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;

[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.

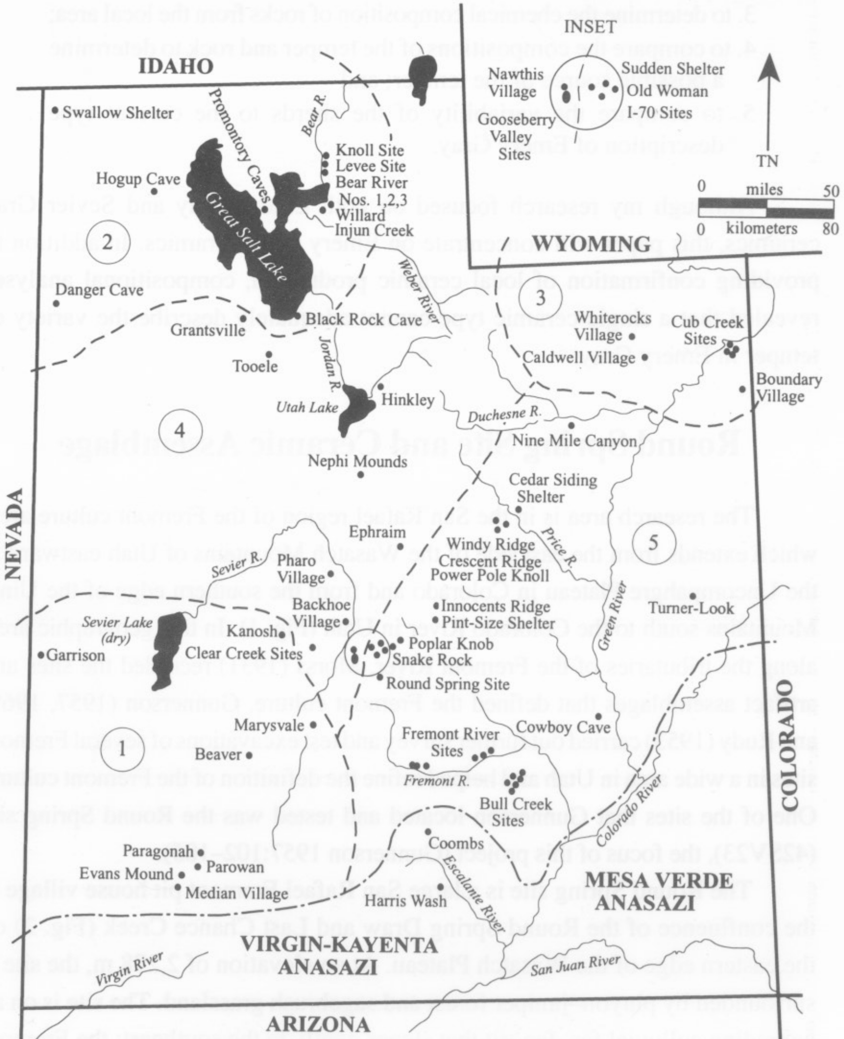

Fig. 1. Map of selected Fremont sites and Fremont regional variants: *1.* Parowan Fremont; *2.* Great Salt Lake Fremont; *3.* Uinta Fremont; *4.* Sevier Fremont; and *5.* San Rafael Fremont. Redrawn after Marwitt (1970:Figure 84). Courtesy of the University of Utah Press.

