

## 14. CERAMIC TECHNOLOGY I: PETROGRAPHY, FIRING, AND SURFACE DECORATION

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An examination of the thin sections from the 45 pottery specimens listed in tables 14.1-14.3, using standard methods of petrographic microscopy, enabled us to determine the following characteristics: (1) the percentage contribution of the main inclusions to the total ware volume, where that contribution is equal to or in excess of 0.5% (see fig. 14.1); (2) the size range distribution of the longest diameter and grain angularity of individual mineral inclusions, on the basis of species identification of 100 randomly selected grains; and (3) the presence of other minerals and inclusions (e.g., organics).

On the basis of this analysis, two main ware categories, Type A and Type B, were defined for 40 samples—essentially, on the virtual absence vs. significant presence of asbestos as a primary contributor ( $\geq 0.5\%$ ) to the mineral inclusion suite—and a third category was then labeled Misc. (for Miscellaneous), to accommodate the remaining five samples, each of which had a unique mineralogy within the framework of the studied corpus.

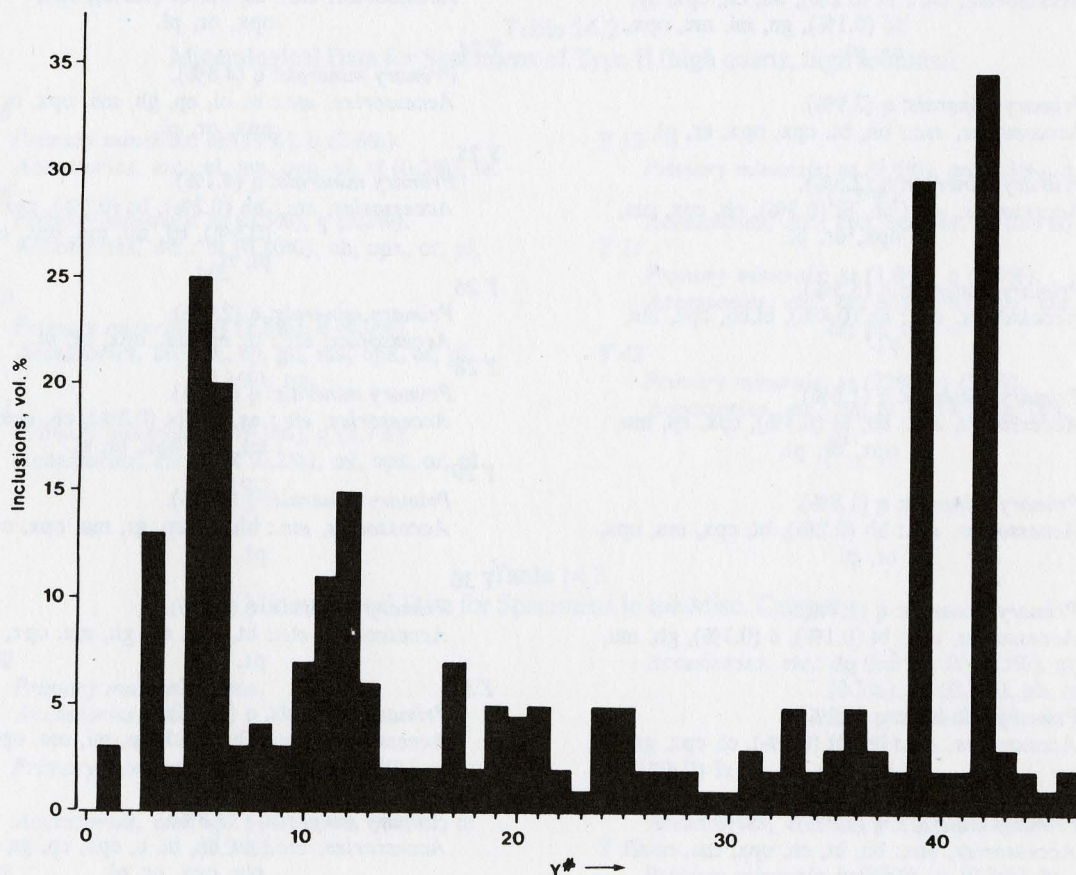


fig. 14.1: Volumetric contribution of inclusions (quartz, asbestos, etc.) to the fabric of the analyzed series of sherds.

