

5 Fabrics: clay types

The hypotheses concerning the composition and properties of the pottery fabrics were presented in chapter 2.5, together with the main types of variables and the methods for observation. This chapter deals with all variables for the raw material, except the temper, which is the subject of chapter 6; all pottery in the samples is tempered with organic material. The analyses consist of three parts, *the type of clay, the type and amount of nonplastic and plastic natural inclusions, and of quartz particles*. Some preliminary remarks on the firing methods are included here, because the firing process determines the visibility of several of the variables used and the overall fabric characteristics and properties. The actual analysis of firing methods is presented in chapter 6. To repeat, the main questions are the following:

- Are there significant differences in the overall mineralogical and chemical composition of the clays used for the pottery in each of the sites.
- What is the nature and/or effect of the several forms of plastic and nonplastic inclusions, including quartz particles in the clays; were clays selected because of the presence of such inclusions.

The variables and methods used for each part of the analyses are presented in detail in each section. The analysis of natural inclusions in the clays is divided into two sections, one for quartz particles and one for all others, because the methods of analysis were different. Most observations and measurements are carried out on—sherds from—the pottery itself. For a small sample of sherds, the chemical composition was established by Röntgen-fluorescence and Induced Coupled Plasma techniques. The level of precision and detail of observation is low, as much as possible geared to possible knowledge and criteria of potters (chapter 2.4-6); it was also attempted to use simple methods which can be applied by any archaeologist and replicated for other pottery assemblages. The test clays played an important role in defining the types of clays used for the pottery and in the analysis of firing techniques. In paragraph 4 a more detailed comparison of the pottery fabrics and the test clays for all variables is presented.

Sample size

The main sample for *Uitgeest* consists of 126 sherds from the vessels in sample 1 (table 3.1). For the counting of the

quartz grains in the fabric, an additional sample of sherds was analyzed as well (n=52), mostly from the creek fill and some other features with quite a lot of pottery. For all other variables, the sample of 126 refired sherds is used.

The sample of *Schagen* consists of 108 vessels, of which 95 or 96 were used in the fabric analysis¹.

Preliminary remarks on firing methods

The techniques used for firing pottery, although the last step in the making of pottery, determine to a large extent the properties and characteristics of the fired product. The main variables involved are (a) the maximum temperature, (b) the rate of temperature increase and (c) the atmosphere around the pottery, the amount of available oxygen and (d) the duration of firing. Together, and in combination with the type of clay, these factors determine the colour, or colours, of the surfaces and the core of a vessel. As discussed in chapter 2.4, the amount of iron and the ratio of Ca : Fe are the main determinants for the colouring; everything else being equal, the percentage of iron will cause any shade of buff at lower firing temperatures, through orange, red and brown, to purple with higher temperatures under *oxidizing* circumstances (see chapter 4, fig. 4.1). The amount of oxygen available and the length of the firing have a significant influence on the degree of oxidation and therefore on the *brightness of the colours*, especially when the fabric contains organic material. The combustion of organic matter takes place first and in this process even the oxygen bound to Fe-compounds will be used. The oxidation of the minerals in the clay takes place *after* the organic matter is completely carbonized, starting at the surfaces. The complete combustion of organic matter takes place between roughly 400 and 600 °C (*Keramiek* 1973; Johnson *et al.* 1988). Altogether, the colours and their brightness in pottery with organic temper can therefore be used as an indication for the firing atmosphere, the degree of oxidation of the minerals in the clay and to some extent for the maximum firing temperature (abbreviated to T-max.).

5.1 Clay composition

5.1.1 METHODS

The 126 sherds in sample 1 from *Uitgeest* and 96 of *Schagen* were refired at 950 °C. This temperature was chosen as

the lowest possible that would allow the discrimination of different types of clay in the pottery by colour comparison with the test clays, but before too great a change was expected to occur in the composition of the clay matrix and/or inclusions.

Clay types

The type of clay used for the pottery was defined in the following way. The *colours* of both the core surface and exterior surfaces of the refired sherds were compared to those of the test clays, fired at the same temperature. The best matching test clays were recorded for both surfaces. The positive results of the first comparisons between clays and pottery suggested that this method would be a reliable and quick way of classifying the types of clays used by the prehistoric potter. Two problems were encountered, however, especially in the case of the Schagen pottery. Firstly, in the majority of the sherds the colour of the surfaces differ from that of the core, the former usually being lighter and paler (fig. 5.1-2); the surface colour is nearly white in some cases, while the cores are mostly pale orange to red². Such differences can be caused by several factors, for example by the formation of a scum layer during drying (see Jacobs 1983) or by changes in the chemical composition after deposition. Secondly, a large number of sherds clearly show secondary, postdepositional changes in the form of infiltration of iron and manganese oxides. This was already visible in the original vessels as a rust-coloured line around the edges of sherds (fig. 5.1.3). In both the original and refired sherds these secondary depositions of Fe and Mn occur not on, but *just below the surfaces*. In sherds in the Schagen sample, the sometimes extreme infiltration took place throughout the core (fig. 5.1.2). It is quite possible that the same process also altered the chemical composition and therefore the colour of the surfaces.

Chemical alterations of fabrics related to the depositional context have been studied by several authors (see Franklin & Vitali 1985; Heimann & Magetti 1981; Maniatis *et al.* 1983). The results indicate that such changes are likely to have occurred in any pottery complex and certainly in the low-fired and porous fabrics of most prehistoric pottery; this presents a serious problem in the interpretation of elemental analyses, as the degree of such alterations usually cannot be established. The study by Freestone *et al.* (1985, 172-174) is particularly helpful in interpreting the changes observed in the pottery from Uitgeest and Schagen. They examined the retention or precipitation of phosphates in several types of fabrics. A significant increase in the amount of phosphates as well as iron was observed especially in the surface layer; depending on the porosity of the fabric, these compounds were also found in the core of the sherds and around voids. The phosphates were mainly formed with calcium, which

could have dissolved from the pottery itself. The explanation of Freestone *et al.* is that a fired clay has an increasing capacity to retain phosphates and iron, because of the amorphous silicate phases produced during firing³.

The postdepositional changes clearly complicated the matching of sherds and test clays and even made this impossible in some cases. The core surface of the refired sherds was therefore used as the primary variable for the definition of the clay types. The colour of the exterior surfaces was used as an additional indication only. The sherds were assigned to one of the three groups distinguished in the test clays (fig 4.2; table 4.2; see note 2) with the following definition:

- clay type 1:* Uitgeest: similar to test clay 61 and 65
Schagen: all sherds with extremely intense Fe infiltration
- clay type 2:* similar to clay 62 and 64, 81 for both samples
- clay type 3:* similar to clay 63 and 60, 82 for both samples

For Uitgeest, sub-types were distinguished initially for sherds with secondary deposition or for cases that fitted clay type 1 and 2 equally well (table 5.2), but these were dropped in the subsequent analyses. For the sample from Schagen, the secondary infiltration with Fe and Mn was often so intense that the type of clay could not be established. These sherds were all classified as 'clay type 1'. The definition of clay types 2 and 3 is the same as for Uitgeest.

Surfaces

The surfaces of both the original and the refired sherds were also used to record evidence for the presence of a scum layer, of a so-called 'double' surface, and for observations on their textures. All three variables together may be indicative of a high Ca-content of the clay. The definitions were based on the following observations. As mentioned above, some relatively well oxidized vessels had a very pale, light yellow to nearly white colour; when the texture was also chalklike (and staining like chalk) these features were recorded as a possible indication for a Calcium-rich clay. The difference with a scum layer was not always clear. Scum is a whitish layer *on*, not *in*, the outer surface, caused by the recrystallizing of salts in the clay during the drying of the vessels. If it is not wiped off, such a layer further solidifies during firing. A scum layer could usually be distinguished from a so-called 'double-layered surface'. The latter consists of two layers, a light yellow one on the outside with a bright orange to red-purple layer underneath. The thickness of both layers seldom exceeds 1 mm. This type of surface is a recurring feature in indigenous pottery from North-Holland⁴. It is not at all clear

why this occurs and why on the surface only. Jacobs (1983) carried out an experiment with iron-rich clays to establish the cause of the loss of colour in the surface layer or in the core in pottery from Near Eastern sites. The major factor for a pale surface is the presence of CaCO_3 and the formation of a scumlayer, in combination with the firing temperature. In one of the test tablets, however, the presence of CaSO_4 and NaCl resulted in an *increase in iron*, in redness, in the surface layer. This result seems to correspond with the 'double' surfaces in the Dutch pottery, although the presence of a lighter surface on top of this Fe-rich layer is not mentioned. It is, however, also possible that the very light coloured surfaces are the result of postdepositional chemical alterations; the lighter colours could hypothetically be caused by the formation of Ca/P compounds or by the leaching of minerals from the surface. These changes are discussed in paragraphs 1.3 and 4.