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

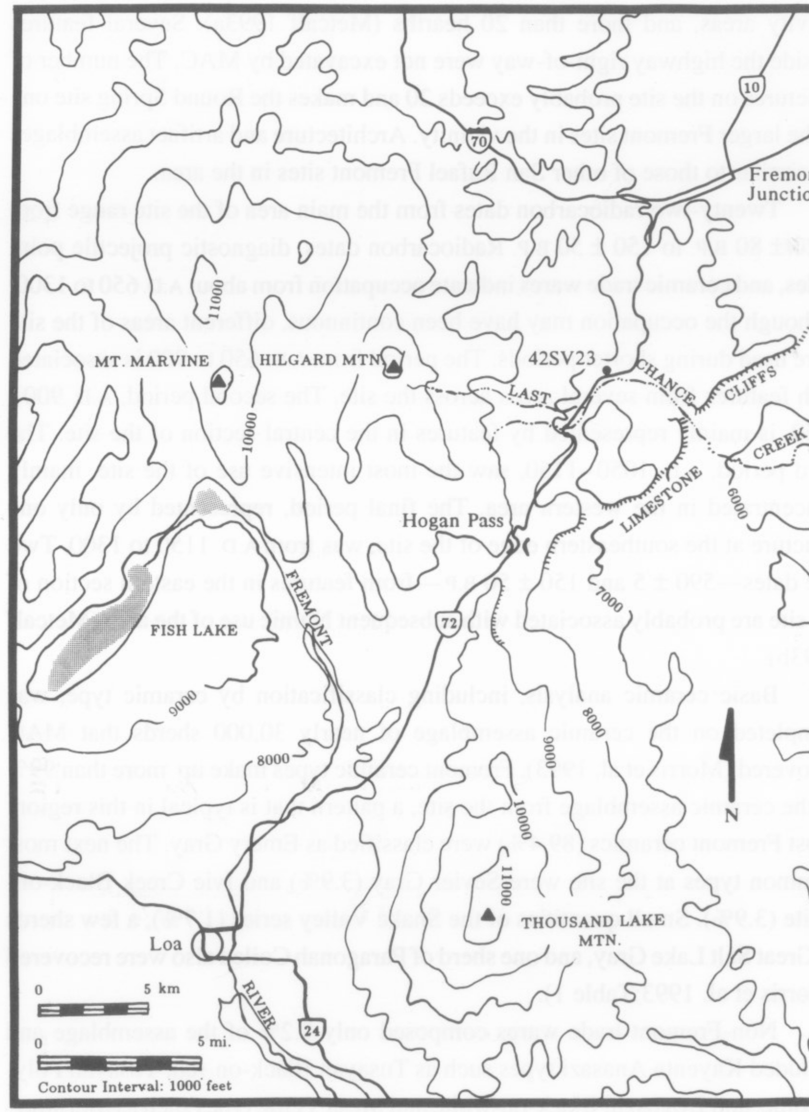

Fig. 2. Map of the project area, showing the location of 42SV23, the Round Spring site. Redrawn after Rood et al. (1988:Fig. 1).

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.

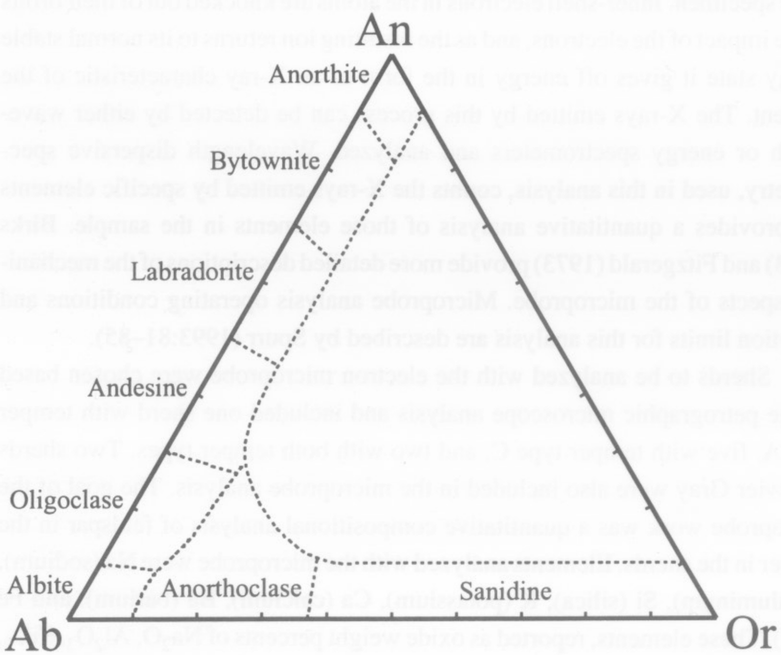

Fig. 3. Ternary diagram of the feldspar system, with conventional nomenclature.

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 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.

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.

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.

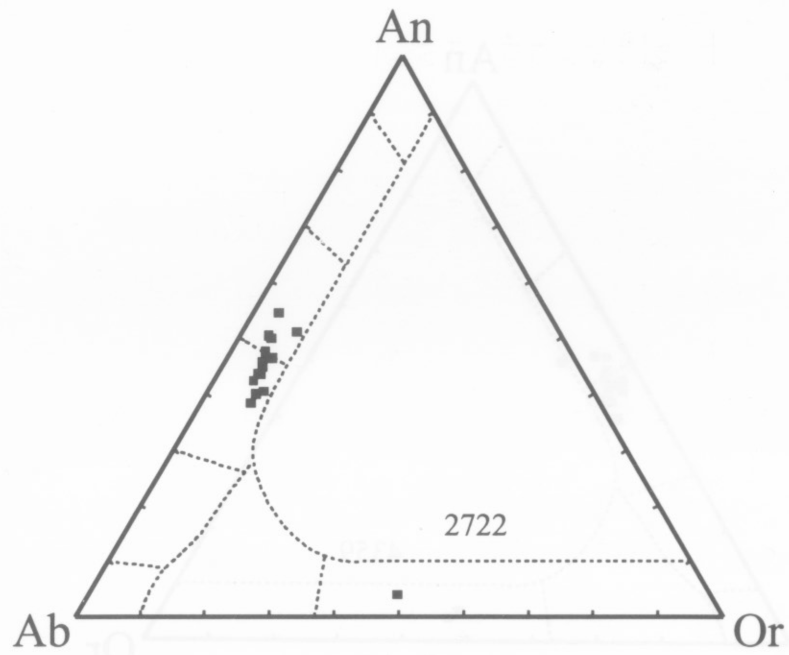

Fig. 4. Results of electron microprobe analysis of sherd 2722.