## Key to Mineralogical Descriptions in Tables 14.1-14.3

ap (apatite)	fd (feldspar)	or (orthoclase)
as (asbestos)	ga (garnet)	pl (plagioclase)
bh (brown hornblende)	gg (grog)	q (quartz)
bt (biotite)	gh (green hornblende)	rf (rock fragments)
c (calcite)	gn (gneiss)	ss (sandstone)
ch (chert)	gr (granite)	ta (talc)
cl (chlorite)	hy (hypersthene)	tm (tourmaline)
co (corundum)	mi (microcline)	vr (volcanic rock)
cpx (clinopyroxene)	mu (muscovite)	
ep (epidote)	opx (orthopyroxene)	

In the tables themselves, individual minerals are recorded in the *Primary minerals* row if they contribute more than 0.5 vol.%, and in the *Accessories, etc.* row if they contribute less than 0.5 vol.% (not quantified below 0.1%).

Table 14.1  
Mineralogical Data for Specimens of Type A (high quartz, minimal asbestos)

Y 01 <i>Primary minerals:</i> q (2.9%). <i>Accessories, etc.:</i> bt, bh, ch, cpx, gr, mu, opx, or, pl.	Y 22 <i>Primary minerals:</i> q (1.5%). <i>Accessories, etc.:</i> bh, bt (0.3%), ch, cpx, mi, mu, opx, or, pl.
Y 04 <i>Primary minerals:</i> q (1.6%). <i>Accessories, etc.:</i> bt (0.2%), bh, ch, cpx, ep, fd (0.1%), gn, mi, mu, opx, or, pl.	Y 23 <i>Primary minerals:</i> q (0.8%). <i>Accessories, etc.:</i> as, bh, bt (0.2%), cpx, opx, or, pl.
Y 07 <i>Primary minerals:</i> q (2.9%). <i>Accessories, etc.:</i> bh, bt, cpx, opx, or, pl.	Y 24 <i>Primary minerals:</i> q (4.8%). <i>Accessories, etc.:</i> bt, cl, ep, gh, mu, opx, or, opx, or, pl.
Y 09 <i>Primary minerals:</i> q (2.5%). <i>Accessories, etc.:</i> bh, bt (0.3%), ch, cpx, mu, opx, or, pl.	Y 25 <i>Primary minerals:</i> q (4.1%). <i>Accessories, etc.:</i> bh (0.2%), bt (0.3%), cpx (0.3%), ep, mi, mu, opx, or, pl, rf.
Y 13 <i>Primary minerals:</i> q (5.5%). <i>Accessories, etc.:</i> bh (0.4%), bt, ch, cpx, mu, pl.	Y 26 <i>Primary minerals:</i> q (2.0%). <i>Accessories, etc.:</i> cl, ep, mu, opx, or, pl.
Y 14 <i>Primary minerals:</i> q (1.6%). <i>Accessories, etc.:</i> bh, bt (0.3%), cpx, ep, mu, opx, or, pl.	Y 28 <i>Primary minerals:</i> q (1.6%). <i>Accessories, etc.:</i> as, bh, bt (0.2%), ch, cpx, mi, mu, opx, or, pl.
Y 15 <i>Primary minerals:</i> q (1.8%). <i>Accessories, etc.:</i> bh (0.2%), bt, cpx, mu, opx, or, pl.	Y 29 <i>Primary minerals:</i> q (0.9%). <i>Accessories, etc.:</i> bh, bt, ep, gr, mu, opx, or, pl.
Y 16 <i>Primary minerals:</i> q (1.7%). <i>Accessories, etc.:</i> bt (0.1%), c (0.1%), gh, mu, or, pl.	Y 30 <i>Primary minerals:</i> q (0.8%). <i>Accessories, etc.:</i> bt, cpx, ep, gh, mu, opx, or, pl.
Y 17 <i>Primary minerals:</i> q (6.2%). <i>Accessories, etc.:</i> bh, bt (0.2%), cl, cpx, gr, mi, opx, or, pl, rf (0.4%).	Y 31 <i>Primary minerals:</i> q (1.9%). <i>Accessories, etc.:</i> bh, bt, cl, ep, mi, mu, opx, or, pl.
Y 18 <i>Primary minerals:</i> q (1.8%). <i>Accessories, etc.:</i> bh, bt, ch, cpx, mu, opx, or, pl.	Y 32 <i>Primary minerals:</i> q (1.8%). <i>Accessories, etc.:</i> as, bh, bt, c, cpx, ep, gr, mi, mu, opx, or, pl.
Y 19 <i>Primary minerals:</i> q (4.3%). <i>Accessories, etc.:</i> bh, bt (0.4%), c, ep, hy, mu, opx, or, pl.	Y 33 <i>Primary minerals:</i> q (4.6%). <i>Accessories, etc.:</i> as, bh, bt (0.2%), c, cpx, ep, mi, mu, opx, or, pl, tm.

