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COOKING POTS AS INDICATORS OF CULTURAL CHANGE

A Petrographic Study of Byzantine and Frankish Cooking Wares from Corinth

ABSTRACT

Two styles of cooking pot were used sequentially at Corinth from the 12th to the 14th century A.D., a time during which Frankish crusaders occupied the Byzantine city. Utilizing thin-section petrography, the author investigates possible differences in the provenance and production technology of the two forms of cooking ware. The Byzantine form was made in many fabrics while the Frankish form, introduced some 50 years after the Frankish incursion, was limited largely to one fabric. The fabrics are all consistent with the local geology, suggesting that both forms were produced locally and that the observed differences are the result of changes in the procurement and/or production of the vessels over time.

INTRODUCTION

Recent excavations in a Frankish complex at Corinth uncovered two distinct cooking wares, an earlier ware typical of the Byzantine and Early Frankish period, and a later Frankish ware (Figs. 1, 2).[1] The two types of cooking ware can be dated to before and after the Frankish incursion into Corinth in A.D. 1210. At the time of excavation, Charles Williams raised several questions about the origin of these wares. Were they produced locally or

1. The study of Byzantine and Frankish cooking wares from Corinth was undertaken in 1993–1995 at the Fitch Laboratory, British School at Athens, with the permission to obtain ceramic samples kindly provided by the Greek Ministry of Culture, Direction for the Conservation of Antiquities, in cooperation with the (then) 6th Ephoreia of Byzantine Antiquities of Patras. Funding for this project came from the Corinth Excavations, American School of Classical Studies at Athens. The project was inspired by questions raised by Charles K. Williams II, the director of the Corinth Excavations (1966–1997), about cooking wares recovered from the 1992–1994 excavation seasons. I wish to thank Charles Williams, Guy Sanders, Ian Whitbread, Ruth Siddell, and Denys Pringle for their invaluable support and helpful discussions during the course of this work, and also John Morgan, Maria Papakonstantinou, and Ian Dennis for providing help in preparing the illustrations. I am also grateful to the editor and two anonymous *Hesperia* referees for comments that have greatly improved this paper.

The terms "Franks" and "Frankish" are used here to refer to the Catholic population of Europe or "western Christians," and not only to the people who came from France. For discussion of these terms, see Lock 1995, pp. 8–9, 271; Ilieva 1991, pp. 19–20; *ODB*, p. 803, s.v. Frankoi (R. B. Hitchner and A. Kazhdan); and Boas 1999, p. 7.

Figure 1. Western sector of the Frankish settlement at Corinth, southeast of Temple E, ca. 1300. Williams 2003, p. 427, fig. 25.2

were they imported? Were they made using different clays? Were they produced in the same workshops?

To try to answer some of these questions, I undertook a program of fabric analysis at the Fitch Laboratory of the British School at Athens. Given the coarse-grained nature of these fabrics, petrography rather than chemical analysis was selected as the most appropriate method. Petrography could be expected to reveal any differences between the clay fabrics of the Byzantine and Frankish forms; if the vessels were local in origin, the differences in fabric would reflect developments in the pottery industry of Corinth during the period under study. The purpose of this article is to present the results of this analysis and to draw inferences about the changing forms, production technology, and function of these wares over time.

The cooking pots date from the 12th to the early 14th centuries.[2] This time span has been divided into four phases: (1) Byzantine, 12th century to A.D. 1210; (2) Early Frankish, A.D. 1210 to ca. A.D. 1260; (3) Middle

2. For the cooking wares excavated at Corinth, see Robinson and Weinberg 1960, p. 234; MacKay 1967, pp. 288–300; 2003, pp. 417–419; Sanders 1987, pp. 179–182; Williams and Zervos 1991, p. 33; 1993, pp. 19, 31; 1994, pp. 16, 22, 29, 35–36; 1995, pp. 9, 23, 33–37; 1996, pp. 23, 26, 29–30, 33–34; Williams, Barnes, and Snyder 1997, pp. 17, 21, 28, 34, 36; Joyner 1997; and Williams et al. 1998, pp. 232, 249–250, 255–256.

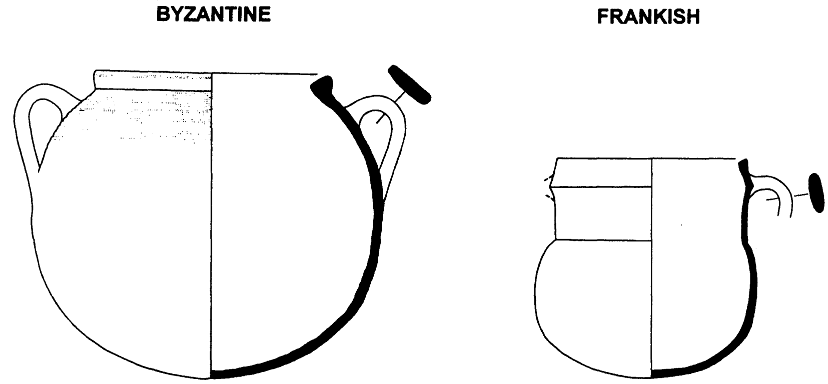


Figure 2. Byzantine and Frankish styles of cooking pots at Corinth

Frankish, ca. A.D. 1260–1312; and (4) Late Frankish, ca. A.D. 1312–1350. Dated by associated ceramic and numismatic evidence, the Byzantine-style cooking ware belongs to the first two phases, and the Frankish-style ware to the last two. Excavations during the 1990s at Corinth revealed part of the Frankish city located southeast of Temple E (Fig. 1).[3] Within this Frankish complex are seven distinct architectural units. The cooking pots studied have primarily come from units 1 and 2, and are assumed to have been used by the persons dwelling there. Unit 2, the earlier of these units, is an ecclesiastical complex focused around a Byzantine church. The church was probably constructed in the mid- to late 12th century A.D.,[4] and rooms were attached to give it its monastic form in the early 13th century.[5]

Unit 1 appears to have been built in the reign of William II de Villehardouin, sometime after the mid-13th century, in the Middle Frankish period, possibly as the result of the arrival of a new group of settlers.[6] It comprises a paved courtyard surrounded by other architectural units. Various functions have been suggested for these buildings, including a hostel, hospice, hospital facility, or inn set up to cater for the sick or poor, or for the pilgrims who were passing through Corinth on their way to the Near East.[7] Hospital facilities are inferred from the pharmaceutical containers found in room 5 of this unit.[8]

As unit 1 was being constructed, the church and buildings in unit 2 were reused extensively as a burial ground for the inhabitants of the hospice or infirmary in unit 1.[9] According to numismatic and ceramic evidence, this reuse occurred during a short period of time in the 1260s.[10] Judging from the amount and range of organic refuse (chicken eggs; bird, fish, and mammal bones; marine invertebrates, and tortoise shells), together with

3. Reports on the excavations of the Frankish complex at Corinth can be found in Williams and Zervos 1991, 1992, 1993, 1994, 1995, and 1996; Williams, Barnes, and Snyder 1997; Williams et al. 1998; and a summary in Williams 2003.

4. Williams and Zervos (1995, p. 11) identified the church in unit 2 as being Byzantine in style, having a cross-in-square plan, with its foundation perhaps dating to the second half of the 12th century A.D. (p. 16). Williams et al. (1998, p. 261) also date unit 2 to the 12th century. See also Williams and Zervos 1994, p. 26.

5. Williams and Zervos 1995, p. 16, fig. 4.

6. Williams and Zervos 1994, p. 36.

7. See Williams and Zervos 1995, pp. 3–4, figs. 1, 2; Williams and Zervos 1996, p. 3, figs. 2, 3; and Williams 2003, p. 427, fig. 25:2.

8. See Williams and Zervos 1994, pp. 16–22, figs. 5, 6, pls. 4, 6; 1995, p. 4.

9. Williams et al. 1998, pp. 261–262.

10. Williams et al. 1998, p. 262.

the substantial ceramic and glass assemblage recovered from unit 1, some have suggested that the occupants were maintaining a lifestyle well above subsistence levels.[11] The architectural remains recovered from units 1 and 2 clearly reflect non-Byzantine influences, and it has been postulated that the stone blocks were carved by Frankish monks or master builders following a northern European design.[12] Thus, units 1 and 2 appear to have been closely interconnected.[13]

During the 12th century, Corinth continued in its role as a major center and port frequented by travelers and traders within the Byzantine empire. Following the start of the Fourth Crusade in 1203, French and Venetian crusaders captured the Byzantine capital of Constantinople in 1204. The Franks, as these western European Christians were known, established Frankish states across the Aegean. Corinth became part of the Latin Principality of Achaia under Geoffroy de Villehardouin in 1210. The Frankish occupation of Corinth was much diminished after 1312, when the Catalan Grand Company from northeast Spain sacked the city.[14]

BYZANTINE AND FRANKISH COOKING POTS

Typology

Distinct differences exist in the typology of the Byzantine and Frankish cooking wares, particularly with respect to body form and rim type (Fig. 2).[15] The Byzantine-style pots tend to be thick-walled (Fig. 3), and they have spherical bodies and no necks, with thickened rims that are either triangular or folded (Fig. 4: types A–F). Generally large (averaging ca. 18 cm in rim diameter), they have strap handles that are attached to the upper body. Their fabrics are fired to a red color. In contrast, the Frankish pots tend to be thinner-walled and have deep sac-like bodies with high necks and tall rims, which may be carinated (Fig. 4: types G, H). They are generally smaller than their Byzantine counterparts (averaging ca. 15 cm in rim diameter). Handles are attached to the neck or rim. They tend to be fired to either a red or a gray color.

Byzantine-style cooking pots with triangular rims of several types dominate until the mid-13th century;[16] some have grooves on the rim, and others have grooves on the vessel shoulder (Fig. 4: A–D). During the same period some vessels display folded rims, produced by bending the clay rim back on itself; these also occur with grooved or smooth shoulders

11. See Williams and Zervos 1995, p. 9; Williams, Barnes, and Snyder 1997, p. 42; Lev-Tov 1999, p. 93.

12. Williams, Barnes, and Snyder 1997, pp. 31–32.

13. Williams et al. 1998, pp. 261–262.

14. For more details on this period at Corinth, see Miller 1908; Cheetham 1981, pp. 39–40; MacKay 2003, pp. 401–403; Sanders 2003; Williams 2003.

15. Robinson and Weinberg (1960, p. 234) described the two types of cooking pot recovered from excavations at Corinth in 1959. They noted that the 13th-century forms from a Frankish deposit had high rims and the 12th-century forms from Byzantine levels had low rims. MacKay (1967, pp. 288–300) described in more detail these two types of cooking pot from excavations at Corinth in 1959–1961, also noting the change in style from the earlier Byzantine form to the later Frankish form. Sanders (1987, pp. 179–182) subsequently described Frankish cooking pots excavated at Corinth in 1986.

16. Williams, n.d.

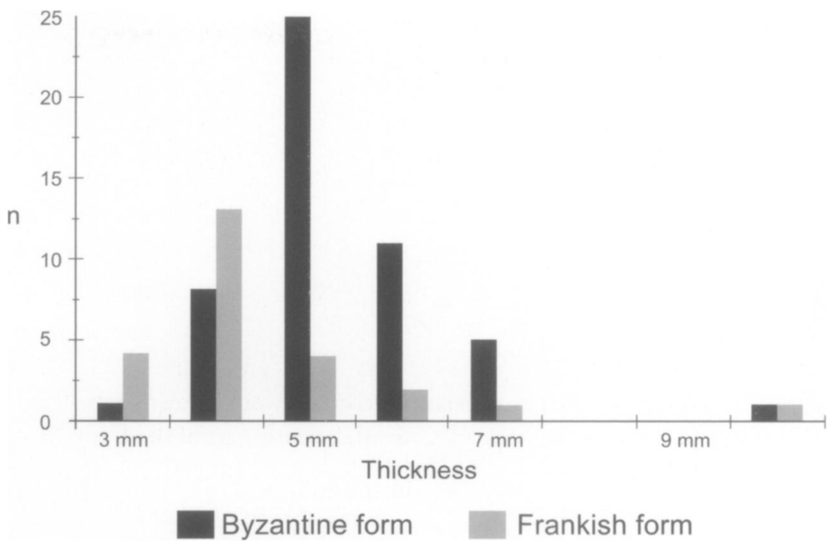


Figure 3. Range in wall thickness of Byzantine and Frankish cooking wares

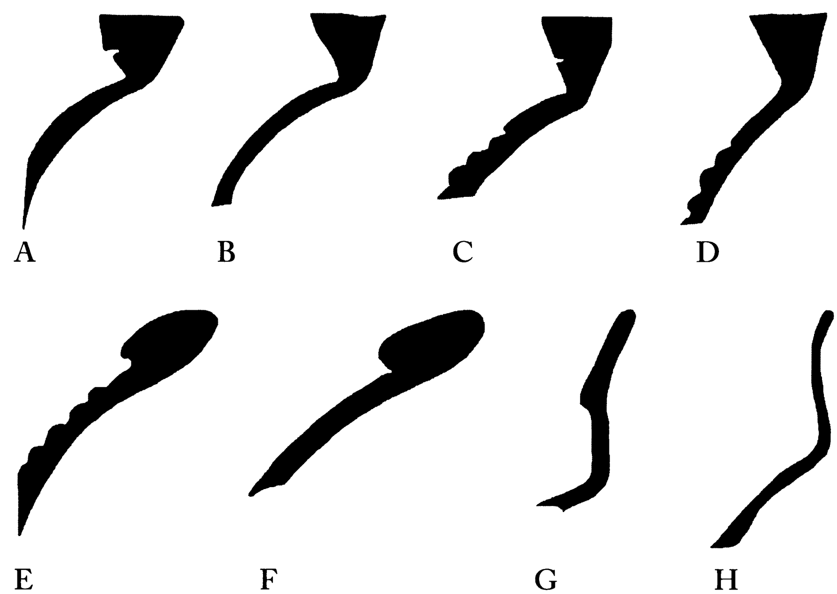


Figure 4. Rim typology of Byzantine (A–F) and Frankish (G, H) cooking pots: A–D: triangular rims; E, F: folded rims; G, H: tall rims

(Fig. 4: E, F). The high-necked Frankish cooking pots, with or without carinations, dominate after 1260 (Fig. 4: G, H). Thus, the cooking wares at Corinth change from a globular thick-walled Byzantine form with a thickened rim and no neck to a thin-walled, longer-bodied Frankish form with a tall narrow neck that contracts slightly inward to the rim. In addition, a change from body-handled to rim-handled varieties occurs.

In the majority of cases, the cooking pots appear to be wheel-thrown, judging from striations left on the interior and exterior surfaces. The decoration on the pots, if any, tends to be very simple, comprising incised spiral or wavy patterns. None of the cooking pots are glazed.