Chemical analyses

Nine sherds from Uitgeest and thirteen from Schagen were analyzed by Induced Coupled Plasma (ICP) techniques, to establish the chemical composition; five sherds for each site were analyzed by X-ray fluorescence (XRF) for the relative amount of Calcium and Calcium-oxides in the clays. The data should provide an independent check on the identification of types of fabrics for both pottery complexes, in comparison to the test clays (chapter 4; table 4.3). The selection of sherds was based on the first results of the fabric analysis; variations in the amount of quartz, the type and amount of inclusions and the indications for Ca-rich clays were the main criteria (table 5.1)⁵. Secondly, microprobe analyses were carried out for a few sherds from Texel-den Burg to measure the Fe- and Ca-content in the 'double surfaces' (van Haaren 1991). The sherds from Texel were selected, because they showed such surfaces very clearly. The sherds were refired to 850 °C before the analyses, to exclude influences of the firing temperature and atmosphere and of the organic temper⁶.

5.1.2 CLAY TYPES, UITGEEST

Refired sherds

Of the sherds with clearly defined clay types (1, 2, 3), the highest number was assigned to clay type 2 and the lowest number to clay type 1 (table 5.2). The number of sherds with the addition .1 (referring to Fe infiltration) is quite high for these two groups, but low for group 3. Group 1.2 represent sherds that were equally similar to clay type 1 and 2. The subtypes were assigned to the main types in most tables, to have larger numbers of cases in the cells; the effect of the infiltration is thus disregarded. Group 1.2 was added to group 1 as well, based on other fabric characteristics, especially the type and amount of inclusions. Clay types 1 and 2

are both represented in about equal numbers, while clay type 3 is present in a smaller number of cases (n=30).

Within group 1, most sherds are similar to clay sample 65 and 62, while a similarity with clay sample 61 occurs only incidentally. Those in group 2 are similar to clay samples 62 and 64. The sherds in group 3 are most similar to test clay 63 and occasionally to clay 60 and 82. Thus the majority of the pottery of Uitgeest is made of clay types 1 and 2, defined by the clay samples 62, 64 and 65. These three clays are themselves quite similar in composition; the Ca : Fe ratio is less than 1. This does not mean that the absolute content of Fe and Ca is also similar, as the test clays made clear, only that clays with a higher percentage of CaO or higher Ca : Fe ratio, represented by clay type 3, were used much less frequently. The apparent porosity curves at different firing temperatures (fig. 4.2, 4.3) are also quite similar, especially for clay samples 64 and 65; that of clay 62 is lower for temperatures up to 950 °C, while that of clay sample 63 is slightly higher (clay type 3). See also paragraph 4.2 for a more detailed comparison with the test clays.

Chemical composition

Table 5.3 shows the results of the XRF and ICP analyses for the main elements, together with data on secondary infiltration and clay types for the nine sherds examined (see table 5.1). The percentage of CaO and the amount of Ca is variable. The values of the amount of Ca (ppm) are most similar to those of clay samples 62 and 64, which were defined as clay type 2, but are not as high as in clay samples 65 or 63. There is no clear relation with the presence of Ca-rich inclusions, as defined in the original sherds, except perhaps in sherds 31-6 and 31-10. Vessels 19-10 and 35-37 both show a Ca-rich fabric by the variables for the surfaces and the Ca-content is also high, but for the vessels 31-6 and 35-33 the amount of Ca does not correspond with the classification of the clay types. This can partly be explained by the influence of the infiltrated Fe-oxides. The Fe-content varies between 26470 and 40973 ppm which corresponds with those of clays 65, 81 and 82 (also with a high percentage of CaO). The secondary infiltration with Fe, however, has clearly added to the values, notably in vessels 14-7, 19-10, 20-2, 31-6 and 31-10; this is also indicated by the rather high values of Mn, which is probably secondary as well, in these sherds. The postdepositional changes probably caused some sherds to be classified as less Ca-rich than is actually the case. In other sherds, like 18-2, the Fe concretions might have influenced the Fe value.

In all cases, the amount of iron is higher and the amount of calcium is lower than in clay 63, 81 and 82, also in the three sherds that were classed as clay type 3. Compared to the test clays, the P and S contents of the sherds are rather high as

well. According to van Haaren (1991), the phosphates are linked to the iron oxide as Fe/P mineral compounds. The very high S content of some sherds could theoretically be indicative of organic material, but the refiring to 850 °C in an oxidizing atmosphere before analysis will have removed any such remains. More likely the high amount of S, as well of Fe and P, is due to chemical changes in buried ceramics, as were discussed above, perhaps together with a leaching of calcium oxides.

Taking all of these factors into account it can be concluded that the nine sherds show a reasonable match with the clays 62, 64 and 65, that is to clay types 1 and 2, to which most of the sherds were assigned. But this match is to some extent co-determined by postdepositional changes. Of the clays collected from the vicinity of the settlement, type 81 was not and 82 only occasionally present in the sample.

5.1.3 CLAY TYPES, SCHAGEN

Refired sherds

Group 1 is defined by the intensity of secondary Fe infiltration; the original clay type cannot be established. The remaining sherds were assigned to types 2 and 3 (table 5.2b). Nearly half of the pottery is made of clay type 2. The subtypes were added to the main groups by the same criteria as used for Uitgeest. More than half the pottery is made from clays similar to samples 62 and 64. Again the number of vessels in group 3 is rather low, 9 cases or 15 when group 1.3 is added, maximally 20% of all vessels. Considering the distribution within group 2 and 3, it is not unlikely that most of the sherds in 'class' 1 would have been classified as group 2.

Clays 62, 63 and 64 were collected from the site itself during excavations. As clay 62 contained fine shell fragments which were not present in the pottery, the best match for the majority of the pottery is clay 64. This clay was extracted from the same layer reached by a series of -clay extraction-pits and it is therefore likely that some of that clay was indeed used for the production of pottery.

Chemical analysis

Table 5.4 shows the results of the chemical analyses in combination with clay type and secondary changes within the sherds. The most important conclusion to be drawn is that the data are clearly influenced by the secondary deposition of Fe and Mn. Sherds with extreme infiltration also have extremely high rates of Fe and/or Mn. As a result, no conclusions can be drawn about the amount of Fe originally present in the clay or about the Ca : Fe ratios. The sherds with little infiltration seem to fit into the range of the Fe content of clay 65, which is much higher than that of the clay samples from Schagen. The percentage of CaO and amount of Ca in all sherds however fits well into the range

presented by clay 62 and 64 and is much lower than that in clay 63, although only one sherd of clay type 3 was examined. Most of the sherds have a very high phosphor content compared to the clays and in some cases a high sulphur content. There also is a correlation between the amount of Sr and Ca. Possible explanations for the high P and S contents were given above for Uitgeest and apply to the Schagen pottery as well. In this case there could also be a connection with the specific composition of the ground water due to the peaty environment during and after occupation.

Clay type, postdepositional changes and pottery contexts

The intensity of iron infiltration in the pottery is quite clearly connected with the specific depositional context (Table 5.9a). The pottery recovered from pits shows less secondary Fe and Mn than the pottery from surface features such as hearths, the concentration of pottery refuse along the house and the cremation urns (fig. 3.8). There is no significant relation between secondary deposition in relation to the two areas distinguished in the site, North and South. The infiltration clearly is of a postdepositional date. Although it is difficult to say whether this was a recent process or took place directly after deposition, the latter seems more likely. The pottery data can even be used to reconstruct the specific postdepositional conditions at the site⁷. The Fe and Mn must have been present, in a reduced form, in the ground water in large quantities in this peaty area. During the occupation, the pits were probably filled with water, preventing the oxidation of Fe in the sherds. For the pottery to be infiltrated with Fe and Mn at the old land surface, the level of the water-table must have been as high as that surface; this suggests that the infiltration took place after occupation. It is possible that the site became waterlogged and/or that peat growth continued after the Roman period, due to a rise in the water-table. Both processes could be related to the Dunkirk-III transgression in the Medieval period. The oxidation of the minerals must in both cases have occurred *after* the water-table was lowered again. Still it is surprising to see such an amount of iron oxides formed throughout the vessel walls. Quite likely, the high permeability of the fabrics is one important factor⁸.

The pottery made of clay types 2 and 3 also shows a slight difference in distribution over the site, although the sample is too small for statistical testing (table 5.9b). About 32% of the pottery in the southern area and only circa 10% in the northern area was made of more calcareous clays like sample 63. In both areas there is a link with the feature context: this pottery was found in pits only (table 5.9c). A chronological difference is highly unlikely. There could be a connection with the processes described above, in that not only infiltration took place but also, possibly simultaneously, the removal of minerals through leaching. This should have

happened, however, to all pottery within a pit, which is not the case. It is also possible that different clay winning pits were used for this special pottery. As the sample size is much too low, these interpretations are as yet highly speculative but they are plausible considering the specific conditions and depositions at the site. Part of the answers might be provided by the other indications for Ca-rich clays, presented in the next paragraph.