Y 34 <i>Primary minerals:</i> q (2.7%). <i>Accessories, etc.:</i> as, bh, bt, c, cpx, ep, gr, mi, mu, opx, or, pl, rf.	Y 41 <i>Primary minerals:</i> q (1.7%). <i>Accessories, etc.:</i> bh, bt (0.2%), ch, cpx, ep, gr, mu, opx, or, pl, rf.
Y 35 <i>Primary minerals:</i> q (2.9%). <i>Accessories, etc.:</i> as (0.1%), bh, bt, cl, ep, mu, opx, or, pl, tm.	Y 43 <i>Primary minerals:</i> q (2.6%). <i>Accessories, etc.:</i> as, bh, bt (0.3%), ch, cpx, ep, mi, mu, opx, or, pl.
Y 36 <i>Primary minerals:</i> q (4.6%). <i>Accessories, etc.:</i> as (0.1%), bh, bt, ch, cl, ep, gr, mi, mu, opx, or, pl, rf.	Y 44 <i>Primary minerals:</i> q (1.7%). <i>Accessories, etc.:</i> as (0.2%), bh, bt (0.1%), cl, ep, mu, opx, or, pl.
Y 37 <i>Primary minerals:</i> q (2.9%). <i>Accessories, etc.:</i> as, bh, bt, c, mi, mu, opx, or, pl, rf.	Y 45 <i>Primary minerals:</i> q (0.8%). <i>Accessories, etc.:</i> as (0.1%), bt (0.1%), ch, cl, ep, gh, mu, opx, or, pl.
Y 38 <i>Primary minerals:</i> q (1.7%). <i>Accessories, etc.:</i> as, bh, bt (0.2%), ch, ep, hy, mi, mu, opx, or, pl.	Y 46 <i>Primary minerals:</i> q (1.7%). <i>Accessories, etc.:</i> bh, bt (0.2%), cl, ep, mu, opx, or, pl, tm, vr.
Y 40 <i>Primary minerals:</i> q (1.9%). <i>Accessories, etc.:</i> ap, bh, bt, cpx, mu, opx, or, pl.	

Table 14.2  
Mineralogical Data for Specimens of Type B (high quartz, high asbestos)

Y 06 <i>Primary minerals:</i> as (17%), q (2.6%). <i>Accessories, etc.:</i> cl, mu, opx, pl, rf (0.2%), ta.	Y 12 <i>Primary minerals:</i> as (9.5%), gn (2.3%), q (2.9%). <i>Accessories, etc.:</i> cpx, opx, or, pl (0.3%).
Y 08 <i>Primary minerals:</i> as (0.5%), q (3.2%). <i>Accessories, etc.:</i> bt (0.20%), ch, opx, or, pl, tm.	Y 21 <i>Primary minerals:</i> as (1.0%), q (3.9%). <i>Accessories, etc.:</i> bh, bt (0.1%), cpx, mu, opx, or, pl, tm.
Y 10 <i>Primary minerals:</i> as (2.8%), q (4.0%). <i>Accessories, etc.:</i> bt, ep, gn, mu, opx, or, pl (0.1%), tm.	Y 42 <i>Primary minerals:</i> as (22%), q (11%). <i>Accessories, etc.:</i> bh, bt (0.3%), ch, cpx, opx, pl.
Y 11 <i>Primary minerals:</i> as (6.9%), q (3.7%). <i>Accessories, etc.:</i> cpx (0.2%), mi, opx, or, pl (0.1%).	

Table 14.3  
Mineralogical Data for Specimens in the Misc. Category

Y 02 <i>Primary minerals:</i> none. <i>Accessories, etc.:</i> q.	<i>Accessories, etc.:</i> ep (0.3%), fd (0.5%), ga, gn (0.3%), gr (0.3%), gh, mi, mu, opx, pl (0.5%), ss, vr (0.3%).
Y 03 <i>Primary minerals:</i> as (2.0%), gn (1.8%), mu (5.5%), q (3.3%). <i>Accessories, etc.:</i> cpx (0.1%), co, opx, or, pl (0.3%).	Y 20 <i>Primary minerals:</i> q (4.5%). <i>Accessories, etc.:</i> bh, ch, gg, pl, ss.
Y 05 <i>Primary minerals:</i> bh (2.3%), bt (1.8%), cpx (1.5%), q (17%).	Y 39 <i>Primary minerals:</i> q (27%), as (0.3%), bt (0.3%), bh (1.8%). <i>Accessories, etc.:</i> cpx, ep, gn, gr, mi, mu, opx, pl (0.6%), rf (0.3%).