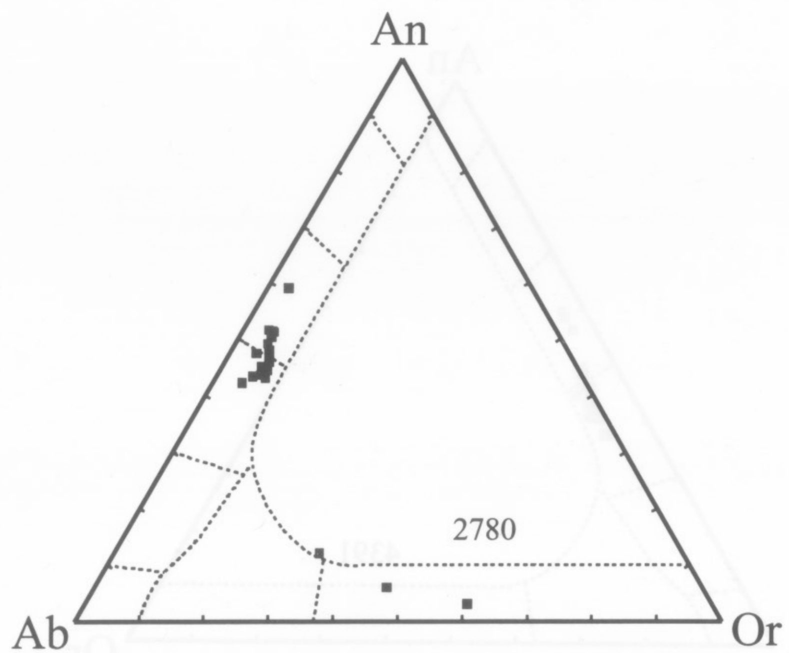

Fig. 5. Results of electron microprobe analysis of sherd 2780.

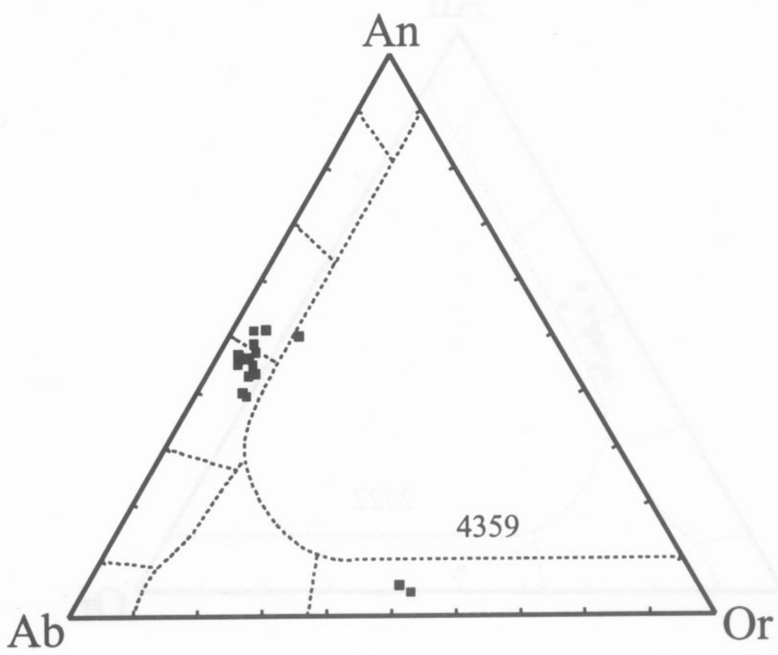

Fig. 6. Results of electron microprobe analysis of sherd 4359.

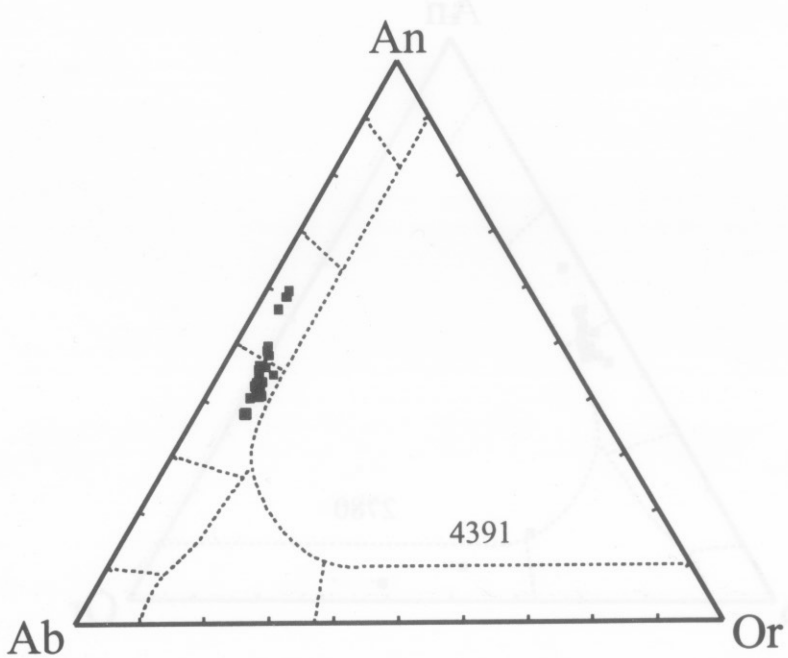

Fig. 7. Results of electron microprobe analysis of sherd 4391.

