# 2 Pottery, society, and culture

## 2.1 Introduction

In this chapter, the general model and methodology, outlined in the previous chapter, is specified for the pottery and society concerned. To repeat, the relationships between the technology of manufacturing[1], the taxonomies for the function and the actual use practices of ceramic vessels are the subject of this study. The research strategy is to follow the cycle of any vessel, from its production to its use and through to the discard of sherds or deposition. The replacement, the re-production of a similar vessel, is the beginning of a new cycle. All of these stages will be interrelated in a specific way in practice and each of the stages will contribute its own characteristics to a vessel and to the ceramic assemblage. Of the main subjects, the analysis of depositional practices is limited to Schagen.

The question dealt with in this chapter is *how* to study each of these fields; how to find out which of the 'many dimensions of pottery' (Van der Leeuw & Pritchard 1984) were considered important by the makers and users? In other words, how can the criteria for the original classifications of vessel functions be established and how should the links with the production, use and discard practices be analyzed. The aim of this chapter is therefore twofold. Firstly, to formulate specific assumptions and hypotheses concerning the technology, functions, and types of use of the pottery for both sites. Secondly, to choose the appropriate variables and their dimensions, as well as the level of detail and precision appropriate for the analysis of each of these fields of research. As outlined in chapter 1, the level of the analytical precision should be geared to the characteristics of vessels that were used for their classification in the past. The methodological problem is how to establish these levels, while at the same time they should be the result of the analysis. Especially for the study of fabrics there are a vast amount of potential variables, as well as techniques and levels of detail to analyze these. Clearly most of these techniques are far beyond any level of detail and precision of the potter's knowledge. Theoretically, the similarities and differences within a specific assemblage should be analyzed to establish the internal variability and coherence of variation *both within each and between all individual vessels*. The main sets of variables for each part of the research can be deduced from the model and research questions. However, the dimensions of the variables and the level of precision at which these ought to be observed, can not be determined a priori, because these will be specific for the pottery concerned. The way out of this hermeneutical circle as followed here is through a combination of different sources: the theoretical framework, the information from other pottery studies, especially ethnographic research, and previous research on the same type of pottery. As a guideline for the choices made below, it is argued that *as long as the level of precision of observations is higher than it is justifiably expected to be in the original context*, it should result in the distinction of meaningful variations.

In the first part of this chapter the process of making pottery is modelled as a series of steps and choices by the potters (fig. 2.1). This model contains basic groups of variables to be analyzed. It is derived from the approach to the Assendelver polder pottery and from the vast literature on pottery production. The second part contains a review of ethnographic studies on function and use. The review is the basis for the specification of the variables for the analyses of these subjects as well as for depositional practices (paragraph 2.3). Thirdly, all aspects involved in the choices in raw materials and their possible effects of fabric composition *in relation to the function* of a vessel are discussed in paragraph 2.4.

## 2.2 The making of pottery

### 2.2.1 General aspects

In this study, the manufacturing process forms the basis for the analysis of groups of variables, that are involved in the making of each vessel (fig. 2.1). The manufacturing plays an essential role in the cycles of pottery in more than one way. This process in itself contains the life-cycle of pottery. The potter as a member of the community *combines* her knowledge of *all the relevant rules and variables* in the act of constructing a vessel: the technological and cultural traditions about how a pot should be made, what it should look like and what it is to be used for. This knowledge, be it conscious or not, guides her decisions and thus the outcome of her work. In the making of a vessel, the recursive relations between technology, function and use and cultural values are transformed into a specific material object with

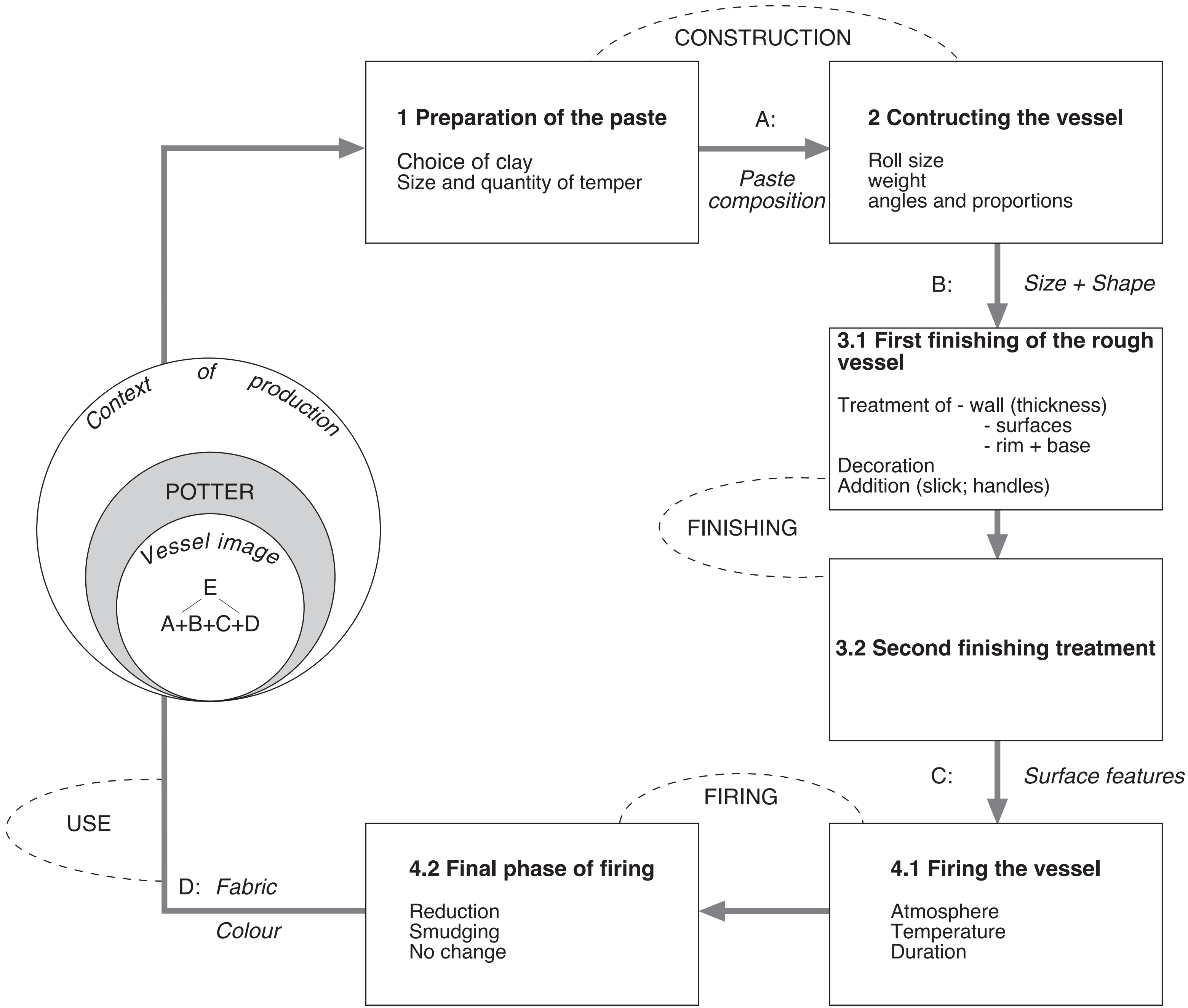


Fig. 2.1 The cycle of pottery production.

specific characteristics and properties. At the same time the shared cultural and productive traditions of a group of people, as well as experiences with the actual use of that product, are reproduced trough the replacement of vessels. These include stylistic aspects, morphological aspects of size and shape, fabric properties, etc.. Moreover, the potter is, as an individual agent with individual skills and characteristics, practising her own abilities in each manufacturing process. All of these factors together result in a *specific combination* of characteristics—visible and invisible—of the end product, the vessel. Two important presuppositions follow:

(a) The production of one potter and of all potters together results in a set of 'typical' artifacts, defined by similarities and differences in characteristics, at both the local and the regional level. Both will be related to definitions of function, as well as to use-experience.

(b) Every else being equal, each new vessel will be a copy of the one it is replacing, if made by the same potter and within a short period of time. The individual vessels are therefore the proper unit of observation for all variables.

Several factors can cause fluctuations and variations within the production of pottery in a region, a settlement, and even within each type of vessel. The first is the organisation of the potter's craft, as well as the rules behind them. Ethnographical sources show almost all possible forms of organisation between two extremes: at one end the production within each household by one or two members (usually mother and daughter) for the needs of that household only and at the other end the industrial, standardized production in factories (see Van der Leeuw 1984, fig. 2; also Balfet 1993). The type of organisation will influence the degree to which pottery 'types' (forms) are *standardized* (Balfet 1984). Theoretically, it can be argued that making pottery at the individual household level will result in a minimum of standardization in a cultural assemblage, as so many potters are involved and each will have her own particularities and skills. One of the aims of this study is to establish if pottery was indeed produced at the household level. The second source of variation is the strictness with which the expected traits of the pottery are defined and/or the perceived freedom or the wish for variation within the shared tradition. Such personal variations should also become intelligible when the manufacturing process is analyzed in detail for every individual pot[2]. A third factor is of course the spatial variation in raw material composition. All factors will be directly or indirectly related to the degree of functional differentiation in the classificatory system of pottery functions: how precise were these functions defined.

Many ethnological and experimental studies are available on the subject of pottery production and the main aspects are further discussed in paragraph 2.4.

#### 2.2.2 Aspects of style in the production process

The problem of defining style in material culture is an old one. Most stylistic typologies are based on the recognition of similarities and differences for a few specific variables. Within the theoretical framework outlined here, the concept of style can be approached in a more encompassing way. Style, however defined, is produced and reproduced in the manufacturing process, like all other aspects of pottery. The question is which aspects of pottery are based on shared cultural traditions of 'what a vessel should look like', which aspects are referring to local or individual identities and which aspects are signifying the functional classifications. Most important is of course how all three aspects are connected. Secondly, similarities and differences in *all* aspects of material culture, not only in style, are indeed what it is all about. They will exist in material culture at several levels as the individual, the immediate community and the larger society of shared culture are always recursively linked.