Table 14.4  
Refiring and Surface Decoration Data for Individual Specimens

## Type A

- Y 01  
Original state: —; ware (10R 5/8-6/8); no core; int. and ext. slip (10R 5/8).  
Refiring temp.: 900°C.  
Refired state: —; ware (10R 6/4); core (medium, 10R 6/4); slip (10R 4/8).
- Y 13  
Original state: —; totally reduced (gray).  
Refiring temp.: 600°C.  
Refired state: —; ware (10R 6/6); no core (some 10R 6/4 coloration); ext. slip (10R 5/8); int. slip (10R 4/6).
- Y 14  
Original state: —; ware (2.5YR 6/6); no core; int. slip (red).  
Refiring temp.: 700°C.  
Refired state: —; no color changes.
- Y 16  
Original state: —; totally reduced.  
Refiring temp.: 800°C.  
Refired state: —; ware (7.5YR 7/4); no core.
- Y 17  
Original state: —; ware and ext. surface (7.5YR 8/2); int. surface (7.5YR 8/2 with some blackening); core (thick, intermixed black, 10R 6/4, 7.5YR 7/4, and 7.5YR 8/2).  
Refiring temp.: 700°C.  
Refired state: —; ware and surfaces (7.5YR 8/2); core (thick, 7.5YR 7/4 with some blackening).
- Y 19  
Original state: —; ext. ware (7.5YR 7/4 with some blackening); int. ware (7.5YR 7/4); no core; int. and ext. slip (10 R 4/6).  
Refiring temp.: 800°C.  
Refired state: —; ware (5YR 7/6); no core; slip (10R 5/8).
- Y 22 (fig. 14.2)  
Original state: NV; ware (10R 6/6); no core; int. and ext. slip (10R 5/6).  
Refiring temp.: 900°C.  
Refired state: V; ware (10R 6/8); no core; slip (10R 5/6).
- Y 24  
Original state: —; ext. ware (5YR 6/3); otherwise totally reduced.  
Refiring temp.: 700°C.  
Refired state: —; ware (5YR 7/6); no core; int. and ext. slip (10R 6/6).
- Y 28  
Original state: IV; ware (10R 5/6-6/6); no core (but thick 5YR 6/3 int.); int. and ext. slip (10R 5/6).  
Refiring temp.: 600°C.  
Refired state: V; no color changes.
- Y 29  
Original state: —; int. ware (5YR 7/3) and ext. ware (10R 6/6), the latter extending across about 75% of the cross-section.  
Refiring temp.: 900°C.  
Refired state: —; ware (5YR 8/4); no core; probable surface efflorescence, extremely friable.
- Y 33  
Original state: —; int. ware (10R 6/6) and ext. ware (5YR 6/4), each extending about 50% across the cross-section; int. surface (10R 6/6); remnant of ext. slip (10R 4/8).  
Refiring temp.: 700°C.  
Refired state: —; int. ware (2.5YR 6/4); ext. ware (2.5YR 6/6); no core; surfaces (2.5YR 6/4).
- Y 34 (fig. 14.3)  
Original state: IV; int. ware (5YR 7/6); ext. ware (2.5YR 6/6); blackening in rim area; no core; int. and ext. slip (10R 4/4-4/6 with some blackening).  
Refiring temp.: 500°C.  
Refired state: IV; int. ware (5YR 7/6); ext. ware (10R 4/4 with some blackening); no core (some 10R 6/6); int. slip (10R 5/6); ext. slip (10R 4/4 with some blackening).

Table 14.4 (cont'd)

- Y 35  
Original state: —; ware (10R 6/6); no core (some 10R 6/3); int. and ext. slip (red).  
Refiring temp.: 500°C.  
Refired state: —; no color changes.
- Y 37  
Original state: —; ware (one side, 10R 6/6; other side, 5YR 6/3), each extending across about 50% of the cross-section; surfaces (5YR 6/3).  
Refiring temp.: 800°C.  
Refired state: —; ware and surfaces (10R 6/4); core (medium, 5YR 6/4).
- Y 38  
Original state: —; int. ware (10R 6/4), extending across more than 75% of the cross-section; ext. ware (2.5YR 6/8); int. and ext. slip (10R 5/6).  
Refiring temp.: 500°C.  
Refired state: —; no color changes.
- Y 40  
Original state: —; ware (10R 6/3); no core; int. slip (10R 3/3); ext. slip (10R 4/6).  
Refiring temp.: 800°C.  
Refired state: —; ware (10R 6/3); no core (some 2.5YR 6/4); ext. surface (white cast, probably efflorescence, where slip is missing); ext. slip (10R 4/6).

