This paper presents results of technical, functional and stylistic analyses on pottery from two Early Neolithic sites on Öland – Resmo and Runsbäck. Analyses include thin sections and XRF of clays and wares, lipid residue analysis and recording of stylistic attributes. The two sites are situated 15 km apart on the west side of the island. C14 dates place the activities at the sites at c. 3900–3600 BC and 3600–3100 BC respectively. While overall similarities are obvious, some structured differences are noted in the design as well as in the wares whereas vessel use patterns are strikingly similar between the two assemblages. In general, the Resmo assemblage is characterised by great homogeneity while the Runsbäck pottery displays more variation. It is suggested that the observed differences reflect differences in function and duration between the analysed sites.

Keywords: Sweden, Neolithic, Ceramic analysis, Petrography, P-ED-XRF, LipidAnalysis

Ludvig Papmehl-Dufay received his doctorate at Stockholm University in 2006. His thesis dealt with Pitted Ware pottery in southeast Sweden, in particular from the island of Öland. He is currently working in the field of contract archaeology, where he combines fieldwork and research in order to continue studying the Neolithic of Öland. The study presented in this paper was part of his postdoctoral project at Linnaeus University, Kalmar, dealing with the Early Neolithic TRB culture, pottery, monuments and the meaning of place.

Ole Stilborg is Ass. Professor in Archaeological Science at the Archaeological Research Laboratory, Stockholm University, Sweden and has carried out contract work involving ceramics analyses since 1997. Since 2009 this research has been conducted within the framework of the company SKEA (Stilborg Ceramics Analysis). Studies have been carried out in all periods of Scandinavian prehistory, as well as outside Scandinavia. His special interests are in the Middle Neolithic B era and intchnical ceramics (i.e. crucibles, furnace walls etc.).
Anders Lindahl is Professor of Archaeology at Lund University and head of the Laboratory for Ceramics Research. He has worked with ceramic analyses for more than a quarter of a century on materials from a broad range of periods and regions – primarily Scandinavia and Africa. He has special research foci on African pottery, ethnographic studies and experimental pottery making.

Sven Isaksson is Ass. Professor/Reader in Archaeological Science at the Archaeological Research Laboratory, Stockholm University, Sweden. His primary research interest concerns prehistoric cultures of food and subsistence. Working within the field of biomolecular archaeology he applies the chemical characterisation of food residues adhering to and absorbed in ceramic vessels. He advocates an integrated approach, including archaeological evidence, the application of several analytical techniques and contextual considerations, for sampling strategies and analyses as well as for the interpretation of data. In 2000 he presented his thesis ”Food and Rank in Early Medieval Times”. Since then he has led research projects on “Tracing Ancient Vegetable Food”; “By House and Hearth” (Late Iron Age/Early Medieval food culture) and “A Spartan way of life?” (Food culture in Bronze Age Sweden). He is currently involved in an international collaboration on early hunter-gatherer pottery use, with analyses on one of the world’s oldest ceramic sequences: the Japanese Jomon.
Introduction

Early farming in southern Scandinavia is generally attributed to the Funnel Beaker Culture (TRB), dating to c. 4000–2800 BC (Larsson 1992; Midgley 1992). Associated traits include polished flint axes, elaborate pottery, megalithic burial traditions, permanent settlements and ritual enclosures, as well as incipient cereal agriculture and domesticated animals (Andersen 1997; Malmer 2002). Hunting and fishing continued to be of major importance, and in many areas people did not fully depend on agriculture until the late Neolithic or even the onset of the Bronze Age (Eriksson et al. 2008). In the ensuing Middle Neolithic (MN) period, the Funnel Beaker Culture on Öland as well as on the neighbouring Mainland is replaced by the Pitted Ware Culture (PWC) with a markedly different pottery design and technology and partly based on a marine hunting economy. The details of, let alone the reasons behind, this transition are still poorly understood.

The origin of the Funnel Beaker Culture in Northern Europe is the topic of a long-standing discussion primarily centred on the pottery (Koch 1998, 26 ff.; Müller 2011, 294 f.). Observations in southern Scandinavia point towards an internal gradual development of late Mesolithic Ertebölle pottery craft, from primitive H- and U-coil building techniques to the developed N-technique (Andersen 2011, 199 ff.; Stilborg/Bergensträhle 2001, 31), and there are good reasons to believe that the TRB pottery tradition reaching Öland in the Early Neolithic (EN) owes most of its existence to developments in the Late Mesolithic societies in eastern Denmark and Scania. The TRB potters in southern Sweden mastered the N-coiling technique and in general they seem to have accepted a variation in raw material ranging from fine to medium coarse clays, in most cases avoiding the really coarse and often unsorted clays (ibid). They preferred granite or quartzite as a temper and started relating the coarseness of the tempering – especially the maximum grain size – to the size of the vessel.

This general picture of the TRB pottery craft tradition, which is based on analyses of pottery primarily from Scanian sites (Hultén 1977; Stilborg 2002, 59 ff.), will be used as one of the base lines for the technological interpretations presented in this study. The other base lines are the especially difficult natural conditions for pottery production offered by the geology of Öland (see below). Most of the clays accessible in the topsoils are calciferous to calcium rich, something that any Neolithic potter in her/his right mind would always try to avoid due to the risks of firing/postfiring damage to the vessels. From previous analyses of clay samples from the southern and central parts of the island, as well as of pottery samples from the TRB site at Alby and the Pitted Ware sites at Köpingsvik and Ottenby, also on Öland, it is clear that non-calciferous clay beds were preferred but are few, generally small and often of a coarse unsorted quality (Stilborg 2006, 319 f.). This raw material scarcity logically results in a marked diversity in the clays used for pottery even within each settlement, and in the use of clays that would not have been deemed suitable for pottery making on the mainland.