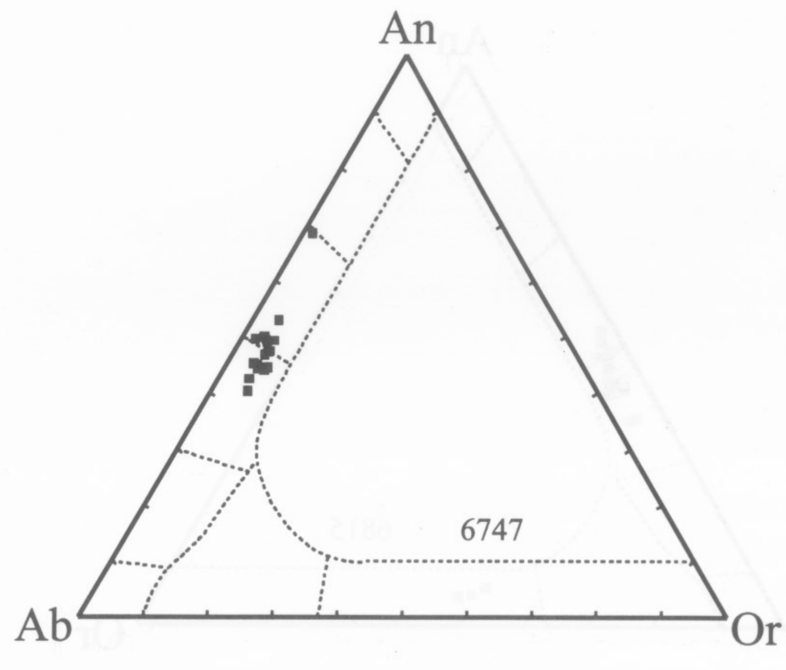

Fig. 8. Results of electron microprobe analysis of sherd 6747.

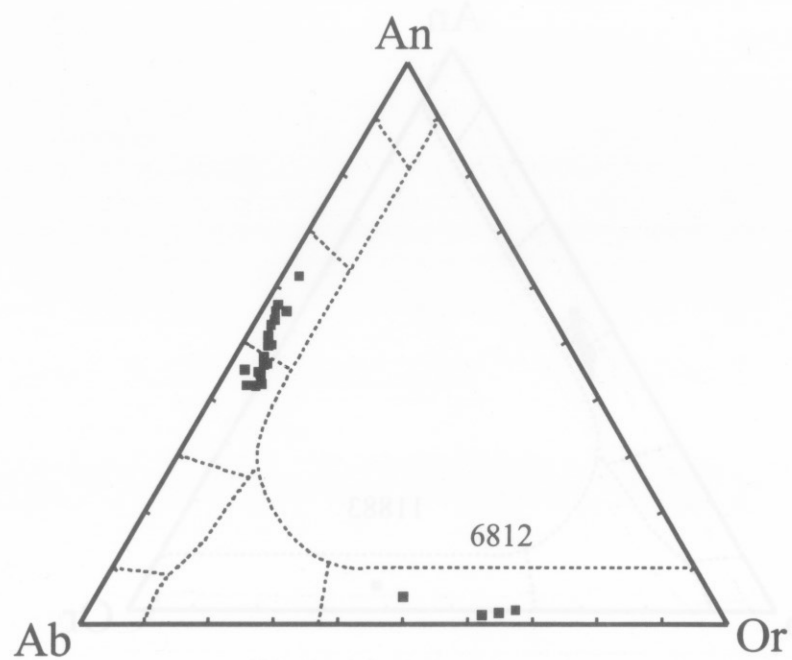

Fig. 9. Results of electron microprobe analysis of sherd 6812.

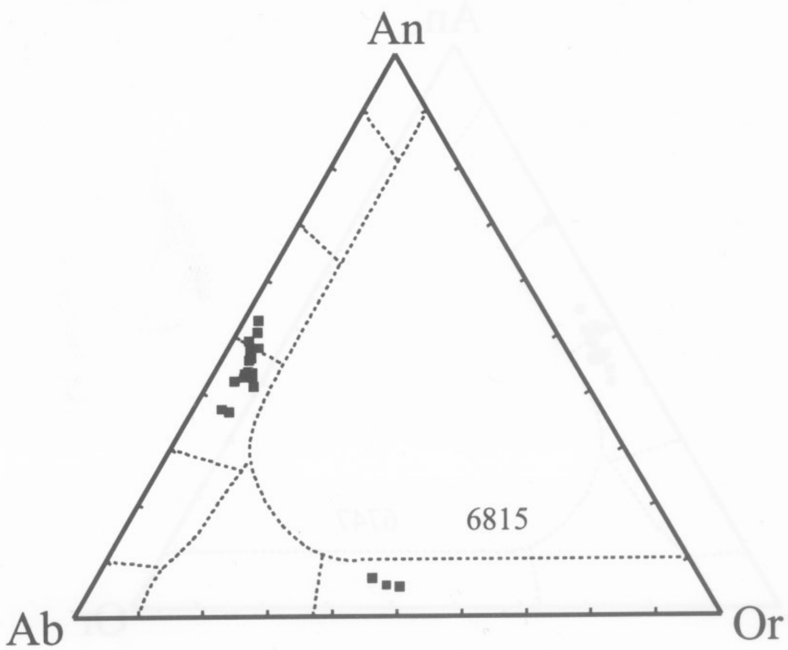

Fig. 10. Results of electron microprobe analysis of sherd 6815.