## Type B

- Y 10 (fig. 14.4)  
Original state: IV; int. ware (2.5YR 6/4); ext. ware (2.5YR 6/6); no core; surfaces (black mottling and white carbonate deposit).  
Refiring temp.: 800°C.  
Refired state: V; ware (5YR 7/4-4/6); no core.
- Y 12  
Original state: —; totally reduced.  
Refiring temp.: 700°C.  
Refired state: —; ware (2.5YR 6/6); surfaces (some blackening).

## Misc.

- Y 02 (fig. 14.5)  
Original state: CV; totally reduced.  
Refiring temp.: —.  
Refired state: not refired.
- Y 03  
Original state: IV; totally reduced.  
Refiring temp.: 700°C.  
Refired state: V; ware (7.5YR 6/8); no core.
- Y 05  
Original state: IV; ext. ware (2.5YR 5/6-6/6); core (thick, 10YR 5/2); int. surface (10YR 5/2); ext. surface (10YR 8/4, efflorescence?); int. and ext. slip (10R 5/8).  
Refiring temp.: 500°C.  
Refired state: V; no color changes.
- Y 20  
Original state: IV; int. ware (10YR 8/4, intermixed with 2.5YR 6/4); ext. ware (10YR 8/4); no core; ext. slip (10R 5/6-6/6 with some blackening).  
Refiring temp.: 900°C.  
Refired state: V; ware (10R 6/6); ext. slip (10R 6/6).
- Y 39  
Original state: —; ware (gray); no core (but thick 10YR 6/6 int.); surfaces (5YR 6/2-6/4).  
Refiring temp.: 600°C.  
Refired state: —; ware and surfaces (5YR 6/4); no core (but thick 10R 6/6 int.).

The mineral suite of Type A ware (33 examples) is dominated by quartz but often includes a significant amount of biotite (0.2-0.3%), along with other accessory minerals such as clinopyroxene, epidote, hornblende, muscovite, plagioclase, etc. A sherd-by-sherd mineralogical breakdown is given in table 14.1. The volumetric percentage of the quartz ranges between 0.8% and 6.2%, and averages close to 2.6%. The

quartz grains themselves have rounded edges, exhibit little size variation (average diameter c. 0.06 mm), and are unimodally distributed. Where other accessory minerals were present in amounts greater than 0.1%, their rounded form, size, and distribution are comparable to those of the quartz inclusions. What has been here identified as asbestos (most probably the amphibole, actinolite-tremolite) was present in trace amounts (i.e., occurring in the mineral suite with a frequency of no more than ten grains per 100-grain count) in twelve of the samples—specifically, in *Y 23, Y 28, Y 32, Y 33, Y 34, Y 35, Y 36, Y 37, Y 38, Y 43, Y 44, and Y 45*.

Calcite is represented to only a very limited extent here (in fact, only above trace levels in *Y 16*) even though limestone is a common sedimentary surface rock in the Middle East. With few exceptions, organics were also present, but their volumetric contribution could not be quantified from thin-section study.

The mineral suite of Type B ware (7 examples) is dominated by an admixture of quartz and asbestos (table 14.2). The volumetric percentage of the quartz ranges between 2.6% and 11%, and averages close to 4.5%. The quartz grains themselves are comparable in form, size, and distribution to their counterparts in the Type A category. The volumetric percentage of the asbestos is very variable, ranging between 0.5% and 22% (*Y 08* and *Y 42*, respectively). The contribution of asbestos to the mineral suite here varies from 13 grains (*Y 08*) to 88 grains (*Y 06*) per 100-grain count.

The same common accessory minerals are present in the Type B specimens as in the Type A specimens and they are comparable in form, size, and distribution. There are also some organics present, but again their volumetric contribution could not be quantified from thin-section study.

Unusual though the scale and frequency of this asbestos component is here, its occurrence as a trace constituent in many Type A samples, along with the high variability in its volumetric percentages in Type B samples, suggests that there is still some mineralogical affiliation between the two categories. Treated as a single group, the fabrics included in the Type A and Type B categories are best understood as deriving from fluvial, detrital sands which were formed by drainage of igneous and metamorphic terrains. The inclusions could either have been original components of the clay used, or have been added as temper. As for the asbestos component, it is unusual for that mineral to occur in stream sediments, so it is possible that the clay (or temper) used to make Type B wares was collected near the source of the asbestos, whereas materials for Type A wares were gathered farther downstream. Additional geological exploration in the area is needed to clarify this issue.