5.1.4 INDICATIONS FOR CALCIUM AND SALTS IN THE CLAYS; 'SPLIT' SURFACES

The presence of scum and texture of the surfaces were recorded as indications for differences in the Ca-content and salts in the clays; the 'double'-coloured surfaces can have different origins, but could also be an indication for a higher Ca : Fe ratio (see fig. 4.1b). There is a clear relation with the firing atmosphere: double surfaces are visible only when the surface of a vessel has been sufficiently oxidized. Examples were shown to several experts (among them L. Jacobs, FAL, and A. Bruyn, ROB), who agreed that the following explanation could be correct. It seems likely that a separation of elements or minerals took place within the surface layer. As the outer layer has a lighter colour—mostly off-white—than the overall matrix, it might contain more calcium, or vice versa, this part of the surface might be depleted from Fe, which was concentrated in the second layer. The question is when and how this happened: when the vessel is drying, in the same way a scum layer is formed, or by the oxidation and recrystallisation of Fe and/or other minerals at different temperatures or stages during the firing process? Such a process might be directly linked to the use of organic temper, which determines the amount of oxygen available during the firing (chapter 6.8). Microprobe analysis was carried out on such surfaces to determine the chemical composition of the two layers (van Haaren 1991).

Uitgeest

The presence of a scum layer was noted with certainty in only 14 cases, the presence of a double surface in 11 cases whereas indications for a Ca-rich clay were noted for 26 cases. For all three variables the number of cases with a 'possible' scum, Ca-rich clay and double surface is quite high, respectively 28, 22 and 29 cases (table 5.5.1a). The uncertainty is caused by several factors: the state of preservation of the surfaces, changes of these surfaces due to use and the problem of distinguishing between the light, yellowish-white colour of the surface itself and a scum layer on the surface. The variables *scum* and *Ca* are co-varying to a certain extent; this was to be expected as the underlying variable is the amount of Ca and salts in the clays which can appear in different forms in the pottery. Combining both

variables, a Ca-rich clay is indicated in circa 30% of the vessels of Uitgeest; contrary to expectations, there is no clear correspondence to clay type 3 (less than 25%), nor for that matter with the other types. 'Double' surfaces also represent circa 30 % of the pottery, again without a clear relation to clay type. Finally, there is no relationship between these variables and the context. Obviously, the number of reliable observations is too small for statistical testing. For these reasons, these variables were not used in subsequent analyses.

Schagen

Scum was definitely present in 5 cases, indications for a Ca-rich clay in 23 cases and for a 'split' surface in 13 cases (table 5.5.2a). As for Uitgeest, the recorded 'possible cases' for these variables are quite high, 25, 11 and 12 respectively. The total of these scores represent circa 30%, 25% and 15% of the pottery. These percentages are lower than for Uitgeest, but observations were also more difficult because of the often badly preserved surfaces of the Schagen vessels. No clear relation exists between these variables and the types of clay.

5.1.5 MICROPROBE ANALYSIS

Because the 'double' surfaces occur regularly in the indigenous pottery from several sites in North-Holland, most clearly in that from Texel, den Burg (Lems 1989) and Schagen, thin sections made of three sherds from den Burg were tested by microprobe analysis (van Haaren 1991); a sherd without such a surface was used as a control⁹. The thin-sections were refired to 600 °C to remove the organic material. The Electron Microprobe can analyze the chemical content of very small and thin surfaces, through a focused electron emission, which induces X-rays; the results are presented as distributions of the various minerals through the sherd wall (see Freestone 1982); these linescans are based on variable measuring 'distances' to avoid the overrepresentation of the matrix components¹⁰.

The results partly answered the two questions (a) is there a difference in the chemical composition between the two surface layers and (b) can the outer layer be considered as a kind of scum layer, consisting of Ca-rich minerals or (other) salts. There is indeed a moderate to strong increase of the Fe content in the surface layers (in respectively 2 and 1) of the sherds, although the values are not much higher than those in the core. However, just below the surface the Fe and P contents are clearly lower. The control sample showed no signs of either an in- or decrease of Fe or Ca in the surface layers. This may indeed point to a 'movement' of Fe from just below to the surface layer. There is also a clear covariation between the distributions of the Fe- and P-contents, indicating postdepositional chemical changes (see

Freestone *et al.* 1985). The analysis of the 'double' surface layer did however not show up any locational difference in chemical composition. In one sherd a slight increase in Ca-content was found in the surface, but this occurred at the same level as the Fe increase. This is difficult to explain when in the sherds the separation in two layers is so clearly visible, and it is possible that the two layers were not discriminated in the spacing of the scans (see note 10). The measurements of the amount of Ca, K, Mg and Na through the sherd wall produced rather puzzling results. In two samples (113-5 and 113-23), the amount of these minerals varies considerably across the wall of the sherds. In the second sample, the K-content is strongly reduced and the Ca and Na-contents are increased in the surface layer. It is therefore possible that not only Ca, but also K, Mg or Na-compounds, in other words any type of salts, are involved in the formation of the 'double' surfaces. The two line scans made for the third sample gave conflicting results and are not interpretable (see note 10).

Although very limited in scope, this research indicates that irregular concentrations of certain minerals do occur, that there is a certain increase in Fe, together with P, in the surface layers and that iron and perhaps other elements like Ca, K and Na are to some extent mobile elements in clays; this is conform the results of Freestone *et al.* (1985) and others. When the dis- or replacement took place, during drying or firing or when the pottery was buried, cannot be concluded from the microprobe results; both processes may be represented in the tested sherds. Further analyses of the results and more tests must take place before the observed phenomenon can be explained satisfactorily.

5.1.6 SUMMARY

The evidence of test clays, refired sherds, and observations on the original vessels together allow some conclusions to be made about the samples of pottery fabrics. *Firstly*, slight differences in the amount of Ca, Fe, and possibly K and Na result indeed in slightly different overall colours, depending on the firing temperature. The use of refired sherds is therefore a good starting point to infer data on overall—variations in—chemical composition. *Secondly*, refiring helped to determine the postdepositional changes in the chemical and/or colour composition. *Thirdly*, the clays used for the manufacturing of pottery are very similar both within and between each site; most of the pottery was made from clay types 1 and 2, that is similar to the clay samples 62, 64 and 65. These clays all have a Ca : Fe content ratio lower than 1 (the amount of Calcium is lower than the amount of iron), although the CaO percentage is variable. The apparent porosities are also similar. Fabrics similar to the clays with extremely high or low amounts of Ca or Fe, like clay samples 61 and 82, do not occur in the sherd samples. At the

same time there are indications that the potters preferred a clay with slightly more Ca, and/or a slightly higher Ca : Fe ratio of 1.0-1.5, above one with high amounts of Fe, like test clay 61. This type of clay was seen only sporadically in the pottery, whereas clay type 3, mainly clay 63, did occur regularly. This 'preference' could have been determined by the composition of locally available clays; for both sites the clay deposits are nowadays relatively rich in Calcium. The indications for the presence of scum and calcium-compounds support this conclusion to some extent. On the whole, these variables were, however, of little use in determining the clay types. The observations are too dependent on the firing methods, the preservation and secondary alterations of and on the surfaces. Moreover, all analyses of the clay types were hampered by postdepositional changes in the elemental composition of the fabrics; especially the enrichment with iron, together with phosphates and sulphides affects the results both of the macro-observations and of the elemental analyses. Only by combining several types of observations on original and refired sherds, some minimal results were obtained.

5.2 Natural inclusions

5.2.1 INCLUSIONS IN SOILS AND IN POTTERY

Iron-rich concretions, Fe-inclusions, for short, occur regularly in most soils in the Western Netherlands. They are formed by the oxidation of Fe, which is present in a reduced form in the ground water, in the zone just above the fluctuating water-table where oxygen is available and/or by oxygen supplied along roots of plants, worm holes etc. Unless the prehistoric potters cleaned their potting clays, these are likely to have contained Fe concretions. An alternative but unlikely possibility is that the concretions were not present in the clay, but were added by the potters on purpose.

Although Shepard (1963) already wrote a separate paragraph on Fe-inclusions, they have been largely ignored in archaeological studies. Ms V. Shelton Bunn was the first to recognize such inclusions in the Assendelver Polder pottery (internal report, IPP) and to point out *that they have been confused with 'grog' temper*. They are present in most pottery from both sites and indeed are a much more common feature of pottery from all periods and regions than hitherto recognized, like, for example, in pottery from Denmark (pers. comm. M.L. Stig Sørensen). The latest example of misinterpretation can be found in Van Heeringen (1992). The main reason for this confusion is that the visibility of Fe-inclusions is dependent on the degree of oxidation of a fabric. Only when the iron is oxidized do Fe-inclusions show up as such. This is usually only the case on the exterior surface of sherds, whereas they may be present in a reduced and hence invisible form in the core. Pottery fired under

neutral to reducing circumstances may mislead the archaeologist, but the Fe-inclusions will show up after refiring in oxidizing circumstances. There is moreover a clear difference in form and structure between Fe-inclusions and grog: obviously the latter is made up of crushed potsherds and therefore much more angular and often larger than Fe-inclusions. Grog also will have the same texture and colour as the clay to which it was added, unless a completely different type of pottery was used. Fe-inclusions on the contrary are mostly round, they have a different texture than the fabric itself and are much softer. Once recognized, the distinction between grog and Fe-inclusions is very easy to make. It is hoped that this study will contribute to ending the misinterpretations.