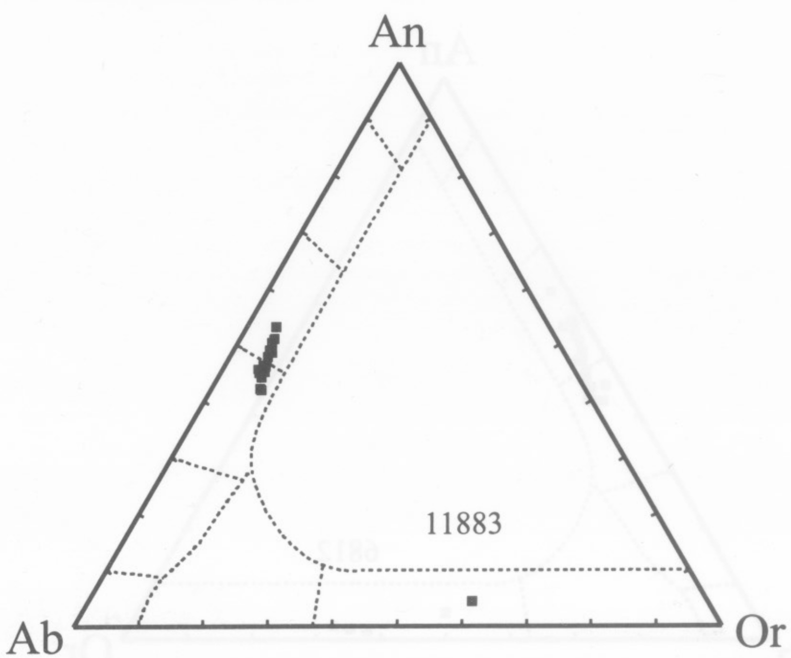

Fig. 11. Results of electron microprobe analysis of sherd 11883.

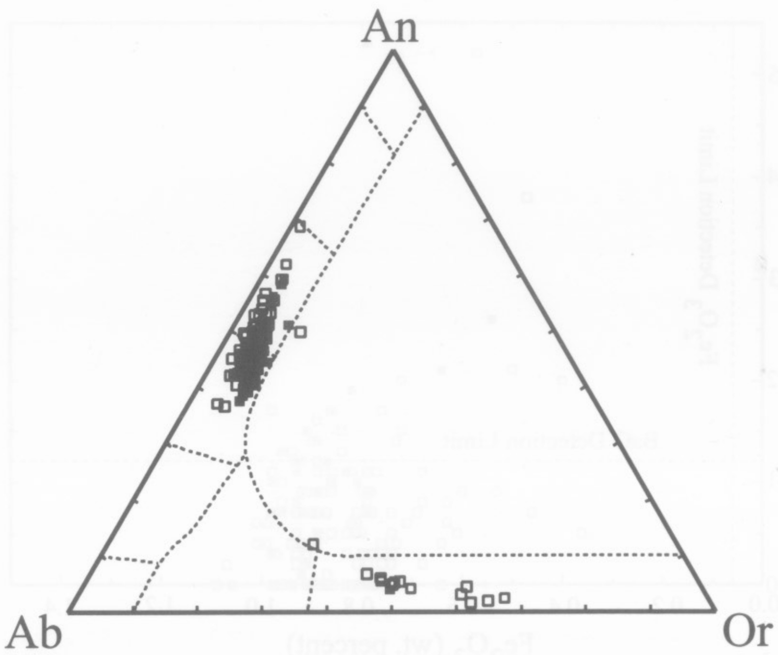

Fig. 12. Comparison of feldspar composition in sherds with temper type A (■) versus temper type C (□).

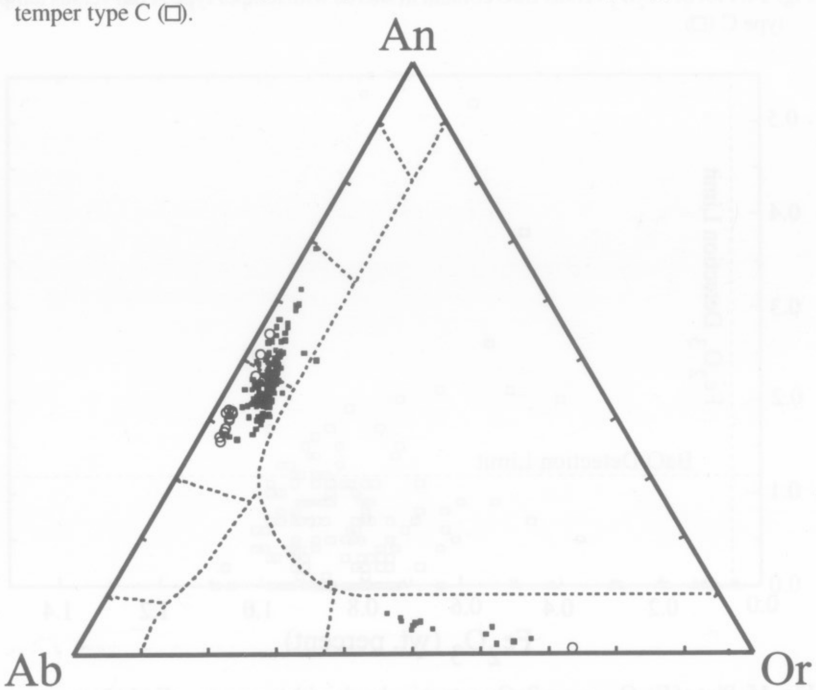

Fig. 13. Comparison of feldspar composition in sherds with temper type E (○) versus temper types A and C (■).

