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Pottery Production in Anglo-Scandinavian Torksey (Lincolnshire): Reconstructing and Contextualising the *Chaîne Opératoire*.

By Gareth J Perry[1]

England in the 9th century witnessed a revolution in pottery production. For the first time since the Roman period, pottery was wheel-thrown and produced on a near industrial scale. Research into this ceramic revolution has focused on chronology and, in particular, whether the technology was introduced before Scandinavian settlement. Yet, little attention has been paid to technological choices made by the potters or how these choices were influenced by wider societal changes. This paper takes a holistic approach to production, employing a range of analytical techniques to reveal the production sequence followed by potters working at one of the new industries — Torksey (Lincolnshire). With new insights into raw material choices, processing procedures, vessel forming practices and firing regimes, the paper challenges long-standing assumptions about manufacturing practice and the spread of the potters' wheel. Opening a window into the mind of the potter, this article offers a greater understanding of the mechanisms that facilitated the diffusion and ultimate success of this new technology.

INTRODUCTION

In the 9th century England witnessed major social upheaval; Viking armies moved through the north and east, towns flourished for the first time since Roman rule, land ownership was fundamentally transformed and new forms of material culture were produced. This era's material record displays a revolution in ceramic production; in a departure from earlier practices, pottery was wheel-thrown, kiln-fired and made on a near industrial scale. This sophisticated production emerged in a country that had not witnessed such techniques for over 500 years and, most surprisingly, it prospered in eastern England — the Danelaw — an area controlled by Scandinavian elites hailing from aceramic regions.[2] Although it is widely accepted that these technologies were introduced by immigrant potters from continental Europe,[3] it is still unclear *how* and *why* they were founded and thrived, presenting a major obstacle for understanding the period's economy and the emergence of new identities in the wake of Scandinavian settlement.

Traditionally, both type-specific and overarching syntheses of this pottery have focused upon dating and descriptive characteristics, eg vessel form, colour, and fabric.[4] A notable deviation was Alan Vince's *'Forms, Functions and manufacturing techniques of late 9th- and 10th-century wheelthrown pottery in England and its origins'*.[5] Combining new dating evidence with a consideration of four easily visible characteristics — form, fabric, base type, and decoration — Vince demonstrated that, as the technology spread, a series of regional potting traditions emerged. As we shall see, the boundaries of these traditions need reassessment, yet his work highlighted the potential that studying technological choice has for comprehending the diffusion of potting techniques. In this respect Vince's work accords with more recent analyses of contemporary material culture, particularly Steve Ashby's work on bone/antler combs. Ashby argues that it is often the 'less visible aspects of design ... those related to the choices taken in the basic construction'[6] of an object which provide most insight into the organisation of production, transfer of knowledge between practitioners, development of regional traditions, assimilation of new styles and techniques into existing repertoires, and creation of new identities.[7]

Building on these works, this paper argues that the less visible aspects of production and, in particular, the social, political and economic circumstances in which manufacturing choices were made, are key to understanding the success of these new pottery industries. It focuses primarily on pottery production in Torksey (Lincolnshire) (Fig 1) and so-called Torksey ware: an industry which was among the earliest to produce wheel-thrown pottery. An overview of previous research into Torksey ware will be followed by the results of a detailed analysis of Torksey ware, kiln structure, and geological samples, using thin section petrology and scanning electron microscopy. The resulting insights into raw material choices, vessel-forming procedures and firing regimes will be combined with excavated evidence, providing a complete overview of the production sequence followed by Torksey's potters. With this new understanding of artisanal practice, the paper then considers the techniques employed at other industries. Finally, the emergence, success, and developments in manufacturing practice at Torksey and neighbouring industries will be placed in the context of local and regional social, political and economic developments in the late 9th–11th centuries.

TORKSEY WARE: EXCAVATIONS, CHARACTERISTICS AND DATING EVIDENCE

Evidence of pottery production in Torksey was first confirmed in 1949 when a kiln (Kiln 1) was excavated in a field to the south of the modern village. A summary of this pottery was presented by Gerald Dunning in 1959.[8] Maurice Barley's excavations, between 1960–1968, re-excavated Kiln 1 and uncovered six more.[9] In the early 1990s a series of developer-funded excavations unearthed a further eight, bringing the total to 15.[10] The levels of preservation and extent of excavation is extremely variable. Kiln 1, for example, had fragments of kiln wall surviving in situ, while Kiln 3 was identified by magnetometer survey but was built over before Barley could investigate, and Kilns 10–12, 14 and 15 were represented only by redeposited fragments of kiln furniture and areas of burning. Only Kilns 1, 2, 4–9, and 13 are unequivocally pottery kilns (Tabs 1, 2; Fig 5).

Since 1960 Barley's kilns, and their pottery, have been subject to a number of analyses. Archaeomagnetic dates for Kilns 1, 2, 4 and 5 were presented in a number of articles in the 1960s.[11] In the 1980–90s scientific techniques were frequently used to provenance medieval pottery from consumer sites (ie settlements where particular types were used, but not produced) to the kilns in which it was manufactured. Of particular significance here was the study of York's pottery, where Torksey ware formed a substantial proportion of assemblages from within the city. So prevalent was Torksey ware that it was thought that this pottery could not have been made in Torksey, c 80 km south of York, but must have been a similar type made closer to York. Scientific comparison of pottery from York and Torksey's kilns suggested that York did indeed obtain its pottery from an alternative, yet unidentified, production centre.[12] Alan Vince subsequently undertook an extensive programme of thin section and chemical analysis, using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), comparing pottery from consumer sites with that from Barley's Torksey kilns. He aimed to provenance the pottery and trace minor chemical differences between kiln waste and consumer-site pottery in order to refine the dating of individual kilns. Although dating refinements proved impossible, his findings contradicted earlier studies, revealing that York's Torksey wares *were* produced at Torksey.[13]

Numerous dates have been proposed for the Torksey industry's lifespan. Based on pottery from Hungate (York), Dunning argued that Kiln 1 belonged to the 11th/12th century.[14] Archaeomagnetic dating of Barley's kilns concurred: Kilns 1 and 5 were dated AD 1050–1150, and Kilns 2 and 4 AD 900–1000.[15] In light of excavated evidence and archaeomagentic dates from other kiln sites, John Hurst suggested that Kiln 1 belonged to the earlier part of the AD 1050–1150 range.[16] Based on archaeomagnetic dates, as well as decoration, and rim and basal forms of Torksey ware found in stratified contexts at domestic sites, Barley placed the kilns in the following chronological order: 2, 3, 4, 5, 6, 7, 1, with the caveat that Kilns 1, 5, 6, and 7 could be placed in any temporal relationship and were probably connected in time and/or ownership.[17] While no archaeologically datable finds have been recovered from any of Torksey's kilns, recent finds from consumer sites enable refinement of Torksey ware dates. At Flaxengate (Lincoln), small amounts of Torksey ware have been recovered from prestructural phases (pre-Phase I), representing Lincoln's earliest late-Saxon activity. Direct dating evidence for this prestructural phase is lacking but numismatic evidence (St Edmund memorial penny c AD 905; a coin of Alfred, AD 890s) and archaeomagnetic dates (from a Period I hearth, AD 850 ± 50) suggest that Phase I ended c AD 900. The beginning of this phase is less securely dated: assuming a life expectancy of c 15–25 years for wooden structures, Dom Perring suggested that Phase I began c AD 870/80.[18] Clearly, a definite date for Torksey ware's first appearance in Lincoln is lacking, but seems likely to have taken place later in the 9th century. Between c AD 970–1070 Torksey ware became the town's dominant non-Lincoln ware-type and it appears to have been residual by the late 11th century.[19] Similar dates are suggested by finds from York; Torksey ware was absent from Fishergate's earliest deposits, where coins provide a *terminus post quem* of c AD 860, but present in Coppergate contexts dated numismatically and archaeomagnetically to c AD 850–900.[20] By AD 1000 it had become York's dominant ware-type. In the second half of the 11th century its importance declined but it was still present in late 11th-century deposits.[21] In sum, independent dating evidence provided by finds from consumer sites suggests that production began in the late 9th century, flourished from the mid-10th–mid-11th, and had ceased by the late 11th century.

Turning now to the characteristics of Torksey ware, its surfaces are almost always grey or black, while cores and margins are often oxidised, being red to reddish-brown. Many sherds possess a characteristic 'sandwich firing' – grey/black surfaces, red margins and reduced grey/black cores. Occasionally sherds are fully reduced, with harder fired examples having lighter grey cores and surfaces than their lower fired counterparts (Fig 2). The grey/black surfaces were probably achieved by switching the atmosphere from oxidising to reducing in the latter stages of firing.[22] Significantly, pottery from Kiln 2 is almost always reduced grey/black throughout the vessel wall, suggesting a different firing regime from the other kilns.[23]

Throughout the industry's life, pottery was produced in a single fabric, characterised by rounded and sub-rounded quartz grains, long thought to have been added to the clay as temper.[24] Windblown cover sands, found throughout the Trent Valley, are believed to be the source of this temper.[25] There is some debate as to the source of the clay. Barley originally reported that the potters used the Keuper Marl clays (hereafter the Mercia Mudstone, as it is now known) on which Torksey is located.[26] After noticing occasional calcareous clasts in the fabric, he modified his view, claiming that potters used the Lias clay, available c 1.5 km east of the site.[27] Vince's ICP-MS analysis of Torksey ware demonstrated that pottery produced in adjacent kilns (eg Kilns 1 and 2; Kilns 6 and 7) could not be distinguished chemically, but was separable from pottery produced at other kilns within the village (Fig 3). These differences, he argued, were due to potters obtaining their raw materials *on site*, with the potters of Kilns 1 and 2 sharing the same clay source and those from Kilns 6 and 7 sharing another.[28] Although not stated explicitly, his conclusions support Barley's assertion that the underlying Mercia Mudstone was the source of potting clay.