Chronology

As noted above, Byzantine-style cooking ware occurs both in Byzantine and Early Frankish levels at Corinth,[17] while the high-necked Frankish cooking ware does not appear until ca. 1260, the beginning of the Middle Frankish period, some 50 years after the Frankish incursion into the city.[18] The two forms overlap, with the development of transitional types with short necks and tall rims,[19] but by the end of the 13th century the Frankish style is the most common cooking vessel found in units 1 and 2, a pattern that continues into the Late Frankish period.

The disappearance of the Byzantine-style cooking ware appears to have occurred at roughly the same time as the arrival of Venetian refugees who had fled from Constantinople when it was reoccupied by the Byzantines in 1261,[20] and at the time of the marriage of Isabelle, daughter of William de Villehardouin, the Prince of Achaia, to Philip, son of Charles of Anjou (King of Naples), in 1266.[21] In the same year, William de Villehardouin, who had no son, made a treaty with Charles of Anjou that he would cede the succession of Achaia to him.[22] This marriage was intended to secure the area with Charles of Anjou becoming suzerain of Achaia.

Around this time, Williams has documented an increase in the amount of pottery imported into Corinth, particularly glazed wares from Italy, including Veneto and metallic wares.[23] This increase presumably reflects the growth of trade with Italian merchants, and possibly indicates a better standard of living at Corinth than had previously existed.[24] Also coinciding with the change in the cooking-pot typology in the mid-13th century is the introduction of glazed wares in a Frankish style.[25]

The Venetians or other Italians may have brought with them a preference for the Frankish style of cooking ware, thereby bringing about a change in the design of cooking pots at Corinth. The association of the

17. An Early Frankish deposit (dump 1992-1, west of units 1 and 2 of the Temple E Frankish complex) described in an unpublished report by Williams (n.d.) supports this statement. This deposit is an assemblage of cooking wares used after the Frankish capture of Corinth in A.D. 1210 until the mid-13th century. The cooking wares are Byzantine forms with triangular and folded rims.

18. The earliest appearance of the Frankish-style cooking pot at Corinth is documented by Williams (n.d.) in a well deposit (1991-1). This deposit shows that as the Byzantine form of cooking pot declines in use, a transitional form of cooking pot with a low, but distinct, neck and a tall vertical rim appears. Excavations at Corinth in 1959 and 1961 turned up Byzantine and Frankish pottery in closed deposits or relatively undisturbed fills; see MacKay 1967, pp. 249, 288–300, figs. 2–5. The change in cooking-ware style was also noted by MacKay (1967, p. 289), who observed that the late-13th- to early-14th-century thin-walled forms were well made, and were of the same red clay with white grits as the 12th-century ones, but that they had fired to a gray color.

Frankish-style stewpots were also recovered from a manhole (1934-13); no stewpots with triangular rims were found. The assemblage contained a mixture of glazed wares dated to the end of the 13th century by Williams (1991, pp. 31–33). Frankish cooking pots were found during excavation in 1993, associated with the Catalan destruction in 1312 (Williams 1994, p. 16). In the Middle Frankish period, the Frankish-style rim was used for both stewpots and flat-bottomed, one-handled jugs in a similar fabric (Williams, n.d).

19. Williams, Barnes, and Snyder 1997, pp. 34, 36, fig. 9, pl. 15 (C-1996-8); Williams 2003, p. 432.

20. Williams and Zervos 1994, pp. 35–36; Williams et al. 1998, p. 249, n. 51.

21. G. D. R. Sanders (pers. comm.); MacKay 2003, p. 401.

22. MacKay 2003, p. 401. For the history of the control of Corinth in the Frankish period, see MacKay 2003, pp. 401–402, with references.

23. Williams et al. 1998, pp. 254–255.

24. MacKay 2003, p. 403; Williams 2003, p. 426.

25. Williams and Zervos 1994, pp. 35–36.

tall-necked Frankish style with other types of cooking vessels (baking dishes and sieves) that are believed to be of Italian origin suggests that different gastronomic ideas and ways of food preparation were introduced into Corinth at this time.[26] It has also been suggested that the change of cooking-pot style accompanied a change in diet.[27]

Thus, the cooking pot form appears to have changed from the Byzantine to the Frankish form not at the time of sociopolitical change in 1210, but some 50 years later, coinciding with the arrival of the Venetian refugees from Constantinople and the treaty with Charles of Anjou.[28]

Function

Cooking pots can assume a number of functional and social meanings within a society.[29] Different types of pot can be used to cook particular types of food in specific ways. In contrast, the social meanings of cooking pots may not be explicit. A distinctive style of cooking pot may also reflect the identity of the cultural group using it. Pottery in general has been used as a means to distinguish different groups; ethnographic studies have shown that certain cooking-pot forms are associated with particular ethnic groups, as well as reflecting the status of the people using them.[30]

Much research has been conducted on the relationship between the physical properties of pottery vessels and their function. Scholars have looked at the effects of physical properties (e.g., temper type, density, grain size, grain shape, wall thickness, surface treatments, and firing conditions) on the performance of vessels for certain functions (e.g., permeability, strength, toughness, resistance to thermal shock, crack propagation).[31] Important studies include those by Braun, who observed a decrease in vessel-wall thickness with a decrease in the grain size and density of the temper added; Steponaitis, who noted the effects of changes in temper on the properties of cooking pots; and Kilikoglou and his colleagues, who studied the effect of quartz temper on the physical and mechanical properties of pottery.[32]

There may well have been socio-functional and techno-functional differences between the Byzantine and Frankish cooking pots. Depending on the type of food cooked, and how it is cooked, potters may adapt the physical and compositional characteristics of a vessel's clay body to achieve an optimum form with the raw materials available. The shape and clay composition of any vessel will affect, to varying degrees, its performance in use. The round-bottomed shape of both Byzantine and Frankish cooking pots suggests important adaptive advantages over flat-bottomed pots.[33] Round-bottomed vessels are more adept at dispelling thermal stress during cooking (which is exacerbated by sharp angles), tend to cool more uniformly, and are more resistant to cracking.[34] The presence of aplastic inclusions in the clay paste can also reduce the effects of thermal stress by providing a barrier to propagating cracks, which acts to disperse the energy forming the cracks on contact with the inclusions.[35]

Although Byzantine and Frankish cooking pots possess many common features reflecting a similar function, the change in their form may be related to a change in diet, and possibly also to a change in the cultural group

26. Williams and Zervos 1995, pp. 34–36.

27. Williams (1994) was the first to suggest this, although MacKay (1967, pp. 288–300) had previously noted the change in the style of cooking pots without relating this change to diet. See Joyner 1997.

28. Williams and Zervos 1994, pp. 35–36.

29. For detailed accounts of the wide range of social and functional dimensions of pottery, see, e.g., Goody 1982; Miller 1985.

30. See, e.g., Miller 1985, pp. 184–196; Skibo 1992, p. 34; Orton, Tyers, and Vince 1993, pp. 227–228.

31. See, e.g., Arnold 1985, pp. 21–32; Tite 1999, pp. 218–222.

32. Braun 1983; Steponaitis 1984; Kilikoglou et al. 1998.

33. Cf. Woods 1986, p. 157; Rye 1976, p. 114; Sinopoli 1991, p. 84.

34. Rye 1981, p. 27; Kilikoglou et al. 1998.

35. Rye 1981, p. 31; Kilikoglou et al. 1998.

using them. Changes in diet, cooking practices, and settlement mobility have been shown to have an effect on cooking-pot design.[36] According to Arnold, a cultural change in a society can be identified when new pottery styles enter or old ones disappear from the ceramic assemblage.[37] These new pottery styles often suggest new utilitarian uses for ceramics.[38]

The Byzantines are reported to have had a diet based on bread, vegetables, pulses, and meat, together with olives, fruit, fish (usually marine varieties), and wine.[39] Dairy products (except for cheese) were not as common.[40] The Frankish diet included meat stews and, according to Niketas Choniates, a Byzantine from Constantinople, the Franks were "beef-eating Latins" who drank "unmixed wine" and ate "chine of oxen cooked in cauldrons, chunks of pickled hog boiled with ground beans and a pungent garlic sauce."[41] The most detailed dietary information from this period comes from monasteries, which could reflect a specific dietary perspective, and may therefore provide an apt comparison with the Corinth assemblage discussed here. The reported differences in the diets of the Byzantines and Franks, however, are not borne out by the faunal assemblages at Corinth. These assemblages suggest that the Franks at Corinth adapted their diet to include locally available foods, mainly goat, sheep, and pig, with smaller quantities of cattle, as well as birds, fish, and mollusks; there is also evidence that they hunted wild game, which appears not to have been part of the Byzantine diet.[42]

The shapes of the Corinthian cooking pots were possibly adapted to cook certain foods or to cook foods in certain ways. One can postulate that the wide-mouthed Byzantine form promoted the escape of moisture from a stew, and that the thicker walls helped retain and distribute heat during cooking. Williams has suggested that the Byzantine stewpots were used to cook legumes and beans by simmering.[43] The tall-necked style of the Frankish form was probably an adaptation to retain a greater proportion of liquid, keeping the stew relatively moist. The neck and carination in the Frankish cooking pot may have acted as an evaporative guard; a proportion of the rising steam from the stew came in contact with the relatively cooler surface of the neck of the pot, condensed, and dripped back into the stew. The stews are likely to have included meat, given the Franks' reputation for eating considerable quantities of meat.[44]

The accumulation of soot deposits on the exterior of many of these cooking vessels indicates that they were used over a fire.[45] There is, however, some question about the relative positioning of the pots. It has been suggested that Byzantine cooking pots could have rested on metal cooking stands *(pyrostatai)* or portable braziers.[46] Williams, however, has suggested that the Byzantine cooking pots possibly sat in the embers of a fire, whereas the Frankish forms may have been suspended during cooking.[47] Sticks may have been inserted through the strap handles on both forms to aid in lifting the pots from a fire. The Frankish form, with its vertical strap handles attached to the neck or rim, would have indeed been suitable for suspension. Lids may have been used with these cooking pots, although the positioning of the handles would not have permitted a tight fit, and no examples have yet been found.

36. See Skibo 1992, p. 34.
37. Arnold 1985, pp. 234–237.
38. Arnold 1985, p. 234.
39. Haldon 2000, pp. 67, 72.
40. See *ODB*, pp. 621–622, s.v. Diet (A. Karpozilos and A. Kazhdan).
41. Nik. Chon. *Historia,* p. 594 van Dieten [= pp. 785–787 Bekker]; trans. Magoulias 1984, pp. 326–327.
42. Williams, Barnes, and Snyder 1997, pp. 43–46; Lev-Tov 1999, pp. 85–98.
43. Williams 2003, p. 432.
44. Williams 2003, p. 432.
45. Williams et al. 1998, p. 250.
46. Bakirtzis 1989, p. 130; MacKay 1967, p. 288; 2003, p. 418.
47. C. K. Williams II (pers. comm.).

GEOLOGY OF THE AREA

Before turning to the petrographic analysis of the cooking wares, I present here a brief summary of the geology in the area around Corinth. The region is underlain by the Sub-Pelagonian zone, which was originally part of a small sea-basin floor, composed of an ophiolitic suite of Triassic and Jurassic limestones.[48] Some of the oldest rock outcrops in the area are Middle Triassic to Lower Jurassic limestones, which form the mountains of Geraneia, Acrocorinth, Penteskouphi, Oneia, and those to the south and southeast of the Corinthia.[49] Acrocorinth, while having a small outcrop of Middle Triassic to Lower Jurassic limestone, is largely composed of Middle Jurassic limestone and shale (green and red) sequences. The limestones are dolomitized in places with nodules or bands of chert. A shale-chert formation is composed of sandstones, clays, and brown to green marls with ophiolitic bodies in them.

Neogene sediments composed of cyclical sequences of marls, sandstones, and conglomerates, and occasional lignite horizons occur in the Corinthia. Across Greece similar sedimentary sequences of rock were deposited contemporaneously.[50] Ancient Corinth is sited on a terrace of Pleistocene sandy limestone. The terraces below Ancient Corinth are composed of Pliocene and Pleistocene deposits. The Pliocene deposits consist of marls with intercalated sandstones, conglomerates, and marly limestone, sometimes with lignite beds in the upper marls, for example, near Penteskouphi. The Pleistocene deposits are composed of marine and nearshore sediments including conglomerates, marls, marly sandstone, and fossiliferous sands.

PETROGRAPHY OF COOKING WARES

Thin sections of 74 samples of Byzantine and Frankish cooking wares were taken and studied using a polarizing light microscope.[51] The samples were grouped into fabric types on the basis of the fabric textures and range of aplastic inclusions. These fabric types were then compared to the stylistic typology of the cooking wares; the range of geological raw materials exploited was noted, as well as the ways in which these materials were manipulated to form the fabrics. By comparing the aplastic inclusions with the local geology around Corinth, it was hoped that a provenance might be determined. If the aplastic inclusions were consistent with the local geology, local production could be suggested, but if the aplastic inclusions appeared exotic to Corinth, the cooking pots might have been imported. If some or all of the fabrics were locally produced, the structure of production workshops in Corinth might then be explored. Detailed descriptions of

48. This account of the geology is based on maps by Bornovas et al. 1972 and Bornovas and Rondogianni-Tsiambaou 1983. See also Whitbread 1995, pp. 261–264, fig. 5.3, for a simplified geological map of the area and a short account of the geology.

49. Whitbread 1995, p. 261.

50. See Büttner and Kowalczyk 1978.

51. The Byzantine and Frankish cooking pots were sampled from either rim fragments or from body sherds when the vessel shape was known.

TABLE 1. FABRIC GROUPS IN BYZANTINE AND FRANKISH COOKING WARES

	Byzantine Style		*Frankish Style*	
Fabric Group	*Byzantine*	*Early Frankish*	*Middle Frankish*	*Late Frankish*
Group 1: Chert		1992-84-8 D 1992-84-13 B 1992-84-14 B 1992-84-15 B 1992-84-16 E 1992-84-21 E 1992-84-23 F		
Group 2: Chert and Quartz	1992-100-21 B 1992-100-22 B 1992-100-23 1992-100-27 B			
Group 3: Mudstone, Well Fired	1992-100-26	1992-84-5 C 1992-84-10 D 1992-84-12 A 1992-84-18 E 1992-84-20 E	NB-857-136 G	
Group 4: Mudstone, Poorly Fired		1992-84-3 C 1992-84-9 D 1992-84-11 A 1992-84-17 E 1992-84-19 E 1992-84-25 F		
Group 5: Sandstone	1992-100-2 C 1992-100-3 D 1992-100-11 1992-100-14 1992-100-15 B 1992-100-18 1992-100-19 1992-100-20 B	1992-84-6 D 1992-84-22 F		

the fabric types are given in the Appendix, and comments on those descriptions are presented below.