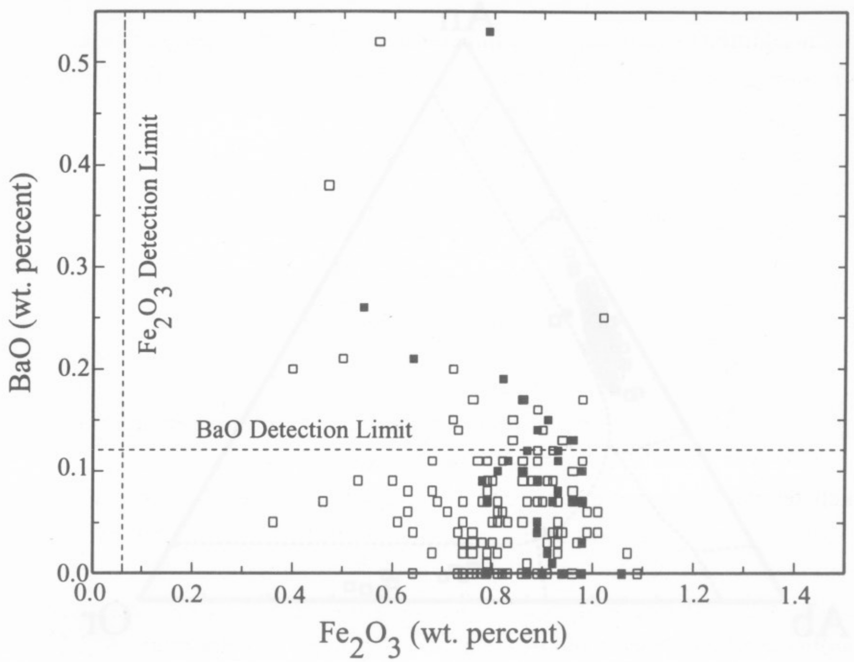

Fig. 14. Plot of Fe_2O_3 versus BaO content in sherds with temper type A (■) versus temper type C (□).

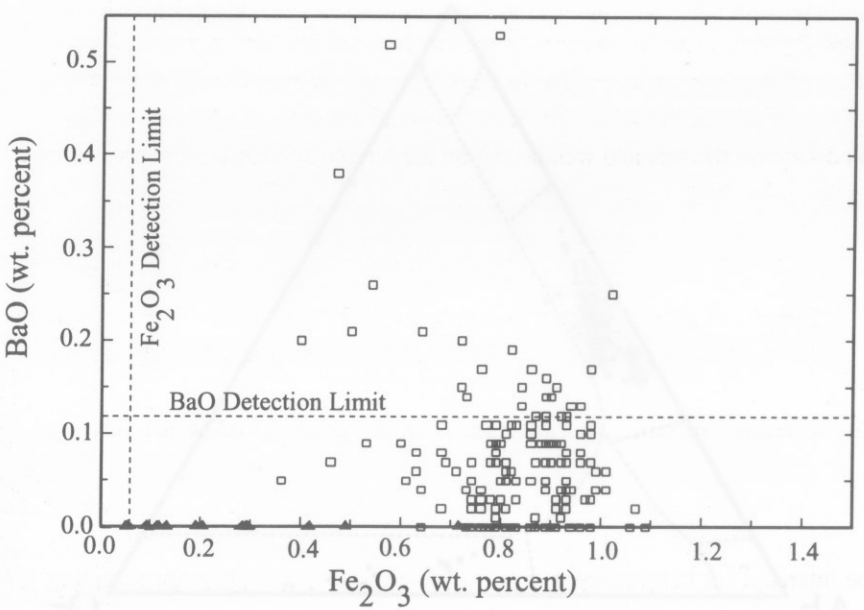

Fig. 15. Plot of Fe_2O_3 versus BaO content in sherds with temper type E (▲) versus temper types A and C (□).

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.

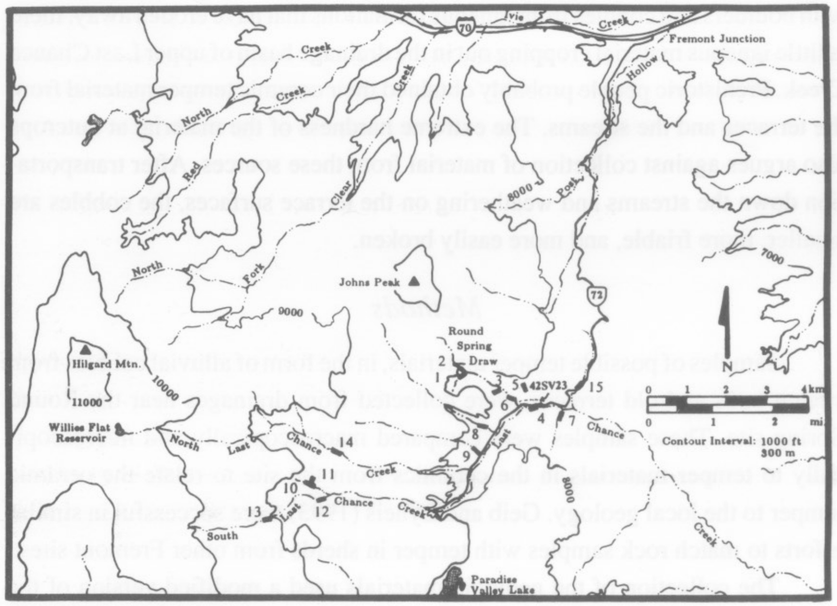

Fig. 16. Location of geologic sampling transects. Base map is Salina, Utah—1:100,000 (1990).

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.

