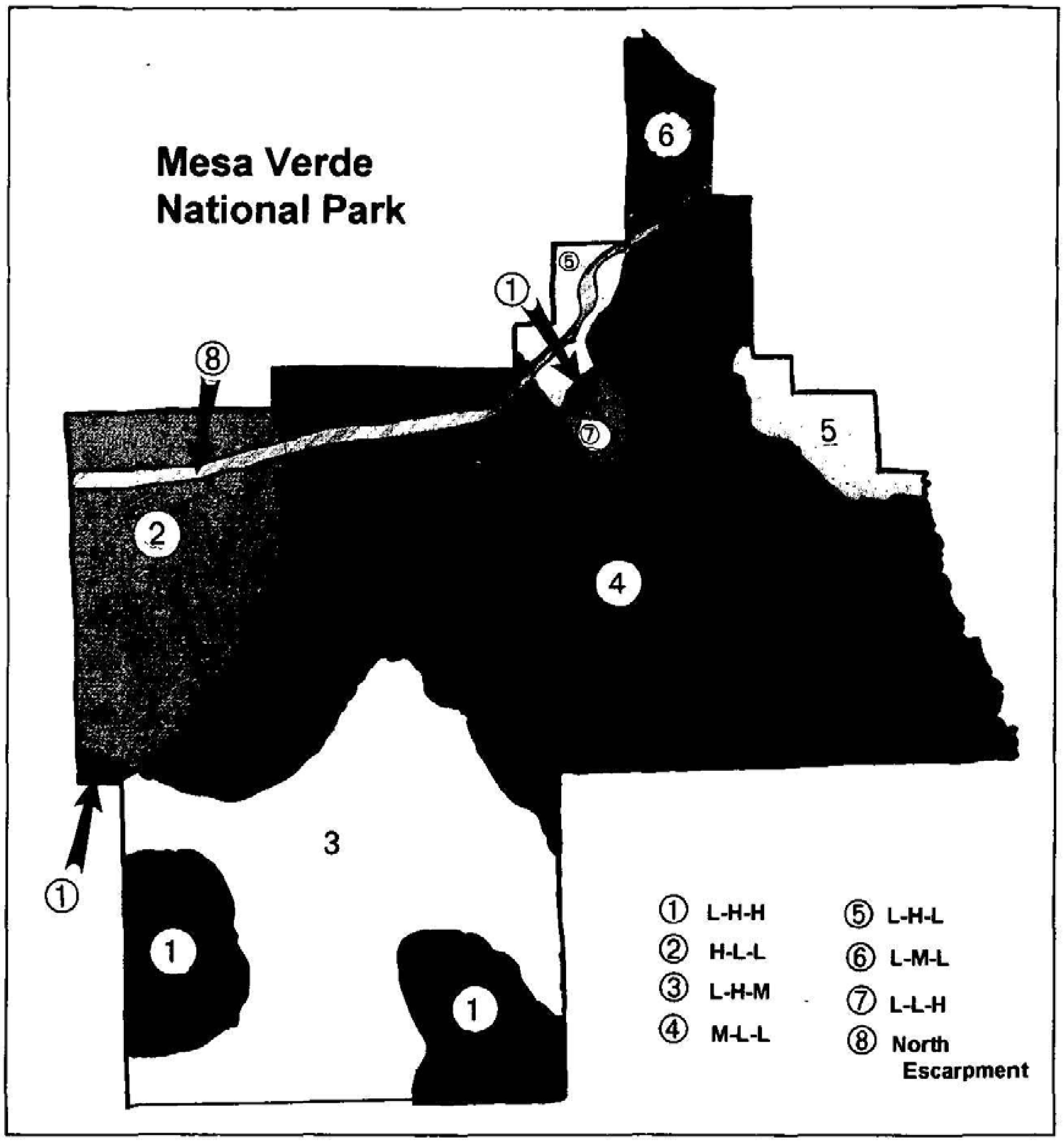

Figure. A fire-risk summary of Mesa Verde National Park showing fire probability–fire intensity–vulnerability of cultural resources; L = low; M = medium; H = high. This is a simplified example of three layers for illustrative purposes.

developed by a group of archaeologists, ecologists, and fire behavior specialists (Romme et al. 1993):

A. Sites with high vulnerability to fire damage:
   1. Native American historic structure (e.g., sweat lodges and corrals)
   2. Alcoves and cliff dwellings containing organic materials (e.g., packet rat middens, wooden beams, corn cobs)
   3. Rock-art panels

    4. Culturally-scarred trees
- B. Sites with moderate vulnerability to fire damage:
    1. Euro-American historic structures (e.g., museum and administration buildings)
    2. Lithic scatter and shallow hearth
- C. Sites with low vulnerability to fire damage:
    1. Deeply buried, unexcavated pueblos
    2. Lithic scatter
    3. Check dams

A risk model is being developed by the authors and other National Park Service personnel where these three categories of risk overlap each other (Figure). Although each data layer is not yet complete, we begin to see the pattern of fire risk at Mesa Verde National Park as a mosaic of superimposed risk probabilities. For example, an area with dense fuels and highly valued cultural sites such as Chapin Mesa is at higher risk than an area that has burned frequently and has few archaeological resources (the north end of the park). Many of the most vulnerable sites—and perhaps those on which fire fighting efforts and presuppression-suppression activities such as fuel reduction should focus—are on the southern ends of Chapin and Wetherill mesas. High risk rating occurs there in two categories. Another high risk area is at the head of Prater Canyon where culturally scarred trees and dangerous fuels exist together.

We will continue to improve on the risk assessment for Mesa Verde National Park. The mass and configuration of woody fuels in each vegetation type will be used to predict actual fire behavior under particular sets of weather conditions (e.g., using BEHAVE, a fire behavior model), and this information will add significantly to our modeling potential. Fire history will be determined for the northeastern and southern portions of the park in 1994. Completion of the inventory and mapping of cultural sites in 1994 and combining of these data with the risk model will allow accurate assessment of the vulnerability of archaeological sites to fire.

Acknowledgments

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