The shared opinions on what pottery should look like is hypothetically based on the *traditions* of a larger time/space unit. They will be mainly expressed in overall similarities in pottery on a supra-local scale[3]. Wether or not there are local variations within these general and shared traits will depend on the factors discussed above, but both will have been defined in relation to each other. An analysis of style should therefore be based as well on similarities and differences *within and between* pottery assemblages (as well as on assemblages from the same type of contexts, see paragraph 2.3.2). Consequently, it is not desirable to separate 'stylistic' from 'techno-functional' variables, nor can the variables which define the similarities and differences at different time/space levels be chosen a priori. The definition of style should be a result of research instead of a starting point. Although the stylistic aspects are not as such part of this study, the analyses of the manufacturing process and the functions of pottery do lay the basis for that of style.

### 2.3 Function, use, and discard variables

As function is the formally defined use of ceramic containers, it should by implication be distinguished from actual use, at least analytically. In archaeology, the determination of vessel functions presents a problem, as no direct evidence is available. The ethnographic literature is the most important source of information on functions and use of pottery and had a large influence on the archaeological literature. Recently, the available data have been reviewed by Varien & Mills (1997), who also improved their comparability (appendix 2, table 2.2a). Several publications contain extensive diagrams and flow charts about the general aspects of pottery functions in the archaeological literature (see Rice 1987; Juhl 1995). The ethnographic studies are

| CATEGORY OF USE | CONTENT OF VESSEL | EXPECTED USE FREQUENCY | MAIN TYPE OF STRESS | EXPECTED BREAK FREQUENCY |
|---|---|---|---|---|
| FIRE- RELATED: COOKING HEATING BOILING | Food | Daily | Thermal + Mechanical | High |
| | Potable liquids | Daily to Periodical | | Variable High |
| | Non-potable substances | | | |
| SHORT TERM STORAGE | Potable/ Consumption goods (Dry)/ Liquids | Regular | Mechanical | Variable Low |
| | Other substances | Regular | Mechanical | Variable Low |
| LONG TERM STORAGE | Potable/ Consumption goods | Periodical | Mechanical | Low |
| | Non-potable goods | Periodical | Mechanical | Low |
| SERVING/ CONSUMING | Food Dry/Liquid Cooked/ Uncooked | Daily to Incidental (Rituals) | Mechanical (+Thermal?) | High to Low |
| SPECIAL USES + RITUAL USES | Potable/ Non-potable goods | Variable? | Mechanical | Variable |
| TRANSPORT (OUTSIDE SETTLEMENT) | All types of goods | Incidental? | Mechanical | Low to High |

Fig. 2.2 General use categories: the functions of pottery and the expected use- and break-frequencies.

used here as a guideline for the aspects and variables involved in functional classifications and actual use practices. One advantage is that anthropologists usually approach the subject of use in a fashion that is congruent with the one this study aims for, establishing the 'native' taxonomies for ceramics in relation to other relevant variables. These studies also deal with the complex relationship between function, use, and social context of pottery inventories[4]. The data themselves are of importance only insofar they illustrate the principles and practices which can lie behind the variations in pottery or sherd assemblages. Of course, in dealing with these studies one has to be aware of the fact that the 'native taxonomies' are mediated by the researcher and his or her methods of questioning (Van der Leeuw 1991).

The main points of attention are the classification of functions, the composition of the ceramic inventory, the relation between use and break-frequencies, and their effects on the composition of the 'death'-assemblages. The hypotheses formulated for the function and use of the ceramics studied here, are presented in paragraph 2.5. The major categories of vessel functions and the related types

| General category | Specific activity | Categories of materials | Main products |
|---|---|---|---|
| FIRE-RELATED FOOD-PROCESSING | cooking<br>heating<br>boiling<br>steaming<br>brewing<br>smoking | liquids<br>dry goods/<br>in liquids | *animals*<br>dairy products,<br>meat, fat<br><br>*agri-/horti-culture*<br>cereals, beans,oil, vegetables,<br>beer |
| FOOD-PROCESSING | cleaning<br>washing<br>soaking | dry + liquid goods<br>dry goods<br>dry goods | |
| FOOD STORAGE | | | cheese, fat,<br>cereals,beans, oil |

Fig. 2.3 Some food-processing activities, involving containers.

of stress are summarized in fig. 2.2 and 2.3. In fig. 2.4 and 5, the results of these types of use are summarized. The figures contain only a selection of all possibilities, geared to expectations for the vessels studied here.

### 2.3.1 GENERAL ASPECTS OF FUNCTION AND USE

*Classification of pottery functions*

Within the specific contexts of a society or culture, the definition of pottery functions will, in general, be related to the type of goods being produced and used in a community, as well as to the specific contexts of use. All ethnographic studies show a link between the definition of the type of activity or material, such as cooking or storage and the type of vessels associated with or assigned to these purposes. The distinction in pottery functions, the number of different types of vessels which can be connected with different use categories, is called the degree of differentiation. However, although many possible categories and subcategories may have been distinguished in actual use, these do not necessarily each involve a specific type of vessel. The extent of functional differentiation in the pottery may well represent a much larger number of different activities or contents. For example, ‘cooking’ may be the major definition, which is associated with ‘the cooking pot’; at the same time there may be a more or less strict distinction in the types of cooking, even though perhaps the same vessels are used. Another possibility, indicated by ethnographic research for many cultures, is that some vessel types are classified for two or more functions simultaneously, for example as cooking/storage vessel. As this type of detailed information is very hard to obtain for archaeological assemblages, this study will, partly out of necessity, be restricted to functions that can be recognized in or through the pottery itself.

The classifications of pottery functions will also be the basis for the composition of *the ceramic inventory* of the basic group of users, the (average) total number of vessels and the number of different types within the inventory. Here it is assumed that each household had more or less the same inventory.

### 2.3.2 ETHNOGRAPHIC AND ETHNOARCHAEOLOGICAL EVIDENCE ON FUNCTION

Some striking similarities emerge from the review of Varien & Mills (1997) (appendix 2.2) in the categories of functions in ceramic inventories in different communities and cultures all over the world. The most frequently listed categories of functions of ceramic containers are the following:

- cooking, heating and boiling
- drinking and eating, serving
- transport of liquids and dry goods
- ritual and ceremonial activities
- storage of liquids and dry goods

Most of these activities are concerned with the processing (especially cooking) and storage of *food*, followed by the storage of a variety of other organic or inorganic substances and/or by the consumption of food and drink. The brewing of alcoholic substances also seems to be a universal activity. In many societies this activity is associated with special pottery. Another near-universal phenomenon is the relation between the function—and functional taxonomy—and the formal characteristics of ceramic containers. *Size and shape* are the most common indications of a function, usually expressed in a name for a type of vessel. The morphology of a vessel is the basis for recognition of the implied function by the makers and users, but classifications usually include other visible qualities, such as specific treatments of surfaces and/or additions like handles, decoration, etc. The connection between form and function is therefore an important means to establish the latter (see Balfet 1983; 1984). As Juhl (1992) argues, the content and activity will set at least some

| A: PRIMARY USE | | | RESIDUE | ALTERATION of surfaces |
|---|---|---|---|---|
| LIQUIDS<br>DRY GOODS<br>COMBINATIONS | FIRE-RELATED | COOKING POTS (FOOD) | soot +<br>charred food residues | cracked<br>burned<br>scratched<br>worn |
| | | OTHER (NON-FOOD) | soot +<br>charred residues | |
| | OTHER | STORAGE + STOCK | dry residues<br>liquid residues in/on wall | variable degree of alteration |
| | | SERVING/ EATING /<br>DRINKING | uncharred residues<br>(chars possible) | scratched<br>worn |
| | NON-EXCHANGEABLE USE<br>EXCHANGEABLE USE | | primary use residues<br>mixed residues | |
| | | | | |
| **B: SECONDARY USE** | | | **ALTERATION / EFFECT** | |
| | SELECTION | HEARTHS<br>FLOORS<br>RAISING LAYERS | secondary oxidation or burning<br>fragmentation<br>wear | |
| | | RITUALS | well preserved + (nearly) complete vessels | |

Fig. 2.4 Categories of use and the resulting use-alterations.

practical conditions for shape and size for such a use; to pour fluids requires a different shape than to store cereals, for example.
Beyond the similarities in the general functions, the data show between communities a large variation in the exact shapes, the number of different shapes and sizes of vessels, as well as additional characteristics. The degree of differentiation in ceramic functions also differs considerably between cultures or communities. In some only a few major distinctions are made between vessel classes, while in others many specific subcategories are recognized and named[5]. This is of course hardly surprising, as these are all defined within specific cultures. The point is that, despite the large variation in functional classifications, distinctions in functional classes are always expressed in visible qualities of vessels, including those with more than one function.

*Composition of household inventories*
One would expect, as most authors do, a relation between the number of functional categories and the number of vessels of each category in a household inventory, but the relation is far from straightforward.
Both the absolute number of vessels and the relative numbers for each category in household inventories vary widely between groups and/or cultures. Many factors together determine the actual composition, such as group size, the type of food production and processing, and the durability of the ware itself, to name but a few. If only relative frequencies are considered, the ranking of functional categories in the societies listed in appendix 2, table 2a is that of the list above; in general, cooking pots and serving ware constitute the highest percentage, and storage and ritual vessels the lowest. Varien & Mills (1997, fig. 4, 155) themselves present a slightly different ranking based on the *average* numbers for *all* data together: calculated that way, the highest numbers are storage containers and serving (eating and drinking) vessels, followed by vessels with a 'mixed' function, cooking vessels, liquid storage and ritual vessels. However, the overall average is a rather meaningless cross-cultural value which does not represent relative ranking within each community. As the highest *variation* in numbers between inventories occurs in cooking pots, followed by serving and transport vessels, the ranking of these groups is affected negatively.
Nelson (1991, table 8.1) tried to establish the mean number of vessels in an inventory per household and per group, using the same data as Varien & Mills. The Kalinga households, for example, make do with eight vessels, while the Tzintzuntzan households have 60 vessels at their disposal. This is not explained by variations in the number of people per household (average of 4.9 and 5.9 respectively for these extremes). He states, that one of the reasons for inventories with large numbers of vessels is 'stockpiling', defined as 'the accumulation of new vessels for eventual use' (Nelson 1991, 171). The consequence of stockpiling for archaeological research is further discussed in the next paragraphs.
An exceptional well-documented case study of inventories (David & David-Hennig 1971) is worth mentioning because it provides direct information at the household level (table 2c, appendix 2). The composition and size of the inventory differ substantially for the Fulani and Gisiga households in the same village in North Cameroon. For both groups, cooking, storage, drinking and eating, ritual and 'other' activities or contents are the six main categories for which pottery is used. However, the average number of vessels per household is 21 for a Fulani and only 10 for a Gisiga household. There is also a difference in relative numbers per category, mainly between the smaller cooking pots and the larger cooking/storage vats. The larger percentage of small and medium cooking pots in the Fulani household is due to the short average use-life, which is to some extent the result of the bad quality of the pottery. The quality, however, is itself related to the social and gender relations among the muslim Fulani. The higher percentage of the large cooking/storage vessels in the Gisiga household is related to the fact that they brew beer, while the much higher quality of vessels can explain the longer use-life and, therefore, the lower overall numbers. In this case a direct link could be made between religion (no alcohol-use among the muslims), social structure, and the quality and number of vessels plus their use-life. All of these aspects will play some, yet unpredictable, role in any pottery-using society.