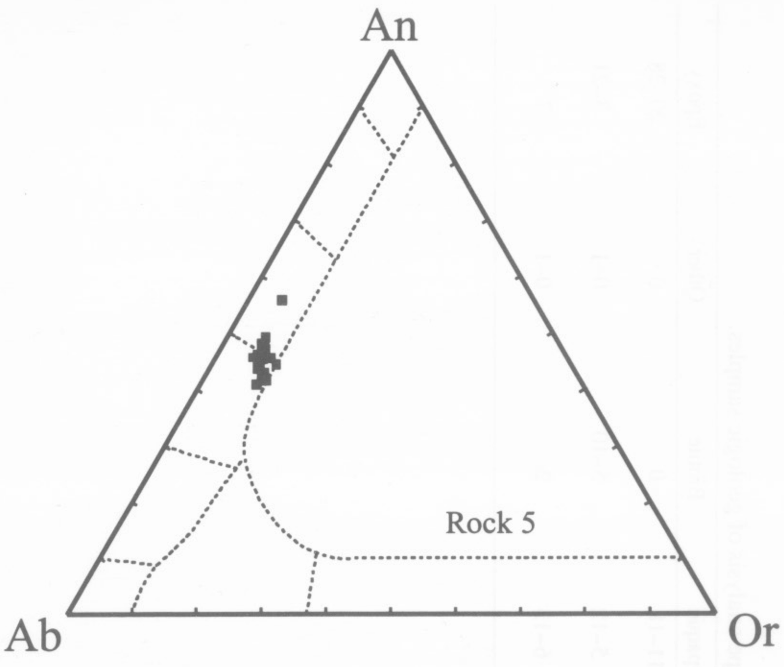

Fig. 17. Results of electron microprobe analysis of geologic sample 5.

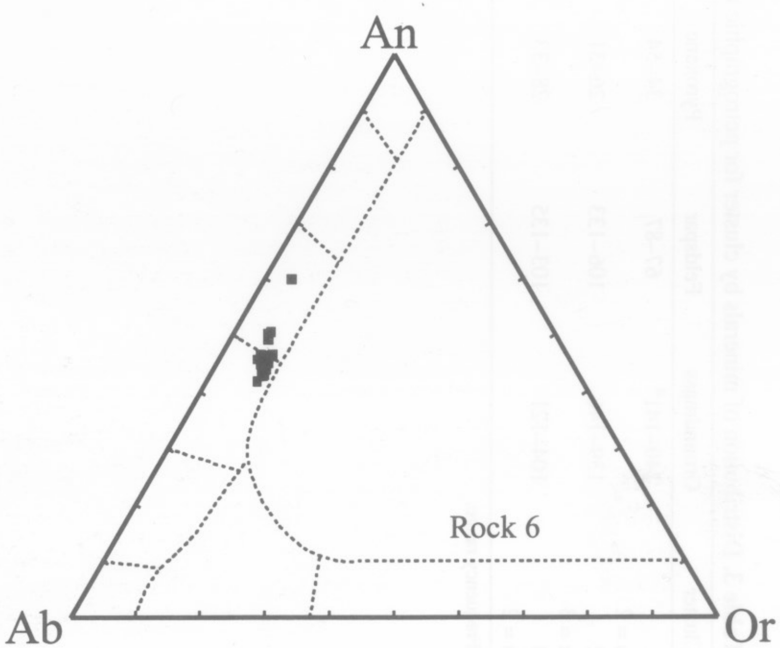

Fig. 18. Results of electron microprobe analysis of geologic sample 6.

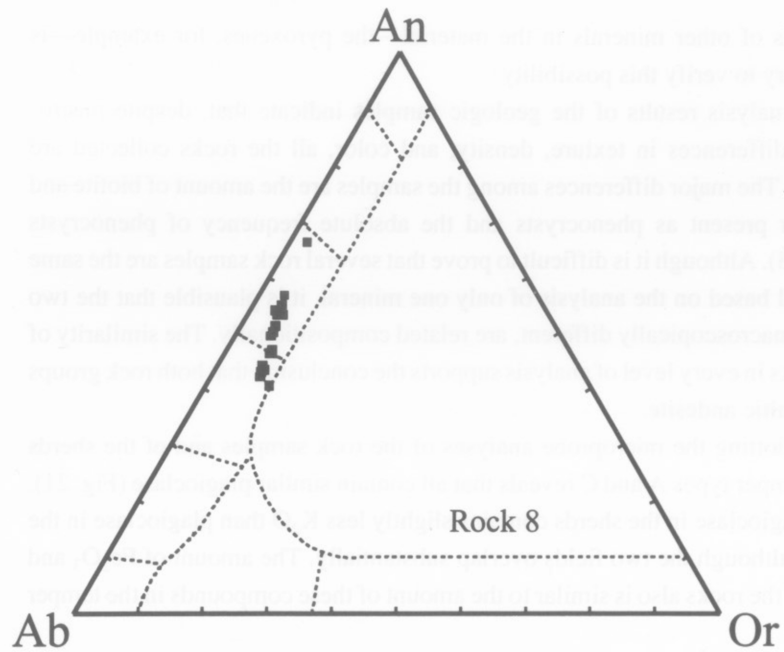

Fig. 19. Results of electron microprobe analysis of geologic sample 8.