Food remains found adhering onto and absorbed into ceramic vessels are today recognised as valuable sources of information in archaeology (Evershedet al. 2001; Evershed 2008a). Even though the analysis of food lipid residues has become a fairly frequent tool
in Swedish archaeology (Isaksson 2009), to date there are only a few studies published on material from Öland (e.g. Papmehl-Dufay 2006). In the present study, analyses of raw materials and vessel use are combined with more general data on pottery design in order to investigate issues regarding Neolithic ceramic craft and site function. While previous studies on Swedish materials have employed a similar multi-analytical approach (e.g. Papmehl-Dufay 2006; Brorsson et al. 2007), in the case of Resmo and Runsbäck we have consistently used the same sample sherds for all the different types of analyses. In this way, comparisons between various aspects of the two sites are enhanced.

**Divided by pottery?**

This study presents the results of technological, functional and stylistic analyses of TRB pottery from two structurally different sites located on the island of Öland in the Baltic Sea. The study area of southern Öland has yielded an abundance of Stone Age sites, most notably four megalithic tombs in the parish of Resmo which make up the easternmost concentration of passage tombs in Northern Europe (Papmehl-Dufay 2006; 2011). Until recently Early Neolithic settlement sites were known in the area mainly from flint scatters identified through field surveys (Alexandersson et al. 1996). In 2008 the excavation of two sites by Kalmar County Museum changed that situation. In both cases a wealth of TRB pottery was found together with flint debris and some burned bones, but the archaeological contexts differ. The analysis presented here targets ceramic technology, pottery design and vessel use in an attempt to understand how these differences were expressed in terms of pottery production and use.

**Sites analysed**

The island of Öland is situated off the Swedish east coast in the Baltic Sea (fig. 1). The island measures 130 km in length and c. 20 km in width. The bedrock consists of Ordovician limestone and, below the western slopes, Cambrian shales, resulting in a level topography. On the southern part of the island, the Neolithic coastline is located some 8–12 m above that of today. Neolithic stray finds are numerous all over the island, indicating a relatively dense settlement in the central and especially western parts of the island during the early and middle Neolithic (Åberg 1923; Gurstad-Nilsson 2001).

**Resmo**

The TRB site at Resmo was excavated in spring 2008 (Papmehl-Dufay 2009; 2012a). Situated on the western escarpment at elevations around 40–41 m above the present sea level (m a.s.l.), it occupies a striking location with extensive views towards the west. A megalithic tomb (dolmen) is situated only some 300 m to the SE, and three passage graves are located at Mysinge, another c. 2.5 km to the south (Arne 1909; Papmehl-Dufay 2006). The most dominant feature at the site is a cultural layer rich in finds of pottery, flint and burned bone. No built structures were identified during excavation, and the origin of the cultural layer remains to be fully understood. The layer covered some 150 m² in the NE corner of the excavated area, and during
a complementary trial excavation in 2012 its full extent was estimated at c. 1000–1200 m², mainly extending to the North and East of the excavated area (PAPMEHL-DUFAY 2012b). In 2008 only some 12% of the uncovered part of the layer were excavated (18 m²), yielding c. 6 kg of pottery, 300 g of flint and 130 g of burned bone. The complementary excavation of the outer parts of the layer yielded a similar density of finds. These figures suggest that the part of the cultural layer that was uncovered during the excavation probably contained roughly around 50 kg of pottery and 2.5 kg of flint. Furthermore, if this is extrapolated against the estimated full extent of the cultural layer, we are faced with a possible c. 400 kg of...
pottery and 20 kg of flint deposited within an area of c. 25 x 50 m. Regardless of the exact figures, clearly this must represent some kind of major activity and/or an extremely lengthy period of occupation. Typological traits as well as radiocarbon dates of burned bones place the formation of the cultural layer mainly in the earliest Neolithic at around 3900–3600 cal BC, which is a few centuries before the assumed date for the construction of the megalithic tomb a short distance to the SE.

Runsbäck

The TRB site at Runsbäck is located some 15 km to the north of Resmo, in the SW part of Färjestaden. It was excavated in 2008 (ALEXANDERSSON/PAPMEHL-DUFAY 2009; PAPMEHL-DUFAY 2012a). The most striking feature at this site was a dense concentration of finds and soil features covering an area of c. 20 x 30 m on the western slopes of an ancient beach ridge, at around 14 m a.s.l. The collected finds from this area include c. 4 kg of pottery, c. 1 kg of flint and other lithic materials, as well as a few fragments of burned bone. Due to necessary prioritizations not all features were fully excavated, but most probably the collected finds constitute the majority of the material deposited and preserved at the site. The chronology of the finds span a period of 5000 years from the early Mesolithic at around 7000 BC to the Late Neolithic c. 2000 BC, although the majority of the finds and most of the pottery can be attributed to the Early Neolithic TRB culture at around 3600–3300 BC. This date is further strengthened by two radiocarbon dates of hazelnut shells contextually associated with TRB pottery.