*Aspects of actual use*
Theoretically, as an ideal concept, the actual use(s) of a vessel will be the same as its function(s). Wether or not there is a difference between the two will again depend on the rules and norms of the community concerned, and on the strictness with which these are applied in daily life. By studying actual use separate from functional definitions, a difference between the two should become evident. Such 'variations around the norm' are referred to as the degree to which vessels are *exchangeable in use*. This will in turn influence the choices made by the potters in the various steps of the manufacturing process, especially with regard to the basic recipes for the pastes for different functional classes (DeBoer & Lathrap 1979; see part 2.4).
Data on actual use can be gained much more directly than those on functions, through the analysis of *use alterations* on the pottery itself. Skibo (1992), continuing the work of Longacre, made an extensive study of such alterations of the Kalinga pottery in relation to different types of use (fig. 2.5). The marks of use alterations are often specific for the type

| | Use-alteration traces | | | | |
|---|---|---|---|---|---|
| Components of use activity | Organic residue | Carbon deposits | | Attrition | |
| | | Interior | Exterior | Interior | Exterior |
| **Cooking** | | | | | |
| User characteristics | - | - | - | + | + |
| Context | - | + | + | + | + |
| Actions | - | + | + | + | + |
| Time/ frequency | + | + | + | + | + |
| Contents | + | + | - | + | + |
| **Pottery cleaning** | | | | | |
| User characteristics | - | - | - | + | + |
| Context | - | - | - | + | + |
| Actions | - | - | - | + | + |
| Time/ frequency | - | - | - | + | + |
| Contents | NA | NA | | NA | |
| **Pottery storage** | | | | | |
| User characteristics | - | - | - | + | + |
| Context | - | - | - | - | + |
| Actions | - | - | - | + | + |
| Time/ frequency | + | - | - | + | + |
| Contents | + | - | - | + | + |
| **Pottery transport** | | | | | |
| User characteristics | - | - | - | + | + |
| Context | - | - | - | + | + |
| Actions | - | - | - | + | + |
| Time/ frequency | - | - | - | + | + |
| Contents | NA | NA | | NA | |

The pluses and minuses illustrate whether a use-alteration trace can potentially inform on that component of cooking, pottery cleaning, pottery storage or pottery transport.
NA: not available.

Fig. 2.5 Use-alteration traces in pottery. Source: Skibo 1992.

of activities. The most general distinction is that between alterations related to heat and those related to—mechanical—wear, cleaning, etc.

The actual uses of any (sub)category in an inventory are especially relevant for archaeological analyses. Theoretically, the frequency and type of use influences the use-life and break-frequency of vessels. The most frequently used vessels will also be broken most often, have the shortest use-life, while *thermal* and *mechanical* stress are considered to be the two most important factors for vessel failure in use. For example, vessels that are handled frequently, will have a higher chance of being broken than vessels that are never moved. This also entails that the replacement rate is the highest for the group of vessels that is broken most frequently. The frequency and type of use therefore influence the relative and absolute composition of household inventories on the one hand, and the *accumulation rates* of sherds from different use-categories on the other. The latter determines the composition of the 'death'-assemblage (DeBoer 1983) and ultimately that of the archaeological assemblages.

Depending on the time-span of occupation, the differential accumulation rates will result in an increasingly higher percentage of the pottery with the shortest use-life. In theory then, the study of the proportions of vessel categories in archaeological assemblages can reveal important information about the type and frequency of use in a specific settlement. Unfortunately, such reconstructions are much less straightforward than one would wish, not only in archaeology but also for the ethnographic examples. A growing body of (ethnoarchaeological) research on break-frequencies and accumulation rates has contributed much insight in the processes and parameters involved (Appendix 2, table 2).

### 2.3.3 ETHNOGRAPHIC AND ETHNOARCHAEOLOGICAL EVIDENCE ON USE- AND BREAK-FREQUENCY

Data from the available studies show a consistent ranking of the use-life for general categories of use, with only minor variation between societies (table 2a-c, appendix 2); from 'short' to 'long' the ranking is:

1 Cooking pots (especially small/medium sized)
2 Consumption ceramics
3 Cooking/storage vessels (double function, large sized)
4 Containers for liquids
5 Storage and ritual ceramics

In the majority of societies the cooking pot, especially the small and medium sized, is the type of vessel with the shortest use-life and the one with the highest replacement rate. How often and how much more frequent cooking vessels are replaced, evidently depends on the failure associated with cooking, as well as the frequency and type of use of the other categories. As can be expected, the *actual* use-life of vessels in a specific category show a very large variation between different societies. As so many factors are involved in these relationships, the replacement and accumulation rates are hardly predictable (Nelson 1991). Important intervening factors, like the change in use or the secondary use of vessels or sherds have been already mentioned before.
Unfortunately, very little information is available on the differences between functional classification and actual use(s). Only Nelson (1991) mentions that 27% of the observed vessels were serving functions other than those for which they were made. He introduced the term 'dead storage' for the secondary use of worn or cracked vessels or sherds; dead storage, as opposed to stockpiling, is "the retention of old vessels after their use-life is basically exhausted". An example is the multi-functional use of cooking vessels that are worn out. Obviously, the secondary use of vessels can have large consequences for both the composition and the characteristics of archaeological assemblages. A first attempt to outline such consequences for the pottery studied here is presented in the following paragraph. A second problem is that of the relationship between use-life data and actual break-frequencies. In principle the two should match, but as Nelson (1991) pointed out, most data on use-life are estimates given by the users. As the length of observation of the use of vessels is often too short for independent data (with the exception of Longacre's study of Kalinga pottery[6]) these estimations may well be inaccurate and differ substantially from the real break-frequencies. At the same time, data on the actual break-frequency and actual replacement rates are very scarce, especially for a longer period of time. The calculation of both for the inventories in San Mateo Ixtatan proves his point (Nelson 1991, table 8.4).

*Ritual use of pottery c.q. ritual pottery*

In the ethnographic literature, the involvement of pottery in rituals is mentioned so frequently, that it seems to be a near-universal phenomenon (as far as my knowledge of that literature goes). In appendix 2, table 2, pottery used in rituals and categories of 'special vessels' reserved for use in specific ceremonies are invariably part of the inventories and are often associated with beer-drinking. A partial explanation is the fact that ritual occasions are so often associated with festive eating and drinking, at least at present. A wealth of information on the ritual meaning of vessels is given by Saraswati & Behura (1966) for India. Although there is evidently a regional differentiation in the type of vessels and rituals, they remark that pottery is involved in ceremonies of birth, initiation, marriage and death everywhere; many of these occasions either require new vessels or involve the breaking of old ones. One example is the "grahapya or worship of the nine celestial bodies (the planets)" which requires nine *unfired* pots (168/9). Another widely spread custom is the "worship of the pitcher (a water jar), which should always be a new pot". They also mention that the use of pottery in rituals is often associated with painting[7]. Associations of special vessels with both water and ceremonies is also mentioned by others, for example Thompson (1958). Yet what happens to these vessels at the end of the ceremonies is not mentioned.

### 2.3.4 DEPOSITIONAL PRACTICES AND ACCUMULATION STUDIES

The third and final stage in the life-cycle of a vessel is that of discard or deposition of sherds and vessels. The most usual reason is that the vessel is broken and/or that it was used for specific depositions. In the foregoing text, references were made to depositional practices several times in the context of function and use, because of their consequences for interpretation in archaeology. Discard practices are the link between the use, the break frequencies and the pottery remains available to the archaeologists (although subject to postdepositional alterations). As was stated before, most communities will have their own rules for dealing with worn or broken artefacts. Differential treatment of the remains of vessels are mentioned in several ethnographic studies[8]. In archaeology they can only be inferred from the analysis of the context of deposition, especially the spatial context, in relation to the composition of the material remains (fig.2.6). Although accumulation studies are growing in importance in archaeology, very few are dealing directly with the overall similarities and differences in the contents of features as an expression of different discard

| PRACTICE | Context | Selection | Chance of Recovery | Chance of Restoration |
|---|---|---|---|---|
| RE-USE OF SHERDS | Hearths<br>Floors<br>Covering/<br>Raisinglayer | +?<br>??<br>??<br>?? | +/-<br>+/-<br>+/-<br>+/- | -/+<br>-<br>-<br>- |
| DISCARD OF SHERDS | Subsurface features[1] | ?? | + | -/± |
| SPECIAL DEPOSITION OF SHERDS | Subsurface<br>At/Above surface[2] | ?<br>? | +<br>- | -/+<br>- |
| SPECIAL DEPOSITION OF VESSELS | Subsurface<br>At/Above surface[2] | +<br>+ | +<br>- | +<br>- |

[1] House-ditches, wells, pits, field-ditches, creek.
[2] As 1, also wall-ditches, underneath hearths and doorways; special locations within any type of ditch.