The samples are divided into six major fabric groups, although there are some overlaps between them: (1) chert; (2) chert and quartz; (3) mudstone, well fired; (4) mudstone, poorly fired; (5) sandstone; and (6) quartz-mudstone-chert (QMC). Four minor fabrics are also identified.[52] A concordance of specimen numbers is given in Table 1, showing the range of fabric groups listed by chronological period.

52. See esp. Whitbread 1995, pp. 379–388, for the description format used here. Grain-size terminology for the aplastic inclusions is that of the Udden-Wentworth scale, found in most volumes on sedimentology texture, e.g., Blatt, Middleton, and Murray 1980, p. 57 (the original source is Wentworth 1922). Common abbreviations used below: PPL = plane polarized light; XP = crossed polars.

TABLE 1—*Continued*

Fabric Group	*Byzantine Style*		*Frankish Style*	
	Byzantine	*Early Frankish*	*Middle Frankish*	*Late Frankish*
Group 6: Quartz-Mudstone-Chert	1992-100-10 1992-100-12 1992-100-13 B 1992-100-16 B 1992-100-28	1992-84-1 C 1992-84-4 C 1992-84-7 D 1992-84-24 F 1992-84-26 E	1993-6-1 G 1993-6-2 G 1993-6-3 G 1993-14-1 G 1993-14-2 G 1993-34-11 G 1993-34-12 G 1993-34-13 G 1993-34-14 G NB-853-86 G NB-853-87 G NB-853-88 G *NB-853-121 G NB-856-65-1 G NB-857-137 G NB-864-25 G NB-865-23 G	1994-10-2 G 1994-10-10 H 1994-10-12 H 1994-12-20 H
Few Inclusions	1992-100-1 A 1992-100-17			1994-10-11 H
Well Sorted		1992-84-2 C		
Packed Quartz	1992-100-25 1992-100-29 A		1992-46-2 H *NB-866-20 G	
Well-Fired Chert and Quartz	1992-100-24			

Sample numbers are given either as lot numbers or field notebook (NB) numbers. Rim types, when known, are designated A–H, as classified in Figure 4.
*Transitional Middle–Late Frankish date

Group 1: Chert

Period: Early Frankish
Number of samples: 7

The chert fabric is the most easily identifiable (Fig. 5). It is characterized by large angular chert inclusions set in a fired clay micromass with smaller inclusions of monocrystalline quartz and irregular elongate voids. Chert, monocrystalline quartz, and polycrystalline quartz are present in both the coarse and fine fractions. The inclusions are not as varied as for other fabric groups. The chert and radiolarian chert are similar to those found by Whitbread in Archaic, Classical, and Hellenistic Corinthian transport amphoras (type B).[53] The chert grains are consistent with a local Corinthian origin. Chert is found locally, for example, outcropping on Acrocorinth within the Middle Jurassic limestone beds as nodules or bands, and also intercalated in a shale-chert formation outcropping on Acrocorinth.[54]

The clay micromass is brown and varies from being optically slightly active to optically inactive, indicating that the samples have been well fired.

53. Whitbread 1995, pp. 274–285, 289–293.
54. See Bornovas et al. 1972.

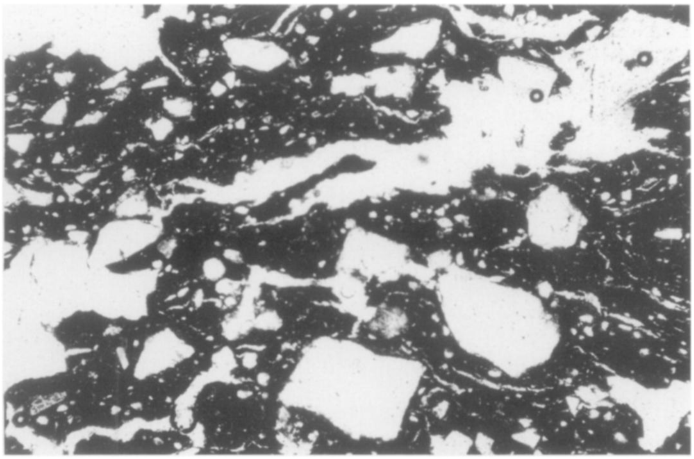


Figure 5. Photomicrograph of a chert fabric in sample 1992-84-15, a Byzantine-style cooking pot of Early Frankish date. The large angular light-colored grains are chert. The large elongated structures are planar voids that are orientated with long axes parallel to the margins. PPL, horizontal dimension 3 mm

Group 2: Chert and Quartz

Period: Byzantine
Number of samples: 4

The chert and quartz fabric group is easily identifiable, characterized by abundant angular monocrystalline quartz and chert inclusions (Fig. 6). There is a greater preponderance of monocrystalline quartz inclusions in these samples than in group 1, with less chert present. There is no reason to suppose that the quartz grains in this sample are anything but local, as quartz is such a geologically ubiquitous mineral. The chert and quartz grains in this fabric are consistent with a local geological source. The quartz could have come from a weathered sandstone source such as the sandstones present in the Middle Jurassic shale-chert formation outcropping on Acrocorinth or the Pliocene and Pleistocene deposits that form the terraces below Ancient Corinth.

The characteristic irregular elongated voids present in the chert group are also seen in this group. The clay micromass is generally optically inactive to optically slightly active, indicating that the samples were relatively well

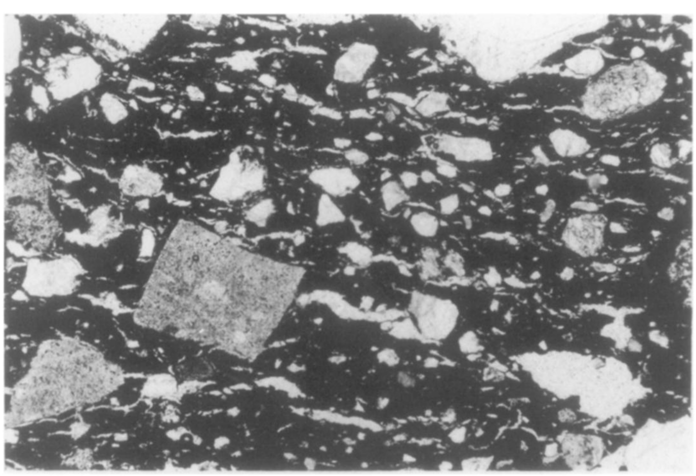


Figure 6. Photomicrograph of a chert and quartz fabric in sample 1992-100-27, a Byzantine cooking pot. The large gray cloudy grains are chert, and the clear light-colored grains are monocrystalline quartz. PPL, horizontal dimension 3 mm

fired. It varies in color from very dark brown/black to dark brown with a reddish tinge in PPL and from very dark brown with a tinge of red to dark red/brown in XP. Together with the abundant monocrystalline quartz and chert, the other main rock fragments and minerals occur in lesser quantities and include polycrystalline quartz, sandstone, and mudstone in the coarse fraction, and monocrystalline quartz, chert, and polycrystalline quartz and Fe-Ti oxides in the fine fraction.

Group 3: Mudstone, Well Fired

Periods: Byzantine–Middle Frankish
Number of samples: 7

The mudstone well-fired fabric group is characterized by the presence of coarse mudstone fragments set in an optically inactive clay micromass, which indicates that the samples have been well fired (Fig. 7). There

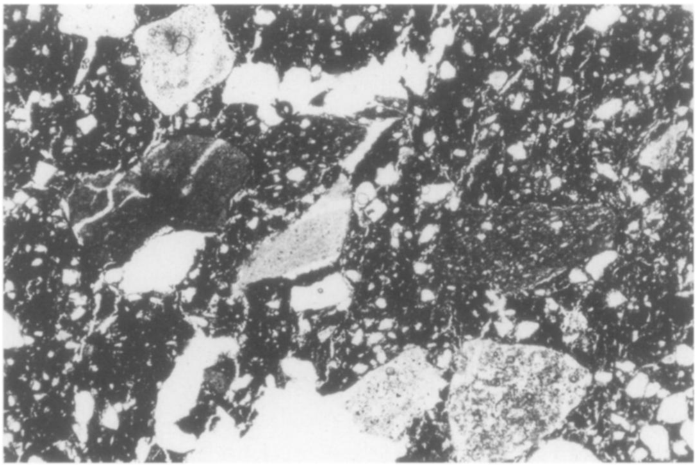


Figure 7. Photomicrograph of a mudstone well-fired fabric in sample 1992-84-20, a Byzantine-style cooking pot of Early Frankish date. The dark grains are mudstone, the gray cloudy grains are chert, and the light-colored grains are quartz. PPL, horizontal dimension 3 mm

are various types of mudstone inclusions, including polygonally cracked mudstone (similar to those found by Whitbread in Corinthian transport amphoras of local origin), mudstone breccia, fine-grained mudstone, red mudstone, silty mudstone, red/brown mudstone, gray mudstone, and cherty mudstone.[55] One or more of these mudstones can appear in any single sample, most typically only in the coarser fractions. Mudstones are ubiquitous in the Aegean and are found locally around Corinth. A number of mudstone-shale outcrops have been reported on Acrocorinth.

The clay micromass varies in color from brown/black to red/orange in PPL and dark brown with a red tinge to red/orange in XP. The other main inclusions comprise monocrystalline quartz, chert, polycrystalline quartz, calcimudstone, sandstone, siltstone, schistose quartz, and schist in the coarse fraction, and monocrystalline quartz, calcimudstone, mudstone, polycrystalline quartz, biotite mica, muscovite mica, Fe-Ti oxides, spinel, siltstone, and sandstone in the fine fraction.

55. Whitbread 1986, pp. 84–86; 1995, pp. 268–271, 278–289.

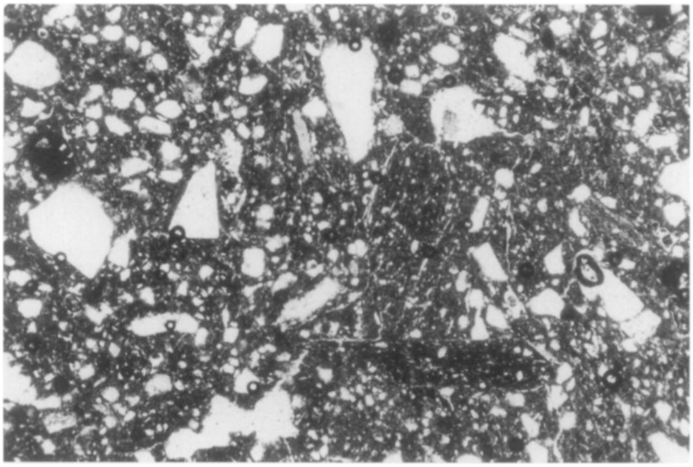


Figure 8. Photomicrograph of a mudstone poorly fired fabric in sample 1992-84-17, a Byzantine-style cooking pot of Early Frankish date. The two large elongated angular dark grains in the middle are mudstones typical of Corinthian fabrics. The light-colored grains are monocrystalline quartz and chert. PPL, horizontal dimension 3 mm

Group 4: Mudstone, Poorly Fired

Period: Early Frankish
Number of samples: 6

The mudstone poorly fired fabric group is characterized by the presence of coarse elongate mudstone inclusions embedded in an optically active clay micromass, which indicates that the samples have not been well fired (Fig. 8). A number of mudstone types are present, including dark brown silty mudstone, mudstone breccia, polygonally cracked silty mudstone, orange silty mudstone, and radiolarian mudstone. A selection of these types can appear in any one sample. As discussed above, mudstone outcrops are commonly found in the vicinity of Ancient Corinth, particularly on Acrocorinth.

The clay micromass is optically active, varying in color from reddish orange/brown to mid-brown in PPL and reddish orange to dark brown in XP. Together with the mudstone, there are monocrystalline quartz, chert, polycrystalline quartz, calcimudstone, and calcite in the coarse fraction, and monocrystalline quartz, chert, calcite, polycrystalline quartz, Fe-Ti oxides, and biotite mica in the fine fraction.

Group 5: Sandstone

Periods: Byzantine, Early Frankish
Number of samples: 10

The sandstone fabric group is not easy to define. It is characterized by the presence of fairly coarse pieces of sporadically distributed sandstone inclusions (Fig. 9). These well-rounded inclusions comprise well-sorted quartz grains with intergranular flakes of biotite mica. The Byzantine samples can have up to six types of sandstone, including quartzwacke to quartz arenite, fine-grained sandstone with little matrix, quartz arenite, quartzwacke with carbonate cement, quartzwacke and sandstone breccia; the Early Frankish samples have only fine-grained sandstones with little matrix, quartzwacke to quartz arenite, and quartzwacke with carbonate cement. The sandstone inclusions are consistent with the local geology around Ancient Corinth,

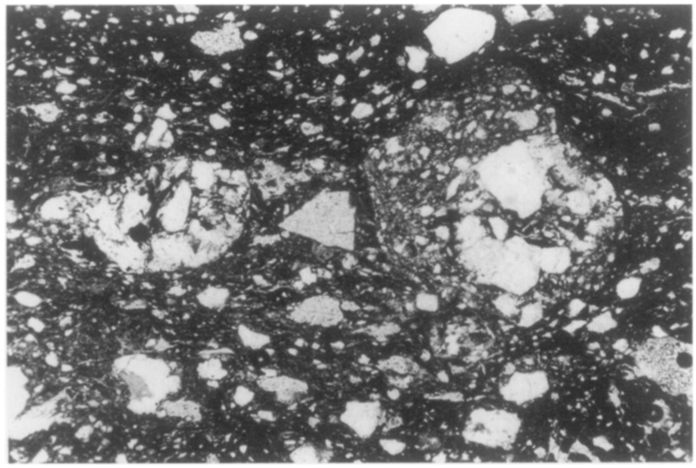


Figure 9. Photomicrograph of a sandstone fabric in sample 1992-100-2, a Byzantine cooking pot. Two large sandstone grains can be seen in the center. PPL, horizontal dimension 3 mm

with sandstone deposits in the Middle Jurassic limestones and in Neogene deposits (Pliocene and Pleistocene).

The clay micromass is generally optically active, indicating that the samples have not been well fired. It displays colors from orange brown to dark brown in PPL and to bright orange/red/brown to red brown in XP. Besides sandstone, the other main inclusions comprise polycrystalline quartz, monocrystalline quartz, mudstone, schist, calcimudstone, siltstone, chert, and Fe-Ti oxides in the coarse fraction, and monocrystalline quartz, polycrystalline quartz, plagioclase feldspar, Fe-Ti oxides, mudstone, and calcimudstone in the fine fraction.