The mineral suite of Misc. wares (5 examples) varies from sample to sample (table 14.3). To the extent that they can be discussed within the framework of this study corpus at all, we note that:

- (1) *Y 39* is unusual only for its very high quartz content of approximately 27 vol.%, together with 1.8% hornblende. Otherwise the composition of its mineral suite (and an apparent absence of asbestos) would place it in the Type A category.
- (2) *Y 05* would fall into the Type A category, except that its mineral suite contains a significant amount of hornblende and clinopyroxene, and a generally higher level of other accessory minerals. It is also the only sample here that contains garnet.
- (3) *Y 20* would fall into the Type A category, except that its mineral suite is the only specimen containing grog temper.
- (4) *Y 03* would fall into the Type B category, except that its mineral suite contains an appreciable amount of muscovite—in fact, it contributes more to the mineral suite than the specimen's quartz and asbestos contents combined.
- (5) *Y 02* is completely anomalous. It contains just a few grains of fine quartz and (perhaps) mullite. Its fabric is extensively vitrified.

The petrographic analysis above bears directly upon the refiring and scanning electron microscope (SEM) studies that were undertaken to determine the original firing temperature range and surface decorations. Thus, groups of samples representing the ware categories Type A and Type B were refired over an appropriate temperature range, to delimit the original firing range for their production (for methodology, see McGovern et al. 1985; McGovern 1986). Four of the samples in the Misc. category—*Y 03, Y 05, Y 20, and Y 39*—were also included in this study. A sherd-by-sherd breakdown of the refiring behavior of individual samples is given in table 14.4. Color changes were recorded (according to Munsell 1975), and the vitrification state of the wares in each case (where studied by SEM) was defined according to the distinctions made by Tite et al. (1982b), as follows:

*NV*, unfused;

*IV*, initial vitrification of clay particles, with the edges of the clay particles fused together;

*V*, intermediate, extensive vitrification, with large areas of fused clay particles;

*CV*, continuous vitrification, with all the clay particles coalesced into a glassy matrix.

These wares, since they are moderately calcareous (c. 5-10% CaO), would be expected to change their vitrification state at around 700°C (*NV* to *IV*), 750°C (*IV* to *V*), and 950°C (*V* to *CV*), respectively (Tite et al. 1982a, 1982b). Examples of each of these states, as observed in the study corpus, are provided in figures 14.2-14.5. With the exception of *Y 02*, which is completely vitreous (fig. 14.5), none of the specimens studied would appear to have been originally fired above 750°C, and one specimen (*Y 22*; see fig. 14.2) no higher than 700°C. One specimen (*Y 29*), when refired to 900°C, became extremely friable, implying that original firings to this temperature or above would have weakened the ware and were consequently avoided by the ancient potters.

An upper temperature limit of c. 700-750°C is also borne out by some mineralogical evidence for the temperature-sensitive mineral hornblende. Pure green hornblende is transformed to brown hornblende at about 750°C (Kozu et al. 1927; Barnes 1930). Three samples—*Y 16, Y 24, and Y 30*—contained only green hornblende, and in several others there were many brown hornblende grains with green cores that would suggest incomplete thermal transformation. In yet other samples—*Y 03, Y 09, and Y 45*—the two mineral species co-occur.

Of perhaps equal significance is the fact that some samples—*Y 16, Y 19, Y 33, Y 34, and Y 37*—contain primary calcite of a macrocrystalline, translucent variety. Previous studies on moderately calcareous clays would suggest that, in those instances, the original firing temperature might have been as low as 600°C, since above that temperature, the calcite was transformed to a cryptocrystalline, cloudy variety (McGovern et al. 1986).

Any assessment of the original firing temperature range can only be approximate, since allowance must be made for temperature gradients in and around the pottery during manufacture, and for unknowns such as the length of firing and the environment (oxidizing and/or reducing). Wasters indicate that there was a production installation in the area, but its location is at present unknown. In the absence of such physical evidence we can say only that, if the temperature range generally predicted here—c. 700-750°C (possibly lower, on occasion)—is correct, it would be quite feasible for the firing to have been carried out either in an open fire or in a kiln operating at a low temperature.

Color changes of wares upon refiring were of primary value in the determination of the final atmosphere of firing. The original wares, whether categorized as Type A, Type B, or Misc., are generally red to light red (Munsell 10R 5/6-6/8 and 2.5YR 5/6-6/8), with some specimens more yellow or lighter-colored (5YR 7/6, 7.5YR 8/2, 10YR 8/4). Several wares are variously colored black or gray (*Y 13, Y 16*: Type A; *Y 12*: Type B; *Y 02, Y 03, Y 39*: Misc.). Refiring in an oxidizing atmosphere resulted in the latter wares' developing a red coloration, which appeared to be somewhat inhibited by the presence of carbon (*Y 16*: Type A; *Y 03, Y 39*: Misc.). Therefore the ancient firings, with few exceptions, must have been carried out in an oxidizing atmosphere.