Barley reported that Torksey potters built vessels on a slow turning wheel from a succession of flattened clay coils. Their sagging bases were produced by rotating the upturned vessel on the wheel, paring off surplus clay with a knife. After trimming, pots were wiped with a cloth.[29] While it is clear from tool marks that the bases were indeed trimmed, Barley neglected to provide any evidence to support the suggestion that the pottery was coiled. Other authors state that Torksey ware was wheel-thrown, but they too have failed to provide any substantiating evidence.[30]

The form of pottery changed little through the life of the industry.[31] Cooking pots (globular jars) accounted for c 70% of vessels from Kilns 1–7, bowls 27%, and socketed-bowls, lamps, storage jars, spouted pitchers, cheese presses, watering pots, and 'ring vases' comprising the final 3% (Fig 4).[32] Rim diameters of jars from Kilns 1–7 are remarkably consistent, all within 9–21 cm (mode 13–15 cm).[33] Although detailed analysis of vessels from Kilns 8–15 is yet to be undertaken, it is clear that they produced the same range of forms.[34] One significant difference between these assemblages is the Kiln 2 potter's apparent preference for flat-based jars; 83% of bases from Kiln 2 were flat, compared to between 2% and 35% in other kilns.[35]

Around 5% of Torksey ware vessels were decorated. Decoration was applied throughout the industry's life, but was most common around the mid-10th century. It consisted of square-, diamond- and triangular-shaped rouletting on rims and shoulders, or thumb-impressed 'pie-crust' rims and applied strips (Fig 4).[36] Finds from consumer sites have helped to produce a broad decorative chronology. Rouletted Torksey ware appeared in Coppergate's earliest phases (c AD 850–900) and remained common until the late 10th century.[37] No rouletted Torksey ware was found at Flaxengate;[38] allied with Torksey ware's rarity in Lincoln until the late 10th century,[39] this suggests that rouletting was most prevalent in the industry's early phases. Thumb-impressed decoration was found in Coppergate's earliest deposits and peaked in popularity in later tenth to mid-11th-century contexts.[40] In Lincoln, thumb-impressed decoration also became common from the late 10th century.[41] Combined with the evidence from York, this suggests that decorative thumbing replaced rouletting in the industry's later stages. The chronologies from Lincoln and York broadly agree with Barley's dating of Kilns 1-7, where rouletting is found on pottery from kilns attributed to the earliest (Kilns 2, 3, 4) and middle years of production (Kiln 6), while thumb-impressed decoration is most common in later kilns (1, 5, 6, 7).[42]

Of the kilns whose forms were discernible, all were circular-ovened, single-flue updraft kilns (Tab 1 and Fig 5). Kilns 1, 5-9 and 13 had firing chambers 1.5–2.0 m in diameter and comprised a series of fire bars radiating from a central pedestal, on which pots are likely to have been stacked.[43] The smaller Kiln 4 also had a suspended floor but in this case unsupported fire bars straddled its 1 m internal diameter. Kiln 2 is similarly small and the only kiln without an internal structure; pots were probably placed directly on the oven floor. These distinctions aside there is considerable uniformity in construction: the majority had stone-lined flues, facing west-north-west to west-south-west; clay fire bars were formed around wood (Fig 6); pedestals were similar shapes/sizes; all were dug into natural clay and sand; and firing chambers were clay lined and in some cases relined.

The fills of all definite kilns contained fragments of fired clay, interpreted as collapsed superstructure, yet kiln fabric has scarcely been addressed. Vince and Steane examined seven fragments from Kiln 13, noting that they were formed of very sandy clay, 'coarser' than the pottery (Fig 6).[44] It is unclear what the significance of this coarser fabric was; were different raw materials used to make the kiln and pottery or did potters use the same raw materials for both, adding more sand to the kiln clay? A 'possible' wattle impression and convex surface led Vince and Steane to conclude that one of these fragments formed part of a domed structure, but as there are numerous places inside a kiln where one might expect to find a convex profile and wattle impression (eg the junction between a firebar and pedestal/wall; the junction between flue and firing chamber), this fragment does not prove that the kilns were domed. Kiln 1 is the only kiln in which fragments of wall survived in situ, standing up to c 23 cm high. Neither the wall nor the fragments in its fill possessed any sign of a supporting structure.[45] In the absence of a frame it is difficult to envisage how a dome might have been supported.

After being lined with clay, Kiln 1 was fired in oxidising conditions to 'harden the structure'; at a later stage more clay was added, then fired under reducing conditions, 'presumably with the kiln full of pottery'.[46] Given the pre-load firing and lack of evidence for a dome, it seems that Torksey's kilns had vertical walls and that pottery was loaded and removed through an open top. As experimental firings show, it is difficult to maintain a reducing atmosphere inside open-topped kilns and the topmost layer of pottery almost always cracks.[47] It seems probable that the kilns were capped with a removable roof, perhaps of broken pottery and/or turf.

To summarise, Torksey ware was produced from the late 9th to late 11th centuries. While decoration changed during the life of the industry, the form and fabric of the pottery remained constant. We know virtually nothing, however, of the *chaîne opératoire* of pottery production in Anglo-Scandinavian Torksey (in other words, the series of operations that transform raw materials into manufactured products)[48] or how this *chaîne* compares to that of other contemporary industries. For example, it is unclear whether potting clay was obtained on site or from outside the village and there is disagreement about whether the pottery was wheel-thrown or coiled. With the exception of Kiln 2, all kilns followed the same firing regime. As Kiln 2 is the earliest in the sequence and the only kiln not to possess a suspended floor, it seems that the potters modified the kiln structure and firing regime early on in the life of the industry; we must ask why this was so? We know that kiln walls were made of sandy clay, coarser than the pottery, but it is unclear whether they were made from different raw materials or whether clay and sand were mixed in varied proportions. This paper will now reconstruct the production sequence and place the industry in the context of the ceramic revolution that occurred in the late 9th and early 10th centuries.

MATERIALS AND METHODS

GEOLOGICAL SAMPLING

A number of clay and temper sources were available to Torksey's potters. To assess their suitability for pottery production and understand potters' choices, each deposit was sampled. Sampled clay was formed into briquettes, dried at room temperature, and fired in an electric kiln. Thin section and SEM analysis (see below) reveal that Torksey ware was primarily fired in an oxidising atmosphere with kilns achieving equivalent firing temperatures generally below 800–850^{o}C. Thus, to facilitate comparison with the pottery, clay samples were fired in an oxidising atmosphere at rate of 250^{o}C per hour and held at a maximum temperature of 750°C for one hour. After drying and firing, defects such as cracking and warping were noted and the percentage shrinkage measured; the briquettes were thin sectioned and compared with thin sections of Torksey ware and kiln fragments.

PETROGRAPHIC ANALYSIS

Previous petrographic work on the pottery from Kilns 1–7 demonstrates that the same fabric was used in all kilns throughout the industry's life.[49] To test whether these findings are applicable to the pottery from the newly discovered kilns, pottery was sampled from all definite kiln structures and their associated waster dumps (Kilns 1–9, 11, 13) — a total 79 sherds (Tab 3). A further 68 sections of Torksey ware from consumer-sites in Lincolnshire, Humberside, and Yorkshire (Fig 1 and Tab 3) were examined to ascertain whether they were produced at Torksey. To establish whether different raw materials were used to make the kiln structure and the pottery it was necessary to sample fragments of kiln wall. These are typically discarded by excavators, so it was fortunate that the excavators of Kiln 13 retained seven fragments for future research; two of these were subjected to thin section analysis.

The orientation at which a ceramic thin section is made can provide information about forming methods. Those taken tangentially through a vessel wall are useful for identifying preferred orientation — the alignment of elongated features in the fabric (eg voids, inclusions, clay domains) — indicative of wheel throwing. Vertical sections are useful for identifying manufacture by wheel-throwing, wheel-finishing and coiling.[50] Where possible all thin sections were taken vertically through vessel walls, while two Kiln 13 pottery samples were sectioned tangentially. All thin sections were examined using a polarising microscope, and classified, grouped, and described according to the Whitbread system.[51] This advocates grouping samples according to the frequency, shape, size, sorting and mineralogy of inclusions, as well as the colour, optical activity and texture of the clay matrix. These criteria reveal information about raw material selection, processing strategies, forming and finishing techniques, and firing temperature and atmosphere.

MICROSTRUCTURAL ANALYSIS USING SCANNING ELECTRON MICROSCOPY

The behaviour of clays when subjected to various combinations of firing temperature, heating rate and atmosphere is well-studied.[52] Particular firing conditions initiate predictable changes in clay microstructures. Observation of these microstructures in a fresh fracture using SEM, in combination with geochemical data, provides insight into the control of firing temperatures; this insight is extremely valuable when considering potters' technological choices. Sixteen Torksey ware samples were examined by SEM. These were selected according to variation in firing conditions identified under the polarising microscope, enabling comparison of the firing regime in a 'typical' kiln (Kiln 13) with that of the 'atypical' Kiln 2. The character of observed microstructures was described using the terminology of Maniatis and Tite, with estimates of 'equivalent firing temperatures' being determined by comparison with their established vitrification stages for calcareous (CaO > 6% of matrix) and non-calcareous clays (CaO < 6% of matrix) fired in oxidising and reducing atmospheres.[53]

RESULTS

TEMPER SOURCES

Three sources of sand temper are available in the vicinity of Torksey: Glacial Sand (under the modern village); Older River Deposits (c 1.5 km east of the village); and Wind

Blown Sand (c 2 km south of the village). There is very little difference in grain size, sorting or mineralogy of these sands,[54] a point confirmed by thin section analysis (Tab 4). If these sands were used as temper it would not be possible to determine which was exploited.