Fig. 2.6 Depositional practices for vessels and sherds in settlements in North-Holland.

practices and meanings attached to refuse. In some recent studies, the frequencies of breakage and the vessel assemblage, reconstructed on the basis of a sherd assemblage, are used to calculate the occupation-span (Pauketat 1989). Varien & Mills (1997) argue, in my opinion correctly, that instead of using all remains, those of cooking pots are the most useful, because they are the most frequently broken category with the fastest accumulation rate. However interesting, such studies necessarily make quite a few assumptions, first of all for the average use-life of a (cooking) pot. I would much prefer the opposite, to use the occupation-span for calculations of the life-span of vessels, as such data could provide information about a subject that we know little to nothing about as yet. Either way, such inferences require special assemblages, such as one period settlements/ dwellings, burnt down houses etc. and such opportunities are rather scarce in archaeological contexts[9].

### 2.3.5 Depositional practices in settlements in North-Holland in the Roman period

Some known and unknown aspects of depositional practices in North-Holland are listed in fig. 2.6. These show how the composition of the archaeological assemblage may be influenced by or connected with the context of deposition. The use of sherds in the construction of hearths is one well-known phenomenon (Therkorn 1987a; chapter 3, this volume). Although more systematic study is needed, the impression is that hearths generally contain sherds from a few, possibly specially selected, vessels. Much larger quantities of sherds are usually collected from other settlement features, such as floors, creeks and ditches. The general impression is that most of this pottery does indeed represent refuse without any special meaning or selection criteria. Such dumps may therefore be representative of the pottery used. Large amounts of sherds were used also as part of covering or raising layers, such as those in settlements in the Assendelver Polders (Therkorn & Abbink 1987), in Schagen (Therkorn forthcoming) and on Texel (Woltering 1997). To have those amounts of sherds available, they must have been collected over a period of time. This practice not only is raising questions about the origins and dates of pottery in such layers, but also about that from the other settlement features. Special depositions of often complete vessels in settlement features are for example quite common as well. Depending on the excavation methods, they will tend to form the majority of the pottery that can be restored to sizeable parts of vessels or even complete ones. It is therefore possible that this pottery is the main basis for typologies. If the special depositions consist of specially selected vessels, the sample composition will not represent that of the total assemblage. The composition of any archaeological sample from settlements in North-Holland may therefore be affected by such factors, emphasizing the importance of starting from the feature context. In this study, the pottery from Schagen is analyzed in that manner, but the information available for Uitgeest is insufficient.

## 2.4 The manufacturing process

The process of making a vessel is divided into a series of activities and choices, schematically represented in fig. 2.1: the preparation of the paste, the construction of the vessel, followed by one or more finishing treatments and the firing of the finished product. Each of these four steps involves a series of possibilities and choices, embedded in traditions and technological know-how. The potter will always start with a ‘model’ in mind of the vessel she is going to make.

That model includes guidelines for all aspects (technological, functional, and other requirements) of the vessel and will determine its properties and characteristics.
The most important conditions and possibilities can be formulated by exploring for each step the decision-making process. Such a stepwise approach should in turn lead to the choice of specific variables, together with the choice of the level of detail and precision these variables need to be studied in each vessel. In the following paragraphs, the main types of variation relevant to each of the four steps is discussed briefly on the basis of literature. The analysis of the manufacturing techniques is aimed mainly at defining specific properties of a vessel in relation to its types of use. Much attention is given to the study of the fabrics as a major determinant of vessel properties, notably mechanical and thermal strength. This is followed by a review and evaluation of the results of 'performance' studies, dealing with the properties of fabrics in use. Details of this review can be found in appendix 2.1.

### 2.4.1 SELECTION OF RAW MATERIALS AND THE PREPARATION OF A PASTE

After deciding which type of vessel she is going to make, the potter first of all has to select and prepare the clay and tempering materials for the paste. The term temper or filler is, as usual, reserved for those materials that have purposely been added by the potters to the clay. The choice of both clay and temper, the *paste composition*, determines to a large extent the resulting fabric properties and will therefore be related to the expected primary use of the vessel. A useful concept that fits in well with the model is that of the 'ideal' or 'standard' recipe (DeBoer 1983); potters will arrive at certain solutions for the composition of a paste, through trial and error and experience. Such recipes are likely to be based on the most important category of use, the type of vessel that is used and/or is broken most frequently; they can be expected to stay more or less unchanged, unless there is a change in 'functional' demands or technology. In general, cooking pots tend to set the standard for the ideal recipes. How and how much the recipes for other functional categories differ from this standard, will depend on many factors, most importantly the technological know-how, the degree of functional differentiation and the types of stress involved. There are two extreme options: the potter will use the same recipe, the same type of clay and more or less the same amount of temper for all categories, or, at the other end of the scale, she will have different recipes for each category, varying both the type of clay and the type of temper. The following paragraphs deal with the most important properties of the raw materials.

*The clays: composition, extraction and preparation*

Clay beds are formed by deposition of clay particles by and in water, the most common form in the Netherlands, or by weathering and subsequent decomposition of solid rock. In both cases the origin of the clay determines its specific composition. The specific mineral composition of a clay can be used as a 'fingerprint' in the assessment of its source. Clays are usually divided into three main groups, kaoline, montmorillonites, of which illites are an important subgroup, and muscovites. Illites are most common in Holland and are characterised by a three-plate structure, usually fine-grained minerals and a relatively large ion exchange and water adsorption capacity; the latter refers to the capacity to bind water to the clay crystal (*Keramiek*, 1973, chapter 4). Both capacities are important for the plasticity of clays. *Plasticity*, "the characteristic property of moist clay that permits it to be deformed without cracking and to retain its new shape when the deforming stress is removed" (Bronitsky 1986b, 213), is determined by the structure and texture of a clay[10]. In general a finer clay particle size and a more homogeneous clay increase plasticity (Shepard 1963). The size and distribution of non-plastic minerals and impurities in the clays also have an effect on the plasticity. Non-plastic materials can be divided into two kinds: minerals adhered to the clay structure and separate constituents in the clay deposits. The latter often consist of sand particles and humus, or organic materials, metal compounds, lime, salts, etc. Plasticity is important from the potters point of view for the workability of the clay. *Workability* or formability is the capacity for and ease of constructing forms (Bronitsky 1986b, 123), an assessment that is relative to the techniques of construction. Ethnographic evidence suggests that potters make a conscious selection of clay beds to extract potting clay from. They usually asses and know the qualities of clays in their environment by 'feeling' their specific composition and properties and often take much trouble to get the 'right' clays in relation to the construction techniques they are using (van As 1986; Krause 1985; Nicklin 1979; Saraswati & Behura 1966). Potters can improve the properties of raw clays in a number of ways: homogeneity is increased by rotting and kneading, by sieving or levitation—letting the clay settle in water and separating finer and coarser silts—or by simply picking out the larger impurities. All of these clay treatments are known from non-industrial potters in recent history[11]. The reasons for these treatments vary from place to place. The study of pre-treatments of clays for archaeological materials is not easy, as so many variables are involved. One should be able to establish the exact location of the clay extraction pits as well as the similarities and differences in the composition of the clays, both then and now[12]. It can be argued that a very heterogenous texture of fabrics, with natural inclusions clearly present, might point to the absence of pre-treatment.

*Argillaceous and non-plastic inclusions*

A separate paragraph on 'natural inclusions' in clays is warranted as these form a distinctive feature in the pottery studied here. They are here defined as any *macro-sized* component in the fabric that is clearly distinguishable from the overall clay matrix as a separate constituent, and has not been added as temper. Inclusions are often a natural constituent of Holocene clay deposits. The three main types occurring in the Netherlands are argillaceous inclusions—or clay pellets type C of Whitbread 1986, see appendix 2.1—, calcitic nodules and, most important, iron concretions. These three types will be discussed in more detail in chapter 4 and 5. 'Macro-sized' in the definition refers to visibility without optical aid, which means approximately 0.1 mm or larger. This is important, firstly because such inclusions could be seen and felt by the prehistoric potter and may therefore have influenced the choices of specific layers. Secondly, there is, technically speaking, no difference between macro-inclusions and temper as far as fabric properties are concerned; both can influence the resulting properties of fabrics. But in contrast to temper, the influence of macro-sized inclusions on the fabric properties is still poorly understood. One of the reasons for this is methodological. Most micro-analytical techniques for fabric studies cannot discriminate between clay, inclusions, and temper, while at the same time the type as well as size of inclusions can greatly influence the results of such analyses[13]. They are therefore not suitable to establish conscious manipulations of fabrics within one pottery complex. The percentages of iron and calcium can, for example, vary considerably between samples taken from different locations within a vessel. Moreover, the use of such techniques generally severely limits the sample size. Depending on the aims of the analysis, such procedures may of course be fully acceptable. They are most successfully applied in provenance and characterization studies, discriminating between different clay sources. For the present purpose, to evaluate the influences of different constituents in the paste on fabric properties and the potter's selection of clays, macro-textural analyses are much more suitable. Thin sections are in some respects a useful means to study these constituents. A problem is that they usually are so small, that larger sized inclusions are easily missed. For the same reason they are unsuitable for the quantification of inclusions, whether naturally present or added.

*Choice of temper: type and quantity*

Temper or filler is defined as added, usually non-plastic, materials. Temper is most often of a different size and quality than other non-plastics that can occur naturally in the clay itself[14]. Since the days of viewing it as a technological rather than a stylistic trait (Shepard 1963; Thompson 1958), many data have been gathered on the use and effect of temper in pottery from both archaeological and ethnographical contexts. These give a firm basis to the assumption that potters usually have good reasons to choose a specific temper. One objective of adding temper is to improve the workability of the potting clay during the construction phase, that is, to improve control over the tendency of clay to sag or collapse during construction of a vessel (Bronitsky 1986; Van der Leeuw 1976, 1987). Temper also is a means of reducing the amount of shrinkage during the drying stage of the vessels[15]. The second objective is to produce a fabric with specific properties, desirable for specific functions of the vessels. The choice of temper thus is a fundamental links between the potter's technological know-how and the functions of the pottery. The potter will decide on the *kind, quantity and size* of temper in relation to the specific composition of the clay—another reason why it is important to study macro-inclusions—to obtain the most 'desirable' paste and fabric. The variable effects of different types of temper on the properties of the fabric are on the whole quite well-known, even though not always well-understood.