Calclitic or calcium-rich nodules, or Ca-inclusion, occur in varying forms and compositions in soils. They have been described by Bullock *et al.* (1985, 122-5). They are formed mainly by soil formation processes and/or by changing water-tables. Calclitic nodules are likely to have been present in the marine clay deposits in and around both sites, probably in various forms such as carbonates, sulphates and/or shell fragments. The latter were present in the Calais IV B deposits in Schagen, but not in the Dunkirk I clays around Uitgeest, except at a very deep level.

Argillaceous inclusions or clay pellets, to be referred to as A-inclusions, are also commonly formed in soils and in pottery. They apparently contain no concentrations of specific minerals other than present in the clay itself. They are due to the inhomogeneous nature of the raw materials (Bullock *et al.* 1985; Whitbread 1986). Strictly speaking these are 'plastic' inclusions when occurring in pottery. According to Jacobs (pers. comm.) many clays contain such clay pellets especially when the clay is very plastic and fine, as is the case in Schagen. They remain as separate lumps even after kneading a clay thoroughly. For that reason they are treated in the same manner as nonplastic inclusions in this study.

5.2.2 METHODS

The analysis concerns *macro-sized* inclusions only, roughly those larger than 1 mm. The three types defined above are present in the pottery of both sites. The definitions for the pottery are based on the colours, the texture and to a lesser extent on form and size visible in the exterior and the core surfaces (see fig 5.1c for examples of each type). For the A- and Ca-inclusions both the original and the refired sherds were used. Since in the original pottery Fe-inclusions are visible only when the surfaces were oxidized sufficiently, data on this type of inclusion can be recorded consistently only for refired sherds.

– An orange to red colour in oxidized parts of the surfaces or in the refired sherds was taken as an indicator for

Fe-inclusions. Their form is mostly rounded, the texture is solid, but softer than that of the matrix.

– Concretions with an off-white colour, varying from light grey to light yellow, were defined as Ca-inclusions if the texture was porous. They are usually round to irregular in shape and vary considerably in size. This type of inclusions often left cavities on the surface. The colour, always lighter than the matrix, is independent of the firing atmosphere.

– As A-inclusions were defined all clay pellets with more or less the same colour and texture as the overall clay matrix but still clearly distinguishable as separate 'lumps', especially in the core of the sherds; the colour and texture should also be more or less the same as the overall matrix after refiring. On the surfaces these A-inclusions can be porous and light and are then difficult to distinguish from Ca-inclusions¹¹.

It should be noted that the definition of Ca-inclusions was based on their specific colour and texture in combination with the overall fabric characteristics. Whether the main element in these concretions is formed by Ca or by some other element, like Na, Mg, K cannot be decided on the basis of the data available¹². It was also often difficult to distinguish between Ca-inclusions and clay pellets, especially on the surfaces of the original vessels. The refiring of sherds did not solve this problem, but compounded it; when A- and Ca-inclusions could be clearly distinguished in the original sherd, the distinction was often much less clear in the refired sherd. The methods were adapted to this problem, by recording them as a combination of Ca/A-inclusions.

The maximum size was measured for each type of inclusion. The measurement of their quantities proved to be quite difficult. In general, the original vessels contained more and larger sized inclusions than the refired sherds. The Ca-inclusions were often not visible after refiring; also, the distinction between Fe- and other inclusions was partly obscured because some inclusions showed combinations of colours after refiring. Various methods were tried, but the data presented here are mainly based on observations on the cores of the refired sherds, because these at least can be compared for all sherds. Because of the differences in type and quantities of inclusions in the samples of Uitgeest and Schagen, the classifications also differ slightly.

Method Uitgeest, refired sherds

Clear Fe- and A-inclusions were noted as such. When the type was not clear and could be either Fe-rich or A-nodules (clay pellets), the inclusions were recorded as Fe/A-inclusions. The inclusions in refired sherds were defined as Ca-rich when they still retained a grey colour within the now pale orange to red matrix, and had a more or less porous

structure. All of the refired sherds with this type of inclusion also had Ca-inclusions in the original vessel. The sherds were then assigned to one of four groups¹³:

Group 1: Sherds with inclusions which consist partly or totally of clearly defined Fe-concretions.

Group 2: Sherds with A-inclusions, with or without Ca-inclusions.

Group 3: Sherds with a combination of different types of inclusions (Fe- and A- and/or Ca-inclusions).

Quantities of inclusions

The quantities of inclusions also are based on measurements on the core of the refired sherds. For sherds in group 1, the number of clearly definable Fe-inclusions measuring ≥ 1 mm were counted over an area of circa 3×3 cm. The maximum size was noted as well, also for other inclusions if present. For sherds in group 2 the amount of clear A-inclusions ≥ 1 mm was counted in the manner described above. If clear Ca-concretions ≥ 1 mm were present these were also counted. For sherds in group 3 all inclusions ≥ 1 mm were counted together. In the statistical tests the total number of all inclusions in each sherd was used.

The minimum size was chosen for several reasons. Firstly, virtually all sherds, including those that did not show any in the original vessel, contained Fe-inclusions, often measuring less than 1 mm. These inclusions do not form a 'variable' as the larger sized inclusions do. Therefore, counting all concretions independent of size would not add significant information about the clays used, but would indeed add significantly to the time involved in quantification.

Secondly, the limit of 1 mm and an area of 3×3 cm correspond to that used for the temper and for the same reasons; the definition of 'coarse' and 'fine' is therefore comparable for both temper and inclusions and so are the actual amounts. Clearly, this method is rather imprecise in mathematical terms and only provides a rough estimate for the amount of inclusions, but it should be sufficient for the purpose of this study.

Method Schagen

The criteria for the types of inclusions are the same as described above for Uitgeest, but proved to be much harder to apply in practice because of secondary changes. Secondary iron infiltration took place not only in the clay matrix but also in and around the inclusions. The abundant A-inclusions were often 'stained' with Fe after refiring; these were described as A/Fe-inclusions. It was also difficult to distinguish between the Ca- and A-inclusions in the Schagen fabrics, both in the original and refired sherds. The texture varies from porous to solid, there is a large variation in shape and size, and the difference from the matrix can be quite vague (fig. 5.3). After refiring, hardly any of the sherds

contained clear Ca-concretions. Vice versa, Fe-inclusions were hardly seen in the original pottery surfaces, but nearly all of the sherds showed some after refiring, although mostly 1 mm or less, or as A/Fe inclusions.

Because of the definitional problems, a different classification system was used for the pottery of Schagen, based on the combinations of clay pellets with other types. Groups 1, 2 and 3 all contained A-inclusions, but they differ in the presence and relative amount of other specific types of inclusion.

Group 0: Sherds with only very few or no inclusions of any type.

Group 1: Sherds which besides A-inclusions also contain clearly defined Fe-concretions ≥ 1 mm.

Group 2: Sherds with A-inclusions which have the same structure and more or less the same colour as the matrix. This group also includes sherds with possible Ca- and A/Fe-inclusions.

Group 3: Sherds with inclusions which have a texture different from the matrix; they are very porous, irregular in shape and often lighter than the matrix.

These rather vague and descriptive definitions and this way of classifying were the best possible solution, feasible within this research. For the final grouping, all sherds were compared visually as well. Inevitably, the assignments are questionable in some cases. For the same reasons, counting the quantities of inclusions was abandoned after a try-out on a subsample. The heterogenous fabric with the large number of possible inclusions and the often unclear edges made this effort rather pointless. Instead, the maximum size of the inclusions is used in some of the tables; the hypothesis is that the rather large sizes may have had some influence on the apparent porosity and/or on the type or amount of temper added by the potters.