Group 6: Quartz-Mudstone-Chert

Periods: Byzantine–Late Frankish
Number of samples: 31

The QMC group is the hardest to define. It is made up of fabrics with many inclusions, and no one inclusion type is dominant or distinctive (Fig. 10). It takes its name from the common presence of quartz, mudstone, and chert in all samples. This group is very broad and complex and is not

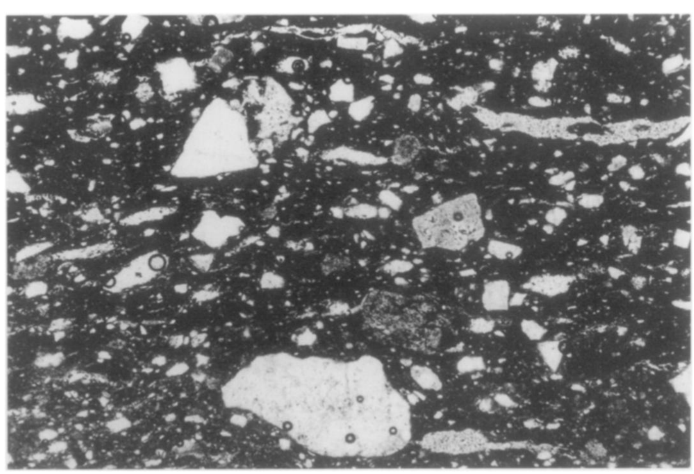


Figure 10. Photomicrograph of a QMC fabric in sample NB-856-65-1, a Middle Frankish cooking pot. The large cloudy light-colored grains are chert; the clear light-colored grains are monocrystalline quartz; and the darker grains are mudstones. The large elongated structures are planar voids that are orientated with long axes parallel to the margins. PPL, horizontal dimension 3 mm

as well constrained as the fabrics described above. QMC fabrics contain a mixture of inclusions that are dominant in the other groups: polycrystalline quartz, monocrystalline quartz, mudstone (up to eight varieties), chert, sandstone (up to four types), and calcimudstone. All the aplastic inclusions, quartz, mudstone, and chert are consistent with the local geology around Ancient Corinth, as discussed above.

The clay micromass varies from being optically active to optically inactive, indicating that the samples were relatively well fired. It displays colors ranging from red/orange to dark gray brown in PPL and red/orange to very dark brown/gray/black in XP. The main inclusions in the coarse fraction are chert, monocrystalline quartz, polycrystalline quartz, mudstone, sandstone, calcimudstone, schistose quartz, and schist, and in the fine fraction, monocrystalline quartz, calcimudstone, polycrystalline quartz, chert, Fe-Ti oxides, plagioclase feldspar, muscovite mica, and sandstone.

Problematic Samples

Three samples, two from the Middle Frankish phase and one transitional Middle–Late Frankish piece, could not be classified without difficulty.[56] At first sight, they seemed to have affinities with both the chert and QMC fabric groups. To determine which group they should be assigned to, these samples and examples from groups 1 (Early Frankish chert) and 6 (a Middle Frankish example of QMC) were subjected to grain-size and composition analysis using Whitbread's grain-size analysis program.[57] The results show that the proportions of chert are similar in all samples analyzed by this method (Fig. 11). However, significant amounts of other types of inclusions (e.g., mudstone, calcimudstone, and sandstone) occur in the clay pastes representing the QMC fabric group, but are absent in the chert fabrics. The analysis shows clearly that it is the underlying matrix properties that characterize the QMC and that the problematic samples belong with this group.

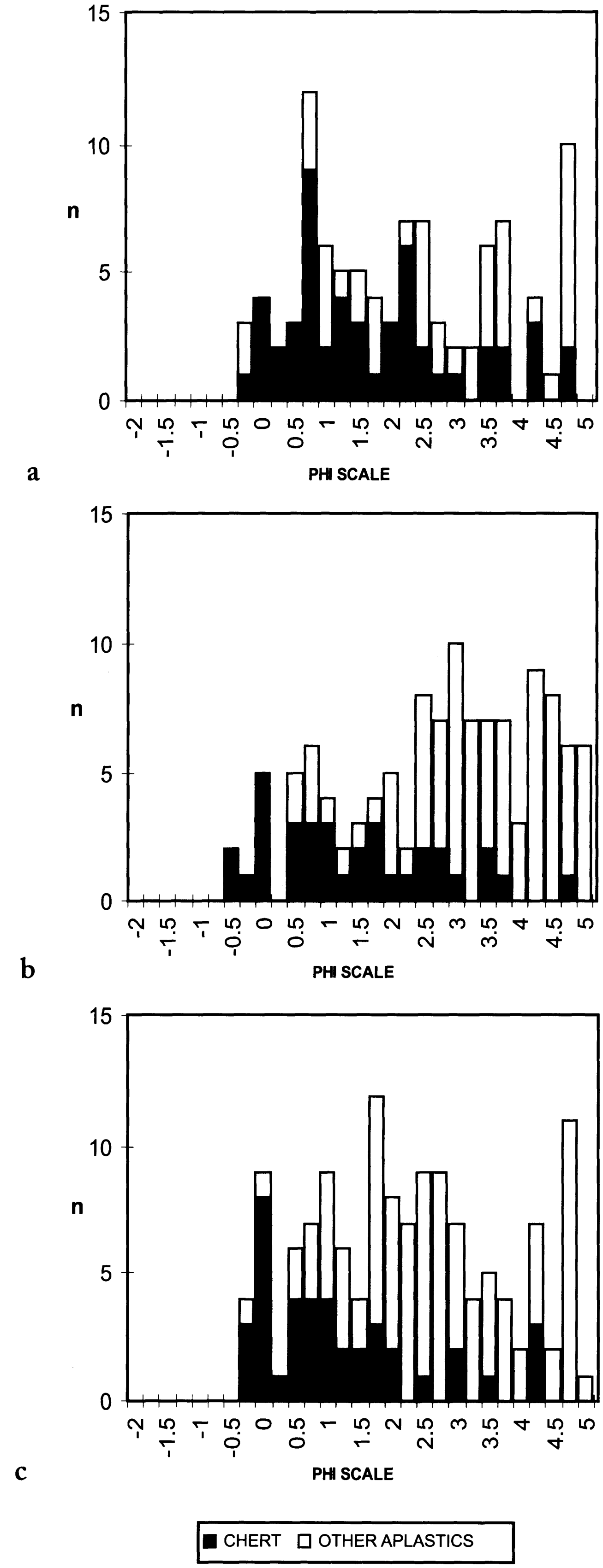
Minor Petrographic Fabrics

Nine samples do not fall into these six major fabric groups, having fabrics that fall into minor groups with only a few members. Listed at the bottom of Table 1, these include one group ("few inclusions") distinguished by having relatively few inclusions set in an unusual orange clay micromass (Byzantine and Late Frankish); a group consisting of well-sorted quartz grains set in a clay micromass (Early Frankish); a packed quartz group with an abundance of monocrystalline quartz forming a closely packed texture (Byzantine and Middle Frankish); and a well-fired chert and quartz group with a well-fired clay micromass in which monocrystalline quartz and chert grains are set (Byzantine).

56. The Middle Frankish samples are lot 1993-14-2 and NB-853-87, and the transitional Middle–Late Frankish sample is NB-853-121.

57. Whitbread 1991, pp. 369–388. For the phi scale used in this program, see Krumbein 1934. Phi is a logarithmic transformation of the Udden-Wentworth scale that is commonly employed as a unit of measure in the study of sediments.

Figure 11. A comparison of chert, QMC, and unclassified samples using Whitbread's grain-size analysis program: *(a)* chert fabric group, sample 1992-84-21 (Early Frankish); *(b)* QMC fabric group, sample NB-864-25 (Middle Frankish); *(c)* unclassified sample NB-853-121 (transitional Middle–Late Frankish)



Summary of Petrographic Analysis

The Byzantine-style cooking wares are found in six main fabric groups, with those from the Byzantine period being found in four of the main fabric groups (chert and quartz; mudstone, well-fired; sandstone; and QMC) and those dated to the Early Frankish period in five fabric groups (chert; mudstone, well-fired; mudstone, poorly fired; sandstone; and QMC). In contrast, the Frankish form of cooking ware is largely limited to one of the six main fabric groups, the QMC group.

PROVENANCE

There is nothing exceptional in any of the fabrics described above to make the determination of provenance straightforward. The aplastic inclusions are consistent with Corinthian geology, but many of the rock types are also very common across the Aegean and are therefore not particularly diagnostic of a Corinthian origin. Nevertheless, the mudstone breccia, polygonally cracked mudstone, and radiolarian chert inclusions in some of the fabrics are certainly consistent with a Corinthian origin.[58] The inclusions do not look obviously exotic for the geology of the Corinth area, and it is a reasonable inference that the cooking wares were produced locally.

Tempering

Some clays require the addition of aplastic inclusions to improve their workability, reduce cracking during drying, improve resistance to thermal shock, and increase mechanical strength. Whether a temper has been added to a clay or not is a matter of debate, as some clays naturally have an appropriate amount of aplastic inclusions in them.

The fabrics described here may have had aplastic inclusions added to them. The angular inclusions in many of these fabrics may be temper that was deliberately crushed and added to the clay paste, or they could be a product of natural weathering. Chert and mudstone inclusions are the most likely possibilities for temper.[59] The relative scarcity of mudstone in

58. Comparative material from Corinth includes Roman cooking wares that resemble the Byzantine cooking wares, fired orange to gray, and heavily tempered with large white inclusions; see Hayes 1973, pp. 467, 470. A Hellenistic pithos from Corinth has a similar clay fabric composed of a red- to buff-firing clay, containing light and dark inclusions; see Boggess 1970, p. 75. In his doctoral dissertation, Whitbread (1987, pp. 341–342) notes comparable mudstone and chert inclusions in Corinthian transport amphoras. Sanders (1993, p. 277) reports wheelmade Byzantine-style cooking wares at Sparta made from local Spartan fabrics, but with "triangular, inwardly thickened rims" similar to those found at Corinth; he also identifies (p. 277) close parallels in late-12th-century deposits from Argos. Frankish-style wheelmade cooking wares excavated at Isthmia, dated to the late 13th–early 14th century, are composed of a coarse reddish yellow clay with frequent large inclusions and voids, fired unevenly gray; see *Isthmia* V, p. 125, pl. 46:d.

59. Given the relative frequency and extent of limestone outcrops in the vicinity of Ancient Corinth, it is surprising that medieval potters were not producing at least a small number of carbonate-tempered cooking wares. It appears, however, that the potters actively avoided using limestone as a temper, nor did they use the marly clays for the clay body. The clay fabrics selected are generally rich in clay minerals and relatively depleted in calcareous material. A small amount of calcareous material is present, some of

the finer fractions of certain clay bodies, together with its characteristic abundance in the coarse fractions, indicates that it was probably added as temper by potters. The inclusions in the QMC fabrics could have derived from a number of sources or possibly from a single conglomerate source. The aplastic inclusions described below are found in the majority of the samples studied.

Mudstone. Mudstones, such as the polygonally cracked variety, silty mudstone (observed in the mudstone well- and poorly fired fabric groups), and mudstone breccia in these samples, prove a good match with those found in other locally produced Corinthian ceramics. The samples are similar to examples in the Fitch Laboratory's reference collection; Whitbread also compared this reference material to mudstones found in Corinthian amphoras and found a good match.[60] The Corinth samples discussed above also compare well with mudstone outcrops on the upper north slopes of Acrocorinth. Given its widespread distribution in the central Mediterranean, however, mudstone is of limited value for establishing Corinthian provenance.

Radiolarian chert. The radiolarian chert from Acrocorinth is very similar to that found in many of the Corinth samples. Some radiolarian chert is quite muddy, almost grading into radiolarian mudstone, which is also similar to that seen in these samples. The radiolarian chert, like the mudstones, is of limited value for determining provenance, given its wide distribution across the central Mediterranean.

Sandstone. Sandstone from Acrocorinth is generally well sorted, containing quartz, plagioclase feldspar, muscovite mica, biotite mica, and chlorite. This composition is unlike that of the sandstone found in the ceramic samples, which generally is defined by well-sorted and rounded quartz grains, with only small amounts of other minerals present. This discrepancy does not, however, rule out the exploitation of other sandstone sources around Corinth.

Calcimudstone. A deposit of calcimudstone crops out to the east of the entrance bridge to Acrocorinth. As in the Corinth samples, it can be found mixed with chert. Calcimudstone containing fossil fragments is also present in the samples.

Schist. The schist found in groups 3, 5, and 6 is commonly quartz-biotite schist. The geological map of Greece (scale 1:500,000) shows a nearby small semicircular exposure of schist associated with limestones, graywackes, and volcanic rocks of Permo-Triassic age (15 km SSW of Ancient Corinth), and a small exposure of ophiolitic material (15 km SSE of Ancient Corinth), which may have contributed to the rare inclusion of weathered volcanic rocks in group 5 and serpentinite in group 6.[61] On the Corinth geological sheet (scale 1:50,000), however, the same exposure is identified as limestones, graywackes, and conglomerates of Permian to mid-Triassic age.[62]

Given these conflicting descriptions, it is unclear if a schist source exists in the vicinity of Corinth. The association of schist inclusions with other possibly local inclusions in the pottery means that a local origin cannot be ruled out. Transportation of sediments (e.g., by water) can bring exotic rock

which seems to be a secondary phenomenon, forming crystalline concentration features around inclusions and voids, as well as forming hypocoatings around void margins, possibly as the result of post-burial precipitation of fine-grained carbonate material from meteoric water.

60. See Whitbread 1986, pp. 84–86.

61. Bornovas and Rondogianni-Tsiambaou 1983.

62. Bornovas et al. 1972.

fragments into an area from elsewhere. Much depends on the catchment area for the alluvial deposits that form sediments along the north coast of the Peloponnese, as well as the rocks from which they originate. This mechanism could explain the presence of possibly exotic inclusions, such as schist, in some of the ceramic samples.

Technology

Workshop Structure

As noted above, it is likely that the cooking ware from Corinth during the Byzantine and Frankish periods was produced locally. The range of fabrics used may indicate the nature of Corinthian workshops operating through this time span. In the Byzantine–Early Frankish period, six major fabrics were employed for cooking ware, but during the Middle–Late Frankish period, with the exception of a single mudstone well-fired sample, only one major fabric (QMC) was used (Table 1).

Although the sample is small, rim types do not appear to correlate with fabric groups in the Byzantine-style cooking ware. The chert and quartz fabric group is represented only in the Byzantine period, while the chert fabric is found only in the Early Frankish period. Mudstone fabrics rarely occur (one example) in the Byzantine cooking pots, but are frequently represented (11 examples) in the Early Frankish cooking pots. The scarcity of mudstone fabrics in the Byzantine period could reflect their classification as QMC, with the presence of quartz and chert inclusions in similar quantities to the mudstones. It is unlikely that the scarcity of mudstone fabrics is due to a sampling error, given that the other fabric groups are well represented.