Among the many features within the dense activity area at Runsbäck, three large post-holes were identified as the roof bearing construction of a two-aisled long house dating to the second half of the Early Neolithic. Measuring c. 12 x 5 m, the house corresponds well in shape, size and orientation to EN houses of the so-called Mossby type, which have been found in parts of southern and central Sweden (LARSSON 1992, 66 ff.; APPEL 1996; ARTURSSON et al. 2003, 64 ff.). The pottery and flint surrounding the house fit this interpretation well. The Runsbäck site represents an EN TRB dwelling site with a house and material traces of various domestic activities, mainly distributed within and around/in front of the house, which was located in a coastal setting a few hundred metres from, and facing, the sea.

Material, methods and limitations

The ceramic assemblages from the two sites form the basis of a comparative study in which technological, functional and stylistic aspects of the pottery are analysed. The main objective is to identify and explain any differences in ceramic craft and pottery use between the two sites. Stylistic aspects were analysed based on macroscopic observations and detailed recording of relevant parameters of the complete assemblages from both sites (for details see PAPMEHL-DUFAY 2006, 156 ff.). Sample sherds were selected in order to reflect the variation and general characteristics of the wares in each assemblage. The same ten sherds from each site have been subjected to thin section, XRF and lipid residue analysis, with the addition of another two sherds and a fired sample of local clay from Resmo being included in the thin section analysis. The selected sherds are shown in figure 2.
Fig. 2: The sample sherds from Resmo and Runsbäck. Photo by Ole Stilborg.
Analysis of pottery design

Stylistic aspects were analysed based on macroscopic observations and detailed recording of relevant parameters of the complete assemblages from both sites (for details see Papmehl-Dufay 2006, 156 ff.). The parameters used in the discussion below include vessel part (and indirectly vessel type), decoration (present or not present) and wall thickness. The composition of the decoration on individual vessels has not been analysed in detail.

Petrographic microscopy

Thin sections of 0.03 mm thickness were prepared. The coarseness of the paste (the amount of silt, fine sand and sand) was estimated under a polarising microscope at magnifications from 25 to 1000 X, as was the presence of iron oxide, ore, mica, calcium carbonate and organic material. The mineralogy of the sand fraction was determined through standard petrographic procedures. Diatoms and other fossils were detected at the highest magnifications. Finally, any added temper was determined as to type and amount, and maximum grain size was measured. The material included in the thin section analysis consists of 22 sherds: 12 from Resmo (no:s 1-10 and no:s 22-23) and 10 from Runsbäck (no:s 12-21), as well as a clay sample from Resmo (no 24).

XRF-analysis with portable equipment

Portable energy-dispersive X-ray fluorescence analysis (P-ED-XRF) is a non-destructive method for chemical and elemental analysis. Clay, and by default ceramics, consist mainly of the elements Silicon (Si) and Aluminium (Al) in the oxide states SiO₂ and Al₂O₃ as well as quite a large portion of Iron (Fe₂O₃/Fe₃O₄), Calcium (CaO) and Potassium (K₂O). All these are normally found in percentage amounts. Other elements are only detected as parts per million (ppm). In the present study, a Thermo Scientific portable (handheld) XRF analyzer (h-XRF), Niton XL3t 970 GOLDD+ with the basic calibration for minerals was used (Helfert/Böhme 2010; Helfert et al. 2011). The method has highly accurate determinations for major elements. A limitation with this equipment is that elements in the range from Sodium (Na) and lighter cannot be detected. The elements that are analysed in this investigation are: Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Zr, Nb, Mo, Pd, Ag, Cd, Sn, Sb, Ba, W, Au, Pb and Bi. The analysis was performed on a polished break of the sherds, and measuring time was set to 6 minutes on an 8 mm radius spot to be analysed. The material included in the h-XRF analysis consists of 20 sherds: 10 from Resmo (no:s 1-10) and 10 from Runsbäck (no:s 12-21). These are the same sherds that were analysed in the thin-section and lipid residue analyses. The two additional samples from Resmo were not included in the XRF analysis.

Lipid analysis

Lipids were extracted by means of ultrasonic aided solvent wash (Heronet al. 1994; Dudd/Evershed 1998; Isaksson 2000; Evershed et al. 2002; Copley et al. 2003; 2005; Craig et al. 2005; 2007; Spangenberger et al. 2006; Mi-
The outer millimetre of the sampled area of each sherd was removed in order to reduce contamination. The sample was ground off using a low-speed pottery grinder, transferred to an extraction vessel and an internal standard (n-hexatriacontane, 20 µg) was added. A mixture of chloroform and methanol (2:1, v:v) was used for the extraction and the lipid residues were analysed as trimethylsilyl derivatives. The analysis was performed on a HP 6890 Gas Chromatograph equipped with a SGE BPX5 capillary column using helium as carrier gas. The injection was carried out by the pulsed splitless technique using an Agilent 7683B Autoinjector. The GC was connected to a HP 5973 Mass Selective Detector. The fragmentation of separated compounds was achieved by electronic ionisation at 70 eV. Using the extract ion-chromatogram tool in MSD ChemStation, samples were screened for specific ions within the retention time windows (c. ±0.05 minutes chromatographic reproducibility) of authentic trimethylsilyl derivatives of a range of lipid biomarkers in the chromatographic system used. The detection limits of each specific lipid compound vary, primarily due to different fragmentation patterns in the ion source of the mass selective detector, but are in the range of 10s of ng/g. All solvents used were of Pro Analysgrade, all glassware was thoroughly cleaned prior to use and experimental blanks were run in parallel with the samples. Exact analytical conditions have been published elsewhere (PAPMEHL-DUFAY 2006, 164). The material included in the lipid residue analysis consists of 20 sherds: 10 from Resmo (no:s 1-10) and 10 from Runsbäck (no:s 12-21). These are the same sherds that were analysed in the thinsection and XRF residue analyses. The two additional samples from Resmo were not included in the lipid residue analysis.