CLAY SOURCES

Five clays were available to the potters: the Mercia Mudstone (on which Torksey is located); Tea Green Marl (a constituent of the Mercia Mudstone, but completely obscured by overlying sands); Lias (c 1.5 km east of the modern village); Rhaetic (c 1.5 km east of the village); and Alluvial clays (0.2 km west of the village) (Figs 7 and 8). Each has different properties, with some more suitable for pottery production than others (Tab 4). The low plasticity and post-firing friability of the Mercia Mudstone render it unsuitable for pottery production. By comparison, the Alluvial and Tea Green Marl clays are highly plastic and fire well. Being largely devoid of inclusions, these clays would require tempering — the addition of non-plastics — in order to provide support during forming and drying and resistance to thermal shock during firing and use.[55] The Lias clays contain substantial amounts of naturally occurring non-plastics in the form of limestone fragments, often up to 20 cm in diameter. Even if potters removed this limestone they would still encounter problems when firing as this clay is calcareous.[56] The most suitable potting clay is the Rhaetic clay. Being non-calcareous it would not suffer from the problems posed by the Lias, while its plasticity and natural sand inclusions would mean that it required no tempering, essentially making it a 'ready-made' potting clay. As we shall see, it was this clay which potters selected.

PETROGRAPHIC ANALYSIS[57]

Torksey Ware

The 79 kiln and 68 consumer site samples form a homogenous group. The fabric is non-calcareous, has a bimodal grain-size distribution (ie there are two modal grain sizes, representing coarse and fine fractions). Mineralogically, the fabric is identical to the Rhaetic clay (Figs 8a and 9a–d), demonstrating that the sand 'temper' was *not* added by the potters, rather they utilised a naturally sandy clay in an essentially unprocessed state.

The preferred orientation of elongated grains, voids, and clay domains in the fabric are indicative of wheel-throwing (Fig 9a, b, e).The tangential sections reveal preferred orientation resulting from the sheer stresses induced by the anticlockwise rotation of the wheel and lift applied by the potter's hands.[58] In the vertical sections the voids, clay domains and elongated grains are aligned parallel to the vessel wall. This corresponds with forces applied when the clay was squeezed between finger and thumb and the stress induced when drawing the clay upwards to form the vessel walls.[59]

Around 30% of samples were subject to reducing conditions throughout their firing, indicated by brown to grey-black margins and cores. Half of the samples (52%) possessed reduced cores and oxidised margins. These, allied with the 19% which are fully oxidised throughout the vessel wall, demonstrate that Torksey ware was initially fired in an oxidising atmosphere. As rim, basal, and body sherds from thick- and thin-walled vessels alike exhibit 'sandwich firing' we must conclude that the firing duration was short, being insufficient for the oxygen to fully penetrate and oxidise the whole body. Samples with fully reduced or fully oxidised margins and cores are likely to result from differential placement within the kiln, with some vessels afforded more oxygen than others.

Although the firing atmosphere was initially oxidising, it is clear from the grey-black surfaces that the latter stages were undertaken in a reducing atmosphere (Fig 9f). As discussed above, vessels from Kiln 2 possess reduced cores, margins and surfaces. As none of the Kiln 2 samples examined in this study had surfaces darker than their margins we must conclude that Kiln 2 firings were undertaken in *entirely* reducing conditions and that no attempt was made to further blacken vessel surfaces.

The optical properties of the clay and minerals within the fabric provide insight into firing temperatures. The majority of samples (69%) possess optically active to slightly active clay matrices (ie the clay changes from dark to bright when the sample is rotated on the microscope stage), indicating equivalent firing temperatures <c 800–850^{o}C (Fig 9a–c). The remaining samples have optically inactive matrices, suggesting equivalent firing temperatures >c 800–850^{o}C. In a few instances muscovite micas had taken on a brown body colour, indicating equivalent firing temperatures >900^{o}C. It is likely that samples displaying higher firing temperatures do so on account of their placement within the kiln. Indeed, the maximum temperatures attained within different parts of a single kiln may vary by as much as 300^{o}C.[60]

Comparisons of consumer-site and kiln-site pottery demonstrate no difference in mineralogy or firing characteristics. Even the rarest inclusions (eg echinoid spines, spherulite, tourmaline, basalt) are present in both kiln wasters and traded pottery. Allied with the fact that the consumer-site pottery fabric is identical to Torskey's Rhaetic clay, we must conclude that all samples examined here were produced at Torksey (Fig 13).[61]

Kiln Structure

The two kiln samples form a heterogeneous group, characterised by sand set in a very silty matrix — the heterogeneity being due to the varying sand content (Fig 9g–h). The mineralogy of the sand is consistent with those that surround Torksey, while the clay background is consistent with the Mercia Mudstone (Fig 8b, d). Naturally occurring pale yellow streaks in the fabric suggest that the clays were little processed after extraction (blending in sand would homogenise the clay, obliterating these streaks). During geological sampling, a band of sandy clay was encountered at the junction of the Mercia Mudstone and the overlaying Glacial Sands. It seems, therefore, that potters were manufacturing kilns from unprocessed Mercia Mudstone clay of variable sand content. It is not known from which parts of the superstructure the kiln samples derive but this variability implies that potters may have selected more/less sandy clay based on where it was to be used in the structure.

SEM ANALYSIS

Vince's ICP-MS analysis of Torksey ware demonstrated the use of non-calcareous clay (ie CaO <6%).[62] In this study the outcomes from SEM analysis complement Vince's findings. Consistent with the results of thin section analysis, the observed microstructures confirm that the kilns at Torksey generally achieved equivalent firing temperatures between c 750–950^{o}C (Fig 10, Tab 5). While it is acknowledged that the sample number was small, it is significant that Kiln 2 pottery displayed the greatest degree of vitrification, indicating equivalent firing temperatures >c 750^{o}C, mainly in the c 800–950^{o}C range. Although similar temperatures were reached in Kiln 13, the microstructures of most samples represent equivalent firing temperatures <c 850^{o}C and mainly between c 750–800^{o}C. Further insights into firing conditions are provided by the presence of fine bloating pores (diameter < 4μm), indicative of rapid heating rates.[63]

THE *CHAÎNE OPÉRATOIRE* OF TORKSEY WARE PRODUCTION

The following discussion combines the results of the above analytical techniques, various hand-specimen observations and excavated evidence and reconstructs the Torksey *chaîne opératoire* (Fig 11).

CLAY AND TEMPER SOURCES AND PROCESSING

A range of suitable potting clays were available to the Torksey potters, some just 200 m from the kilns, yet they chose to exploit the Rhaetic clays c 1.5 km to the east. Although previous interpretations postulated that sand was added as temper, this study demonstrates that, on the contrary, the clay was naturally sandy and underwent little processing. Once dug, the clay was stored in pits close to the kilns. Indeed, Barley interpreted 'a pit, oval on plan, 90 cm deep and steep sided ... filled with *green* clay' (emphasis added) as the 'potters' clay store'[64] — notably, geological sampling demonstrates that the Rhaetic clays are green when dug (Tab 4). This pit was located among a series of postholes close to Kiln 5, thought to represent an associated workshop. A further 'pit full of green clay', also interpreted as the potters' clay store, was found c 5 m from Kiln 3.[65]

VESSEL FORM AND DECORATION

The preferred orientation of clay domains, voids and elongated grains demonstrates that Torksey ware was wheel-thrown. The tangential thin sections of Kiln 13 pottery (Fig 9e) reveal that the potter's wheel rotated anticlockwise — a right-handed potter — while the same rotational direction is indicated by concentric rilling marks inside jars from Kilns 1 and 8 (Fig 12a). Although rilling marks are present on the interior walls of most Torksey ware vessels they are conspicuously absent from their exteriors. This suggests that potters used forming tools such as 'ribs' to assist shaping and to smooth the outer surfaces; notably an unstratified stone object found close to Kiln 13 has been interpreted as a potter's rib.[66] Parallel striations on vessel surfaces demonstrate that they were wiped after throwing.[67] Striations between roulette impressions demonstrate that rouletting was undertaken after wiping, while displaced clay around their edges suggests that the clay was still wet and therefore probably still on the wheel when decorated (Fig 12b).

Spirals on the bases of Kiln 2 jars indicate that the vessels were cut from the wheel-head with wires or cords.[68] It is likely that later potters removed their vessels from the wheel in a similar way, but that the creation of the sagging base, typical of later pottery, obliterated these marks. This transformation represents a significant modification in the *chaîne opératoire*. One explanation for this change may be that the sagging profile made the angle between base and wall more obtuse, inhibiting the development of stresses that cause cracking during drying and firing.[69]

Chamfers and burrs along the basal angles of vessels led Barley to conclude that the sagging bases were achieved by 'knife-trimming', 'paring off' surplus clay when the vessel was upside down on the wheel.[70] If this was the case, vessels must also have undergone a drying period in order for rims to retain their shape when inverted. Significantly, finger impressions on vessel interiors demonstrate that the sagging profile was in fact achieved by pushing the base out from the inside (Fig 12c). The 'trimming' should therefore be seen as a 'tidying-up' activity rather than shaping. Finally, surface striations confirm that the newly modified bases were wiped.