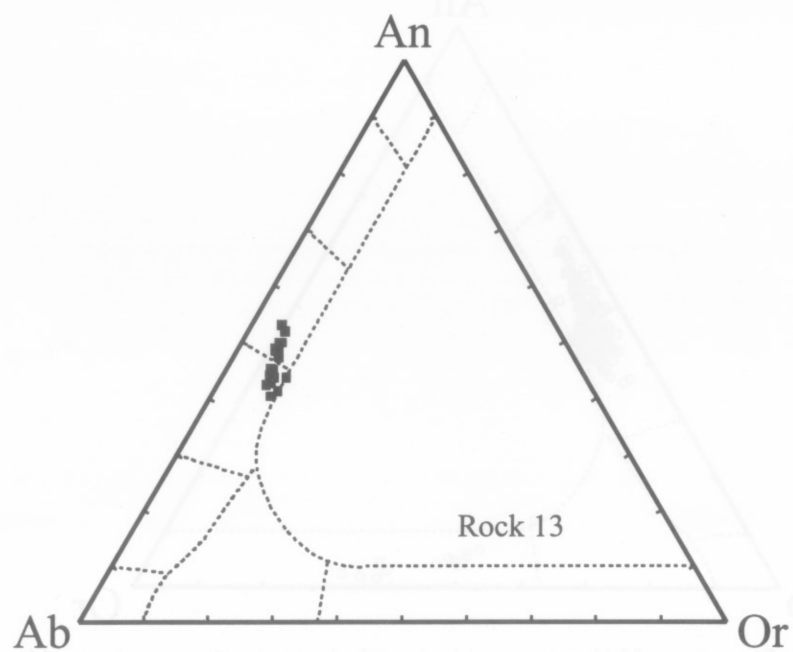

Fig. 20. Results of electron microprobe analysis of geologic sample 13.

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

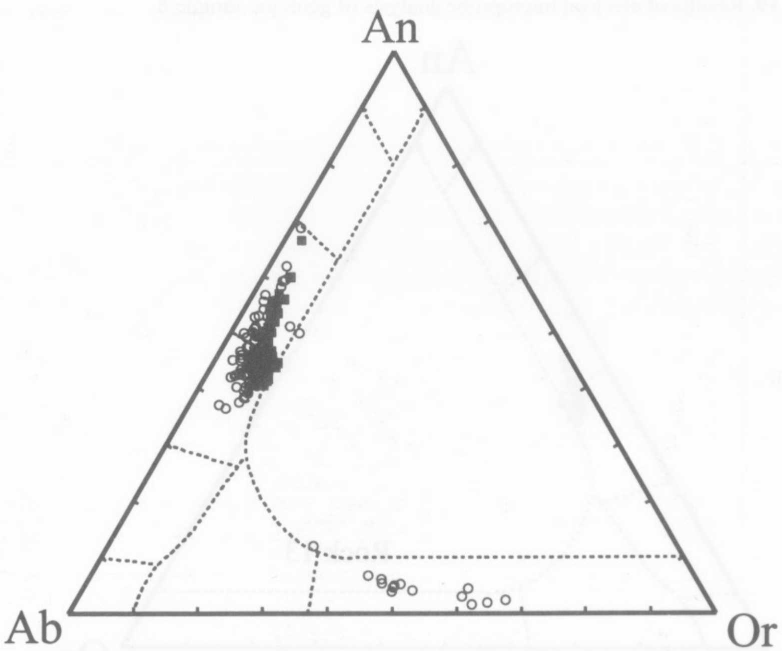

Fig. 21. Comparison of feldspar composition in geologic samples (■) versus sherds with temper types A and C (O).

(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

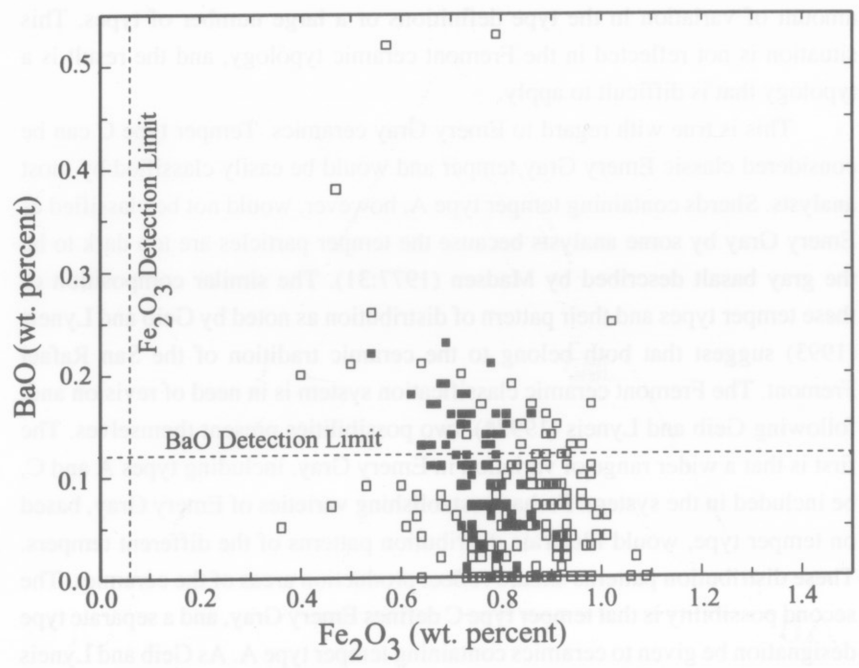

Fig. 22. Plot of Fe_2O_3 versus BaO content in geologic samples (■) and sherds with temper types A and C (□).

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.

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