**Limitations**

The laboratory analyses presented in this study were all carried out on small samples of large pottery assemblages. It is therefore important to address the issue of representativity. In principle, all archaeological assemblages are samples of what was once present, and furthermore, the overwhelming majority of excavations are governed by prioritizations and restrictions concerning what is to be investigated and collected and what is not. In most cases, the area to be investigated is designated by interests other than archaeology, and thus the excavated material generally represents a sample of a site of unknown extent. At Runsbäck, the distribution of finds and features suggests that the excavated area covers the ‘whole’ site. On the other hand, not all features were fully excavated. At Resmo, the cultural layer covered the NE corner of the investigated area. It is clear that the excavated sample here constitutes a small fraction of what was present at the site. The analysed sherds were selected in order to cover the variation in ware and design present in the available assemblages, and every sample was selected to represent individual and different vessels. At Runsbäck, the selected sample should mirror the variation in the assemblage as a whole. At Resmo, two sherds from a complementary excavation to the east and north of the area excavated in 2008 were added to the initial sample. While the possibility of spatial differences in pottery use and deposition within the site cannot be ruled out altogether
(Dimc 2011), the additional two sherds from the complementary excavation of the outer parts of the layer offer a possibility to evaluate this to some extent.

Results

Analysis of pottery design

The only vessel type that has been identified in the Resmo assemblage is the funnel beaker with rim diameters in the range between 15–30 cm (fig. 3). The vessels have been decorated mainly on the uppermost part of the neck and in some cases on the edge of the rim. The dominating decoration technique at Resmo is impressions of twisted cord, which has been applied on most vessels either in horizontal rows or chequerboard patterns.

Funnel beakers are the dominating vessel type at Runsbäck as well, although they are somewhat smaller in size with rim diameters of c. 10–20 cm (fig. 3). Decoration generally covers the upper part of the vessel, while some sherds appear to represent undecorated vessels. Impressions of whipped cord are by far the most common decoration, which has been applied in various fashions including horizontal lines and chequerboard pattern.

<table>
<thead>
<tr>
<th>Vessel part</th>
<th>Resmo Nr</th>
<th>% decorated</th>
<th>Mean thickness mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rim</td>
<td>100</td>
<td>80</td>
<td>7.7</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>48</td>
<td>8.7</td>
</tr>
<tr>
<td>Neck</td>
<td>209</td>
<td>31.1</td>
<td>7.7</td>
</tr>
<tr>
<td></td>
<td>64</td>
<td>51.6</td>
<td>9.3</td>
</tr>
<tr>
<td>Shoulder</td>
<td>26</td>
<td>0</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>50</td>
<td>9</td>
</tr>
<tr>
<td>Body</td>
<td>1058</td>
<td>2.6</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td>357</td>
<td>13.4</td>
<td>10</td>
</tr>
<tr>
<td>Base</td>
<td>8</td>
<td>0</td>
<td>13.9</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Fragment</td>
<td>848</td>
<td>0.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>308</td>
<td>1.3</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>2250</td>
<td>8</td>
<td>8.2</td>
</tr>
<tr>
<td></td>
<td>767</td>
<td>13</td>
<td>9.8</td>
</tr>
</tbody>
</table>

Fig. 4: Data on decoration and mean thickness for different vessel parts in the pottery assemblages from Resmo (bold) and Runsbäck (italics).
<table>
<thead>
<tr>
<th>Sherd info.</th>
<th>Clay</th>
<th>Temper</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thimsec-</td>
<td>Find</td>
<td>Coarse-</td>
<td>Sorting</td>
</tr>
<tr>
<td>tion</td>
<td>number</td>
<td>ness</td>
<td>Sand</td>
</tr>
<tr>
<td>1</td>
<td>L1</td>
<td>289</td>
<td>M</td>
</tr>
<tr>
<td>2</td>
<td>L1</td>
<td>340</td>
<td>M</td>
</tr>
<tr>
<td>3</td>
<td>L1</td>
<td>248</td>
<td>M</td>
</tr>
<tr>
<td>4</td>
<td>L1</td>
<td>338</td>
<td>M</td>
</tr>
<tr>
<td>5</td>
<td>L1</td>
<td>81</td>
<td>M</td>
</tr>
<tr>
<td>6</td>
<td>L1</td>
<td>336</td>
<td>M</td>
</tr>
<tr>
<td>7</td>
<td>A27,158</td>
<td>389</td>
<td>M</td>
</tr>
<tr>
<td>8</td>
<td>A27,158</td>
<td>374</td>
<td>M</td>
</tr>
<tr>
<td>9</td>
<td>A139</td>
<td>505</td>
<td>M</td>
</tr>
<tr>
<td>10</td>
<td>A19</td>
<td>558</td>
<td>M</td>
</tr>
<tr>
<td>12</td>
<td>KLM 44895</td>
<td>3</td>
<td>M</td>
</tr>
<tr>
<td>13</td>
<td>KLM 44895</td>
<td>33</td>
<td>M</td>
</tr>
<tr>
<td>14</td>
<td>Clay sample</td>
<td>C</td>
<td>U</td>
</tr>
<tr>
<td>15</td>
<td>A331</td>
<td>655</td>
<td>M</td>
</tr>
<tr>
<td>16</td>
<td>A573,house?</td>
<td>649</td>
<td>M</td>
</tr>
<tr>
<td>17</td>
<td>A660</td>
<td>900</td>
<td>M</td>
</tr>
<tr>
<td>18</td>
<td>A599,house</td>
<td>762</td>
<td>M</td>
</tr>
<tr>
<td>19</td>
<td>A627</td>
<td>777</td>
<td>M</td>
</tr>
<tr>
<td>20</td>
<td>A573,house?</td>
<td>911</td>
<td>M</td>
</tr>
<tr>
<td>21</td>
<td>A15</td>
<td>583</td>
<td>C</td>
</tr>
</tbody>
</table>