KILNS AND THEIR LOADING

Once dried, the pots were loaded into kilns and fired. Many structural aspects of Torksey's kilns have already been discussed (eg stone-lined flues, fire bars, vertical walls, temporary roofs) but we can now add that Kiln 13 was formed of Mercia Mudstone clay and that clay of variable sand content may have been used for different parts of its structure. As this kiln is located on the Mudstone it is probable that kiln clay was obtained on site. As this is the only kiln from which structural samples were retained for future research we cannot be certain that the other kilns were made of the same clay. Yet, given their consistent forms (Tab 1, Fig 5) and location on the Mudstone, it is feasible to suggest that this was the case. In Kiln 2 the pots were probably placed directly on the oven floor, while in Kilns 1, 4–9, and 13, they were stacked onto the pedestal and firebars. A possible kiln prop found in a pit close to the putative Kiln 14 suggests that the vessels may have been supported and spaced by additional furniture.[71]

FIRING

Thin section, SEM and hand specimen analysis reveal that two distinct firing regimes were employed at Torksey: the 'Kiln 2 Regime', and the 'Typical Regime', practiced by potters using the other kilns. Although kilns following the 'Typical Regime' achieved equivalent firing temperatures of c 750–950^{o}C, their wares were generally fired <c 800–850^{o}C. While bloating pores in two samples from this kiln indicate rapid heating (Tab 5), a general lack of firing faults, such as spalling and fire-cracking, suggests that potters were in control of this rise.[72] 'Typical Regime' firing comprised two stages: oxidation followed by reduction. Evidence from Kiln 4 reveals that reduction was achieved by plugging the flue-arch with clay.[73] Reduction may also have been facilitated by burning green fuel.[74] Kiln 2 also achieved equivalent firing temperatures of c 750–950^{o}C, although temperatures at the higher end of this range were the norm (c 800–950^{o}C). Kiln 2's vessel surfaces are 'usually [fire]cracked from overfiring',[75] indicating a rapid rise between 300–500^{o}C.[76] Although we are dealing with small sample numbers, the SEM analysis supports these observations; fine bloating pores indicative of rapid heating were more common in Kiln 2 samples than in the 'typical' Kiln 13 samples. Unlike the 'Typical Regime', firing in Kiln 2 was undertaken in entirely reducing conditions. As the pottery did not undergo a period of re-oxidation (which would have caused the surface to redden), we can suggest that the oxygen flow was also restricted towards the end of firing, although it is unclear how this was achieved. It appears that the high temperatures, rapid heating and reducing conditions that characterise the 'Kiln 2 Regime' were partly a product of this kiln's structure. In the absence of a suspended floor, pottery would have been closer to the flames and, as experimental firings show, this position placed it in danger of failure;[77] perhaps this is why raised floors were introduced in later kilns (but see below).

LOCATION OF WORKSHOP AND KILN STRUCTURES

Why were the production sites at Torksey located c 1.5 km from the source of potting clay? One explanation might be the properties of available clays. The Mercia Mudstone's low plasticity makes it suitable for constructing kiln superstructures. Large quantities of sand would need to be added to the other clays in order to reduce their plasticity to a similar level. While we do not know how much clay was used in their construction it seems likely that the kilns were located on the Mudstone in order to avoid processing or transporting large amounts of kiln clay, with potters preferring to make occasional c 3 km roundtrips to collect smaller quantities of potting clay. The proximity of the kilns to the River Trent also provided access to water, essential for production but, more importantly, pottery could be easily transferred to trading ships.

THE TORKSEY POTTERY TRADE

The majority of consumer-site pottery studied here has previously been examined by other scholars, but many of their conclusions are now in question (Tab 3). Catherine Brookes and Ailsa Mainman remarked of the samples from Lloyds Bank, that 'with few possible exceptions the Torksey-type wares from York were *not* produced at the kilns currently known to have operated at Torksey' (emphasis added).[78] Their conclusion was based on two scientific studies. The first, Varian Denham's petrological analysis, revealed 'no difference between [Lloyds Bank] Torksey-type ... and the Torksey kiln products'.[79] Despite this similarity, Denham argued that the two groups were distinct. After comparing the number of sand grains in each sample she argued that Torksey kiln waste was on average c 13% sandier than Lloyds Bank pottery.[80] Analysis of sand proportions in the present study (including 29 of Denham's samples) demonstrates that proportions varied by as much as 30% (c 60–90% clay), even between samples from a single kiln (Fig 13a–d). As Denham compared just six kiln samples, one each from Kilns 2–7, with 60 from Lloyds Bank, she could not have appreciated the extent of natural variability that existed at the production site. As such, the separation of these two groups based on sand proportions is not reliable and does not indicate that they were made in different places.

The second body of evidence used to argue that the Lloyds Bank wares were not made in Torksey was Frances Ipson's Neutron Activation Analysis (NAA).[81] Here, the two assemblages formed separate but slightly overlapping chemical groups, leading Ipson to conclude that Lloyds Bank and Torksey pottery must have been made from different clays.[82] This interpretation is problematic, however. Ipson followed Aspinall's NAA method,[83] which ignores the impact of burial environment on concentrations of mobile elements within ceramic fabrics — indeed Aspinall argued that any changes in concentration are unlikely to be significant and need not be considered.[84] Recent analyses reveal that burial environments *do* significantly influence the geochemistry of pottery.[85] Hence, Vince's ICP-MS analysis of Torksey ware from Nottingham, Yorkshire and Lincolnshire (including 18 samples from Coppergate), which *did* account for post-burial elemental changes, is particularly valuable, especially as he concluded that 'it seems likely that all the Torksey ware sampled from Yorkshire was actually made at Torksey'.[86] Unlike the present study, Vince did not have access to pottery from Hungate or the recently discovered kilns, nor did he analyse samples of clay from Torksey. The results presented here reaffirm Vince's findings, demonstrating that Torksey *was* the source of much of York's pottery (Fig 13e, f).

COMPARING AND CONTEXTUALISING THE *CHAÎNE*

It has long been recognised that the potters' wheel and updraft kiln were not an indigenous development but were introduced to East Anglia and the East Midlands in the mid-/late 9th century by craftspeople from the continent.[87] Dunning argued that the new technologies spread from a small number of primary centres (eg Thetford, Stamford), with a second wave established in the 10th/11th centuries (eg Torksey, Lincoln, York).[88] These primary industries were all located in the area that was to become the Danelaw. Aided by new dating evidence, Vince revealed that many of Dunning's 'secondary' industries were, in fact, active at the start of this ceramic revolution and may even have pre-dated some 'primary' industries.[89] Incorporating technological characteristics such as fabric type and firing colour, Vince moved beyond simple chronologies, revealing that as the technology spread, seven regional ceramic traditions were established: white wares of fine un-tempered white clays (Stamford, Northampton); fine greywares 'naturally tempered with quartz silt' (Ipswich); East Anglian grey sandy wares (Grimston, Norwich, Thetford, Langhale); East Midlands grey sandy wares (Torksey, Newark, Leicester); oxidised sandy wares (Stafford, Derby, Nottingham, York); South East Midlands shelly wares (St Neots) and Lincolnshire shelly wares (Lincoln, the Lincolnshire Wolds).[90] The parameters of these regional traditions require redefinition (see below) but Vince's work clearly demonstrates the potential that technological analysis has for understanding the adoption and diffusion of these new technologies.

CLAYS AND TEMPERS

We have seen that Torksey's potters selected the naturally sandy Rhaetic clay, which did not require tempering, for making pottery, refuting previous assumptions that sand had been added to the Lias or Mercia Mudstone clay. A literature survey reveals that similar conclusions have been drawn about clays and 'temper' used in other industries. For example, it has been suggested that sand was added to clay during the manufacture of Thetford ware and Grimston-Thetford ware.[91] Four clay deposits have been identified as potential sources for Thetford ware, with at least four also available for Grimston.[92] Yet, none of these clays have been sampled or compared with the pottery, therefore, it is not possible to claim that the clays were tempered, let alone ascertain which clay sources were exploited.

There are many other contemporary ware types for which no potential sources have even been suggested (eg Nottingham,[93] Leicester,[94] Lincoln Saxo-Norman Sandy ware,[95] Newark Torksey-type ware,[96] Norwich-Thetford,[97] Langhale-Thetford[98] and Northampton wares[99]). These studies also typically assume that inclusions in the clay represent temper added by the potter. Only at Stamford has pottery been compared with locally available clay, but even here the attribution to specific clay deposits is problematic. Kathy Kilmurry identified four clays in the vicinity of Stamford, but only one was sampled, the Upper Estuarine Clay. This clay is extremely variable; nine separate strata were observed in a cliff-face at a local quarry. Kilmurry thin-sectioned clays from two of these strata and matched one with Stamford ware fabrics B and C.[100] It is difficult to see how potters might have exploited this particular band, given that it buried below another 4 m of clay. Moreover, the source of clay used to make the other six Stamford fabrics remains unexplored.