All pottery studied here contains organic temper, more specifically vegetable fibres. Research into its advantages and disadvantages in relation to the functions of the pottery is limited, but some qualities and effects are mentioned in the literature. The nature of the material generally improves the plasticity of the clay, but vegetable matter or dung will shrink during drying; when added in a dry state, it will take up some of the free water in the clay and then shrink again. Nevertheless, organic temper acts as a support during construction; its strength is possibly due to the silica content of the fibres (Braun 1984, 62)[16]. The organic material will substantially influence the porosity of the fabrics by leaving a large number of cavities. The more organic temper is added, the higher the porosity will be.The effects of temper on the fabric properties will be further discussed below.

As for the amount of temper added, the very few data available from ethnographic accounts indicate that they are determined by experience rather than exact measurements. Most non-industrial potters do not measure the amount of temper with any precision, but judge the 'proper' amount by eye and add as much as is needed to a certain amount of clay until the paste 'feels right' (Thompson 1958; none of the many potters in that study seem to measure the amount of temper exactly). The rightness partly depends on the function of the future vessel and partly on the specific type of clay. The proportions of temper to clay, mentioned in the literature, are therefore only approximations. As is to be expected, they vary considerably from place to place and, as Thompson (1958) showed, even within the same technological tradition and functional group[17]. The only reference to exact amounts of organic temper is made by Saraswati & Behura (1966, 44-46) for pottery manufacturing in India. The use of both dung and plants as temper is there a widespread tradition because, as one potter put it: "no amount of sand or ash can prevent the pot from cracking. It is only dung that counteracts the tendency of a pot to crack". Depending on the amount of sand in the clay, the ratio of clay to dung, from horses or donkeys, was 4:1 for clays with more sand or 4:2 + a half measure of ashes for clays with less sand. From another region, with a different clay, the proportions of 4:4 of clay to dung were used for cooking pots and 4:2 plus a little sand for water jars. The organic material was added in a dry state. Krause, in his study of three African potters, noted that one of them used a ratio of 5.44 kg of clay to half a calabash of crushed potsherds, the calabash measuring 17.89 cm in diameter and 8.9. cm deep (no volume is mentioned). The other two women did not add any temper at all, but selected "good clays, as a good clay doesn't need any additions. It is interesting to note that her wares would be identified as sand-tempered if traditional archaeological standard were applied" (Krause 1985, 92).

The potters in these three ethnographic studies had a rather impressive knowledge of their craft and the pottery shows a relatively high degree of functional differentiation. More examples can be given, but the point I wish to make in relation to archaeological studies is that small chance variations in temper quantity can be expected, even with a 'strict' standard. It can further be argued that if the degree of functional differentiation is low an even less precise measurement of quantities is to be expected; alternatively, that the most frequent use-category will set the standard for the amount of temper in this pottery. Some form of quantification of temper, both for the amount and the size, is therefore important in order to establish these variations in archaeological studies. However, if organic temper is quantified at all in archaeology, this is always based on its visibility on the surface or fractures. Such data are very imprecise and unreliable. Firstly, because the surface treatment affects the visibility while vegetable temper cannot be seen on fractures, let alone be quantified. Secondly, as with large natural non-plastic inclusions, only very few fibres will be included in a thin section, if only because these tend to be aligned parallel to the vessel wall. To obtain a more or less reliable measurement of quantities, a large surface as well as good visibility of the fibres is needed. Thin sections are therefore not very useful. For these reasons specific methods were developed in this study for the quantification of temper and natural inclusions.

### 2.4.2 CONSTRUCTION TECHNIQUES

The following is based mainly on the work by Van der Leeuw and Spruyt on the pottery of the Assendelver Polders. All pottery has been constructed by coiling. For the basic modes of construction the reader is referred to Van der Leeuw *et al.* (1987, p. 239-242; several other articles dealing with these techniques can be found in Van der Leeuw & Pritchard (1984). Most vessels from the Roman period are three-partite with a continuous and rounded profile (see fig. 8.1). The following description is based on such a shape.

In the construction of hand-made pottery in general, the potter has to control both the form and the tendency to sag or collapse (Van der Leeuw 1976; 1984). These conditions determine the possibilities of the coiling technique to make a desired shape. The three critical points in the construction are the making of the extremities and of the inflections (Balfet 1984): starting the lower wall construction on the base, the construction of the maximum circumference, and that of the end of a vessel, the rim. The main limitations are set by the angles of the lower wall to the base and of the upper wall to the point of maximum width, but they are always related to the *size* of the vessel. These angles, the vertical tangents, cannot be too wide without having to support the vessel or risk the sagging and collapsing during or after construction. The size and shape of the base are therefore important for the maximally feasible height and width, as well as the sturdiness of a pot, the vertical tangent of the lower wall being the most critical factor for these sizes. The larger the vertical tangent, the sooner the lower wall will collapse or the shorter this wall will have to be. Vice versa, a very small angle, a near vertical built-up will also lead to collapse at a certain point because of the weight of the clay. Basically this means that the desired width of the vessel at the maximum circumference determines the angle of the lower wall and thereby to a large extent its size. The same conditions apply to the construction of the upper wall. Again there is a direct relation between the angle and the possible length of the upper wall and thus also with the size of the opening. Clearly, there should be a balance between the two parts: the possible size and shape of the upper wall is dependent on that of the lower wall. Thus, all of these proportions, their balance and limits, are important determinants for the overall size and shape (Balfet 1984).

The 'end' of a vessel, its rim, can be constructed in many ways, but a particular way often has a final influence on the shape of the smallest diameter and the rim itself. In the pottery dealt with in this study, the most frequently applied technique is to fold the last roll, which forms the smallest diameter, either to the in- or to the outside, or apply an extra roll for the same purpose. The reason is most likely a technical-functional one, as a folded rim is much stronger than an unfolded one and is also easier to finish (Spruyt, pers. comm.). The folded roll can be pushed down and out to almost any angle as long as it is short. Depending on the forces used to finish the rim, the shape of the upper wall can also be slightly altered in the process (Balfet 1984; Van der Leeuw *et al.* 1987). These basic conditions obviously leave ample room for variations at each of the three critical points in the construction, variations that are directly related to the type of vessel the potters and users distinguish. As explained in chapter 1, the results of the analysis of the construction techniques are not published here.

### 2.4.3 FINISHING THE CONSTRUCTION: TREATMENT OF RIM, BASE, AND WALL

The way the vessels were finished, the treatment of the surfaces, bases and rims are the next important step in the manufacturing process. These treatments result in the *visible* features, the appearance of a vessel. There are three general techniques for surface treatment: using the fingers or a tool to smooth the surfaces, or a tool to scrape it. The tools may be hard, like a pebble or wood or bone, or soft, like a cloth. Good examples of such tools are given by Thompson (1958) and Krause (1985), and fig. 8.24.3 presents a possible tool found in Schagen-Muggenburg. In this paragraph the results of the analysis for the Assendelver Polders pottery are summarized. With the coiling technique, the vessel walls may be rather thick, and the construction will also leave irregularities in and surplus clay on the surfaces. The first step in finishing is to even out and smooth the surface and/or to reduce thickness. A second treatment, smoothing by hand or tool, scraping, or polishing can give the surfaces a specific quality. Several treatments can of course be combined or they may vary for different parts of a vessel wall both interior and exterior. The importance of finishing treatments is twofold. Firstly the regularity of wall-thickness and the type of surfaces are important factors in the firing process; a more regular thickness will diminish the chances of cracking or breaking. A polished surface looks different, is smoother and 'shinier' than a scraped surface, that will tend to have an open texture and a dull look. Secondly, the finishing influences the properties of the vessel in use, although this is mediated by the firing methods. Both smoothing with the fingers or a polishing tool will tend to create a less 'open' surface, as opposed to scraping. Intensive polishing in particular can greatly reduce the permeability of the wall as this treatment aligns the clay plates parallel to the vessel wall. It possibly also has an effect on thermal and mechanical strength (Schiffer *et al.* 1990; also paragraph 2.5). Surface treatment may also include the application of extra clay 'thrown' onto the exterior surface and thus roughening it. In the present study, a large percentage of the lower walls of vessels is treated in this manner. The possible functional reasons are to improve the grip on the vessel and/or to improve its thermal stress resistance, to be discussed in chapter 8.

### 2.4.4 FIRING THE VESSEL

The reconstruction of firing methods is a complicated, but also important aspect of fabric analysis, firstly because of possible failure of vessels during the firing and secondly because the 'pyrotechnology' has a decisive influence on the resulting fabric's properties and strength. The atmosphere within the fire, the duration of the firing, the speed of heating up and the temperatures reached, all together determine the nature and intensity of de- and recrystallisation processes and the degree of vitrification of a specific paste. Some of the technical details of vitrification, in so far they are relevant for the present study, are included in appendix 1. Also of influence is the type of fire, which can be an open fire or any kind of kiln. Here only open air firing will be considered. Although kilns are known from the Roman period, there are no definite indications that they were used for pottery, moreover, the characteristics of the pottery itself point to open fires. Control of atmosphere and temperature are much more difficult in an open fire than in a kiln. A vessel fired in this way will show more variation in its resulting features, such as its colour.
The ethnographic data on this subject show among different societies a very wide range of firing methods, maximum temperatures, duration of firing, and the amount of vessels fired in one batch. For example, a total firing times of less than 20 minutes are mentioned by Shepard (1963, 83-6[18]), David & David-Hennig (1971), and Krause (1986). This hardly seems adequate to produce durable pottery, but it was obviously considered 'good enough' or 'the best possible' in those contexts. Little is known about failure rates, that is how often vessels break during firing. As Woods (1990, 169) suggested, this factor may be an important criteria for the potters themselves and even influence the paste composition: *"if pots can survive firing, and open firing in particular, they will usually be able to withstand the heat involved in any subsequent cooking process"*.
Several techniques are available to measure the firing temperature, (such as DTA and dilatometric measurements, see Brongers 1984) as well as for the duration of firing (by assessing the degree of recrystallisation) (Wevers, unpublished). Within the strategy and aims of this study, these analyses would have to be carried out for a large sample. Because of the complexity of the matter and the costs involved it was decided to restrict the analysis of firing methods to those variables which can be observed directly on the vessels and would have been visible or knowable by the potters as well. The selected variables are the colour and the apparent porosity; the latter is discussed in the section on fabric performance. This simplification is justified when it can be assumed that the type and length of firing and the maximum temperatures would have been more or less the same for all pottery, within the variations that are inherent to the use of open fires. This assumption seems acceptable, because there is little reason to assume otherwise.