Fig. 5: Results of the petrographic microscopy of sherds and clay sample from Resmo and Runsbäck. C = coarse, M = medium coarse, F = fine; U = unsorted, S = sorted; * = sparse, + = common, = rich; O = ore, A/P = amphibol and/or pyroxes, Z = zircon, Mu = muscovit; S = sponge spicula, F = limestone fossils; Nat = natural temper, Gr = granite, SST = sandstone.
As can be seen in figure 4, the amount of collected pottery is much larger at Resmo, despite the fact that only 18 m² of the extensive cultural layer were excavated. The Resmo pottery is generally more thin-walled than the Runsbäck pottery. In combination with the larger vessel size at Resmo, this begs the question of quality: does the thin-walled Resmo pottery represent a more skilled production than the Runsbäck pottery, and what would that imply? The data on the frequency of decoration for the different vessel parts (fig. 4) give an idea of the designs present in the assemblage. At Resmo a great majority of the rim sherds display decoration, while the corresponding figure at Runsbäck is c. 48 %. Given the fact that decoration in both cases seems to be concentrated on the upper part of the vessels, these figures clearly suggest that undecorated vessels occur in the Runsbäck assemblage but not to any great extent at Resmo. Still, seen in terms of the whole assemblage, the degree of decoration is higher at Runsbäck than at Resmo, which in turn reflects the fact that decoration is more widely distributed on the vessel bodies at Runsbäck.

Petrographic analysis of clays and wares

For the ten Runsbäck pots analysed, at least three different clays have been used: one medium coarse clay of a well sorted quality (four samples), one poorly sorted, medium coarse clay with iron oxide-rich pellets (four samples; Stilborg 2006,301) and one unsorted, medium coarse clay with sponge spicula needles (one sample) (fig. 5). All of the wares are tempered with crushed granite or granitoid rock in quali-
ties varying from 12 % volume and 2.2 mm max. grain to 20 % volume and 3.6 mm max. grain (fig. 6). Although conditions for pottery making are difficult on Öland, the Runsbäck potters managed to locate at least one good, well sorted clay. Over time, however, less optimal clays had to be used as well. In their choice of tempering the wares with crushed granite, the Runsbäck potters meet the expectations for traditional TRB craft (HULTHÉN 1977, 52 ff.; STILBORG 2003, 220 ff.). The twelve Resmo samples were all made from practically identical clays: medium coarse, well sorted, silt-rich with some mica (fig. 5). The variation in iron oxide content and in the mineralogy of the relatively few accessory minerals is well within the variation to be expected from a single clay bed. In accordance with Runsbäck, all wares at Resmo were tempered with crushed granite or granitoid rock and the range of temper qualities is similar (fig. 7).

*Fig. 7: Variation in temper quality of the analysed Resmo sherds.*

Several of the elements included in the analysis were missing or present in amounts below the detection limit. In the following, the range of elements is therefore limited to: Al, Si, P, S, K, Ca, Ti, V, Cr, Mn, Fe, Cu, Zn, Rb, Sr, Zr, Nb, Pb and Bi.

The two major elements Silica and Aluminium are compared in a two-dimensional plot in figure 8. Here, the Resmo sherds form a concentrated unit while the Runsbäck sherds are more dispersed. Except for the two samples 7 and 8, the Resmo material is located within a small area of the plot. The Runsbäck sherds on the other hand are spread out and do not form any clear groups. However, even though
Abb. 8: Bivariate scatterplot between the elements Silica and Aluminium. Samples 1-10 represent Resmo and samples 12-21 represent Runsbäck.

Abb. 9: Bivariate scatterplot between the elements Potassium and Rubidium. Samples 1-10 represent Resmo and samples 12-21 represent Runsbäck.
Abb. 10: Bivariate scatterplot between the elements Iron and Chromium. Samples 1-10 represent Resmo and samples 12-21 represent Runsbäck.

Abb. 11: Bivariate scatterplot between the elements Titanium and Zirconium. Samples 1-10 represent Resmo and samples 12-21 represent Runsbäck.
Sherds 13, 15, 16, 18 and 20 are slightly to one side of the Resmo sherds, in this plot they correspond to the Resmo material. The sherds Runsbäck 12, 14, 17 and 19, as well as 21, stand out as individual sherds not forming any clear groups.

The elements Potassium and Rubidium display a clear correlation, with the exception of the samples Resmo 7 and 8, which stand out from the linear distribution (fig. 9). It is interesting to note that the Resmo material is concentrated towards the lower left part of the plot whereas the Runsbäck sherds, with two exceptions (Runsbäck 19 and 21), are found mainly in the upper right part. Especially the sherds Runsbäck 13, 15, 16, 18 and 20 differ from the rest of the material.