5.2.3 RESULTS

Uitgeest

The composition of the sample for the three types of inclusions and three classes of their quantities can be found in table 5.5.1b and fig. 5.2a. These data represent observations on the refired sherds. In only 11 of these inclusions were absent. Fabrics with *mainly* Fe-inclusions form 30% of the sample. These inclusions were present in most sherds, but those measuring ≥ 1 mm occurred in 55 % of sample I (n=65). This is a conservative estimate for the abundance of Fe, since only the concretions ≥ 1 mm are included. The largest number of sherds (53) contain a combination of different types. A-inclusions were present in about half of the original sherds, but form the main type (together with Ca-inclusions) in only 21 % of the refired sherds. The number of sherds with definite Ca-inclusions in the refired

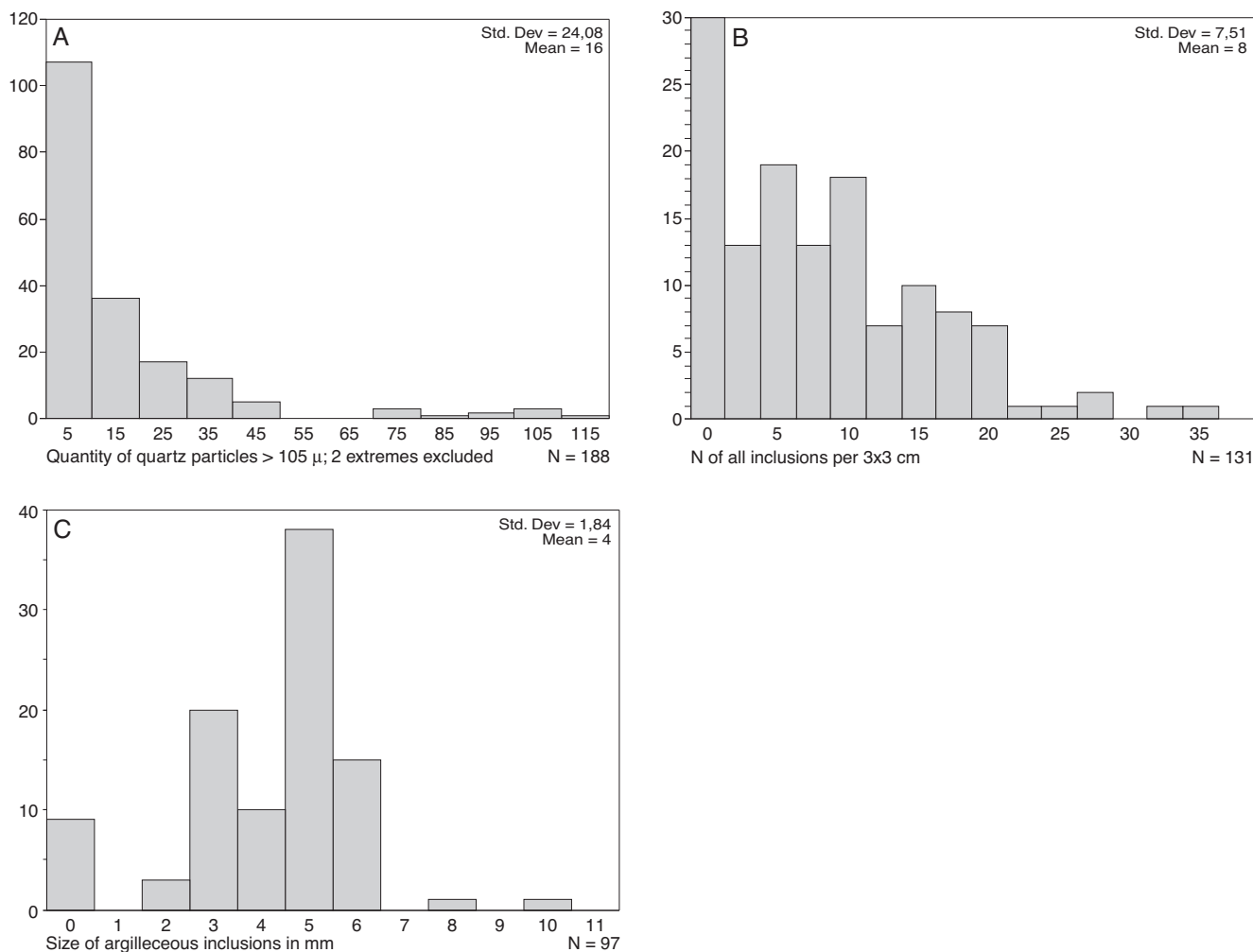


Fig. 5.2a-c Uitgeest. Frequency distribution of the amount and size of inclusions and quartz.

sherds is quite small (39). The average size of the A-inclusions is a little larger (3 mm) than that of the other two types of inclusions (2 mm). The average quantity is highest for the Fe-inclusions and lowest for the Ca-inclusions. Compared to observations on the original vessels, Ca-inclusions occur less frequently in the refired sherds. This suggests that refiring caused a change in composition and/or texture of the Ca-inclusions, and possibly also of the A-inclusions. In the original firing process the duration, amount of oxygen and temperatures of the firing may have been too low for the calcitic compounds in the nodules or the clay to decompose or recrystallize into minerals as part of the overall matrix (see 5.1.2). Refiring to 950 °C under oxidizing circumstances does seem have that result. Dissociation of a stable Ca-compound in the clay matrix takes place is between circa 750-850 °C; above 800-850 °C gehlenite is

formed (Heimann 1989; Magetti 1980; Shepard 1963). The same chemical alterations probably also took place in the Ca-inclusions during refiring at 950 °C, resulting in a decreased visibility. This interpretation is to some extent supported by the test tablets from clay 62 and 63; the small lime fragments, probably shells, seem to diminish and disappear in the higher temperature range. This in turn suggests that the original maximum firing temperature indeed never exceeded 850 °C (see chapter 6.8).

Schagen

In the original pottery surfaces hardly any Fe-inclusions were seen, while all contained often high amounts of clay pellets (fig. 5.4). The texture of the inclusions was usually 'solid' in the core surfaces of both the original and refired sherds. Nearly all of the vessels from Schagen showed the

whitish to grey-yellow and porous concretions, interpreted as Ca-inclusions, on the surfaces of the vessels. They were often leached out, leaving cavities from 1 mm to over 10 mm. In the refired sherds clear Ca-inclusions were rarely seen, however, and it was also difficult to distinguish between Ca- and A-inclusions, most were recorded as A/Ca inclusions. The same applies to Fe- and A-inclusions, as in many cases the Fe-infiltration into the original inclusions showed up after refiring.

These discrepancies between surface and core, and original and refired sherds is due mainly to the secondary changes described above; the inclusions were partly changed in texture and perhaps colour, while some elements in them may have been removed by leaching as well. As this and other microprobe research suggested (see above), leaching is likely to be the reverse side of the same process which caused the intense infiltration of iron and manganese. It is therefore difficult to determine what the composition of the inclusions was in the original fabrics. The exact composition might have been relevant for the potters; they could certainly feel and see all these 'lumps' in the clay and must have had some trial-and-error knowledge about their influence on the fabrics of the pottery.

Taking the definitional problems into account, the following observations were made. Only 7 cases in Schagen contained no inclusions, whereas 52 % of the sherds were assigned to group 2: mostly solid A-inclusions, but often combined with Ca- or Fe-types (table 5.5.2b). Inclusions defined as A/Fe combinations occurred in 44 cases. These are not shown separately in the tables as the combination mainly indicates the postdepositional infiltration with Fe in and around the A-inclusions or Ca-inclusions. Clear Fe-inclusions ≥ 1 mm (group 1) were noted in 29% of the sherds. The porous type of inclusions of group 3 occurred in about 12% of the refired sherds. Although nothing definite can be said about their composition, in most cases the inclusions in the original sherds were described as either clear Ca-inclusions or the so-called 'organic' inclusions. The average size of both Fe- and Ca-inclusions is smaller than that of the more general A-inclusions, which can measure up to 10 mm. In the refired sherds the average size of Fe and Ca-inclusions is 3 mm, and of A-inclusions 5 mm.

5.2.4 SUMMARY

The study of inclusions in the clay proved to be more complex than expected; there are substantial differences between the original sherds and the refired ones. Especially in the case of Schagen, the postdepositional alterations added to the problems of definition. What can be concluded from the results is that Fe- and other inclusions were present in virtually all of the pottery of both sites as part of the original clays. In the case of the Schagen pottery with the ubiquitous

presence of clay pellets, it is likely that the potters in Schagen selected such clays on purpose to improve the workability and drying qualities of the very fine-grained, highly plastic clays. It is even possible that the inclusions were added by the potters themselves as dried clay pellets. They certainly must have had an influence on the fabric properties. Perhaps they caused a high permeability, making the fabrics acting like sponges for ground-water infiltration.

A second important conclusion that can be drawn from the alterations in the inclusions is that the original maximum firing temperature must have been considerably lower than the refiring temperature of 950 °C.

5.3 Quartz particles

Through local variations in clay deposits, the *amount* and the *size* of quartz can vary considerably over short distances. The quartz content has an influence on the workability and plasticity of the clay as well as the fabric properties after firing. The choices made by the potters out of available clay layers might show up clearly in the quartz fractions and quantities in the pottery, when compared to those in the clay samples (chapter 4; table 4.1). Much work has been done on quartz particles in pottery fabrics, mainly through textural analysis. Most studies concern the variations in particle size for the purpose of characterisation. Also the shape and the size of distribution of quartz can give information on whether sand was added on purpose and in what form. For quantification of the quartz content different counting methods and their merits are reviewed by Streeten (1980). He argues that all methods produce good results when the aim is a basic classification of fabrics. Image analyzing with the help of computer programs is being developed as well (Middleton *et al.* 1986), which will greatly facilitate the quantification of nonplastics in the future and finally provide the archaeologist with a tool of greater precision.