*Paste, firing methods and colour:*

The colour of a fabric is basically the result of the firing temperature, the main colouring agents in clay—iron and calcium—, and the firing atmosphere. The colour is determined mainly by the ratio of Fe to Ca. It is therefore a comparatively straightforward indication of at least the firing atmosphere, but indirectly also of the temperature and duration, if the composition of the paste is known. 'Colour' may have been a criterium for the potters in North-Holland to judge the right moment to stop the firing[19].

Iron oxides are the most important colourant of clays. Even a small amount will result in any shade of red or purple under oxidizing circumstances. The more oxygen is available, the brighter the colours will be, the firing temperature and duration being equal. In a reducing atmosphere the colours stay grey to black, while higher temperatures will result in a purple colour. The influence of calcium is that it reduces the brightness of the colours of the iron oxides; an increasing ratio of Ca to Fe results in increasingly lighter, more yellow colouring in oxidizing circumstances. In a reducing atmosphere the presence of lime also results in lighter, increasingly whiter colours at temperatures above 1000 $^0$C (*Keramiek* 1973, 124-5). The second intervening factor in the relation between firing methods and colour is the presence of organic materials, the temper used for virtually all pottery studied here. Organic matter will use most of the available oxygen until most of it has been burnt out. Only then iron oxides can be formed. The burning out of vegetable temper progresses in two stages: dissociation and combustion. The dissociation of organic material starts at about 100-300 $^0$C, depending on the available amount of oxygen. The rate of combustion is in general lower at lower temperatures and takes a "rather long time" (*Keramiek* 1973, 123). Johnson *et al.* (1988) mention that there is quite a variation in temperatures and duration mentioned in the literature. Their own experiments show that the highest rate of carbon loss takes place between 200-400 $^0$C (more than 50 %), dropping between 400-600 $^0$C to less than 20 %; the organic component has virtually disappeared at 800 $^0$C. There is some difference for firing in an oxidizing or reducing atmosphere, but this is surprisingly small. The degree of combustion of the temper, together with the colour of the surfaces, thus are an indirect and admittedly not very precise indication of the firing time and temperature.

### 2.4.5 PERFORMANCE STUDIES: THE RELATIONSHIP BETWEEN POTTERY FABRICS AND VESSEL FUNCTIONS.

Pottery fabrics and their strengths are the complex results of a large number of mutually dependent variables, from paste composition to the firing methods. The strength of a fabric is in turn one of the most important determinants for the 'performance' of the complete vessel in use: how well does the vessel withstand the two main kinds of stress, *mechanical an thermal*, and for how long. The 'strength degradation' is a fabric's reaction to repeated stress; see appendix 2.1 for definition and explanation of terms. Theoretically, the potter can manipulate strength by choosing specific recipes for fabrics, depending on the functions of the vessels. These fabric properties are the subject of the so-called performance studies, a relatively recent development in archaeology. A review of some of these studies is presented in appendix 2.1. Most of these are based on tests in which repeated mechanical stress is applied until the fabric breaks. Unfortunately the results of performance tests are often conflicting. Here only the summary results are used in the attempt to formulate some 'theoretical' conditions and parameters of vessel strength on the basis of the review. The following conditions with regard to (a) fabric composition and (b) vessel properties, are suggested in the literature:

*Mechanical strength and stress resistance is increased by:*
(a): decreasing amount and size of temper (?)[20]
mineral/calcareous temper (?)
decreasing porosity (?)
a more homogenous microstructure
(b): increasing wall thickness
round(ed) forms/ and greater curvature
smaller sized vessels

*Thermal strength and stress resistance: is increasing with/increased by:*
(a): temper with a low thermal expansion coefficient
organic temper; coarse temper
increasing amount of temper (?)
increasing (?) or decreasing (?) size of clay and temper particles (?)
increasing porosity and pore size
increasing conductivity and diffusion rates for heat
(b): decreasing wall thickness
more rounded, spherical forms

The inconsistencies in results are partly due to a lack of uniform methods and techniques used in performance tests but are also symptomatic for the complexity of the subject. Both kinds of stress resistance are to a large extent determined by the same set of properties, but by different and partly contrasting combinations. The 'ideal' recipe for making a mechanically strong vessel will make that vessel less suitable as cooking pot and vice versa. The 'ideal' recipe for a cooking pot would be a thin-walled, rounded vessel and a fabric with a relatively high porosity, while the ideal recipe for a small, frequently used storage vessel would be a thick-walled vessel and a fabric with mineral temper. I agree with Woods (1990), that too much significance is attached to the present-day 'scientific' rationale of fabric properties. In the practices of manufacturing and use, the conflicting demands will be solved by the potter by compromising between the 'ideal' properties for a vessel (as far as these are known and feasible within a social/technical context) and its successful firing. Equally important are the conditions of use outlined above, the interchangeable uses and the degree of functional differentiation. At the same time, it can be argued that thermal strength is perhaps the most important requirement because of the firing process itself and because all vessels, including cooking pots, with the possible exception of storage vats are subjected to mechanical stress because of handling. In this sense, all vessels have to be mechanically strong, whereas any use involving heat requires 'extra' strength. Again, the cooking pot will then tend to set the standard for the basic recipes.

Altogether it can be concluded that it is much to be preferred to approach the potter's choices as a series of knowledgeable compromises within the social-cultural context of the uses of pottery and to analyze pottery at that level rather than apply high-precision micro-analytical techniques for limited samples.

*Porosity measurements*

Another conclusion that can be drawn from the performance studies is the importance of the porosity of a fabric. This quality can to some extent be known and therefore manipulated by the potter.

The porosity is determined by the combination of pore size, pore distribution, the number of pores and their degree of interconnectedness. The main types of pore-patterns are called pocket porosity and channel porosity (Shepard 1963, 127; Reid 1984, 64). They are the result of the kind and amount of temper, the composition of the clay itself, and the firing method. There are two kinds of porosity measurements: the *apparent and true porosity*. The first is the volume of air space that is accessible from the surfaces. Apparent porosity depends to a large extent on the distribution, *i.e.* the interconnectedness of the individual pores. The true porosity is the total of all micro- and macropores within a ceramic body. True porosity can be measured only by special techniques, such as replacing the voids with mercury (Steponaitas 1984). Measuring the percentage of *apparent* porosity of a fabric, the '%AP', for short, has several advantages. It is a relatively easy technique that can be used for large samples. Although the evidence for the effects of porosity on strength is not unequivocal either, it is less conflicting than for other variables. Especially for vegetable temper, the effects can be theoretically and empirically established with reasonable certainty. Firstly, increasing quantities of this type of temper increase the %AP, everything else being equal. Secondly, the porosity has a direct effect on the conductivity and the diffusion rates of heat[21].

A high %AP has a positive effect on a vessel's thermal strength through an increased conductivity of heat, as well as a higher resistance to both initial cracking and crack propagation (*e.g.*, Bronitsky 1986; Bronitsky & Hamer 1986). It also causes a reduction in the thermal gradient across a sherd. The volume of air will absorb the energy and arrest the initial cracking. These properties result from the alignment along the clay-axis, and the low expansion rates of organic matter or the cavities left by them. However, different types of organic matter can cause different pore structures in the vessel wall. Pore size and distribution of pores through the fabric and vessel wall are perhaps more important to performance than porosity per se. *Channel porosity* perhaps makes a vessel more heat resistant than *pocket porosity*, but increases the permeability and may result in leaking. This effect is often mentioned as a desirable property of water containers in a hot climate, but it is undesirable for vessels used for heating or cooking (Schiffer *et al.* 1994). Pocket porosity therefore seems preferable for cooking pots (Reid 1984). The vegetable temper used by the indigenous potters can result in both types of porosity, mainly depending on the quantity as well as size of the individual fibres. Both dimensions are analyzed in this study.

## 2.5 Technology, function, and use: implications for this research

In the foregoing it was tried to clarify some of the many and complex interrelationships between choices involved in the process of making a 'useful ceramic product'. What became most clear is that thus far the conditions that determine strength are still poorly understood. The main reason is the lack of standardisation in the methods and techniques used to establish fabric performance; this in turn has largely to do with the fact that there is so much variation in pottery fabrics from prehistoric and historic assemblages—the possible combinations of all variables involved are innumerable. Each group of fabrics from any period and/or region will have its own characteristics, *by which, of course, we recognize it*.

The nearly unlimited variation not only makes it very difficult, but perhaps even undesirable to try and formulate 'general conditions' for fabric strength and properties, especially if limited to performance only. Successful firing may have been of primary concern to the potters. Clearly, any real understanding of fabric durability requires that all information for a *specific* pottery assemblage is combined. However, at the same time it is necessary to strive for the comparability of methods so that data from different sources can be compared.

### 2.5.1 RELATIONSHIP BETWEEN TECHNOLOGY AND FUNCTION

Despite the limitations and contradictions of performance studies, a few tentative conclusions that are relevant to this study can be drawn. They are used as starting points for the fabric analysis. This is first of all the distinction between thermal and mechanical strength and durability in fabric properties, which can be linked to variations in the basic recipes on the one hand and to the function of vessels on the other. The following conclusions seem valid in this respect:

- The %AP is an important indicator of the overall fabric properties. A high %AP, especially in the form of channel porosity, is favourable to thermal strength.
- Too many quartz particles, especially coarser fractions, will reduce thermal stress resistance through increased cracking and crack propagation, and does not really seem to improve the mechanical strength of a vessel.
- Non-plastic 'impurities' in the clay, the kind of minerals in the inclusions, their size and size-range, and their differential rates of expansion can cause large variations in the resulting fabric properties, but their effects for both types of stress are still poorly understood.
- Vegetable temper, used in all pottery of Uitgeest and Schagen, increases the thermal strength of a vessel without affecting the mechanical strength too much. The size and quantity of temper show a rather straightforward relation with the %AP, every thing else being equal.