In light of the discovery that the Torksey potters did not add sand to their clays, we must consider whether other potters also selected naturally sandy clays, as this has significant implications for Vince's regional fabric traditions. For example, East Anglia's production centres all fired their pottery in entirely reducing atmospheres (Tab 6). Yet, Vince separated Ipswich-Thetford ware from the main East Anglian group (Thetford, Grimston-Thetford, Langhale-Thetford, Norwich-Thetford) because its clay was 'naturally tempered' with silt. Potters working at the other East Anglian centres are assumed to have intentionally added sand (see above). Crucially, if their clays were also 'naturally tempered' (albeit with sand, not silt) then these two groups should be regarded as a single East Anglian tradition (Fig 14).[101]

A significant finding of the present study is the relationship between Torksey's kiln location and the source of kiln and potting clay. The source and character of kiln clay are rarely considered, except to note, for example, that clay is 'sandy' (Stamford),[102] 'chalky'

(Thetford),[103] or filled with organics such as straw (Lincoln).[104] A recent petrographic study of 11th-century Stamford-type ware produced in Pontefract revealed that the kiln was made from the *same* clay as one of four pottery types fired in its superstructure. As no geological sampling was undertaken in the study, the source of these clays remains elusive.[105] Concurrently, Kilmurry's analysis of Stamford's Castle kiln demonstrated that the *same* clay was used to make both the kiln and pottery.[106] This clay was probably obtained on site, although with no analysis of the underlying clay this cannot be confirmed. If Stamford's kiln and potting clay *were* obtained on site, these findings offer an interesting comparison to Torksey. Previous discussions regarding the positioning of kilns have emphasised their proximity to town boundaries and defences. Such marginal locations, it is thought, were chosen to prevent fire, control pollution and enable development of craftzones.[107] We should now acknowledge that raw material availability and access to trade routes could also influence the positioning of Anglo-Scandinavian kilns.

FORMING TECHNIQUES

We have seen that some scholars consider Torksey ware to have been wheel-thrown, others claimed that it was coil built and wheel-finished. Similar contradictory interpretations are found throughout studies of other contemporary potteries. For example, Lauren Adams Gilmore reported that Lincoln Gritty ware was of 'very fine wheel-made production', but Jane Young et al stated that the 'upper part of most [Lincoln Gritty ware] vessels appear[s] to be completely turntable- or wheel-thrown, whereas the lower body and base commonly exhibit signs of coil building'.[108] Neither study outlined how these forming methods had been identified. Similar shifts in thinking are apparent in studies of Stafford-type ware. In 1998–9, Deborah Ford highlighted a series of characteristics interpreted as evidence for coil building and wheel finishing.[109] More recently, Jonathon Goodwin interpreted the same suite of characteristics in a very different way, claiming that 'the majority of vessels could have been wheel-made, with some degree of hand-forming, principally on the bases'.[110]

The identification of thumb impressions on Stafford-type ware bases suggests that bases and walls were piece formed, ie made separately then joined together. [111] Piece forming is often noted in studies of Anglo-Scandinavian pottery. In most cases it is restricted to very large storage jars and pitchers (eg at Thetford), yet analysis of pottery produced at the Silver Street kilns (Lincoln) demonstrates that piece forming can in fact be the main manufacturing method for a range of vessel forms. Rilling marks were evident on internal walls and bases of the earliest pottery produced on the site — suggesting wheel-throwing — but were largely absent from later vessels. The preferred orientation of shell inclusions (identified by X-ray and thin section analysis) revealed that the earliest vessels were indeed fully wheel-thrown. In later pottery only the walls were wheel-thrown, with bases being added separately.[112] These examples demonstrate that we must test empirically any claim concerning forming techniques. If we are to understand how and why the potters' wheel spread, the first step has to be establishing unequivocally how pottery was made at each centre.

FIRING TEMPERATURES

We know very little of Anglo-Scandinavian firing temperatures. The Stafford kilns reportedly reached c 950^{o}C, however as this temperature was the maximum obtained in an experimental firing of a replica kiln, [113] and not by pottery analysis, it must be regarded with caution. Kilmurry stated that Stamford's potters fired their vessels from below 870°C to above 1020°C.[114] As this range was determined by analysis of just three sherds, using an unspecified technique, it is unclear what temperatures the potters generally achieved. A better indication of firing temperature is provided by thin section analyses which have noted the optical activity of the clay matrices, indicating that temperatures similar to those attained at Torksey were typical — generally <c 800–850°C.[115] Yet, temperature determinations cannot be based entirely on optical activity. The vast majority of Torksey ware was fired below c 800–850°C, but SEM analysis demonstrates that Kiln 2 fired to higher temperatures. Clearly more work is needed in determining Anglo-Scandinavian firing temperatures and their relationship to kiln structures and firing regimes.

FIRING ATMOSPHERE

Scholars have previously attributed Torksey ware to the grey, reduced, sandy Thetford ware tradition. Dunning even suggested that it 'derived from [the] Thetford ware' industry.[116] In this context the terms 'grey' and 'reduced' refer only to the surface colour. The surface of Torksey ware is indeed grey/black yet its red/reddish-brown cores and margins indicate that a reducing atmosphere was introduced only in the final stages. This regime contrasts completely with Thetford, where grey/black surfaces *and* cores indicate a reducing atmosphere *throughout* firing.[117] Clearly these are two very different ways of operating a kiln and therefore these two industries cannot be regarded as belonging to a single manufacturing tradition.[118]

Complete reassessment of each industry's firing regime is beyond the scope of this paper, but the following example demonstrates that such analysis would potentially enhance our understanding of how the new technologies spread. While precise dating of individual industries is often problematic,[119] it is notable that all East Anglian industries fired their pottery in entirely reducing conditions, irrespective of their production date. Contrastingly, in the East Midlands, pottery was rarely fired in entirely reducing conditions beyond the mid-10th century, when a second wave of industries was established. While they also produced grey-surfaced pottery, they followed a different regime, initially firing in an oxidising atmosphere before switching to a reducing atmosphere (Tab 6, Fig 14). Notably, this later group forms a tight geographical cluster around the River Trent. Clearly the change in firing regime at Torksey was not site-specific, but regional. We must consider the incentive for this change and why the later regime had such a well-defined geographic distribution.

The preceding discussion demonstrates that we have a limited understanding of production sequences followed by Anglo-Scandinavian potters; reports are undermined by ambiguity and untested assumptions, making it difficult to compare and contextualise Torksey's *chaîne opératoire*. Nevertheless, the methods employed here provide new insights into production practices, revealing previously unrecognised, chronologically significant changes in manufacturing choice. As the subsequent discussion demonstrates, when individual practices are considered in light of wider regional potting traditions and 9th-/10th-century societal changes, they illuminate the mechanisms that facilitated this wholesale transformation in ceramic production.

THE INTRODUCTION OF WHEEL-MADE POTTERY AND THE DEVELOPMENT OF REGIONAL TRADITIONS

As the earliest wheel-thrown industries were established in the area that would later become the Danelaw,[120] it is unsurprising that scholars have attributed the industries' successes to the 9th-century Scandinavian settlement.[121] Yet, as Paul Blinkhorn highlights, discussions surrounding Scandinavian involvement are often brief.[122] For him, the link between Vikings and ceramics 'is unconvincing, as Scandinavian society was at that time largely aceramic'.[123] He argues that the new ceramic industries were part of wider technological transformations that had begun in the 8th century, and included the minting of coins modelled on Carolingian forms and the introduction of mortar mixers — technology originating from the Frankish realm. The appearance of continental technology, Blinkhorn suggests, is indicative of a wider '"Carolingianisation" of Anglo-Saxon society', which was supported by elites keen to demonstrate their links with the Carolingian Empire. Importantly he argues that some of these potteries were active *before* the Scandinavian settlement in the AD 870s.[124]

Five production centres are central to Blinkhorn's argument: Stamford; Ipswich; Thetford; Leicester; and Stafford. He cites an archaeomagnatic date of AD 850±50 and radiocarbon dates of AD 837 ±77 and AD 678±83 from Stamford's Castle kiln to suggest that production may have begun as early as AD 800. Coin finds from Ipswich demonstrate that the production of middle Saxon Ipswich ware had ceased by c AD 855. As this ware-type has been found alongside Anglo-Scandinavian Ipswich-Thetford ware, which has been recovered from deposits beneath the early 10th-century town defences, Blinkhorn suggests that there was an overlap in manufacture and therefore Ipswich-Thetford ware production began by AD 860. The dating of Leicester and Thetford ware is similarly problematic but as both have been found in mid-/late 9th-century deposits in Lincoln, Blinkhorn argues that they may also pre-date the Scandinavian settlement. Finally, charcoal samples from Stafford's Tipping Street kilns yielded radiocarbon dates of AD 870±80 and AD 830±40, which he suggests are also indicative of a pre-Viking industry.[125]

At first glance, Blinkhorn's evidence does suggest that some of these industries could pre-date the Scandinavian settlement. However the evidence does not bear scrutiny. The 14C dates from Stamford's Castle kiln, a crucial element of Blinkhorn's argument, are over 30 years old and require recalibration. Recalibration during the present study returned dates of AD 743±82 and AD 879±82,[126] bringing the kiln in line with the Scandinavian settlement of Mercia and East Anglia in AD 877 and 879,[127] and fitting with the earliest stratified finds of Stamford ware at consumer sites (eg pre-Phase I deposits at Flaxengate — c AD 870/880).[128] The start date for Ipswich-Thetford ware remains problematic but we cannot simply accept Blinkhorn's date of AD 860 when the period of ambiguity lies between c AD 855 and the early 10th century. While Leicester and Thetford ware both occur in mid-/late 9th-century deposits in Lincoln, they cannot be confidently assigned a pre-Scandinavian settlement date as their earliest occurrence is in Flaxengate's pre-Phase I levels[129] — c AD 870/880 (see above). Finally, we have Stafford ware. The 14C dates cited by Blinkhorn were discounted by Carver in 2010 (they were not calibrated) and, indeed, Carver placed production in the 10th and 11th centuries.[130] Bayesian modelling of carbon dates from newly discovered Stafford kilns further complicates matters, placing the onset of production in the period AD 790–890 and certainly before the foundation of the *burh* in AD 913. Most significantly, this analysis gives a 98.8% probability that production began before AD 874, when the Scandinavians made peace with the Mercians.[131] The Scandinavians were active throughout Mercia in the years prior to the peace agreement (hence why it was needed) and these results merely reaffirm the fact that production began around the time of intense Scandinavian activity; they do not demonstrate that it predated the arrival of the Scandinavian settlers.