In this study a rather low level of precision for the measurements of quartz was adopted as the two main purposes were (a) to test the hypothesis that the potters did not add or remove sand from the clays and (b) to establish major variations in quartz content within the two assemblages. Such variations could be related to other fabric variables and/or to specific use purposes of vessels (chapters 8,9). If the potters used local and untreated clays, the amount and size of quartz in the clay will vary according to the specific deposit from which the clay was won. It is not likely that the potters had sophisticated means of purifying clays at their disposal, but they could have chosen clays with a specific quartz content.

5.3.1 METHODS

To establish whether 'sand' had been added by the potter or was naturally present in the clay, the presence or absence of

all sizes (fractions) were recorded by means of a standard reference set as used in soil science, ranging from $<60\ \mu$ to $600\ \mu$ ¹⁴. Using a binocular with an 20× magnification, the number of particles larger than $105\ \mu$ were counted over an area of $1\ \text{cm}^2$. The count was repeated twice and the average of the three counts was used as data. The limit of $105\ \mu$ was set empirically; as virtually all sherds in Uitgeest contained smaller particles, counting those did not add to the variability, which did occur in the larger fractions. It is also very unlikely that these very fine sizes could have been added by a potter, unless they were part of much coarser sand. If, on the other hand, clear gaps would be present in the size distributions these might suggest the addition of sand.

5.3.2 RESULTS

Uitgeest: Size of quartz particles $>105\ \mu$

Among the 188 sherds analyzed, only 24 contained no quartz larger than $105\ \mu$ (fig. 5.2.a; table 5.6c). The majority of the sherds had quartz particles with fractions up to 150 and $210\ \mu$, whereas a small amount (26) had fractions larger than $210\ \mu$. The size distribution within a sherd was discontinuous in circa 50% of the sample. Usually only one, but sometimes more size classes were missing, mostly those between 75 and $105\ \mu$. Although this seems to suggest the addition or removal of quartz particles by the potter, this is very unlikely because the 'missing' sizes are so small. The discontinuity can very well be a natural characteristic of the clay. According to geologists, natural selection of specific size classes often occurs in clay deposits (pers. comm. M. Verbruggen, FAL).

Uitgeest: amount of quartz particles $>105\ \mu$

The amount of quartz measuring more than $105\ \mu$ varied considerably within the sample (fig. 5.2a). More than half of the sherds (59%) contained 0 or less than 10 particles per cm^2 . There is a gradual decrease in the number of sherds with higher amounts. A small group of sherds (11) had an extremely high amount of quartz (> 70 particles per cm^2). Based on the frequency distribution three classes were made (table 5.6c). The small group of pottery with very high amounts of quartz suggests that the potters either selected this very sandy clay or perhaps added some sand. Since there is no difference between the size class and distributions in these sherds and those with low amounts, it is concluded here that no sand was added.

Altogether, the data indicate that the potters from Uitgeest mainly used clays with a not too high amount of the finer quartz particles. The majority of the pottery contained up to 25 quartz particles $>105\ \mu$ per cm^2 . The potters did not add sand. Compared to the test clays, the size and amounts of quartz in the fabrics are most like those in clay samples 65 and 81 (table 4.1).

Schagen

More than 90% of the pottery sample from Schagen only contained very fine quartz particles from 16 to $50\ \mu$, occasionally particles up to 75 or $105\ \mu$ occurred. This data corresponds fully with those of the test clays from Schagen (table 4.1), clay 62 and 64, which also lack quartz particles $>75\ \mu$. Both sherds and clays contained colourless mica in varying but often high quantities. In only 10 vessels—and 6 sherds from feature 27, see below—particles larger than $105\ \mu$ occurred; two of these contained fractions up to $150\ \mu$, five with fractions up to $210\ \mu$, two with fractions of 300 – $425\ \mu$ and one with fractions of 210 – $600\ \mu$. In all cases the size distribution is discontinuous between 50 and 150 – $210\ \mu$. Five of the vessels had less than 6 particles per cm^2 , the other five had from 8 to a maximum of 50 particles per cm^2 . For reasons given above the quartz could have been present as a spurious lens within the otherwise virtually sandless clay deposit. Certainly for the higher fractions and amounts, however, an addition by the potter cannot be excluded, raising the question if this is a special group of pottery. The distribution of this pottery is seemingly random: two of the ten vessels came from features in the Southern occupation area (features 223 and 240); in the northern part two vessels are from feature 79, one vessel from pits 27—with the coarse fraction—and 147, two vessels from hearth 157 and one cremation urn (345). Six sherds, not included in this sample, from feature 27 also contained quartz larger than $105\ \mu$. If the coarser quartz was naturally present in the clay used, then the pots could all have been made from the same stock of clay, and, may be, by the same potter. This interpretation is however contradicted by the fact that all three clay types are represented in this group of pottery, although clay type 2 is dominant with 6 cases¹⁵.

Altogether there is insufficient ground to conclude that sand was added on purpose. The relationships with other characteristics of the fabrics of both sites are presented below.

5.4 Fabric types

5.4.1 RELATIONS BETWEEN CLAY TYPES, INCLUSIONS, AND QUARTZ

Several statistical tests were carried out to establish relations between the different fabric variables discussed above, in order to distinguish types of fabrics in the pottery of both sites. These relations were tested for significance by means of the X^2 test; the significance values in some of the tables are based on the Pearson measurements for dependent variables on a nominal or ordinal scale.

Uitgeest

The following results are based on the 126 vessels of sample 1, for which data on all variables are available. This sample was too small to test the significance using the

finer classifications of variables and therefore a classification into three classes was used for all variables (table 5.2 and 5.5). The results of the tests are largely negative as far as statistical significance is concerned, but some trends are observed, that point to a possible, although weak interdependence of variables for clay composition.

There is no clear or significant relationship between clay types and the types of inclusions (Table 5.6a). In clay type 3, A/Ca-inclusions were found more often than in the other two clay types, which are more often associated with a combination of different types of inclusions. The presence of Fe concretions is apparently independent of clay type, as

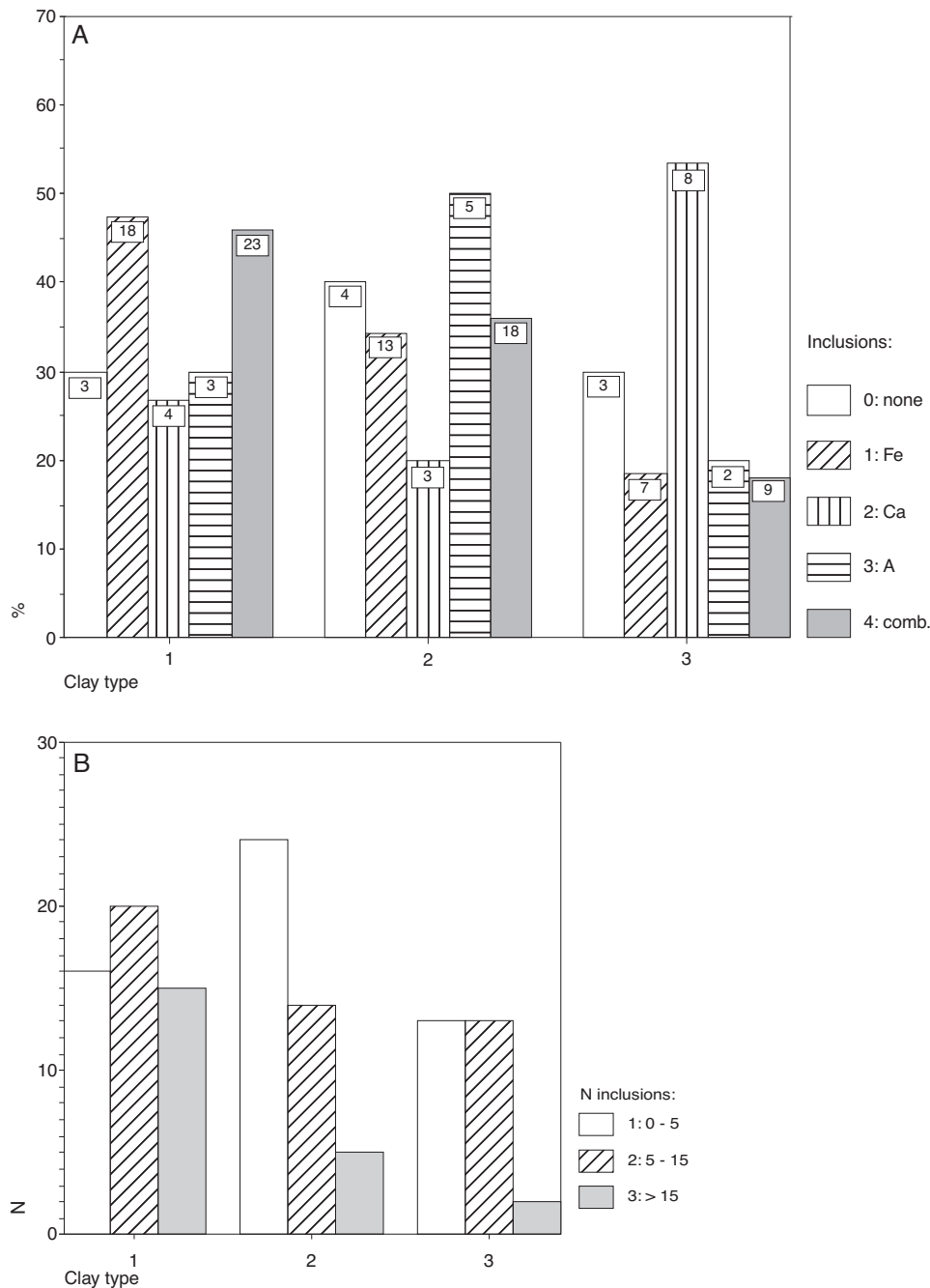


Fig. 5.3a-b Uitgeest-Gr.D. The relation between clay type and inclusions.