The only color change which might be used as a temperature indicator is based on the following observations: (1) the wares of two specimens (*Y 33*: Type A; *Y 10*: Type B), when refired to 700°C and 800°C, respectively, became yellower rather than redder; and (2) in all the specimens refired to 900°C (e.g., *Y 01, Y 22*: Type A; *Y 20*: Misc.) the wares changed to or remained the usual red or light red. This evidence suggests that the wares originally fired to c. 700-750°C in an oxidizing atmosphere generally became red to light red, but above this temperature a yellower coloration might develop, which then reverted to red or light red by 900°C. It might be argued that those specimens (*Y 17, Y 19, Y 24, Y 29, Y 34*: Type A; *Y 20*: Misc.) of yellower wares that remained unchanged or became only slightly more red upon refiring experienced original firing temperatures above 700°C. Refiring studies of the clays used to make this pottery are needed to determine the validity of this proposal.

The thickness of a dark black core, since it reflects the presence of unoxidized carbon, is a measure of the amount of organic matter in the clay or added intentionally as temper, and of the duration, temperature, and atmosphere of firing—organics begin to burn out at around 450°C. Dark cores were rare in the study corpus (only *Y 17*: Type A; *Y 05*: Misc.); with refiring up to 700°C, cores remained thick and only lightened in color. Since the original firing temperature was probably around the same temperature, firings of more than eight hours' duration are implied.

Somewhat darker interior or exterior wares and/or surfaces which sometimes extended into the cross-section, and spot or area blackening, either on the surface or interiorly, were also observed (Y 19, Y 29, Y 33, Y 34, Y 37, Y 38: Type A; Y 10: Type B; Y 20: Misc.); the darker colors were converted to the usual reds and blackening disappeared in those specimens refired above 700°C.

One Misc. specimen (Y 39) had apparently been exposed to an initial oxidizing atmosphere followed by a final reducing atmosphere, since its exterior surface was gray while its ware and/or core had clearly been oxidized. Five specimens (Y 13, Y 16: Type A; Y 12: Type B; Y 02, Y 03: Misc.) were totally reduced and showed no signs of ever having been exposed to an oxidizing atmosphere.

Slips and other surface layers on several of the vessels were characterized for presence vs. absence using low-power microscopy (magn. 20x to 160x), and some were then defined structurally and chemically, using SEM analysis (magn. 300x to 1000x).

Red slips were observed on several specimens (Y 07, Y 19, Y 22, Y 28, Y 33, Y 34, Y 35, Y 38, Y 40: Type A; Y 20: Misc.). With the exceptions of Y 33 and Y 20 (with only exterior slips), these slips had been applied to both the interior and exterior surfaces. They were relatively thick (c. 80  $\mu$ m), vitreous and therefore distinct from the underlying ware, high in iron (giving the same coloration in most of the specimens, viz., 10R 4/6-5/8), and noncalcareous (fig. 14.6). They did not change microscopically or in color upon refiring. The principal advantage of a noncalcareous slip on a calcareous ware is that the expansion coefficients of the two are the same, thus enabling the slip to adhere better to the ware.

A probable white efflorescence (see Matson 1971) was observed on two specimens (Y 29, Y 40) refired to 900°C and 800°C, respectively. Several other specimens (e.g., Y 10) had white surfaces which were less likely to have been caused by efflorescence than by postburial deposition of calcium carbonate and/or noncarbonate salts. The white surface on one Misc. specimen (Y 05) is probably due to a combination of efflorescence and noncarbonate salt accumulation.



fig. 14.2: SEM micrograph of sherd Y 22.