The plots of Iron and Chrome and of Titanium and Zircon respectively display a similar pattern as the plot of Silica and Aluminium (figs. 10 and 11). The Resmo sherds form a tight group with half of the sherds from Runsbäck slightly outside it. The sherds Runsbäck 12, 14, 17 and 19 differ completely from the rest of the material. Almost identical distributions can be seen in the plots of Pb/Bi and Zr/V, which are not shown here.

To achieve a more comprehensive statistical evaluation involving all the elements in the XRF-analysis, a Principal Component Anal-
yses (PCA) was carried out (SPSS ver. 19). More than 80 per cent of the analysis was explained in the three first factor scores. These factor scores were then plotted against each other in a three-dimensional plot (fig. 12). The trend in distribution that could be observed in the previous diagrams is now much clearer. All the Resmo sherds form a very neat cluster. The samples Resmo 7 and 8 are now part of the cluster. The Runsbäck sherds form two groups and one isolated sample (no 21). One group forms a well-defined cluster consisting of the samples 13, 15, 16, 18 and 20 (totally overlapping 13). The second group is more loosely defined and consists of the samples 12, 14, 17 and 19.

The XRF-results match and confirm the mineralogical findings from the thin section analysis. For example, the Runsbäck XRF group of sherds 13, 15, 16 and 18 mirrors the clay 1 group (see fig. 5). To this group the XRF-analysis has added sherd 20, which was separated out in the TS-analysis based on a different sorting of the clay. The other XRF group at Runsbäck matches the clay 2 group, and finally sherd 21 is an outlier in both analyses. The most important result is, however, the great homogeneity of the Resmo pottery and the fact that the clay 1 group at Runsbäck is clearly separated from the Resmo-clay(s) despite some similarity in the coarseness and sorting of the clay.

**Lipid residue analysis**

With the molecular analysis applied in this study it is possible to identify lipids from terrestrial animals (T), aquatic animals (A) and vegetables (V), and mixtures thereof. Terrestrial animal lipid residues are identified by a fatty acid distribution characterised by a higher contribution of stearic acid (C18:0) (i.e. a high ratio (>0.5) of C18:0 to palmitic acid (C16:0)) than is found in vegetable and aquatic animals (Olsson/Isaksson 2008) and/or the presence of cholesterol. Cholesterol may also derive from fingerprints, but in recent contaminations is accompanied by the polyunsaturated hydrocarbon squalene and can thus be detected (DIMC 2011). Aquatic animal oil residues are rich in C16-C22 ω-(o-alkylphenyl) alkanoic acids, should contain three isoprenoidalkanoic acids and have a fatty acid distribution dominated by C16:0 (i.e. low C18:0/C16:0-ratio) (Hansel et al. 2004; Hansel/Evershed 2009). Fish may also leave traces in the form of a low C18:0/C16:0 ratio together with traces of cholesterol (Olsson/Isaksson 2008). Identifying plant lipids is not straightforward (Steele et al. 2010), but the following markers do indicate contributions from vegetables; the presence of phytosterols (campesterol, β-sitosterol, stigmasterol), waxes or wax residues (long-chain fatty acids, alkanols and alkanes) (Charters et al. 1997) or a fatty acid distribution characterised by a low C18:0/C16:0 ratio (Olsson/Isaksson 2008). Some plat oil residues may be distinguished by C18 ω-(o-alkylphenyl) alkanoic acids (Isaksson et al. 2005). One of the three isoprenoidalkanoic acids (phytanic acid) may also derive from the decomposition of chlorophyll, indicating the presence of green vegetables. Several of the plant lipid residues present are also found in soil organic matter, but migration during burial is believed to be limited (Heron et al. 1991). Milk lipids may be detected by the presence of a broad distribution of triacylglycerols, and a high ratio of the branched C17:0 fatty acids to C18:0 is an indication for ruminant lipids in gener-
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*Fig. 13: Summary of the lipid residue results. x = compound(s) detected, - = not detected, tr = only traces detected.*
al (from the animal or from milk; cf. Hjulström et al. 2008, 68). However, to properly separate non-ruminant, ruminant adipose and dairy lipid residues single compound stable carbon isotope analysis must be carried out (Dudd/Evershed 1998). During vessel use, long-chain ketones may form, but probably at temperatures higher than normal cooking (Evershed et al. 1995; Evershed 2008b). Vessels used for alcoholic fermentation with yeast may show traces of ergosterol (5, 7, 22-ergostatrien-3β-ol) (Isaksson et al. 2010). Further, pottery may be used for the storage and processing of tars and pitches (Isaksson 2009, 139). Di- and triterpenes may also enter the vessel walls as soot and smoke.

The results of the molecular analysis of lipid residues are summarized in figure 13. The only significant difference ($\chi^2=6.67$, df=1, Fishers exact p, two-tailed, p = 0.0325) between the two sites is in the number of potsherds with traces of diterpenes, with five in the sample from Resmo and none in the sample from Runsbäck. Otherwise, the distributions of pottery uses in Runsbäck and Resmo are very similar (figs. 13, 14 & 15), with a
slightly higher diversity in the lipid residues from Runsbäck than in those from Resmo. This is seen both in the range of distribution of lipid residue amounts and in the distribution of C18:0/C16:0 ratios (fig. 14). It is also seen in the distribution of pottery use classifications (fig. 15); the diversity index ($= 1/\sqrt{\left(\sum P_i/100\right)^2}$, $P_i$ is each pottery use class in per cent) of these distributions is 1.54 for the Resmo pots and 1.96 for the Runsbäck pots.