The following assumptions and hypotheses were formulated:

1. The potters will have been aware, if only by trial and error, of at least some of the properties of the clays they chose in relation to the construction as well as the fabric qualities after firing. As clay deposits are ubiquitous in the western Netherlands, it is assumed here that 'good clays' were always available in the near vicinity of settlements. It is also assumed that the definition of 'good clays' will stay more or less unchanged if the required properties of the pottery remain the same as well. Within the similarities in overall clay composition in local deposits there may be considerable variation in the nature and degree of 'impurities', affecting the plasticity, workability and firing properties. These can also influence the strength of a fabric and its porosity, but this effect is as yet badly known. It is, for example, not clear whether the coarse inclusions in the pottery studied here will tend to lower or enhance the porosity of a fabric and its thermal stress resistance. *Similarities and differences in the clay matrix, especially in the amount of quartz and in the type and quantity of inclusions, may therefore point to selections of specific clay-layers and/or be related to specific recipes and functions*. Moreover, these aspects of clay types should be analyzed for all vessels in a large sample. This practically excludes the use of specialist laboratory techniques.

2. The addition of vegetable temper can be taken as a conscious manipulation by the potter, in order to improve the workability of the paste and/or the strength and durability of the finished product. The hypothesis for this study is that the amount of temper will be determined by the most important use category of vessels. Most likely, the choice for vegetable temper is related to thermal strength and stress. This type of temper, together with its quantity, will be one of the main factors determining the %AP of the fabrics, perhaps together with the natural inclusions. The quantification of both variables is therefore an important requirement and new methods for this had to be developed. Even when 'standard recipes' were used, there would have been variations in the standard quantities of temper, if only because of the nature of the material and the measuring devices available to the potter. At the same time, taking the 'natural' variation into account, the standard amount of temper can expected to be a yardstick for the amount used for other functional groups, when and if variations on this basic recipe were applied. Such variations in the amount and perhaps the size of temper might therefore be an important criterium for a fabric classification and especially for linking the fabric classes to the data on the function of the pottery.

3. The way in which a vessel was fired is a decisive factor in fabric strength. The duration of firing, the supply of oxygen and the maximum temperature determine the degree to which chemical changes in plastic and non-plastic minerals and vitrification can take place, but also the degree to which the vegetable matter will be combusted, *i.e.* burnt out. Specific minerals, mainly iron and lime, are important determinants for the colour of the product after firing. The colour and its variations can therefore be used as indicators for the firing technology and to some extent for the chemical composition of the clays. Both the atmosphere of firing and the degree of combustion can be observed in any pottery complex[22].

Altogether, the qualitative and quantitative analysis of clay and temper can provide information about the selection criteria of the potters, and through this about the expected quality of the pottery. These data should be analyzed together, but also in conjunction with the firing methods, in order to understand what potters were striving for. The goals of the potters, the 'desirable' properties of the product, clearly depend on the kind of use to which the pottery is put mostly. The standard recipes thus form a direct links between technology, function and the type of stress involved. The fabric analysis should therefore be aimed at the characterisation of—the variations in—the basic recipes. The resulting fabric classification is one step in the analysis to be combined with other data, first of all those on construction and finishing, into a comprehensive set of data on pottery technology.

### 2.5.2 FUNCTION, USE, AND DEPOSITION

The conclusions to be drawn from ethnohistorical studies and the consequences for archaeological research are self-evident. Firstly, there is an overwhelming number of variables involved in the use practices of pottery that determine the composition and size of a household inventory, as well as the resulting 'death assemblage'. In every group the classification of functions, together with actual use and the discrepancy between the two will articulate the actual frequencies of breakage and replacement rates. How this replacement is actually organized, by stock-piling, dead storage, or greater numbers, ultimately makes little difference for the archaeological sherd assemblages, although it does mean that there is no way to predict use-life and frequencies of breakage. Any calculation has to be based on information from a specific assemblage. At the same time, this specificity can be used as a source of information about the group concerned. The internal and relative composition of an archaeological sherd assemblage can, under certain conditions, give insight into the relative frequencies of breakage and through this into the relative use frequencies and composition. For this reason both Nelson (1991) and Varien & Mills (1997) suggest that the reconstruction of a ceramic inventory should concentrate on the group with the highest turnover, which in most societies is the cooking pot. The studies also indicate that the *internal* variation and differentiation in visible features like the morphology and invisible ones like fabric recipes can be used to establish the classifications of functions and functional differentiation in any pottery assemblage. Furthermore, the *sherd* assemblage can provide information on the actual use and, under certain conditions, also on the life-span, and thus on the differences between formal and actual use. The most important variations and conditions were summarized in fig. 2.2 for function, in fig. 2.3 for the actual use, and in fig. 2.5 for breakage variables.

The following general and interrelated notions, 'hypotheses' are the starting points for the research of these subjects[23]:

– *The degree of functional differentiation:*
The more functions are defined and recognized for pottery, the more strict the rules will be for the properties and 'appearance' of the vessels associated with one function. Vice versa, if broad and overlapping categories are defined, the vessels will show only a limited differentiation. Which characteristics of a vessel are recognized by all as the 'label' for its function will have to be inferred from the characteristics of the pottery assemblages.

– *The type of use and the strength:*
The qualities expected of a vessel, thermal or mechanical strength or both, will influence the potter's choice of basic paste recipes, evidently within her knowledge of fabric properties. These choices will, moreover, be influenced if not determined by the degree of functional differentiation and the degree to which a vessel's functions change in actual use. If the former is low and the latter high, any vessel may be subjected to different forms of stress. The potter then has to find a compromise in the recipe for the paste. The extent to which fabric compositions vary can therefore be an important contribution to establishing functional differentiation, which will be discussed in detail in sections 3.3 and 3.4.

– *The changes in use or function:*
The more specific and circumscribed an activity and/or content is, the more likely it is that a specific vessel is made and used for one purpose only. The degree to which vessels from different categories are exchangeable will then be low. In the opposite case it could well be that some vessels are classified as having more than one *function*. This can again be exemplified by 'cooking pots'. These may be seen as one category of vessels, which are used indifferently for all types of cooking, or there may be a distinction in types of cooking pot, related to specific types of cooking and/or types of food, *e.g.*, stews, porridge, or soups, which is strictly applied in practice. Another often mentioned example is the large cooking pot, which also functions as storage vessel. Such detailed information on the relationships between use categories and vessel functions surely is hard, and in many cases impossible, to get from archaeological contexts. Any attempt in this direction can be made only after general categories of functions and functional differentiation within the pottery have been established, but at the theoretical level this aspect should be incorporated.
A related hypothesis is that some pottery may have special meanings or values; these may, for example, be designated by gender or ritual ceremonies. Many ethnographic and archaeological examples can be given of the latter, such as the use of decorated Beakers in grave contexts or the vessels reserved for ritual drinking of alcoholic beverages in both prehistoric and many present day societies (Diepeveen-Jansen 1998). Vessels may even be exclusively made for such occasions or they may be broken on purpose (see paragraph 2.2). Such specific uses and meanings can, but not necessarily are, expressed in special characteristics of the pottery and/or be related to specific contexts of deposition.

As a specification of the ideas formulated above, the following expectations are formulated for the pottery studied here.
– The degree of functional differentiation is expected to be low, but there will be some distinctions between classes of vessels that are associated with categories of use, which are expressed in their morphological characteristics of size, shape and qualitative features.
– There may be categories of vessels with more than one formal use and/or the actual use of vessels may differ

from the formal use. These possibilities will have bearing on the manufacturing technology and the morphological properties of the ceramics, but also on the relation with composition of assemblages in the ways outlined above.
– If the degree of differentiation is low and the actual use is variable, the *variations* in frequencies of breakage of different vessel types may also be limited. As a consequence, the composition of the assemblage will show a relatively slow rate of increase of the category that would be the most frequently broken one by its formal definition.

## 2.6 Research strategy and methodology

From the foregoing sections of this chapter and from chapter 1 some specific requirements for the 'ideal' research strategy and methodology follow directly and logically. Firstly, because of the morphological and use alteration analyses, the sample itself should consist of as many *complete vessels or complete profiles* as possible and be in good condition. Secondly, at the same time, a *large sample size* is required in order to cover all variations for all variables present within a pottery complex. Ideally the size and composition of the sample should be representative for the complete assemblage, based on the context from which the pottery is recovered and through this, on the control over temporal, spatial and depositional aspects. Thirdly, it is necessary to examine *all* variables, related to the technology, the function and use, in the same way for the same sample, that is *for all individual vessels in the sample*. These requirements are the selection criteria for the samples of pottery used in this study. Furthermore, the fabric analysis will have to include at least some data on the basic physical-chemical composition of the clays and some form of quantification of the natural inclusions, the quartz particles as well as the temper, both for the size and the quantity of these. Such data should be the basis for establishing systematic variations in the overall composition which are to be linked to the choices of potters in relation to functional groups. Finally, the methods should be applicable to any sample of comparable handmade pottery to ensure that in the future a comparison of data from different sites may finally be feasible.
Evidently, the methodological requirements and the ideal research design are in many ways conflicting with actual research practice and could only be partially realized. In practice, difficult choices had to be made to limit the number of variables and the considerable time involved in measuring these at a detailed level, in particular for the fabric research. As discussed, very few standard methods are available for macro-observations on fabric composition, whereas the level of precision is usually low. The methodological problems for the fabric research were in part solved by a research strategy in which different techniques were developed and used for different groups of variables. To be able to distinguish between clay composition, macro-sized inclusions and temper, techniques were needed which can study these variables at an appropriate level of observation and accuracy and enable the different data to be combined. The methods and techniques to measure these variables also had to be appropriate to the nature of the variations, that is to the kind and degree of variation in the clay composition the potters themselves could have recognized and acted upon. Most methods were developed through a pilot study of the pottery from Uitgeest. The development and 'trying out' of such methods has subsequently become a substantial part of this research.
The sample size and composition of the pottery of Uitgeest and Schagen also do not meet the ideal conditions outlined above. The main problems for Uitgeest were the small number of complete vessels or complete profiles from rim to base and the lack of control over the context and stratigraphy. Although complete vessels are not a condition per se for the analysis of the fabrics, they are necessary to establish a link with form and function. The sample from Schagen is quite adequate in this respect, but here there is some doubt about the representivity. The sample compositions for both sites are discussed in detail in the next chapter.