The range of fabrics documented for the Byzantine–Early Frankish period could represent the products of several workshops, each exploiting different clay and temper sources. Alternative explanations can be offered, however: a single workshop may have used clays from a number of sources, with these clays then mixed together by the potter; or a single workshop may have utilized a single heterogeneous clay source. The differences between fabric groups are often more subtle than they appear in Table 1. The fabric groups generally contain the same sorts of inclusions, but are differentiated by their dominant or characteristic aplastic inclusions. The only exceptions are the chert and the chert and quartz fabrics (groups 1 and 2), which are easily distinguishable. All the other fabric groups overlap one another to a certain extent.

The Middle–Late Frankish period saw a reduction in styles to two principal rim types (Fig. 4: G, H) and virtually one major fabric group (QMC). The dependence on one principal fabric for cooking pots possibly reflects increasing specialization, either within one workshop, or with several workshops using a single fabric. The continued use of the QMC fabric from previous periods is additional evidence that the new Frankish-style cooking ware was also produced locally, quite possibly by the same workshop(s) that produced the earlier ware. A transitional Middle–Late Frankish cooking pot has been found in the QMC fabric and another occurs in a minor (packed quartz) fabric (Table 1). The presence of the

QMC fabric in cooking pots from all periods indicates a continued reliance on this type of clay source from the 12th century to the Catalan destruction in A.D. 1312, and after.

Clay Exploitation

In addition to the qualities of a particular clay, several social and economic factors play a role in determining whether or not a clay resource is exploitable. For a potter to operate, an accessible clay source should ideally be located nearby, with a water supply, fuel, and space for storage or sale of finished products also available.

Access to a particular clay source is an important consideration. If all potters have equal access to all deposits, then the choice of clay will be limited to an individual potter's needs: the desired distance between clay sources and pottery workshop; the workability and suitability of the clay for the function and shape of vessel being produced; and the potter's personal preference for working with a particular clay. If access is restricted to certain clay deposits, or the potters do not know where suitable local clays can be found, they may be forced to use less suitable clay for making their vessels.

Charles Morgan claimed to have found traces of at least four medieval pottery production sites near the center of Byzantine Corinth.[63] A reevaluation by Guy Sanders suggests that only one of these, the kiln beneath the Frankish monastery of St. John, was certainly a ceramic workshop, but he notes that there were other medieval production sites in the outlying area: one producing glazed wares in the mid-12th century near the Asklepieion; another high on the western slope of Acrocorinth producing glazed and utilitarian wares in the 10th–11th centuries; and another at the base of Acrocorinth, below the spring of Hadji Mustafa, producing amphoras in the 10th–11th centuries.[64]

Clay beds in the vicinity of these sites appear to have been intentionally worked, perhaps for use in the adjacent production sites or for workshops elsewhere.[65] Marie Farnsworth has successfully identified a number of workable clays on Acrocorinth, some of which resemble 4th-century B.C. Corinthian red-ware fabrics and may be potential sources.[66]

The red clays of the medieval Corinthian cooking pots probably came from a terra rossa soil, which commonly develops in limestone regions.[67] According to Sanders, one such clay is located on the upper western slope of Acrocorinth adjacent to the kiln site that was producing glazed and utilitarian wares.[68] The proximity of this clay source to the rock types on Acrocorinth that are commonly found in the cooking-ware fabrics makes it a good possibility that the source was used for the cooking pots.

63. *Corinth* XI, pp. 14–21, and also p. 6, fig. 1. All of the production sites were located in the area once occupied by the Roman Forum, including one beneath the church of St. John Theologos, and another adjacent to the church of St. Paul. Harvey (1989, p. 214) suggests that the pottery workshop adjacent to St. Paul's may have had some connection with the church.

64. Sanders 2003, p. 397.

65. G. D. R. Sanders (pers. comm.).

66. Farnsworth 1970; Whitbread 1987, pp. 378–402; 1995, pp. 308–344; 2003.

67. Whitbread 1987, pp. 400–402; 1995, p. 330; 2003.

68. G. D. R. Sanders (pers. comm.).

Firing Regime

The surfaces of the cooking pots in the Corinth sample are usually light brown to red, suggesting that firing was conducted in an oxidizing atmosphere. Differentiation in color between the cores and margins is sometimes seen, the cores being reddish brown to gray. This difference points to insufficient oxygen having been available for the complete volatilization of carbon in the clay, or to the development of a reducing environment, the oxygen having been used up before it reached the center of the vessel walls, resulting in the deposition of carbon. Alternatively, a reducing environment may have developed during cooling, or carbon could have penetrated the surface during cooking over an open fire.

Only a few samples, generally the Frankish forms, have gray surfaces, suggesting that the vessels were fired in a reducing atmosphere. As noted above, the firing regime for the mudstone groups can be differentiated on the basis of the degree of firing. Those that have an optically active clay micromass generally indicate firing at a relatively low temperature (or firing at a higher temperature for a short duration) and are classified as the mudstone poorly fired fabric group. In contrast, those that have an optically inactive clay micromass indicate a prolonged firing, often at relatively high temperatures, and are classified as the mudstone well-fired group.

DISCUSSION

At the beginning of the Middle Frankish period at Corinth, the introduction of a new form of cooking pot and a change in clay-paste usage appear to have coincided with the arrival of Venetian refugees and the construction of a new architectural complex (unit 1). The arrival of the refugees 50 years after the Frankish incursion may help to explain why the Frankish cooking pot did not appear immediately. The change in form, from the globular Byzantine vessel to the Frankish tall-necked pot, occurs fairly suddenly, with only a few transitional shapes appearing. The Frankish style of cooking ware continued in use from ca. 1260 to 1350, without significant modification, which may indicate stability in the occupancy of this part of the site during this period.

The Byzantine-style cooking pots used by the inhabitants of unit 2 in the Byzantine and Early Frankish periods were almost certainly locally produced. The variety of fabrics from which the pots are made may point to the existence of several workshops, although other scenarios are also possible (see above). While the characteristics of most fabric groups tend to overlap to some extent, at least two workshops are strongly suggested by the clearly distinguishable chert and chert and quartz fabric groups.

To judge from the petrographic analysis, during the Middle and Late Frankish periods the Franks also used locally produced cooking pots rather than imports. In contrast to earlier practices, however, a single fabric (QMC) was favored, one that had also been used previously in Byzantine-style cooking ware. The preference for a single fabric type at this time may indicate that the Frankish cooking pots were produced in one workshop, with potters exploiting one clay source. The Franks appear to have introduced a change in ceramic production, or they may have initiated a stylistic change within an already existing Byzantine workshop, possibly to meet the special needs of a Frankish (Venetian?) kitchen.

The Frankish-style tall-necked cooking pot appears to be relatively rare at Crusader sites in the Aegean area, although this may be a function of few excavations having published their cooking pots from this period.[69] Equivalent styles of contemporary cooking ware have been recovered from elsewhere in the Corinthia, at Isthmia, and from Boiotia,[70] but no Frankish cooking pots have been reported from either Ayios Stephanos or Sparta in the Peloponnese,[71] nor from Crusader sites in the Near East.[72] Conversely, some 13th-century glazed wares common at Crusader sites in Cyprus, Palestine, and Syria have not been found at Corinth.[73]

The functional and social links between food preparation, dining habits, and pottery may go some way to explain the differences in design between the Byzantine and Frankish cooking-pot forms. In Boiotia, Joanita Vroom has suggested that the introduction of the Frankish cooking-pot form coincided with a change in table wares, and presumably dining habits as well: the shallow, open table wares of the Byzantine period are replaced in the Frankish period by smaller, deeper bowls, more cutlery, and fewer cups.[74] At Corinth, faunal analyses indicate that meat consumption did not change substantially over this period.[75] Justin Lev-Tov has suggested, on the basis of these analyses, that the incoming Franks at Corinth were probably "forced to adjust their diet . . . to fit the new circumstances."[76] We need not assume, however, that the Byzantines and Franks prepared and cooked meats in the same way. It is quite probable that the Franks retained their own cuisine, but used locally available food supplies.

As discussed earlier, we know that the Byzantines and Franks had different cuisines, and it is suggested here that the typological variations seen in the cooking wares may reflect the groups' cultural identities, as well as the differences in their cuisine. It is well known that ethnic cuisines articulate and reinforce group identities and that ceramic style is often symbolic of social differentiation.[77] Referring to Early Roman Britain, Karen Meadows has remarked that "diet and culinary practices are inextricably linked to all aspects of social, political and economic life"—a comment of equal relevance to the situation in Corinth, where the Franks (Venetians?) introduced their own cuisine along with a suitable form of cooking pot.[78] The Franks' daily use of their own form of cooking pot to prepare Frankish cuisine would have served to reinforce their identity in a foreign land.[79] It is not unreasonable to suppose that foreign peoples would bring new styles of pottery to a region, and produce them using local clay sources.[80]

While unable to provide firm answers to the questions posed at the beginning of this article, the petrographic analysis of cooking wares at Corinth documents a striking shift in the exploitation of raw materials from the Byzantine to Frankish periods, coinciding with a change in vessel shape. The full implications of this shift for our understanding of ceramic production and cultural change at the site are only beginning to be realized.

69. Sanders (1987, p. 180) also comments on the rarity of published 13th-century cooking wares.

70. For Isthmia, see Gregory 1989, p. 206; and n. 58, above. For Boiotia, see Vroom 2003, p. 169.

71. Sanders 1989, 1993.

72. For example, none were found at Caesarea by Pringle (1985). See also Stern 1997; Williams et al. 1998, p. 249, n. 51.

73. MacKay (2003, p. 413) has observed that, although Aegean, Protomaiolica, and Zeuxippus wares were common at Corinth and Crusader sites in the Near East in the early 13th century, Port Saint Symeon ware—which is common in the Near East—has not been identified at Corinth or elsewhere in southern Greece or Crete.

74. Vroom 2003, pp. 233, 329.

75. See n. 42, above.

76. Lev-Tov 1999, p. 96.

77. See, e.g., Buckser 1999; and n. 30, above.

78. Meadows 1997, p. 21.

79. Other social differences between the Byzantines and the Franks included language, religion, and hairstyles. The Byzantines viewed the cooking practices of the Franks as dirty and distasteful (see p. 190 and n. 41, above). In the period under discussion, there is clear evidence for social segregation of the Byzantines and the Franks; see Lock 1995, pp. 194, 275, 293.

80. See, e.g., McGovern 1986, pp. 37–45.

APPENDIX

PETROGRAPHIC FABRIC DESCRIPTIONS

A hand-specimen analysis was carried out on the sherd samples using the naked eye and a 10× hand lens. The color determinations were based on Munsell soil color charts and taken on fresh breaks, unless indicated otherwise, in natural daylight. Grain-size terminology for the aplastic inclusions is based on the Udden-Wentworth scale, and the thin-section descriptions conform to the format used by Whitbread.[81]

GROUP 1: CHERT

Lot 1992-84-8, 13–16, 21, 23 (7 samples)

Hand-Specimen Analysis

Color: red (2.5YR 5/8) to light brown (7.5YR 6/4) for homogeneous samples. Some samples have margins that range from light red to red (2.5YR 6/8–5/6), and cores from reddish brown to gray (5YR 5/4–2.5YR 5/0).
Hardness: hard
Feel: rough
Fracture: hackly
Inclusions
  Frequency: 20–25%, moderate
  Sorting: moderate to poor
  Average size: ca. 2 mm to 0.1 mm; mode = 0.5 mm
  Rounding: a–r
Composition: dominant to common milky white angular inclusions, opaque, probably quartz, and white/gray, slightly translucent, angular inclusions, probably quartz. Rare dark gray/black and red/brown angular inclusions, possibly mudstones.
Voids: common vughs and planar voids, often approximately parallel to the vessel margins.
Vessel surface: Striations on interior and exterior surfaces possibly indicating that the vessels were wheelmade. The pots are all coarse-textured with inclusions protruding through the clay fabric. Some shrinkage cracks are visible on the interior pot surface. Scratch marks are visible on the exterior of some samples.
Wall thickness: 4–10 mm

81. See Whitbread 1986, 1989, 1995. For grain-size terminology and the Udden-Wentworth scale, see n. 52, above. Abbreviations used in this appendix are as follows: a = angular; c:f:v = coarse:fine:void ratio; PPL = plane polarized light; r = rounded; sa = subangular; sr = subrounded; wr = well rounded; XP = crossed polars.

Thin-Section Analysis

Microstructure

Rare megaplanar voids, frequent to common macroplanar voids, and frequent mesoplanar voids. Frequent to few macro- and mesovughs. Some are equant and others elongate. Voids show an approximately parallel orientation to each other. The grain inclusions do not show a preferred orientation. The coarse-grained inclusions vary from close to double-spaced, and the finer-grained inclusions vary from close to open-spaced.

Groundmass

Homogeneous throughout the sections. The fabrics appear to be well fired. The color varies from light to dark mid-brown in PPL (40×), and a dark reddish brown color in XP (40×). The micromass is optically slightly active to optically inactive.

Inclusions

$c{:}f{:}v_{10\mu m}$ = ca. 20:70:10 to 25:68:7
Coarse fraction = 2.50 mm to 0.25 mm (granules to medium sand)
Fine fraction = 0.15 mm or less (fine sand and below)

The inclusions have a unimodal grading into bimodal grain-size distribution, showing moderate sorting.

Coarse Fraction

Frequent

Chert: a–sa, colorless to pale brown (PPL 40×), sometimes containing radiolarian skeletons. Microcalcite is present in some grains and these are browner (PPL 100×).

Common

Monocrystalline quartz: a–sr. Some have undulose extinction indicating strain during formation, although most have straight extinction. Approximately equant.

Common to few

Polycrystalline quartz: sa–sr, slightly elongate to equant, inequigranular. The grains mainly have undulose extinction, but others have straight extinction. Some have internal sutured grain boundaries, while others are straight.

Very few to very rare

Calcimudstone (micrite): a, slightly elongate. Pale green to yellow/brown in PPL (40×).

Rare to very rare

Fe-Ti oxides: a–r. Approximately equant grains.

Very rare

Biotite mica: laths

Sandstone: sa composed of fairly well sorted, monocrystalline quartz grains (mode = 0.1 mm long dimension). Size = <0.4 mm long dimension. Laths of biotite mica occur between the quartz grains.

Plagioclase feldspar: polysynthetic twinning

Mudstone: a, with radiolarian skeletons. Optically inactive.

Fine Fraction

Dominant

Chert: a–sr. Mainly equigranular microquartz.

Monocrystalline quartz: a–sr, equant grains. Some grains show undulose extinction, but the majority show straight extinction.

Very few to rare

Polycrystalline quartz: sa, sutured boundaries of quartz crystals.

Rare to very rare

Biotite mica: laths

Fe-Ti oxides

Very rare

Plagioclase feldspar: laths with polysynthetic twinning

Spinel

Radiolarian skeletons

Pyroxene?