Aside from the dating evidence there are also significant problems with Blinkhorn's assumption that aceramic Scandinavians did not engage with ceramic production. It has been widely noted that upon their arrival in Britain, Scandinavian settlers quickly began producing and consuming forms of material culture (eg coinage) for which they had no pre-existing homeland tradition.[132] A comparable example of the impact that Scandinavian groups could have on pre-existing ceramic practices in a different region can be found in the ceramic sequence of the Hebrides (Scotland). Here, the start of the Viking period coincided with the appearance of new vessel-forms and forming techniques, which had potential prototypes on the Faeroe Islands and in Irish Souterrain ware.[133] These new techniques may have been introduced by Faeroese and Irish potters brought to the Hebrides by Scandinavian agency. Whether Scandinavia was aceramic or not, Norse influence may well have provided the conduit for accomplished potters (whether continental or from other regions in which Scandinavians were active) to enter and begin producing pottery for a host society who had an enduring tradition of ceramic manufacture and consumption. Scandinavian settlers themselves may, equally, have come directly from locales where they had become accustomed to pottery-use. Shane McLeod has recently argued that the Great Army set out from northern Francia, and that other Scandinavians may have relocated to England after an earlier settlement in Francia.[134] It is not beyond the bounds of possibility that Scandinavian settlers actively encouraged pottery production because its use and manufacture were embedded within the new identities that were forming in the course of settlement.

The success of the wheel-thrown industries is unlikely to be understood by simply constructing chronologies or attempting to prove that they pre- or post-date Scandinavian settlement. Instead, it should be viewed as a complex blend of variables, including economic practice, trade routes, political circumstances, pre-existing ceramic traditions, and crucially, the *chaîne opératoire*. In order to fully comprehend this wholesale change in practice each of these variables needs consideration at regional and site-specific level. This is readily demonstrated by the example of Torksey and other Trent Valley sandy wares.

By the later Anglo-Saxon period Torksey possessed many of the characteristics of a *burh*, including a mint, pottery kilns and at least four cemeteries. It may have been one of the seven burhs recorded in a *Chronicle* entry of AD 1015. Nevertheless, the origins of the early settlement remain obscure.[135] The discovery of large quantities of non-ferrous metalwork and coinage led to the suggestion that Torksey began life as an 8th-century periodic market, developing into a town only when traders or a local lord saw the commercial potential offered by permanent settlement.[136] It is now recognised that the vast majority of these finds are 9th century and derive from a small area c 1 km north of the modern village, interpreted as the location of the Viking Winter Camp of AD 872–3, as recorded in the *Anglo-Saxon Chronicle*.[137] Nonetheless, Torksey's involvement in pre-Viking commercial activity is evidenced by a small number of 8th-century coins, including five continental *sceattas*, found at various locations around the village. For Blackburn these coins demonstrate that 8th-century Torksey enjoyed direct trade with the continent.[138] These continental links may represent the means by which potters arrived in Torksey, supporting the notion of a pre-Viking pottery industry, yet it is important to recognise that excavations within the village have failed to provide evidence of middle Saxon settlement. Torksey was hardly the burgeoning *wic* that might have attracted continental craftspeople.

On the other hand, as the earliest dated Torksey ware finds (see above) coincide with the establishment of the Viking Winter Camp, we can postulate that the two circumstances were connected. According to *The Anglo-Saxon Chronicle* the Viking army repeatedly crossed the English Channel to raid on the continent,[139] and may therefore have subsumed continental potters into their entourage; we may look to these potters as the founders of the Torksey industry.

Torksey's topography suggests that it occupied an island location, bounded on the west by the River Trent, south by the Fossedyke and to the north and east by marshlands; indeed the name Torksey (Old English *Turcesige*) derives from 'Turc's island'.[140] Stocker suggests that in the early period Torksey island, and its putative market, may have formed part of a parish whose centre was located on the banks of the Trent. He suggests that Marton church, c 1.5 km north of Torksey, with its high number of Hiberno-Norse stone sculptures — the earliest of which date to the second quarter of the 10th century — would be a likely candidate for this parochial centre.[141] Marton's monuments could represent the gravemarkers of Torksey's early trading elite and Marton church may therefore have predated the town, with Torksey breaking away only after permanent settlement had been established.[142] Not only were Torksey's kilns positioned to take advantage of the source of kiln clay, their location would also provide the potters with direct access to this market.

Although Torksey ware emerged in the late 9th century it was not until the second quarter of the 10th century that it began to make a significant impact at consumer sites such as York. Over the subsequent decades Torksey ware grew in importance, and by the late 10th century it was York's dominant ware-type.[143] While we do not know the exact nature of the relationship between Torksey and Marton, it is significant that this is precisely the time that the Hiberno-Norse sculptures appeared in Marton churchyard, suggesting the presence of a trading elite.[144] If Torksey ware was somehow linked to this elite group, it is notable that Marton's earliest sculptures show great affinity with contemporary sculptures from York, indicating the exchange of goods and ideas between York and Torksey.[145] Support for the pottery industry may have extended beyond the Anglo-Scandinavian elite to the Church; indeed a major early church existed at Stow, just 4 km north-east of Torksey.[146]

Being just c 15 km east of Torksey and linked by the Fossedyke canal, one might expect Torksey ware to have enjoyed similar success in Lincoln, yet it was not so. Little Torksey ware reached Lincoln before the late 10th century; that which did was probably carried overland.[147] In the late 10th century a rise in water level is thought to have re-opened the Fossedyke and greater quantities of Torksey ware entered the town.[148] The influx of Torksey ware coincided with two important events in Lincoln's ceramic history: the decline of Lincoln-made oxidised shelly wares and the emergence of a Lincoln-made grey-surfaced sandy ware — so called Lincoln Saxo-Norman Sandy ware.[149] Morphological similarities between this new type and an earlier shelly ware have led to the suggestion that 'potters previously making [oxidised] shell-tempered pottery' were attempting to produce 'reduced, sand-tempered wares'; indeed, waster sherds from the shelly ware production were found in the wall of the sandy ware kiln.[150] By the early/mid-11th century Lincoln Saxo-Norman Sandy and Torksey wares dominated Lincoln's ceramic profile.[151]

Unlike the other 10th-century sandy ware industries centring on the Trent, Lincoln's Saxo-Norman Sandy ware potters fired pottery in entirely reducing conditions (Tab 6). This difference is potentially due to potters adapting their regime, firing in an unfamiliar way. This raises a host of questions. What other aspects of the production sequence did they change and how do the changes compare to other contemporary types? Were they selecting sandy clays or adding sand to the same clay they had always used? Was the clay and sand available locally or imported to the production site? Perhaps most importantly, was this change a response to an alternative source of pottery — Torksey ware — entering the town? Such questions will only be addressed once the Lincoln pottery has been subject to analysis on the scale presented here.

Lincoln's potters may have modified their production sequence in order to imitate Torksey ware, but Newark's late 10th-century potters produced pottery so similar to Torksey ware that it has been argued that the Newark industry was started by a potter who came from Torksey.[152] It seems no coincidence that Newark's industry began at the time that Lincoln's potters changed their production practices and the original Torksey industry was at its zenith. Research into the Newark industry is currently being undertaken but early indications are that the potters located their kilns on the Mercia Mudstone and that similar clay choices were being made by both Newark and Torksey potters. A full reconstruction of the Newark *chaîne opératoire* will allow this industry to be placed in the context of regional technological traditions, illuminating the mechanisms that assisted the spread of this new technology.

CONCLUSIONS

Using a range of analytical techniques, this paper has reconstructed the Torksey ware *chaîne opératoire*. Not only do the results emphasise the potter's agency, providing insight into choices made at each step of production, they demonstrate that previous discussions about the production of Torksey ware have largely been based on assumption. These fresh insights into artisanal practices prompt us to question the validity of similar assumptions made about potters working in other industries. By focusing on the less visible aspects of production, such as raw material choice and the manipulation of firing atmosphere, this study has revealed significant chronological changes in regional pottery traditions, such as the 10th-century changes to firing regimes seen in the East Midlands. It is entirely possible that similar patterns existed in terms of clay choice and vessel forming but these will only become apparent once each Anglo-Scandinavian type is revisited and analysed to the level of detail presented here. Extending this type of analysis to pottery manufacture on the Continent would allow detailed comparison of Anglo-Scandinavian pottery making practices with those in the homelands of the potters who introduced this technology to England. This, along with the excellent documentary evidence for the raids and movement of Scandinavians in France, may provide a better understanding of the mechanisms that facilitated this transfer of technology.