expected. There is some correlation between the clay type and the quantities of inclusions (Table 5.6b), caused mainly by a higher amount in clay type 1, or a lower amount in clay type 2 and 3.

The variation in the amount and size of the quartz particles is also independent of the clay type, even for the few sherds with very high amounts of >70 per cm², although they tend to be made of clay type 3. Their numbers are, however, too low to draw firm conclusions. No significant relations were found between the type of inclusions and the size or amount of quartz either (table 5.6c).

Although the data on the %AP are discussed in full detail in chapter 6 and 7, it is mentioned here that there is a slight, but statistically not significant correlation between clay type and the %AP of the sherds (table 7.1). Sherds of clay types 1 and 2 tend to have a lower porosity than those of type 3—although this relationship is also influenced by the amount and size of the temper, see chapter 6. This result is in agreement with the difference in %AP as measured in the test clays (fig. 4.2). There is no relation between the type and the amount of inclusions, nor between the quantity of quartz and the %AP.

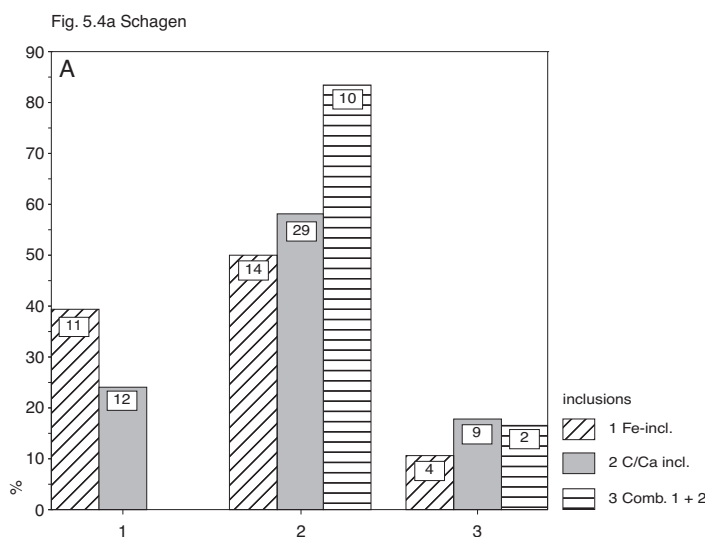
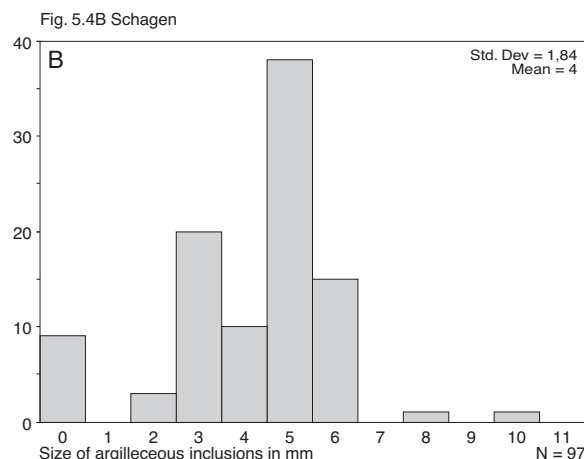


Fig. 5.4 Schagen-M1. The relation between the type of clay and inclusions.



Schagen

The low sample size for Schagen together with the secondary changes in the pottery clearly affected the reliability of the tests for the relationships between the various fabric variables. There is no statistically significant relation between any of these variables, but there is a tendency for clay type 2 and 3 to be associated more frequently with A/Ca-inclusions (table 5.7; fig. 5.4). Clay type 1 contained no sherds with a combination of inclusions, because all inclusions will show up as Fe-inclusions due to the Fe-infiltration. There is also a weak relation between the clay types and the %AP in the sense that this is slightly higher in clay type 3 (table 7.3). As the same relationship was found in the Uitgeest pottery, this indicates that the method for defining clay types 'worked'.

5.4.2 FABRICS OF THE TEST CLAYS AND THE POTTERY Uitgeest

Most of the pottery showed the best visual match with clay 65 or 62 and 64. These three clays are rather similar in chemical composition. They vary slightly in the amount of quartz and in the amounts of iron and calcium. As far as the secondary alterations of the pottery fabrics allow any conclusions, their key elemental composition is quite similar to that of these test clays. The potters from Uitgeest mainly used a clay with some sand, matching the quartz content of clay sample 65, but not its Fe-content and/or ratio of Ca : Fe; these are much lower in the pottery and more similar to that of clay samples 62 and 64. When the postdepositional changes are also taken into account, these values were probably lower for the original clays. The size and amount of

quartz grains may have been a selection criterium: coarse grains ($>600\ \mu$) are virtually absent, while the amount of quartz $>105\ \mu$ should not be 'too high', an assessment which amounts to not more than circa 50 particles per cm^2 . Only a small group of vessels contained higher quantities.

There are clear differences between the pottery clays and the test clays from Uitgeest, samples 81 and 82, except for the occurrence of iron concretions and it is unlikely that these types of clays were used to make pottery. Clay sample 82 has a very high natural porosity, never observed in the sherds, even though the general texture and the amount of quartz are comparable to those of the pottery. In clay sample 81, the amounts of coarse quartz grains is much higher than in the pottery. The Ca-content of both test clays is also extremely high, both in absolute values as in comparison to the pottery, but this may be because of the recent use of fertilizers. The combined data for test clays and pottery demonstrate that the clay composition can vary considerably even over small distances within one deposition phase. Together with the limited variation in fabric composition of the pottery, this is, however, a strong indication that specific clays were indeed selected from the available clay deposits in the vicinity of the site. The potters chose clays with a rather heterogenous texture with only the finer fractions of quartz grains and inclusions. These clays were probably quite easy to work with during construction (as Ms Spruyt suggested, pers. comm.).

Schagen

As far as the overall texture of the clay matrix, the amount and size of quartz, and the presence of colourless mica are concerned, the test clays and the clays used for the pottery from Schagen are very similar indeed. All three clay samples collected at the site during excavation (62, 63 and 64) could have been used for the pottery. The homogeneous clay matrix is made up of very fine clay particles and contains very few and fine quartz grains, not larger than $75\text{--}105\ \mu$. Both the clays and the pottery also contain quite a lot of colourless mica. The texture of the pottery is usually slightly 'powdery' and the Ca-content of clays 62 and 64 match that of the pottery to a high degree. Nearly 60% of the pottery was classed as similar to these clays (table 5.7) and this percentage would probably have been much higher when the clays of the pottery with too much secondary changes could be defined as well; the structure and texture of the fabrics in this group of sherds is the same as for the other groups. The CaO percentage of clay 63 is much higher than observed in the sherds, although the Ca-content and Ca : Fe ratio are similar to those found in the sherds. This type of clay was used much less frequently, only 18% was classed as similar to this clay type. It is possible that the elemental analysis was influenced by Ca-rich inclusions in the sample, or vice

versa, that calcium- and/or iron -compounds were leached from the fabrics into the acid environment. The cavities as well as the very light colours of the surfaces of many vessels support this interpretation. At higher firing temperatures the tablets of clay sample 63 showed a 'lamination', the presence of light yellow 'trails' in the overall red colour. In the pottery, a 'double' coloured surface was observed regularly. It is quite likely that both refer to the same chemical processes, see below.

There is one important difference between the fabrics of the pottery and that of the test clays of Schagen. Clay pellets are abundantly present in the vessels, but are, rather surprisingly, completely lacking in the test clays. Some Fe- and Ca-inclusions do occur, mainly in the tablets of clay 62, but in far lower quantities. On the other hand, clay 62 contained tiny shell fragments, which were not seen in the sherds; the size and texture of these fragments is quite different from that of the inclusions in the sherds. These differences cannot be explained by the preparation method used for the test tablets; although the clay was pounded and kneaded for a long time, according to Jacobs (pers. comm.) it is virtually impossible to remove inclusions in this way, especially clay pellets.