Textural Concentration Features (Tcfs)

Tcf = ca. 1% or less (of total field)

Three types of tcfs are found:

1. Orange/brown to dark brown, paler than the enclosing micromass, r, equant. Size = 1.5 to 0.2 mm long dimension. Contain small, a–sa monocrystalline quartz inclusions. Texturally similar to the micromass, having a neutral optical density (ND). Their prominence is faint (in PPL) to distinct (in XP) and their boundaries are sharp to diffuse. They are discordant grading into concordant with the micromass. Possibly clay pellets.
2. Dark brown in PPL (40×) and yellow/brown in XP (40×); a little paler than the micromass. Size = <0.6 mm long dimension. They have a slightly lower optical density than the micromass (D-). There is no internal preferred orientation. Prominence is faint, and the boundaries are diffuse. They are discordant with the micromass fabric. They contain small grains of sr monocrystalline quartz. They are slightly optically active. Possibly clay pellets.
3. Black brown in PPL (100×) and black gray in XP (100×). They look like part of the micromass, but have a more well-fired texture in XP. They have a slightly higher optical density (D+). Size = <0.7 mm long dimension, equant. They contain grains of monocrystalline quartz. Often surrounded by a shrinkage void. Prominence is faint, and diffuse boundaries persist. They have no internal preferred orientation, but are concordant with the groundmass. Possibly clay pellets.

GROUP 2: CHERT AND QUARTZ

Lot 1992-100-21, 22, 23, 27 (4 samples)

Hand-Specimen Analysis

Color: red (2.5YR 5/8) to yellowish red (5YR 5/6) to brown/dark brown (7.5YR 4/2) to dark gray (10YR 4/1) to very dark gray (7.5YR 3/0)

Hardness: hard

Feel: rough

Fracture: hackly to slightly laminated

Inclusions

Frequency: 20%, moderate

Sorting: moderate

Average size: ca. 1.5 mm to 0.1 mm; mode = 0.5 mm

Rounding: sa

Composition: common to few milky white opaque inclusions, possibly quartz. Few light gray translucent inclusions, possibly quartz. Few to rare mid-gray inclusions,

possibly chert. Few to rare pale pink/buff inclusions, possibly chert or quartz. Rare orange and red inclusions, possibly mudstones. Rare to very rare, very fine grained, sparkly inclusions, probably mica.
Voids: mainly vughs. Some samples have a parallel orientation of both planar voids and vughs parallel to their vessel margins.
Vessel surface: striations on the exterior and interior surfaces, possibly indicating that the vessels were wheelmade.
Wall thickness: 5–7 mm

Thin-Section Analysis

Microstructure

Rare megavughs, common macrovughs, few mesovughs. Few macroplanar voids and frequent mesoplanar voids. Size = <0.08 mm and 0.02 mm wide, respectively. There is a well-developed long axes parallel preferred orientation of the voids, and a crude orientation of the large inclusions. Both the coarse and fine inclusions are single- to double-spaced.

Groundmass

All fairly homogeneous throughout the sections. The color varies from very dark brown/black to dark brown with a reddish tinge in PPL (40×) and very dark brown with a tinge of red to dark red/brown in XP (40×). The micromass varies from optically inactive to optically slightly active.

Inclusions

$c{:}f{:}v_{10\mu m}$ = ca. 20:70:10 to 25:65:10
Coarse fraction = 1.5 mm to 0.25 mm (very coarse sand to medium sand)
Fine fraction = 0.2 mm or less (fine sand and below)

The inclusions have a unimodal grading into bimodal grain-size distribution and are moderately sorted.

Coarse Fraction

Dominant to frequent
Monocrystalline quartz: sa–sr, equant. Mainly undulose extinction with some straight extinction. Mode = 0.3 to 0.25 mm long dimension.
Frequent to few
Chert: a–sa. Pale to mid-brown in PPL (40×). Some contain radiolarian skeletons. Mode = 0.3 mm long dimension. Microquartz veins transect a few grains, and some are quite muddy.
Few to very few
Polycrystalline quartz: sa–sr, inequigranular. Some sutured contacts and others are straight. Straight and undulose extinction. Mode = 0.4 mm long dimension.
Very few to very rare
Sandstone, in the following three types:
1. Quartz arenite. Inequigranular, moderately sorted, sa–sr. Mode = 0.4 mm long dimension.
2. Quartz arenite grading into a quartzwacke. Similar to quartz arenite, but with a wide range of grain sizes. Poorly to well sorted, sa. Mode = 0.9 mm long dimension. Some of the quartz grains show signs of compaction, with sutured margins developed. Undulose extinction common.

3. Sub-litharenite. Coarse-grained sandstone with angular grains of monocrystalline quartz and chert. Mode = 0.5 mm long dimension.

Rare

Mudstone, in the following five types:

1. Brown mudstone: sr. Mid-brown/gray in PPL (40×) and gray/brown in XP (40×), optically inactive with a well-fired texture. Mode = 0.4 mm long dimension. Looks like the classic Corinthian mudstone. No internal preferred orientation.
2. Radiolarian mudstone: sa. Radiolarian skeletons infilled with mud. Orange in PPL (40×) and gray/brown in XP (40×). Mode = 0.6 mm long dimension.
3. Dark brown mudstone: sa. Dark brown in PPL (40×) and red/brown in XP (40×), optically inactive and no preferred orientation. Mode = 0.3 mm long dimension.
4. Mudstone breccia: sr. Yellow/brown in PPL (40×) and yellow/gray/brown in XP (40×). Composed of sa fragments of similar mudstone. Mode = 0.76 mm long dimension.
5. Yellow/brown mudstone: sa. Yellow/brown in PPL (40×) and orange/yellow brown in XP (40×). Mode = 0.6 mm long dimension. No preferred orientation.

Rare to very rare

Chalcedonic quartz: sa. Mode = 0.3 mm long dimension. Equant to slightly elongate.

Very rare

Recrystallized quartz: sa, possibly a quartz mylonite? Undulose extinction pervasive, crude parallel orientation defined by undulose extinction. Mode = 0.5 mm long dimension.

Quartz with biotite inclusions

Quartz-amphibole grain, possibly granite or amphibolite?

Fine Fraction

Dominant to common

Monocrystalline quartz: a–sr, equant to slightly elongate. Mainly straight extinction. Mode = 0.04 mm long dimension.

Few to rare

Chert: sr. Grades into cherty mudstone. Mode = 0.14 mm long dimension.

Very few to rare

Polycrystalline quartz: sa–sr, inequigranular. Undulose extinction. Mode = 0.1 mm long dimension.

Rare

Fe-Ti oxides

Very rare

Sandstone

Mudstone, similar to the classic Corinthian mudstone

Glauconite

Biotite mica

Muscovite mica

Chalcedonic quartz

Amphibole or epidote?

Spinel

Radiolarian skeletons

Biogenic fragment: ossicle, possibly from a crinoid?

Textural Concentration Features

Tcf = ca. less than 2% (of total field)

Five types of tcfs are present:

1. Dark brown in PPL (40×) and dark red/brown in XP (40×), r, elongate. Size = <0.9 mm long dimension. Contain inclusions of monocrystalline and polycrystalline quartz. Neutral optical density or a little higher (ND/D+). Prominence is faint. Boundaries are clear to diffuse. Discordant with internal micromass. No internal orientation. Probably clay pellets.
2. Dark brown in PPL (40×) (darker than micromass) and red brown in XP (40×), r, equant. Size = <1.5 mm. Merge with the micromass. Contain inclusions of monocrystalline and polycrystalline quartz, and chert. Neutral optical density (ND). Prominence is faint. Boundaries are merging. Concordant with the micromass. No internal orientation discernible.
3. Mid-brown in PPL (40×) (lighter than micromass) and red brown (like the micromass) in XP (40×), wr, equant. Size = <0.6 mm long dimension. Inclusions include monocrystalline and polycrystalline quartz, and radiolarian skeletons. Low optical density (D-). Prominence is faint/distinct. Boundaries are merging to clear. Discordant with the micromass. No internal orientation. Probably clay pellets.
4. Very dark black/brown in PPL (40×) and black in XP (40×), sr–wr, equant. Size = <0.4 mm long dimension. Inclusions of monocrystalline quartz. High optical density (D+). Prominence is distinct. Boundaries are clear. Discordant with the micromass. No internal orientation. Probably clay pellets.
5. Yellow/gray/brown in PPL (40×) and brown yellow, optically active in XP (100×), r, elongate. Size = <2.5 mm long dimension and 0.15 mm wide. Inclusions of monocrystalline quartz. Low optical density (D-). Prominence is faint to distinct. Boundaries are clear. Discordant with micromass. No internal orientation.

GROUP 3: MUDSTONE, WELL FIRED

Lot 1992-84-5, 10, 12, 18, 20; lot 1992-100-26; NB 857-136 (7 samples)

Hand-Specimen Analysis

Color: margins are brown (7.5YR 5/2), light brown (7.5YR 6/4), yellowish red (5YR 5/6), reddish yellow (5YR 6/6) to light red (2.5YR 6/8). Cores are reddish brown (5YR 5/4), grayish brown (10YR 5/2) to gray (2.5YR 5/0).
Hardness: hard
Feel: rough
Fracture: hackly, smooth, laminated
Inclusions

Frequency: 15%–20%, sparse to moderate
Sorting: moderate
Average size: 2 mm to 0.1 mm; mode = 0.5 mm to 0.1 mm
Rounding: sa–sr

Composition: frequent to few dark gray inclusions, possibly lithic fragments. Frequent to few milky white inclusions, possibly quartz. Common to few red, yellow, and pink-buff inclusions, probably mudstones. Common to absent gray inclusions, possibly chert. Few to absent black inclusions, possibly chert or lithics.

Voids: vughs and planar voids, with long axes approximately parallel to the vessel margins.
Vessel surface: interior and exterior striations are visible, possibly indicating wheelmade production. There are a few lime spalls on the interior and exterior surfaces.
Wall thickness: 4–6 mm

Thin-Section Analysis

Microstructure

Very rare to absent megavughs, common to rare macrovughs, and common to few mesovughs. There are frequent to rare macroplanar voids and frequent to few mesoplanar voids. There is a crude, well-developed parallel preferred orientation of the vughs and planar voids, generally parallel to the margins of the vessels. The coarse inclusions are single- to double-spaced, while the fine inclusions are single- to open-spaced. There is no preferred orientation of the aplastic inclusions.

Groundmass

Dark brown to mid-yellow/brown in PPL (40×) and brown with a red/orange tinge in XP (40×). Some samples have oxidized margins from orange/brown in PPL (40×) and red/brown in XP (40×), while the cores are dark brown/black in PPL (40×) and dark brown with a red tinge in XP (40×), suggesting firing in a partially reducing atmosphere. Margins are generally optically active and the cores are very slightly optically active or optically inactive.

Inclusions

$c{:}f{:}v_{10\mu m}$ = ca. 20:78:2 to 20:70:10
Coarse fraction = 2.25 mm to 0.2 mm (granules to fine sand)
Fine fraction = 0.2 mm or less (fine sand and below)

The inclusions have a bimodal grain-size distribution. Moderately sorted inclusions with no preferred orientation.

Coarse Fraction

Dominant to rare

Mudstone, in the following seven types:

1. Polygonally cracked mudstone with or without radiolaria: sa–sr. Dark brown/black to light brown/yellow in PPL (40×) and dark gray/brown to dark gray/black in XP (40×). Texture is optically inactive—slightly more fired than the micromass? Polygonal cracks are infilled with microcarbonate material. Inclusions of monocrystalline quartz, Fe-Ti oxide, and biotite mica. Radiolarian skeletons are infilled with micro-quartz.
2. Mudstone breccia: sa–sr, equant, contains different types of mudstone, including polygonally cracked mudstone as above (with or without radiolarian skeletons), and some radiolarian chert. Mudstones vary in color: yellow brown, red brown, dark brown, gray brown in PPL (40×), and dark gray brown and red brown in XP (40×). Occasional mono-crystalline quartz inclusions. Size = <1.75 mm long dimension.
3. Fine-grained mudstone: sr. Mid-yellow/brown in PPL (100×) and gray/yellow in XP (100×).
4. Red mudstone: sr. Red/brown cores and light gray/brown margins in PPL (100×), and in XP (100×) cores are red/brown and margins dark gray. Inclusions of monocrystalline quartz and biotite mica are

present. Poorly developed polygonal cracking, and no internal preferred orientation.

5. Silty mudstone: sr, slightly elongate, mid- to dark brown in PPL (100×) and red/brown in XP (100×). Optically active texture. There is a long axes parallel preferred orientation of the fabric. Inclusions of monocrystalline quartz, muscovite mica, calcimudstone (micrite), and biotite mica.
6. Red/brown mudstone: sa–sr, mid-brown/orange in PPL (100×) and red/brown in XP (100×). Few inclusions, only mica flakes and monocrystalline quartz. Crosscut by microquartz veins that appear to anastomose. A crude internal long axes parallel preferred orientation. Size = <1.75 mm long dimension.
7. Gray mudstone: sr–r. Dark gray in PPL (100×) and gray brown with an orange tinge in XP (100×). Polygonal cracking is evident. No internal preferred orientation. Very few inclusions of monocrystalline and polycrystalline quartz, chert, Fe-Ti oxides, and hematite. More optically inactive than micromass. Looks like classic Corinthian mudstone. Size = <0.9 mm long dimension. Mode = 0.3 mm long dimension.

Frequent to very rare

Monocrystalline quartz: a–r, equant to slightly elongate. Mainly straight extinction, some undulose extinction. Size = <0.5 mm long dimension. Mode = 0.3 mm long dimension.

Common to few

Chert: a–r, equant to elongate. Colorless to pale brown/yellow in PPL (40×). Microquartz veining in some grains. Pale brown chert usually contains radiolarian skeletons. Some radiolarian cherts grade into radiolarian mudstone. Size = <1.5 mm long dimension. Mode = 0.35 mm long dimension.

Common to very few

Polycrystalline quartz: a–sr, inequigranular, equant to slightly elongate. Some grains have sutured contacts. Undulose extinction is prevalent. Some hematite staining along grain boundaries. Size = <0.6 mm long dimension. Mode = 0.25 mm long dimension.

Few to very rare

Calcimudstone (micrite): sa–wr. Mid-brown/yellow in PPL (40×) and yellow with brown tinge in XP (40×). Size = <0.75 mm long dimension. Mode = 0.4 mm long dimension. Some polygonal cracking.

Few to absent

Sandstone: quartz arenite. Inequigranular, sa, poorly sorted. Mode = 0.4 mm long dimension. Straight and undulose extinction in the quartz grains.

Siltstone: sa–r, equant to elongate. Dark brown/gray in PPL (40×) and dark gray with an orange tinge in XP (40×). Tightly packed quartz grains with relatively little matrix. Mode = 1.25 mm long dimension.

Very few to absent

Schistose quartz: r, elongate, inequigranular with sutured contacts. Probably biotite schist.