In order to illustrate the similarity of the two sites, the vessel use results can be compared with those from Köpingsvik (fig 16a & 17), a previously analysed PWC site on Öland dating to the MNA, around 3000 BC (PAPMEHL-DUFAY 2006, 214 ff.). Here, pottery use is much more homogenous (diversity index = 1.35), with aquatic animal residues dominating, a trait typical of PWC pottery use in eastern Sweden (e.g. BRORSSONET al. 2007; DIMC 2011). From the Euclidean distance matrix in figure 17 it is clear that the distributions of pottery use classes in the two Funnel Beaker assemblages are much more similar to each other than to the sample of PWC pots from Köpingsvik. Ottenby is another excavated and analysed PWC site on the island,
Fig. 16: Distribution of pottery use classes (per no. of samples) in samples from the PWC sites (a) Köpingsvik (n=18) and (b) Ottenby (n=12), both on Öland. Modified from Papmehl-Dufay 2006. T = terrestrial animals, A = aquatic animals, V = vegetables, E = empty.

Fig. 17: Euclidean distance matrix illustrating the differences between the distributions in figure 15 and 16.
but pottery use there is actually more similar to Runsbäck than to the Köpingsvik results (Papmehl-Dufay 2006, 220 ff.).

Discussion

The pottery assemblages from Runsbäck and Resmo both adhere to the same broad, archaeologically defined tradition, i.e. Funnel Beaker pottery, and they most probably overlap chronologically or follow each other closely during the Early Neolithic. Stylistically the assemblages display overall similarities, while at the same time distinct differences could be identified. This observation initiated the analyses, which seek to clarify the relation of these ornamental differences to other aspects of pottery production and use at these sites. Apart from details in the design, the degree of diversity in clay choice separates the two assemblages, with the Resmo pots displaying a remarkable homogeneity. At Runsbäck, the potters used the same quality of clay for some of their pots as the Resmo potters used for all of theirs. Also, they seem to have agreed on both type of temper and appropriate temper qualities in line with what is generally expected for Funnel Beaker pottery in southern Sweden. Concerning lipid residues, the striking impression is the similarity between the two sites in the distribution of pottery use classes, with only a slight difference in diversity, Resmo being the more homogeneous of the two. The patterns of vessel use are similar at both sites, with a clear dominance for terrestrial and/or origin of the lipids detected. While the present data does not allow the separation of domestic and wild species, the Resmo and Runsbäck results could well reflect an economy with a certain input of domesticated animals and/or cereal agriculture, fitting the attribution of both sites to the Funnel Beaker Culture. It should also be noted that at both sites, impressions of cereal grains have been identified in the pottery (Mats Regnell personal comment) and that at Resmo four cow teeth were found during excavation (Papmehl-Dufay 2009). The PWC, on the other hand, is generally associated with marine hunting and fishing, as seen in pottery use at Köpingsvik, which was completely dominated by lipids of aquatic and/or vegetable origin. Thus, among the three parameters design, raw material and vessel use, differences between the Resmo and Runsbäck sites are articulated in the first two aspects, while in the third category, i.e. vessel use, the striking impression is instead a great degree of similarity between the two. This provides interesting clues as to the role of pottery making in relation to its social and practical function. The reasons dictating the choice of decoration were apparently different at Resmo and Runsbäck, as was the degree of variation represented in the clay choices. Clearly, the potters responsible for the assemblages at these sites were following rules and traditions that marked them out from their neighbours, while at the same time they all clearly adhered to the same overall pottery making tradition, i.e. TRB pottery (cf. Papmehl-Dufay 2006, 228 ff.). When it comes to using the pots, however, a wholly different set of rules was at work. Pottery use in this context is best understood in terms of food culture, which sets it apart from pottery making, which is best understood as a craft tradition. The similarity in pottery use between the two sites thus may reflect a different level of cultural attribution than does the choice of decorative tools or variation in
clay raw materials. Possibly, the results of the present analysis could be interpreted as indications of a greater regional homogeneity in the food culture of the TRB culture than in pottery production.

The homogeneity in clay raw material and tempering technology represented at Resmo is very remarkable, not only in relation to the specific conditions on Öland but also in relation to previously analysed TRB pottery from the Swedish mainland (Hultén 1977, 52 ff.; Stilborg 2003, 220 ff.). Alongside the availability of raw materials for pottery production in the resource area, the number of potters involved and the duration of production over generations constitute the main ‘mechanical’ factors behind the degree of homogeneity in any given prehistoric pottery material. Cultural rules restraining the options for pottery making or socially induced changes in pottery design may override or change these mechanical factors towards more or less homogeneity (e.g. Sillar 1997, 11). With the limitations of the present study in mind, some possible alternative explanations for the remarkable homogeneity observed in the Resmo material can be formulated:

• The Resmo potters utilised a large, homogenous clay bed, and they used it for a long time.
• The Resmo pottery was made over a short period of time and by one or a couple of potters working closely together.
• Resmo pottery manufacture was controlled by rigid restrictions as to the choice of clay.