There are two possible explanations: either the composition of the natural clays may have changed since the Roman period habitation through natural processes, or the clay pellets may have been added by the potters. Possibly, the alterations are related to changes in the ground water-table and/or in vegetation; supportive evidence is the secondary infiltration of iron and manganese, present in almost all of the pottery. As discussed above, these compounds can only have been formed secondarily by changes in ground-water levels and perhaps in the mineral composition. Such an explanation seems, however, to contradict the lithostratigraphical data; at the time of occupation, a peat layer, certainly $>50\ \text{cm}$, covered the Calais-IVB clay-deposit. During and after occupation the water-table must have been quite high, higher than the clay deposits under the peat. The data on secondary infiltration in the pottery clearly indicate that the postdepositional changes occurred most intensely on the old land surface. Perhaps renewed peat growth and/or a raising of the water-table took place in the centuries after the habitation; all peat has disappeared, however, since the drainage in the Medieval period. It seems altogether unlikely that iron concretions were formed under the former circumstances and not under the latter¹⁶. On the other hand, considering the overall similarities and the strong archaeological evidence for clay-winning pits at the site, it seems equally unlikely that the potters used clays from an altogether different deposit. Especially clay 64 is too similar to the pottery in all respects but for the inclusions, and this could be a strong indication for their addition to the paste, even though it is

hard to imagine how the potters could have obtained such a variety of inclusions.

Taken all arguments together, it is suggested here that (a) the inclusions were formed before or during the peat growth and were still present during occupation and/or (b) that variations in the ground water table took place during and after occupation. It is possible that the clay pellets with different compositions occurred only in the upper layers of the clay substratum during occupation and that the potters exclusively used these layers. All of these possible explanations however still beg the question why and when most of the inclusions were dissolved subsequently. At present no definite explanations can be offered.

5.4.3 SUMMARY AND CONCLUSIONS

The overall chemical composition of the clays used for the majority of the pottery in each site is quite similar and indicates a conscious selection of specific clay types by the potters. In both sites the potters seem to have preferred clays with a certain amount of calcium compounds and a low Ca : Fe ratio. It is quite likely that they did not make or recognize any difference between clay types 1 and 2 as defined here. In both sites a small group of pottery was made from a different clay with a higher amount of Ca or a higher Ca : Fe ratio. This clay, which is comparable to the test clays 63 and 60 also has a slightly higher %AP. The CaO content of these clays, are much higher than the values in the tested sherds, however. The difference is probably due to secondary changes in the pottery, which also accounts for the variation in the iron and phosphor contents (see below). It was not possible to define distinct types of fabrics within each pottery complex on the basis of *all* fabric variables together. There is no clear association or correlation between the type of clay and other variables. The lack of a correlation between the type of clay and the type of inclusions suggests that the latter were formed through natural processes in the clay deposits. It is possible that the potters took the quantity of inclusions into account when adding temper to a paste (chapters 6 and 7). As the analysis included variations in the clays and fabrics which could have been seen or felt or 'known' by the potters, it is concluded here that the potters used a *standard clay type* for most if not all of their pottery. The only exception may be the small group of vessels in both sites that was made of a more Ca-rich clay. In chapters 7 and 9, the possible relation with the amount of temper and the form and function of this pottery will be further examined.

There are also some differences between the fabrics from both sites. The potters of Uitgeest used a slightly more sandy clay, but with far less natural inclusions than those of Schagen, where they are a characteristic feature of the fabrics. The variation in the amount of quartz in the fabrics of

Uitgeest is probably due to accidental sand lenses within the preferred clay beds. The high amounts, large size and specific types of inclusions in the Schagen pottery could indicate that such clays were specially selected or that the potters added the clay pellets on purpose. This would have improved the workability of the very fine-grained clay.

There are no indications in either site that the different clays or the use of the Ca-rich clay mark a chronological difference. For Uitgeest, this information is restricted to the closed finds of the wells and of some other features, for which a relative stratigraphy was established (table 5.8). Although the number of cases is small, there is no systematic difference in clay composition between or within features. For the settlement at Schagen it was established that the vessels with a Ca-rich fabric occurred exclusively in the ritual pits (table 5.9). The relations between vessel and fabric types and the context are discussed in more detail in chapters 8.13 and 9.

Postdepositional changes and fabric analysis

The pottery of Uitgeest, but especially that of Schagen has been postdepositionally affected in two main ways:

- the infiltration and deposition of iron- and manganese oxides in the surface layers and the core of the vessels and
- the removal i.e. leaching of minerals from the surface, which caused a change in composition and therefore in colouring when the sherds were refired.

Both changes constituted a serious problem in the analyses, firstly for the definitions and observations of variables and secondly for the interpretation of the chemical/mineralogical analyses of fabric composition. The data presented here confirm once again that results of such analyses must be treated with caution if not scepticism. The exact location of a sample taken from a specific vessel will determine the outcome of its chemical and mineral composition. Taking samples from different parts of a vessel wall, as was done by Stein *et al.* (1992), is a laudable attempt to control such variations but does not solve the problem at all¹⁷. Postdepositional changes of the kind described here will have occurred in almost any archaeological context and will influence the analysis of any sample, especially in the Western Netherlands. It may even be impossible to extract an uncontaminated and representative sample from a vessel. As Freestone *et al.* (1985) argued, it is necessary to find a way to control these influences, if conclusions about provenance and/or characterization are to be drawn.

The second problem is that the distinction between a specific composition of the original surface and one affected by deposition is quite difficult to make. This is especially true for the surfaces consisting of two separate layers, light yellow and red. The test tablets of clay samples 63 and 81 confirm that a 'split' or separation in compounds can occur in some clays.

notes

1 Some vessels were not available for the fabric studies at the time; because of the extreme secondary changes, expansion of the sample was not attempted.

2 The colours of the sherds were not defined by Munsell chart because the differences were too small (see also table 4.2 for the test clays) and visually finer distinctions could be made.

3 They moreover detected a substantial fluctuation in the amount of K, Na, Ti and Mg oxides across the wall of the sherds (Freestone *et al.* 1985, 163).

4 Double surfaces were also seen on pottery from the terps in Groningen and Friesland in the collection of the State Museum (Rijksmuseum voor Oudheden) in Leiden (by the author).

5 The sherds had not been refired when the selection was made. Some of these, with no apparent inclusions in its original state, did however show inclusions after refiring.

6 In hindsight it is rather unfortunate that the sherds were refired to 850 °C, before the analysis, as it weakens the comparison with the classification into clay types, based on sherds refired to 950 °C. This temperature was chosen, because it was supposed to be closest to the original firing temperatures. The elements and compounds in the tables are the main determining elements for colour, as well as indicators for the influence of organic material. A full publication of the data is expected in the near future.

7 And through this may help to explain the differences in clay composition during occupation and in recent times, that is between the pottery and the test clays, see chapter 5.4.2.

8 The surfaces of many vessels from Schagen were badly damaged, but this is apparently of minor import for the infiltration; there is no difference between pottery from pits and surface features in this respect.

9 Sherd nrs.: (79.113)-5 and (79.113)-31 with a very clear DBS, (56.170)-23 with DBS present in some areas and (56.170)-30 with no DBS.

10 As van Haaren remarked (1991,3), this was not completely successful in the cases discussed here, “probably as a result of slight displacements of the emission focus.”

11 Within group 3 a subtype was defined for the Schagen pottery, where rounded inclusions occurred with a colour darker than the matrix and a more porous structure. These inclusions seem to contain organic material. They were not included in the scores.

12 Tests with HCl did not help either, as most sherds showed no reaction. This does not mean that no Ca is present, only that it is not present in an unstable form (pers. comm. dr. H. Kars, ROB). This could indicate that the Ca-compounds had not yet dissociated, which in turn suggests a firing temperature of less than 850 °C). One inclusion, defined as Fe-rich, was analyzed separately but the results were inconclusive (Van Haaren 1991).

13 Several classifications were constructed, the one presented here is the best possible compromise. It proved to be very difficult to combine the information from the surfaces and cores of the original and refired sherds, as there was so much variation in these data for each sherd.

14 In the pottery concerned, no crushed material is present, only natural, rounded particles.

15 These pits were used for ritual deposition (chapter 3). The features 27 and 79 are especially important. The data on quartz could support the idea that these pits were in use at the same time. The five vessels from these pits with quartz coarser than 105 μ were all made from clay type 2.

16 In fact, the opposite should be more likely: the formation of concretions due to the lowered water-table after reclamation.

17 The results of this study of one vessel from the settlements at Oss apparently stem hopeful: there is no statistically significant difference between all samples. I have two objections: a. the results cannot be generalized, not even to the pottery from the same site and period, and b. the cost and time involved in this type of approach is prohibitive.