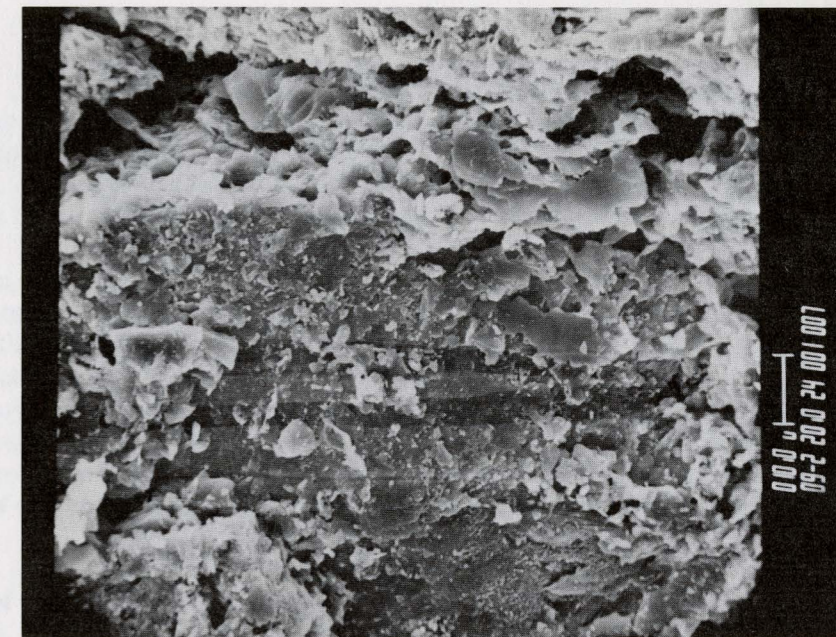


fig. 14.4: SEM micrograph of sherd Y 10.



fig. 14.3: SEM micrograph of sherd Y 34.

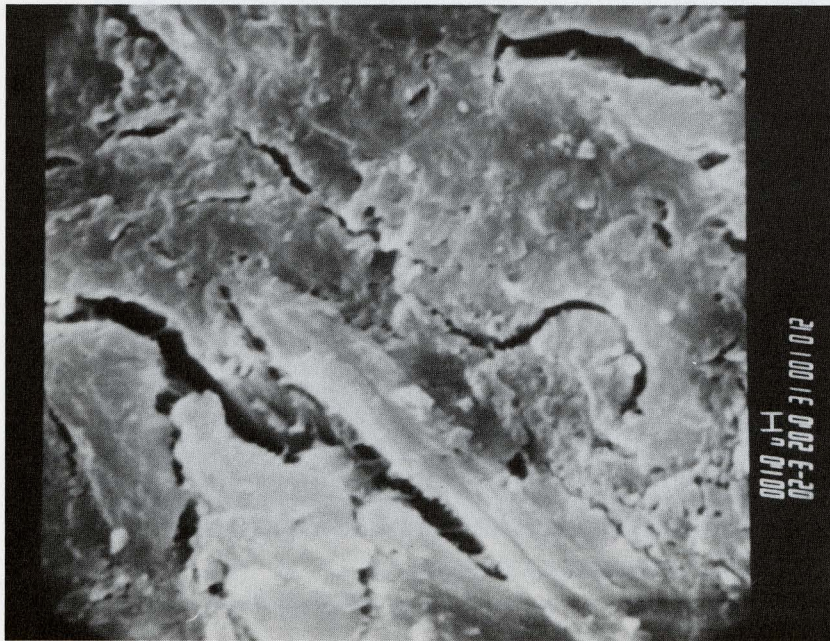


fig. 14.5: SEM micrograph of sherd Y 02.

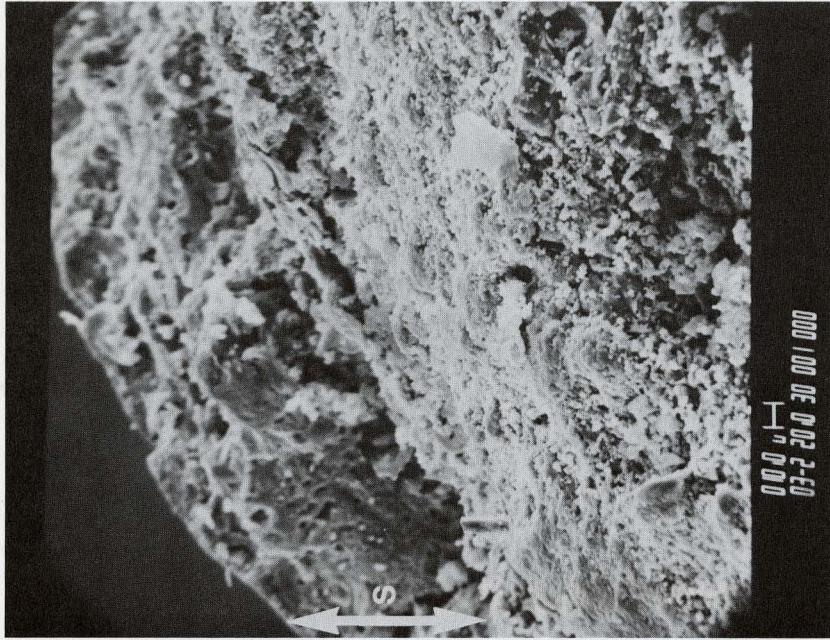


fig. 14.6: SEM micrograph of the fabric and slip (arrowed s) of sherd Y 34.