Rare to absent

Schist: sa, elongate. Quartz chlorite schist. Mode = 0.8 mm long dimension.

Very rare to absent

Radiolarian skeletons
Fe-Ti oxide
Spinel

Fine Fraction

Dominant to common

Monocrystalline quartz: a–r. Mainly straight but some undulose extinction. Equant to slightly elongate grains. Size = <0.18 mm long dimension.

Common to rare

Calcimudstone (micrite): sa–r. Pale brown/yellow in PPL (100×). Size = <0.12 mm long dimension.

Chert: a–r. Colorless to pale brown in PPL (100×). Some radiolarian chert.

Common to absent

Mudstone: sa–r. Gray, brown, and red varieties.

Few to absent

Polycrystalline quartz: a–sa, inequigranular

Rare to very rare

Biotite mica: laths
Muscovite mica: laths
Fe-Ti oxide

Rare to absent

Spinel
Siltstone
Sandstone: sub-arkose?

Very rare to absent

Schistose quartz
Schist
Plagioclase feldspar
Hematite
Pyroxene or amphibole?
Radiolarian chert
Radiolarian skeletons
Calcite
Glauconite
Chalcedonic quartz
Calcimudstone (micrite)
Microfossil: rounded shape with an internal multiglobular structure. Possibly a foraminiferan test.
Nepheline or apatite?

Textural Concentration Features

Tcf = ca. 10% to absent (of total field)

The following tcfs are present:

1. Orange/brown in PPL (100×) and red/brown in XP (100×), sa–wr, equant. Size = <0.8 mm long dimension. A higher optical density (D+) than the micromass. Boundaries are sharp and prominent. The internal fabric is discordant with the external micromass. Contain inclusions of monocrystalline quartz, biotite mica, calcimudstone (micrite), and Fe-Ti oxide. Most are surrounded by a void that is infilled by micro-quartz and microcalcite. No internal preferred orientation. Possibly clay pellets.
2. Dark brown with orange tinge in PPL (40×) and dark red/orange in XP (40×), r–wr. Size = <1.25 mm long dimension. Usually equidimensional to slightly elongate. They have a slightly higher optical density (D+) than the micromass. The boundaries are clear and prominent. The internal fabric is concordant with the external micromass. They

contain inclusions of monocrystalline quartz, polycrystalline quartz, and chert. Polygonal cracks are prevalent, not infilled. There is no internal preferred orientation. Possibly clay pellets.

3. Orange/yellow in PPL (100×) and orange/red in XP (100×): r, approximately equidimensional. Up to 0.5 mm long dimension. They have slightly lower optical density (D--) than the micromass. The boundaries are clear to diffuse and the tcfs are faint. The internal fabric is approximately concordant with the external micromass. They contain inclusions of monocrystalline quartz, white mica laths, Fe-Ti oxides, and polycrystalline quartz. There is a preferred orientation of the clay matrix that is folded in one of the tcfs. Possibly clay pellets.

GROUP 4: MUDSTONE, POORLY FIRED

Lot 1992-84-3, 9, 11, 17, 19, 25 (6 samples)

Hand-Specimen Analysis

Color: margins range from red (2.5YR 5/8) to reddish yellow (7.5YR 6/6) to red (2.5YR 5/8). Cores are dark grayish brown (10YR 4/2).
Hardness: hard
Feel: rough
Fracture: hackly
Inclusions
Frequency: 15%–25%, sparse to common
Sorting: poorly to moderately sorted
Average size: 2 mm to 0.1 mm; mode = 0.5 mm
Rounding: sa–sr
Composition: common milky white inclusions, possibly quartz. Common gray/buff, dark gray/black, and red/brown inclusions, slightly elongate, possibly mudstone. Common to few gray translucent inclusions, possibly chert or quartz.
Voids: vughs and planar voids aligned approximately parallel to the vessel margins. Some infilled with a white mineral, possibly carbonate.
Vessel surface: striations on exterior and interior surfaces, suggesting that vessels were wheelmade.
Wall thickness: 5–7 mm

Thin-Section Analysis

Microstructure

There are few voids in these samples, including common to few macrovughs and frequent to few mesovughs. There are planar voids, including few macroplanar voids and frequent to common mesoplanar voids. The planar voids have a crude long axes parallel preferred orientation, in some parallel to the vessel margins and in others at an angle to the vessel margins. There is no long axes parallel preferred orientation of the aplastic inclusions. The coarse inclusions are single- to close-spaced and the fine inclusions are double- to close-spaced.

Groundmass

Homogeneous throughout the sections, although some have an oxidized red margin with a gray/brown core. The margins are reddish orange/brown in PPL (40×) and reddish orange in XP (40×). The cores are mid-brown in PPL (40×) and reddish brown in XP (40×). The margins are more optically active than the cores, although all the samples are optically active.

Inclusions

$c:f:v_{10\mu m}$ = ca. 25:70:5 to 20:70:10
Coarse fraction = 2.5 mm to 0.2 mm (granules to fine sand)
Fine fraction = 0.2 mm or less (fine sand and below)

The inclusions appear to have a bimodal grain-size distribution with the coarse inclusions set in a finer-grained groundmass. The inclusions are poorly to moderately sorted, and they have no preferred orientation.

Coarse Fraction

Dominant to few

Mudstone to siltstone in a number of varieties (not all of which are present in all samples):

1. Dark brown silty mudstone: sr, elongate. Dark brown color in PPL (40×) and yellow/brown in XP (40×). There is a variable grain-size distribution, often heterogeneous within a single inclusion. Contain inclusions such as polycrystalline and monocrystalline quartz, Fe-Ti oxides, and biotite mica. The mudstone fragments grade into siltstone.
2. Mudstone breccia: sa–sr, generally elongate. Variable brown colors (mid- to light brown) in PPL (40×) and brown to yellow/gray in XP (40×). Size = <2 mm long dimension. Mudstone fragments within the breccia are angular. Mudstones include grains of chert, radiolarian skeletons, monocrystalline quartz, calcite, calcimudstone (micrite), biotite flakes, plagioclase feldspar, and spinel.
3. Polygonally cracked silty mudstone: r–wr. Crude polygonal cracking is evident, infilled carbonate material. Inclusions include chert, monocrystalline and polycrystalline quartz, and plagioclase feldspar. These mudstones are a darker brown in PPL (40×) than the mudstone breccias, and a dark brown in XP (40×). There are usually shrinkage voids around these inclusions, possibly formed during the firing process, which are infilled with fine-grained carbonate material.
4. Orange silty mudstone: sa–r, varies from yellow/orange to the same orange-red color of the micromass in PPL (100×). In XP (100×) it is yellow brown to a reddish brown. Inclusions of monocrystalline and polycrystalline quartz, and chert. No internal preferred orientation.
5. Radiolarian mudstone: sr, elongate. Dark to mid-brown in PPL (100×) and a red brown in XP (100×). There is an internal parallel preferred orientation.

Frequent to common

Monocrystalline quartz: sa–r. Some show undulose extinction, while others show straight extinction.

Chert: a–sr. Varies from colorless to pale brown in PPL (40×). Radiolarian chert occurs and is a pale brown color in PPL (40×). Some quartz veining is evident.

Common to rare

Polycrystalline quartz: sa–sr, inequigranular. Often with straight extinction. Sutured boundaries between the grains are common.

Common to very rare

Calcimudstone (micrite): wr–sr, usually elongate. Inclusions of feldspar (perthite?), chert, monocrystalline quartz, and amphibole.

Few to absent

Schistose quartz: sr, elongate with sutured boundaries. Biotite and muscovite mica flakes occur between the quartz grains.

Very few to rare

Sandstone: sa–r, inequigranular. Poorly sorted to well-sorted varieties.

Rare to absent

Calcite: a–sa, single rhomb-shaped crystals and polycrystalline calcite

Very rare to absent

Amphibole: hornblende?

Granophyre: sa, granophyric texture of quartz intergrown with alkali feldspar

Plagioclase feldspar: laths, polysynthetic twinning

Shell fragments: infilled with microquartz

Mica: aggregate of white mica flakes and biotite flakes

Calcite ooid: concentric calcite bands. Yields a pseudo-uniaxial cross in XP (40×).

Fine Fraction

Dominant

Monocrystalline quartz: a–sr. Mainly straight extinction.

Common to few

Chert: a–r. Colorless to pale brown in PPL (100×).

Common to absent

Calcite: single-crystal rhombs

Few to absent

Polycrystalline quartz: sr, inequigranular. Some have undulose extinction and sutured grain boundaries.

Rare to very rare

Fe-Ti oxide

Rare to absent

Biotite mica

Very rare

Muscovite mica

Very rare to absent

Radiolarian skeletons

Calcimudstone (micrite)

Mudstone: the rarity of mudstone as fine inclusions suggests that mudstone was added as a temper.

Plagioclase feldspar

Amphibole or pyroxene?

Textural Concentration Features

Tcf = ca. less than 2% (of total field) to absent

Two types of tcfs form the end-members of a spectrum of variation. A third tcf is found only in sample 1992-84-25.

1. Dark reddish brown in PPL (100×) and reddish brown in XP (100×), wr, equant, containing inclusions of chert, monocrystalline and polycrystalline quartz. Size = <0.75 mm long. They have high optical density (D+), are prominent, and their boundaries are sharp. They are discordant with the external micromass and have no internal preferred orientation. Possibly clay pellets.
2. Orange brown in PPL (100×) and red/orange in XP (100×), slightly darker in color than the micromass; r, equant. A slightly higher to neutral optical density (D+/ND), prominence faint to distinct, with clear to diffuse boundaries. Size = <0.2 mm long dimension. They are discordant with the external micromass and have no internal preferred orientation. Possibly clay pellets.

3. In sample 1992-84-25 the tcfs are very black in PPL (40×) and are dark brown to red brown in XP (40×), sr. Diffuse to merging boundaries, high optical density (D+), faint to prominent. They contain inclusions of monocrystalline and polycrystalline quartz, and white mica laths.

GROUP 5: SANDSTONE

Lot 1992-84-6, 22; lot 1992-100-2, 3, 11, 14, 15, 18, 19, 20 (10 samples)

Hand-Specimen Analysis

Color: margins range from light red (2.5YR 6/6 and 2.5YR 6/8) to reddish yellow (5YR 6/6) to reddish brown (5YR 5/4) to light red (2.5YR 6/6) to red (2.5YR 5/6). Cores range from gray (10YR 6/1) to grayish brown (10YR 5/2) to light brownish gray (10YR 6/2) to light reddish brown (5YR 6/4).
Hardness: hard
Feel: rough
Fracture: hackly to laminated to smooth
Inclusions
Frequency: 15%–20%, sparse to moderate
Sorting: moderate to well sorted
Average size: 2 mm to 0.1 mm; mode = 1 mm to 0.1 mm
Rounding: sa–sr
Composition: frequent to few milky white opaque inclusions, possibly quartz. Frequent to very few mid-gray inclusions, possibly chert, quartz, or sandstone. Common to very rare very fine grained sparkling grains, possibly mica. Few dark gray inclusions, possibly chert or sandstone. Few to rare pale brown/pink, orange, and red/brown inclusions, possibly mudstone or tcf.
Voids: some vughs with no particular orientation, while other vughs and planar voids are aligned parallel to the vessel margins
Vessel surface: striations on interior and exterior surfaces possibly indicating that vessels were wheelmade. Small amount of lime spalling in some samples.
Wall thickness: 3–6 mm

Thin-Section Analysis

Microstructure

Common to few mesovughs, common to rare macrovughs, and rare megavughs. Common to absent meso- and macroplanar voids, and very rare to absent megaplanar voids. There is a well-developed long axes parallel preferred orientation of the planar voids and a less well developed orientation of the vughs, all approximately parallel to the vessel margins. The coarse and fine inclusions are single- to double-spaced. There is a very crude parallel orientation of the coarse inclusions.

Groundmass

Fairly homogeneous throughout the sections. Most samples are optically active. Most samples are orange brown in PPL (40×), sometimes with a slightly darker core, and bright orange/red/brown in XP (40×).

Inclusions

$c{:}f{:}v_{10\mu m}$ = ca. 25:73:2 to 20:75:5
Coarse fraction = 2 mm to 0.25 mm (very coarse to medium sand)
Fine fraction = 0.2 mm or less (fine sand and below)

The inclusions appear to have a unimodal grain-size distribution in some samples and a bimodal distribution in others, and range from poorly to well sorted. There is no preferred orientation of the aplastic inclusions.

Coarse Fraction

Common to few

Sandstone, in the following six types:

1. Quartzwacke to quartz arenite: a–sa quartz grains and some plagioclase and orthoclase feldspar grains. Very well to well-sorted sandstone. Matrix composed of muscovite and biotite laths and Fe-Ti oxides, as well as clay minerals. Size = <0.3 mm long dimension.
2. Fine-grained sandstone with little matrix: r. Well sorted. Quartz-rich. Rare plagioclase feldspar.
3. Quartz arenite: wr, medium-grained sandstone with little matrix. Some of the quartz grains are in direct contact with other grains, showing signs of compaction and possibly cementation. Well to moderately sorted.
4. Quartzwacke with carbonate cement: sr, carbonate crystals (probably calcite) form an interlocking mosaic texture between the sr quartz grains. Approximately 50% of this sandstone is composed of cement. Other constituents include few chlorite, biotite mica, polycrystalline quartz, and Fe-Ti oxides. Moderately sorted.
5. Quartzwacke: sr, has a clay matrix. Moderately sorted. Biotite and muscovite flakes are present in the matrix.
6. Sandstone breccia: wr grains of sandstone enclosed in a similar sandstone matrix. Fairly well sorted.

Common to very few

Polycrystalline quartz: sa–sr, inequigranular. Some sutured grain contacts. Undulose and straight extinction, often within the same grain. Some of the polycrystalline quartz grains are merging into schistose quartz with the stretching of the quartz grains (no micas present) and undulose extinction.

Common to rare

Monocrystalline quartz: a–sa, equant. Undulose to straight extinction.

Common to very rare

Mudstone, in the following five types (not all of which are present in all samples):

1. Brown mudstone: sa–r. Internal preferred orientation is well developed. Inclusions of monocrystalline quartz and occasional radiolarian skeletons.
2. Radiolarian mudstone: sa. Radiolarian skeletons are infilled with amorphous clay minerals.
3. Mudstone breccia: sa–sr. In addition to mudstone fragments, it also contains calcimudstone (micrite), polycrystalline and monocrystalline quartz, Fe-Ti oxides, hematite, chert, and radiolarian chert.
4. Dark gray mudstone: a–r. Optically inactive in XP. Polygonal cracking is developed. Very like the classic Corinthian mudstones.
5. Red mudstone: sa–r. Inclusions of monocrystalline quartz and calcimudstone (micrite). No internal preferred orientation.