The comparison of consumer-site pottery with kiln waste and geological samples has allowed greater understanding of pottery trade. Notably, the widely propounded view that York's Torksey-type ware was not made at Torksey can now be discounted. By considering the production and distribution of Torksey ware alongside socio-political changes it has been suggested that York's Torksey ware may be associated with an ascendant trading elite. It is quite possible that such elites provided the impetus for establishing 'daughter' industries. Elite involvement in pottery manufacture and distribution leads us onto the next point of significance, that the focus of wheel-thrown pottery production was the Danelaw. While it has been argued that these industries pre-date Scandinavian settlement, the evidence does not withstand interrogation. Undeniably, the new types were introduced around the time of this settlement but until wheel-made pottery is found in well-stratified, pre-Scandinavian deposits, it will be impossible to prove that they pre-date it. Whether or not the Scandinavians were directly, or indirectly, responsible for introducing these new technologies, we cannot deny that the industries flourished in the decades immediately following the settlement. The focus of research should now be on understanding the mechanisms that allowed these industries to prosper; Scandinavians should not be excluded from these discussions simply because their homelands were largely aceramic. Furthermore, as this paper demonstrates, a programme of re-calibration of older 14C dates obtained at kiln sites is crucial if we are to fully understand the chronology of this ceramic revolution.

Finally, it is worth noting that petrographic studies of British post-Roman pottery are primarily concerned with provenance[153] and that Vince has drawn attention to a lack of consistency in the way that these studies present their results.[154] In contrast Whitbread's method, used in this study, is systematic, ensuring that scholars report on and consider the presence and absence of particular characteristics. The author knows of only one other published study of British post-Roman pottery which employed this methodology: Harriet White's analysis of post-medieval slipwares.[155] The results of White's study resonate with the findings presented here. She demonstrated that in thin section similar slipwares displayed 'characteristic textural features that reflect[ed] technological practices carried out at different workshops'.[156] Not only does Whitbread's methodology solve the problem of standardisation, but it provides us with a window into the mind and actions of the medieval potter.

APPENDIX: PETROGRAPHIC DESCRIPTIONS

See Whitbread (1995) for definitions of terminology.

Torksey ware

I Microstructure:

(a) Few voids, predominantly macro-vughs and planar voids, few meso vughs and planar voids. Rarely mega-vughs (<4.25 mm), possessing reduced rims and carbonised material. (b) Bimodal grain-size distribution, predominantly single to double spaced. (c) Voids show well-developed preferred orientation parallel to vessel walls. Clay domains parallel to vessel walls. 188 and 190, preferred orientation diagonal across the section.

II Groundmass:

(a) Non-calcareous, ferruginous clay, homogenous throughout individual sections and fabric group. (b) Micromass (<0.01 mm), c 60-90%, predominantly active to slightly active, occasionally very active or inactive. PPL: orange-brown in oxidised margins and fully oxidised samples; brown-black in optically active reduced cores and fully reduced samples. XP: orange to red-orange in oxidised samples to brown and orange-brown in reduced optically active samples; grey-black in reduced optically inactive samples. Cores and margins grey black in reduced optically inactive samples. Thin brown-black rims visible at surface.

III Inclusions:

c:f:v $_{0.01\ mm}$ c 60:35:5 to c 80:10:10.

Well sorted, predominantly sr-sa and eq. el. grains aligned with voids and b-fabric, parallel to vessel walls.

(i) Coarse Fraction (2.2 mm to 0.1 mm, mode 0.25 mm)**:**

Frequent: **Quartz:** monocrystalline eq. and el., sa- r, undulose extinction, very rarely orthanogenic. ***Common***: **Quartz**: polycrystalline eq. and el. sa-r., fine grained with sutured boundaries. ***Few-Very Few:*** **Feldspars**, eq. and el. sa-r. predominantly orthoclase, rarely plagioclase and microcline, commonly weathered, rarely perthitic; **Micaceous Sandstone,** eq, sa., coarse silt to fine sand-sized grains of quartz and muscovite in ferruginous matrix; **Volcanic Rock Fragments:** el and eq, sa-r, possibly rhyolite. ***Very Rare to Absent:*** **Clynopyroxene,** eq and el, sa-sr.; **Spherulite** el and eq, sr.; **Chert**, el and eq, a-sa.; **Igneous Rock Fragments**, el, sa-sr, composed of quartz, plagioclase and orthoclase feldspar, occasionally hornblende and muscovite mica, opaques, alkali feldspar and quartz intergrowths forming a micrographic texture; **Metamorphic Rock Fragments**, eq. and el. sa-sr., composed of fine grained quartz with sutured boundaries and muscovite along bedding planes; **Basalt,** el and eq, sr. very weathered; **Limestone:** el and eq, a-sr, variable composition including fine sand-sized calcite grains forming fibrous mosaics, brachiopod shell fragments, fine grained spary calcite, echinoid spines — structures destroyed in higher-fired samples; **Tourmaline,** eq, sr-r.

(ii) Fine Fraction (0.1 mm and below):

Predominant: **Quartz**; ***Few-Very few:*** **Muscovite mica** (brown in samples with inactive matrices).***Very rare to absent***: **Calcite**.

TCFs and ACFs

Tcfs <2% Two types. First are r, eq. <2.5 mm, mode 0.6 mm; sharp to merging boundaries; neutral to high optical density; concordant with matrix; colour and optical activity match the surrounding matrices. Same silt-sized fraction as the matrix and are probably clay pellets. Second type have sharp to merging boundaries; eq, wr; high optical density; discordant; brown-black to black (XP and PPL), possess same silt-sized fraction as groundmass; occasionally showing concentric structure of optically dense material and clay; they are pisoliths.

Acfs <3%. Present in most samples. Merging boundaries; have high optical density; concordant; generally eq and rarely el, r-sa, <0.5 mm, mode 0.1 mm; rarely forming streaks <2.0 mm; optically inactive, black in reduced samples; red-brown to black in oxidised samples. Rarely containing fine silt-sized quartz grains. Probably ferruginous concentrations in the clay.

Kiln Lining

I Microstructure:

a) Few voids. Predominantly mega-vughs and channels, few meso-vessicles. b) Bimodal grain-size distribution. Inclusions predominantly open spaced, with occasional clusters of closed spaced grains. c) No preferred orientation.

II Groundmass:

a) Non-calcareous, ferruginous clay, heterogeneous throughout individual samples and the fabric group — on account of coarse fraction. b) Micromass (<0.01 mm), 40-55%. Slightly optically active to optically inactive, stipple speckled b-fabric in slightly active areas. PPL: orange-brown to grey-black. XP: orange to red-orange and grey-black.

III Inclusions

c:f:$v_{0.01mm}$ c 10:89:1 to c 40:59:1.

(i) Coarse Fraction (1.15 to 0.14 mm, mode 0.25 mm)

Frequent: **Quartz:** eq. and a few el., sa- r. Grains predominantly show undulose extinction and are traversed by vacuoles and rarely micro-fractures. ***Common:*** **Polycrystalline Quartz:** eq. and el. sa-r, fine grained, with sutured boundaries. ***Few-Very Few:*** **Feldspars:** eq. and el. sa-r. Predominantly orthoclase and rarely plagioclase and microcline, commonly weathering, orthoclase rarely perthitic and with micrographic textures. ***Rare:*** **Volcanic Rock**

Fragments: el and eq, sa-r, possibly Rhyolite; **Clynopyroxene:** eq and el, sa-sr; **Basalt:** el and eq, sr, very weathered; **Tourmaline:** eq, sr-r.
(ii) Fine Fraction (0.14 mm or less, mode 0.06 mm)
Predominant: **Quartz:** eq and el, a-sa. ***Common***: **Orthoclase Feldspar:** eq and el, a-sa, frequently weathered. **Calcite:** el and eq, a-sa. ***Very Rare-Absent:*** **Plagioclase Feldspar:** eq and el, a-sa, frequently weathered. **Microcline Feldspar:** eq and el, a-sa, frequently weathered. **Muscovite:** el.
TCFs and ACFs
TCFs <5%: Two types. First <5.6 mm, mode 0.3 mm, a-wr; prolate to equant; sharp to merging boundaries; optically neutral; yellow-brown (PPL and XP), discordant and concordant with surrounding matrix. Coarse fraction absent from tcf, fine fraction <0.14 mm, dominated by sa-sr calcite; frequent sr-sa quartz <0.14 mm. These are probably pellets of Tea Green Marl. Second <0.5 mm, mode 0.2 mm; largely inclusionless; sharp to merging boundaries; optically neutral; rounded and equant; concordant and discordant with surrounding matrix; orange-brown (XP and PPL). They are clay pellets deriving from the parent clay, the Mercia Mudstone.
ACFs <10%. Devoid of inclusions, streaks <6 mm; optically slightly dense; red-orange (XP and PPL); merging boundaries. They are ferruginous concentrations in the clay.