As for the first suggestion, perhaps the simplest explanation would be that the Resmo pottery was not made on Öland but on the mainland, where the chances of finding large, homogenous clay beds are much better. From analyses of PWC pottery from Ottenby Royal Manor (Öland) and Kalmar (mainland), we know that pottery was actually being transported across the Kalmar Strait in the Neolithic (Papmehl-Dufay 2006, 204ff.; Stilborg 2012). However, the homogeneity among the Resmo samples is still greater than any observed even on the mainland and, more importantly, a fairly similar clay (albeit more varied) was used for four of the pots analysed from Runsbäck. This indicates that this quality of clay could be found on Öland, although substantial clay beds of this quality are unlikely. We can neither exclude the possibility for nor confirm the existence of strong cultural rules guiding raw material choice, but there is nothing to indicate such strong rules in the TRB culture as a whole and certainly they were not being applied at Runsbäck. Following these arguments, we are left with the alternative that the Resmo pottery may represent a short-lived, concentrated pottery production activity. Runsbäck, on the other hand, can be interpreted as a settlement site where pottery production and use was carried on for some time and distributed over a number of potters and pottery users. This interpretation is in good accord with observations during excavation, with the identification of house remains at Runsbäck and the lack of such structures at Resmo (Alexandersson/Papmehl-Dufay 2009; Papmehl-Dufay 2009). Possibly, the activities at Resmo in some way involved extensive burning that would have introduced diterpenes from soot or smoke into the vessels from Resmo, which is missing in the analysed vessels from Runsbäck.

The ware variation of the two TRB materials was compared to that of the previously analysed PWC pottery from the island (Papmehl-Dufay 2006; Stilborg 2006). The Runsbäck
potters not only used a broader selection of clays more in line with the ware variation at the PWC sites, they also used the same type of poorly sorted clay with pellets which dominated the PWC production at Ottenby (STILBORG 2006, 310). This raises the question of whether the Runsbäck production is culturally closer to the PWC than to the Resmo tradition. The same pattern is seen in the categories of pottery use, where Runsbäck is more similar to Ottenby than it is to Resmo (fig. 17). The exclusive tempering with crushed granite at Resmo and Runsbäck - a temper used only sporadically for PWC pots - marks a clear cultural craft difference. A small EN TRB pottery assemblage from Solberga, Köpingsvik, may shed some light on this issue (STILBORG 2011). These pots were decorated with twisted cord in a way similar to the Resmo pots, and are probably contemporary with them, but the variation in clay choice was more akin to the situation at Runsbäck. All Solberga wares were tempered with granite. However, four out of six samples displayed temper volumes below 10 %. In conjunction with a relatively large maximum grain size this represents a suboptimal temper quality that has no parallels at either Resmo or Runsbäck. Instead, comparable temper solutions exist among the sandstone tempered PWC wares found locally at Köpingsvik (STILBORG 2006). This may signal a gradual development from TRB pottery traditions, with their limited clay variation and stereotypic granite tempering, towards a greater diversity of clays followed by an increased variation in the temper qualities before, finally, the culturally redefining changes of temper type and vessel design were realized. Furthermore, a similar trajectory may be visible in pottery use, with mainly terrestrial and vegetable vessel use in the EN TRB pottery gradually moving towards the typically highly aquatic pottery use of the MNA PWC.

Of potential significance in the context of the Resmo pottery is the group of four Neolithic megalithic tombs located in the area (PAPMEHL-DUFAY 2006; 2011). One is a dolmen situated north of Resmochurch, only some 300 m to the east of the excavated site, and the other three are passage graves located a few hundred metres apart in the village of Mysinge c. 2.5 km to the south. The southernmost of the graves was excavated in 1908 (ARNE 1909), while the other three remain unexcavated. Seen in relation to the distribution of megalithic monuments in Northern Europe, the Öland tombs are located at the eastern periphery, some 150 km as the bird flies to the east of the nearest concentration of megaliths on the Swedish mainland (see PAPMEHL-DUFAY 2011, 132). This seemingly peculiar occurrence indicates that the Resmo area was seen to possess some form of quality apparently lacking in other neighbouring and more distant areas where megaliths were not built (PAPMEHL-DUFAY 2012c). This quality would have been associated with the meaning of place, probably connected in some way to the physical appearance/objective morphology of the area, to activities by and interactions between people there, and/or to meanings and histories related to the collective memory of the place (RELPH 1976; CASTELLO 2010). It has often been argued that megalithic monuments refer to existing architectural or natural features (see THOMAS 1996, 90; RICHARDS 1996). At Resmo, the monumental and dramatic landscape setting on the crest of the western escarpment may be one such aspect of physical appearance, as could be the rich spring located c. 500 m to the west of
the dolmen at Resmo. However, in an objective sense none of these features are unique to this specific locality. Instead, while not excluding aspects of physical appearance altogether, memory and human interaction are more likely to be responsible in this case. The rich cultural layer and large amounts of high quality Early Neolithic pottery at Resmo are highly interesting in this respect. The striking homogeneity revealed by the pottery analyses fits well with the impression that this was a special place. The site and the results provide undisputable evidence of intense activities in the Resmo area preceding the construction of the dolmen a few generations later. Thus at the time of monument construction, the place of this megalith already had a long history of human–environment interaction, memory and meaning.

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Addresses:

Dr. Ludvig Papmehl-Dufay
Kalmar county museum
Box 104
S-391 21 Kalmar
Sweden

Dr. Ole Stilborg
SKEA, Stilborg Ceramics Analyses
Linköping

Prof. Dr. Anders Lindahl
Laboratory for Ceramics Research
Lund

Dr. Sven Isaksson
Archaeological Research Laboratory
Stockholm