Common to absent

Schist: common only in sample 1992-100-14; a–sr, elongate. Stretched quartz grains have undulose extinction, and some sutured contacts. Biotite laths occur between the quartz grains.

Few to rare

Calcimudstone (micrite): sa–wr, equant to slightly elongate.
Siltstone: sr–r. Inclusions of monocrystalline quartz, chert, calcimudstone (micrite), and hematite.

Few to very rare

Chert: a–sr. Very pale brown in PPL (40×). Radiolarian skeletons are present in some. Microquartz veining transects some of the cherts.

Rare to very rare

Fe-Ti oxide

Rare to absent

Biogenic fragments: shell-like fragments
Olivine or epidote?

Very rare to absent

Marble
Cordierite?

Fine Fraction

Frequent to common

Monocrystalline quartz: a–sr, equant. Mainly straight extinction.

Common to few

Polycrystalline quartz: a–sa, inequigranular. Mainly undulose extinction.

Very few to rare

Plagioclase feldspar: polysynthetic twinning
Fe-Ti oxide

Very few to absent

Dark gray mudstone

Rare

Calcimudstone (micrite)

Rare to very rare

Muscovite mica
Biotite mica
Hematite

Rare to absent

Orthoclase feldspar
Sandstone
Red mudstone
Schistose quartz: probably biotite schist
Amphibole?

Very rare

Spinel
Radiolarian skeletons

Very rare to absent

Glauconite
Weathered volcanic fragment: weathered volcanic fragments are not unusual in Corinthian sediments, coming originally from spilites associated with fairly local ophiolite sources.
Olivine or epidote?

Textural Concentration Features

Tcf = ca. 2% and less (of total field)

Three types of tcfs are present:

1. Dark mid-brown in PPL (40×) and brown with orange tinge in XP (40×); wr, elongate. Size = <4 mm long. Inclusions of polycrystalline and monocrystalline quartz, chert, mica, and calcimudstone (micrite). Neutral optical density (ND) compared with the micromass. Boundaries are diffuse to merging. Prominence is faint. There is no particular internal preferred orientation. The texture is very similar to the micromass, but is darker in color, possibly meaning that it is concordant with the micromass. Possibly clay pellets.
2. Red with a tinge of orange in PPL (40×) and red/orange in XP (40×), wr–r. High optical density (D+) compared with the micromass. Boundaries are clear. They are discordant with the micromass. They contain only a few inclusions: monocrystalline quartz and Fe-Ti oxides.
3. Mid-brown in PPL (100×) and red brown in XP (100×), wr. Packed full of inclusions: monocrystalline quartz. There is no internal orientation of the fabric. They are discordant with the micromass. Prominence is distinct. The boundaries are clear. They are clay pellets.

GROUP 6: QUARTZ-MUDSTONE-CHERT (QMC)

Lot 1992-84-1, 4, 7, 24, 26; lot 1992-100-10, 12, 13, 16, 28; lot 1993-6-1, 2, 3; lot 1993-14-1, 2; lot 1993-34-11, 12, 13, 14; lot 1994-10-2, 10, 12, 20; NB 853-86, 87, 88, 121; NB 856-65-1; NB 857-137; NB 864-25; NB 865-23 (31 samples)

Hand-Specimen Analysis

Color: some samples have a homogeneous color: very dark gray (2.5YR 3/0), dark gray (5Y 4/1), reddish brown (5YR 5/3), or red (2.5YR 4/6). Others have cores that range from grayish brown (10YR 5/2) to very dark gray (7.5YR 3/0) to dark gray (2.5YR 4/0) to grayish brown (2.5Y 5/2) to pale brown (10YR 6/3). The margins range from light reddish brown (5YR 6/4) to reddish yellow (5YR 6/6) to red (2.5YR 5/6) to light brown (7.5YR 6/4).
Hardness: hard
Feel: rough
Fracture: hackly to smooth to laminated
Inclusions
- *Frequency:* 15%–25%, sparse to common
- *Sorting:* moderate
- *Average size:* 3 mm to 0.1 mm; mode = 0.5 mm to 0.1 mm
- *Rounding:* a–sr

Composition: common to very few mid-light gray, slightly translucent grains, possibly quartz or chert. Common to rare milky white opaque inclusions, possibly quartz. Few white translucent inclusions, possibly quartz. Few elongate orange/red/brown inclusions, possibly mudstone or sandstone. Few to very rare dark gray/black inclusions, possibly lithic fragments or chert. Very rare sparkly inclusions, possibly mica.
Voids: vughs and planar voids have a fairly well developed long-axes orientation that is parallel to the vessel margins. Some vughs have no preferred orientation.
Vessel surface: striations on interior and exterior surfaces, possibly indicating that vessels were wheelmade. Exterior surfaces can also have "brush" marks. Lime spalls occur in some samples.
Wall thickness: 2–10 mm

Thin-Section Analysis

Microstructure

Few to absent megavughs, common to very rare macrovughs, frequent to rare mesovughs, and few to absent microvughs. Rare to absent megaplanar voids, frequent to rare macroplanar voids, frequent to few mesoplanar voids, and frequent to very rare microplanar voids. There is a crude long axes parallel orientation of the planar voids to the vessel margins. In some cases the planar voids can be aligned at an acute angle to the vessel margins, but are still parallel to each other. The coarse and fine inclusions are close- to double-spaced. There is a very crude long axes parallel orientation of some elongated grains to the vessel margins.

Groundmass

Fairly homogeneous. The clay fabrics are quite similar, but there is variation between the samples. The micromass varies from optically inactive to optically active. The color is generally dark brown in PPL (40×) and very dark brown with a red tinge in XP (40×). Some samples have differentiated cores and margins. Cores: dark brown in PPL (40×) and very dark brown with a red tinge in XP (40×); margins: red/orange/brown in PPL (40×) and orange/red in XP (40×).

Inclusions

$c{:}f{:}v_{10\mu m}$ = ca. 20:75:5 to 25:70:5
Coarse fraction = 2.5 mm to 0.1 mm (granules to fine sand)
Fine = 0.2 mm or less (fine sand and below)

The inclusions appear to have a gradational grain-size distribution from bimodal to unimodal. Moderately to poorly sorted. No preferred orientation of the grains, except crudely in the large elongate grains.

Coarse Fraction

Frequent to very few

Chert: a–sr. Equant to slightly elongate. Colorless to pale brown in PPL (40×). Some quartz veins cut larger grains. Others grade into cherty mudstones, or have remnants of radiolarian skeletons, grading into radiolarian chert. Mode = 0.5 mm long dimension.

Frequent to rare

Monocrystalline quartz: a–sr. Straight and undulose extinction. Equant to slightly elongate. Mode = 0.3 mm long dimension.

Common to very few

Polycrystalline quartz: a–sr. Inequigranular. Sutured contacts between quartz grains. Straight and undulose extinction. Equant to slightly elongate. Mode = 0.3 mm long dimension.

Common to very rare

Mudstone, in the following eight types (not all of which are present in all samples):

1. Gray brown mudstone: sa, approximately equant. Dark gray brown in PPL (100×) and gray brown yellow in XP (100×). No preferred internal orientation. Very few inclusions: monocrystalline quartz. Has some polygonal cracking. Resembles the classic Corinthian mudstone, but browner. Mode = 0.4 mm long dimension.
2. Gray mudstone: sr, approximately equant. Gray in PPL (100×) and yellow gray, optically inactive in XP (100×). No internal preferred orientation. Some cracking is evident. Looks very much like the classic Corinthian mudstone. Mode = 0.2 mm long dimension.

3. Gray mudstone with inclusions: sr, approximately equant. Gray matrix in PPL (100×) and yellow light brown in XP (100×), optically inactive. Contains inclusions of monocrystalline and polycrystalline quartz. Mode = 0.4 mm long dimension.
4. Yellow mudstone: sr, equant. Yellow light brown in PPL (100×) and yellow/orange in XP (100×). No internal preferred orientation. Very few inclusions of monocrystalline quartz and Fe-Ti oxides. Mode = 0.2 mm long dimension.
5. Radiolarian mudstone: sa, approximately equant. Gray brown in PPL (100×) and yellow brown gray in XP (100×). No internal preferred orientation. Mode = 0.25 mm long dimension.
6. Red mudstone: sa, approximately equant. Brown orange in PPL (100×) and red orange in XP (100×). No internal preferred orientation. Inclusions of monocrystalline quartz. Mode = 0.2 mm long dimension.
7. Brown mudstone: sa, elongate. Mid-brown in PPL (100×) and gray red brown in XP (100×). No internal preferred orientation. Inclusions: monocrystalline quartz and Fe-Ti oxides. Mode = 0.5 mm long dimension.
8. Mudstone breccia: sa, elongate. Overall light/mid-brown in PPL (100×) and yellows, grays, and oranges in XP (40×). No internal preferred orientation. Inclusions of monocrystalline quartz. Mode = 0.7 mm long dimension.

Sandstone, in the following four types:

1. Sub-arkose: sa, approximately equant. Composed of monocrystalline quartz and plagioclase feldspar. Little matrix (red clay). Inequigranular. Moderately sorted. Mode = 0.25 mm long dimension.
2. Quartz arenite: sa–r, elongate. Well-sorted, equigranular, monocrystalline quartz grains. Size = <1.1 mm long dimension. Matrix of red clay.
3. Sub-litharenite: sr, equant. Contains monocrystalline quartz, plagioclase feldspar, muscovite mica, chert, and Fe-Ti oxides set in a clay matrix. Moderately to well sorted.
4. Sandstone with a carbonate cement: sr. Contains monocrystalline quartz, plagioclase feldspar, and muscovite mica within a calcite cement. Moderately to well sorted. Mode = 0.9 mm long dimension.

Few to very rare

Calcimudstone (micrite): sa–r. Pale green/brown in PPL (100×). Slightly elongate. Mode = 0.7 mm long dimension.

Very few to absent

Schistose quartz: sa–sr, inequigranular with biotite laths between quartz grains giving a very crude alignment. Fe-Ti oxides also present.

Schist, in the following three types:

1. Quartz chlorite schist: sa, elongate. Stretched quartz grains show undulose and straight extinction. Intergranular chlorite laths are aligned with the long axes of the quartz grains and the long axis of the schist fragments. Mode = 1 mm long dimension.
2. Quartz biotite schist: a, elongate. Stretched quartz grains show undulose and straight extinction. Intergranular biotite mica laths are aligned parallel to the long axes of quartz grains. Mode = 1 mm long dimension.
3. Quartz muscovite schist: a, elongate. Stretched quartz grains show undulose and straight extinction. Intergranular muscovite mica laths are aligned parallel to the long axes of quartz grains. Mode = 1 mm long dimension.

Rare to absent

Oolitic limestone: sa–sr, equant to slightly elongate. Oval ooids of calcitic material set in calcite cement. Size = <0.6 mm long dimension.

Siltstone: sr, inequigranular. Quartz grains in a clay matrix.

Calcite: sa, slightly elongate. Mode = 0.2 mm long dimension.

Radiolarian skeletons

Fe-Ti oxide

Spinel

Very rare to absent

Plagioclase feldspar

Chalcedonic quartz

Alkali feldspar

Microcline

Olivine or pyroxene?

Muscovite mica

Altered granitic fragment

Olivine: pseudomorphed by serpentine

Limestone

Shell: possibly a lamellibranch?

Metagraywacke

Cordierite?

Fine Fraction

Dominant to common

Monocrystalline quartz: a–r, equant to slightly elongate. Mainly straight, but some undulose extinction. Mode = 0.05 mm long dimension.

Common to absent

Calcimudstone (micrite): sa–r, slightly elongate. Mode = 0.08 mm long dimension.

Few to rare

Polycrystalline quartz: sa, approximately equant. Inequigranular. Straight and undulose extinction. Mode = 0.08 mm long dimension.

Few to very rare

Chert: a–sr. Some with radiolarian skeletons: radiolarian chert. Mode = 0.08 mm long dimension.

Very few to very rare

Fe-Ti oxide: sa–r, approximately equant. Mode = 0.04 mm long dimension.

Very few to absent

Plagioclase feldspar: a–sa. Polysynthetic twinning. Mode = 0.1 mm long dimension.

Muscovite mica

Sandstone: quartz arenite

Rare to very rare

Hematite

Rare to absent

Gray brown mudstone

Red mudstone

Brown mudstone

Yellow mudstone

Biotite mica

Radiolarian skeletons

Quartz biotite schist

Very rare to absent

Gray mudstone
Pyroxene or amphibole?
Amphibole: green pleochroism
Orthoclase feldspar
Spinel
Glauconite
Calcite
Chlorite?
Epidote?
Chalcedonic quartz
Limestone
Ooid
Microfossils: foraminifera

Textural Concentration Features

Tcf = ca. less than 5% (of total field)

Six types of tcfs are present:

1. Very dark brown in PPL (40×) and very dark brown/gray in XP (40×), sr–r, equant. Size = <0.8 mm long dimension. Neutral optical density (ND) compared with the micromass. Boundaries are diffuse. Prominence is faint. Internal fabric is not oriented. Fabric is concordant with the micromass. Contain inclusions of monocrystalline quartz and chert. Possibly clay pellets.
2. Mid-brown in PPL (100×) and red/orange in XP (100×), wr. Mode = 0.25 mm long dimension. Inclusions of monocrystalline quartz, Fe-Ti oxide, and chert. High optical density (D+) compared with the micromass. Prominence is distinct. Boundaries are clear to diffuse. Discordant with the micromass. Crude internal orientation. Probably clay pellets.
3. Black in PPL (40×) and black with red-tinged margin in XP (100×), r. Size = <0.8 mm long dimension. Contains monocrystalline quartz. High optical density (D+) compared with the micromass. Prominence is prominent. Boundaries are sharp. Discordant with the external micromass. No internal preferred orientation.
4. Mid-brown in PPL (100×) and orange brown in XP (100×), r. Size = <0.5 mm long dimension. Inclusions: monocrystalline quartz and plagioclase feldspar. Neutral optical density (ND). Prominence is faint. Boundaries are merging. Concordant with the micromass. Internal orientation similar to the micromass. Probably clay pellets.
5. Dark red/brown to orange brown in PPL (40×) and dark red/brown/black in XP (40×), wr. Size = <0.9 mm long dimension. Mode = 0.5 mm long dimension. Contains a few inclusions of sandstone, monocrystalline quartz, chert, muscovite, and biotite mica. No internal preferred orientation. Optical density is a little higher than the micromass (D+). Prominence is faint. Boundaries are sharp to merging. They are discordant with the micromass. Probably clay pellets.
6. Orange in PPL (100×) and bright orange yellow in XP (100×), sa. Mode = 0.4 mm long dimension. Inclusions: monocrystalline and polycrystalline quartz. Low optical density (D-) compared with the micromass. Prominence is distinct. Boundaries are clear. Concordant with the micromass. Possibly clay pellets.

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