*Specific methods and variables*

The most important variables used can be found in the data base in appendices to chapters 5 to 8. The main choices of methods and techniques for observations are presented below, whereas detailed information is given in each following chapter.

I. *Fabric Analysis (chapter 5-7)*

The fabric analysis was divided into two parts. Chapter 5 discusses the *matrix*, clay and natural inclusions, and chapter 6 deals with the temper. A pilot study was used to establish the main variation in the characteristics of clay and temper and to develop specific techniques for measuring these variables at the macro-level on the pottery itself without any aid but a binocular. These observations and methods are considered the most important and basic as far as variation in fabric composition is concerned and they should be the basis on which to classify fabrics and temper. These methods were complemented in two ways by: (a) the use of test clays as a reference and (b) the chemical analysis of these clays and of a limited sample of sherds from Schagen and Uitgeest.
For the analysis of composition of the clays used for the pottery, and for the quantification of natural inclusions and temper in particular, a specific technique was developed. As both the organic, fibrous temper and the inclusions are large

and visible without magnification, the best way to observe their size, shape and quantity is macroscopically over a large area. As explained above, neither the surfaces nor the fractures are suitable for such observations. The solution to this problem was found by mr. F. Wiegmans, who assisted me with measurements of the primary data, and is surprising in its simplicity and elegance: *a sherd from each vessel, preferably larger than 3 × 3 cm, was sawn lengthwise through the core, parallel to the surfaces. The resulting 'core-surfaces' were used for most of the primary measurements.*[24]

1 The core-surface of a sherd from each vessel in the samples was used to measure:
– the amount and size of quartz particles > 105 $\mu$
– the amount and size of natural inclusions (iron concretions, calcitic nodules and clay pellets)
– the amount and size of the vegetable temper
All of these measurements were carried out over a surface area of 3 × 3 cm.

2 The interior and exterior surfaces of each vessel were used for the following observations:
– indications for a high Calcium content, by colour, the presence of scum and/or the presence of two-coloured surfaces
– the firing atmosphere, through the degree of oxidization of both surfaces and the core

3 Tablets made of test clays from several locations in North-Holland were fired at temperatures from 700-1150 $^0$C. (chapter 4). Furthermore, a set with controlled amounts of different types of temper was produced by the Institute of Ceramic Technology, Leiden (chapter 6).

4 A selection of sherds was refired to 950 $^0$C for observations on:
– the clay type, by comparing the colours with the colours of the test clays, fired at the same temperature
– the type of inclusions
– postdepositional changes in the fabrics

5(a) Chemical analysis (XRF and ICP) was carried out on a sample of sherds from both sites and on the test clays by Van Haaren (internal report) at the Laboratory for geophysics, University of Utrecht, under supervision of prof. dr. H. Kars (ROB). The chemical or mineralogical characterisation concerns the total fabric as present in the sample without discriminating between clay, natural non-plastic inclusions and/or temper. As this distinction is the most important one in this study, only small sample of sherds was tested. The main purpose was to establish the relative amounts of iron and calcium in the clays.

5(b) A few sherds were tested by microprobe analysis (ibid.) to establish the chemical content of the natural inclusions and of the two-coloured surfaces which occurred regularly in both pottery samples.

II *The analysis of morphological properties (chapter 8)*
Part II consisted of a series of observations on construction and finishing techniques, as well as on the resulting size and shape of each vessel. The main samples from both sites are described in chapter 8 and the appendices. Of all variables, the following selection has been analyzed in full detail in this study:

1(a) Of the analyses of the treatments of the interior and exterior surfaces, observed for each part of a vessel, only the final treatments of the exterior surfaces are presented here.
1(b) Special attention was paid to the application of a thick and roughened 'slick' layer on the exterior surfaces, the so-called 'thrown' or 'besmeten' surface, to the types of rim-finish, and to the presence of handles.

2 The metric analysis consisted of as many size and shape variables as could possibly be measured on any vessel.

III *The analysis of use alterations (chapter 8.12)*
The study of the use alterations was based on a pilot study of a sample of Uitgeest. The use *residues*, *i.e.* the added remains caused by use, were classified on this basis. A small sample of use residues was examined by drs. Oudemans (1991; 1993; in prep.) by means of pyrolysis-gaschromatography, discussed in chapter 8.13. This part of the research has been incorporated in the analysis on form and function.

## notes

1 The term manufacturing is used here in the sense of constructing, finishing and firing a vessel; it does not refer to a specific type of organization of production (following Balfet 1984).

2 Another possibility to study individual potters is through dactylographic research or to study the remains from one household only. The latter situation hardly ever occurs in archaeology, although the pottery assemblage from Schagen-Muggenburg comes close. In the present study, the individual traits were not analyzed in any detailed or systematic way.

3 Clearly, this view of style is essentially that of the traditional culture-historic approach and in my opinion one that needs to be maintained in the structural approach.

4 One of the most fascinating studies in this respect is that by Thompson (1958).

5 Saraswati & Behura (1966), for example, mention six major categories for Bhadrawati pottery, with a total of 22 subclasses.

They are defined by size and rim shape, specific for a (sub-)class, and by shape and finishing treatment.

6 A similar discrepancy is mentioned by Longacre (1981, 63-64): the Kalinga pots for cooking rice and vegetables both are in use for an average of ca two years. Water jars tend to last three times as long and wine jars ten times as long (*ibid*., 63). The Kalinga's own estimates are slightly higher. But he also mentions that breaking a vessel is 'a monthly phenomenon', which seems very frequent in view of these use-lives. This could be related to the use for secondary purposes.

7 In most regions of India pottery is produced by professional potters, as is the case in many others listed in the table by Varien & Mills, which is probably not the situation in Roman period North-Holland, but the point made here is the universal involvement of ceramics in rituals.

8 For example, Deal 1985; Hayden & Cannon 1983; Hodder 1977, 1982a,b; Longacre 1981; Moore 1982. Most of these contain examples of depositional rules that are full of symbolism. Longacre for example reports that vessels broken in the house are carried off to a bush at the outskirts of the settlement, while vessels broken in open settlement spaces are added to a general midden.

9 Examples are the burnt house in Archsum on the isle of Sylt, Germany (Arnold 1990) and that in the Ginderup settlement in Jutland, Denmark (Juhl 1996); Pauktetat 1989 for Mississippi homesteads in the American Bottom (Illinois). A first attempt to estimate the number of vessels used in one dwelling was also made by Therkorn (1987b) for some of the farmsteads in the Assendelver Polders, but the pottery was not classified by form/size.

10 (Micro)structure is defined as 'the array of constituents in a material visible with the aid of a microscope', whereas texture is defined as 'the morphology, configuration and size distribution of crystals, amorphous material and macro-and micro voids' (Bronitsky 1986, 223).

11 See Krause 1978; Papousek 1984, 487; Saraswati & Behura 1966; Thompson 1958.

12 Most clay layers in the Netherlands are secondary deposits; in the Western Netherlands their ubiquitous presence practically precludes establishing specific sources by other than archaeological means. In Schagen-Muggenburg and Assendelft site F, we were fortunate enough to find some extraction pits and layers, probably used for potting clay. Clays from these layers were used in the experiments (chapter 4).

13 As mentioned in chapter 1, a large number of techniques is available to establish the chemical and mineralogical composition of clays, as well as techniques to analyze the texture and structure, but they all have serious shortcomings and are, moreover, very expensive.

14 Basic categories of temper are: a. mineral (any kind of crushed rock, stones, sand, etc), b. argillaceous (crushed potsherds, natural clay pellets), c. materials of a calcareous nature (including organic forms such as shell and bone) and d. organic matter (plants, dung, etc).

15 At that stage, the amount of temper added seems to be more important than its size (*Keramiek* 1973), although Arnold (1985, 22) mentions that granular particles with a large size range are the most effective. In test briquettes, sand temper provided a reduction in shrinkage roughly equivalent to its percentage in the clay body, independent of size (Jacobs 1983). This reduction is caused by the fact that temper acts as a kind of skeleton for the clay minerals, giving the whole structure the necessary coherence and stability, as well as by reducing the amount of water adsorbed by the clay minerals and by opening up pores through which water can evaporate (Arnold 1985, 22). The naturally present non-plastic inclusions in the clay, discussed above, have essentially the same effect as comparable additives. Some clays have for this reason not been tempered at all (for example, the clays from Hadidi, van As 1986, 111).

16 The effect of shell temper is quite different; it improves workability and reduces shrinkage, while its expansion rate is more or less the same as that of the clay itself. For these reasons it is often used for cooking pots (Rye 1981). A problem with this type of temper is that it causes spalling (Steponaitas 1984). Shell tempered ware is known from several periods and regions in Holland (see Taayke 1996/7). Spalling can be noted sometimes, but on the whole the pottery is in good condition. Obviously, the prehistoric potters knew the secret, which could well be the use of 'salty' clays. More research on the subject seems called for.

17 Controlling measurements show that the proportions of sascab, a limestone temper used by potters in Yucatan varies from 1:1 to 3:1 for the same vessel types.

18 She mentions a maximum firing temperature ranging from 625-940 $^{0}$C and a firing time of only 14-17 minutes for the Rio Grande Pueblo firings!

19 Examples of this way of judging when a vessel is 'ready' are also mentioned by Shepard (1963, 86).

20 The question marks refer to conflicting results in performance studies (see appendix 2.1).

21 "Conductivity of a vessel wall is its ability to conduct heat from one face to the other, determining the rate at which a change in temperature is transmitted to the other" (Braun, 1983, 118; also Bronitsky 1986b, 251-2). The rate of transmission is called diffusivity.

22 As Skibo (1992) pointed out fire-related use can possibly change the original colour(s). If so, then it should show in the analysis as a distinction in the degree of oxidation between different categories of vessels.

23 The word 'hypothesis' is not used in the sense of the hypothetical-deductive methodology. As will be clear from the remarks on methodology in chapter 1 and 2, the strategy used here is not to test hypotheses against data. The term is used as a formulation of some general ideas and principles pertaining to the subjects of research.

24 Mr. F Wiegmans has sawn all sherds in this study on a self-built sawing machine. The apparatus was constructed from a washing-machine; the sawing blade is a regular diamond, used for cutting stones. The resulting surfaces are of high quality.