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ABBREVIATIONS

AVAC Alan Vince Archaeological Consultancy
CLAU City of Lincoln Archaeology Unit
HMSO Her Majesty's Stationary Office
SEM Scanning Electron Microscope

FIG 1

Location of Torksey and consumer sites that provide comparative samples. *Map by Gareth Perry.*

FIG 2

Torksey ware firing colours. (a) Fully oxidised. (b) Oxidised core. (c) Low fired reduced core. (d) High fired reduced. (e) 'Sandwich firing', grey/black core. (f) 'Sandwich firing' light grey core. *Photographs by Gareth Perry.*

FIG 3

Kiln locations in Torksey Village. *Map by Gareth Perry.*

FIG 4

Torksey ware forms and decoration. *Illustrations by Vicky Crewe, after Barley 1981.*

FIG 5

Torksey ware kilns. *Illustrations by Gareth Perry, redrawn from Barley 1964; 1981; Palmer-Brown 1995; Rowe 2008.*

FIG 6

Fragments of Kiln 13. Note timber impressions in the clay, and finger marks where clay has been squeezed around the timber. *Photograph by Gareth Perry.*

FIG 7

Torksey geology, showing where geological samples were taken from. *Map by Gareth Perry.*

FIG 8

Photomicrographs of geological samples. (a) Rhaetic clay. (b) Mercia Mudstone clay. (c) Tea-Green Marl clay. (d) Sand. (e) Alluvial clay. (f) Lias clay. *Photographs by Gareth Perry.*

FIG 9

Photomicrographs of Torksey ware and Kiln 13. (a) and (b) Optical activity of clay matrices — note the change of light to dark as sample is rotated through c 30^{o}, indicating firing temperatures <c 800–850° C. (c) Optically inactive matrices, indicating temperatures > c 800–850^{o}C. (d) Base of jar from Kiln 13 — compare with Rhaetic clay Fig 9(a). (e) Tangential section of Kiln 13 jar, note the diagonal preferred orientation of the clay, indicating wheel-thrown manufacture. (f) Dark grey-brown surface, grading into orange-brown core, indicating the change from oxidation to reduction in latter stages of firing. (g) and (h) Kiln 13 superstructure — compare (g) with Fig 8(b), the Mercia Mudstone clay. *Photographs by Gareth Perry.*

FIG 10
Vitrification structures viewed by SEM. (a) Sample 191, no vitrification NV, <750^{o}C. (b) Sample 123, initial vitrification IV c 750–800^{o}C. (c) Sample 120, vitrification V, c 800–900^{o}C. (d) Sample 189, continuous vitrification with fine bloating CVFB, c 850–950^{o}C. See Tab 6. *Photographs by Gareth Perry and Cheryl Shaw.*

FIG 11
The Torksey ware *chaîne opératoire.*

FIG 12
Techniques of forming. (a) Concentric circle on the interior base of Kiln 8 jar, indicating wheel-throwing. (b) Roulette decoration on Kiln 3 jar, note the wiped striations between the elements of the roulette, indicating the vessel was wiped before being decorated. (c) Finger impressions on the inside of a jar base. (d) Rilling marks on the interior of a large bowl, indicating wheel-throwing. *Photographs by Gareth Perry.*

FIG 13
(a) and (b), and (c) and (d), demonstrate the variability in the amount of sand in Torksey ware Kiln 8 (a)(b) and Kiln 9 (c)(d). (e) and (f) Comparative samples from Lloyds Bank and Coppergate (York) demonstrating that York's 'Torksey-type ware' is mineralogically identical to that produced in the kilns at Torksey. (g) Echanoid spine in a Torksey Kiln 13 sample — petal shaped inclusion at centre of image. (h) Remains of an echanoid spine in a sample from Lloyds Bank (York). *Photographs by Gareth Perry.*

FIG 14
The development of regional firing traditions. See Tab 6 for details of dating and pottery characteristics. *Map by Gareth Perry.*

TAB 1
Characteristics of Torksey ware kilns. Details from Barley 1964; 1981; Palmer-Brown 1995; Rowe 2008.

TAB 2
The character and evidence for unproven and unexcavated Torksey ware kilns.

TAB 3
Torksey ware thin sections examined in this study.

TAB 4
Characteristics of the clays and sands that surround Torksey.

TAB 5
Equivalent firing temperatures of samples studied by SEM. (R) Reduction; (O) Oxidation; (NV) No Vitrification; (IV) Initial Vitrification; (V) Vitrification; (CV) Continuous Vitrification;

FB(fb) High (low) concentration of fine bloating pores; * Oxidation after a period of reduction (see Maniatis and Tite 1981).

TAB 6

Surface and core colours of late 9th- to 12th-century sandy wares and their suggested firing regimes. See Fig 14 for their geographical locations and the development of regional firing traditions.

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[2] Blinkhorn 2013; Dunning 1959; Vince 1993.

[3] Dunning 1959; Vince 1993.

[4] Barley 1964; 1981; Dunning 1959.

[5] Vince 1993.

[6] Ashby 2011, 310.

[7] Thomas 2000; Ashby 2011; 2013; ten Harkel 2013.

[8] Dunning 1959.

[9] Barley 1964; 1981.

[10] Anon 1996; Field 1990; Palmer-Brown 1995; Rowe 2008.

[11] Aitken and Weaver 1962; Aitken and Hawley 1966; Hurst 1962.

[12] Brookes and Mainman 1984; Mainman 1990.

[13] Vince 2006.

[14] Dunning 1959, 44.

[15] The Kiln 2 date should be treated with caution, as its reliability was described by the analysts as ‘doubtful but worth considering’ (Aitken and Weaver 1962, tab IIIA, 12; Aitken and Hawley 1966, tab 1).

[16] Hurst 1962, 26.

[17] Barley 1981, 279

[18] Perring 1981, 33–6.

[19] Adams Gilmour 1988, 120; Young et al 2005, 90.

[20] Mainman 1990, 382, 427; 1993; Vince 1993, 161.

[21] Mainman 1990, 427.

[22] Hurst 1976, 326; Vince and Steane 2008a, 2; Young 2008, 2–3; Young et al 2005, 88.

[23] Barley 1964; 1981; Vince 2006.

[24] Barley 1981, 275.

[25] Barley 1964, 177; Barley 1981, 275–77; Vince 2006, 2.

[26] Barley 1964, 177.

[27] Barley 1981, 275–77.

[28] Vince 2006, 6–8.

[29] Barley 1981, 277–78.

[30] Adams Gilmour 1988, 120; Dunning 1959, 44; Vince 1993; Vince and Young 2009, 397–401.

[31] Barley 1981, 275.

[32] McCarthy and Brooks 1988, 153.

[33] Barley 1981, fig 15.

[34] Wilkinson and Young 1995, 3–4; Young 2008, 3.

[35] Barley 1981.

[36] McCarthy and Brooks 1988, 153.

[37] Mainman 1990, 427–30.

[38] Miles et al 1989.

[39] Young et al 2005; Young and Vince 2009.

[40] Mainman 1990, 427–30.

[41] Young et al 2005, 88.

[42] Barley 1981, 278–9.

[43] Barley 1964, 176–7.

[44] Vince and Steane 2008b.
[45] Barley 1964; 1981.
[46] Barley 1964, 177. Rim-impressions in the firebars at Thetford suggest that kilns were not fired before their first loading (Musty 1974, 52–3). The lack of rim-impressions on Torksey firebars supports the notion of pre-load firing.
[47] Bryant 1977.
[48] van der Leeuw 1993, 240.
[49] Vince 2006.
[50] Woods 1985; Whitbread 1996.
[51] Whitbread 1986; 1989; 1995.
[52] Maniatis and Tite 1981; Maniatis et al 1984; Kilikoglou 1994; Froh 2004; Belfiore et al 2007.
[53] Maniatis and Tite 1981, tabs 1 and 2. Temperatures fluctuate considerably during firing. The final product is influenced by the maximum temperature and the time that it is held at this temperature, ie the total 'heat input'. For this reason, archaeothermometric investigations consider the 'equivalent firing temperature' — the temperature which, if maintained for one hour, would produce the mineralogy or microstructure observed in the archaeological ceramic (Tite 1995, 40; Quinn 2013, 190).
[54] Price 1975, 3–5, 21, 27–8, 40, 45.
[55] Orton et al 1993, 115; Rye 1981, 26–35.
[56] At temperatures between c 650–900^{o} C calcium carbonate forms calcium oxide. This absorbs water, resulting in volumetric expansion and the development of stress in the surrounding clay, which can cause cracking and lime spalling; in extreme cases the entire vessel may crumble. This can be avoided by adding salt or firing to temperatures >1000^{o}C or <650^{o}C (Rice 2005, 97–8).
[57] See appendix for full petrographic descriptions.
[58] Rye 1981, 80; Whitbread 1996, 414, 416; Woods 1985, 108–11.
[59] Whitbread 1996, 421.
[60] Eg Bryant 1977; Livingston Smith 2001.
[61] A kiln producing Torksey-type ware has recently been discovered in Newark (Abbott et al 2005). The consumer-site pottery studied here was compared with Newark wasters; none was attributable to the Newark kiln.
[62] Vince 2006.
[63] Maniatis and Tite 1981.
[64] Barley 1981, 270.
[65] Barley 1981, 266.
[66] Vince and Steane 2008b.
[67] Barley 1981, 278.
[68] see Rye 1981, 75 and 80.
[69] see McCarthy and Brooks 1988, 24–4.
[70] Barley 1981, 278.
[71] Anon 1996.
[72] Spalls (large lens-shaped pieces which separate from the vessel wall) occur with rapid increases up to c 300^{o}C, whilst fire-cracks (networks of fine surface cracks) develop between c 300–500^{o}C (Rye 1981, 104–14). Just one of the 1634 sherds from Kilns 8–12 was spalled and not a single spalled sherd was identified in the 345 Kiln 13 sherds (Wilkinson and Young 1995; Young 2008).
[73] Barley 1981, 271.
[74] Vince and Steane 2008a, 2. Little evidence exists for the types of fuels used. What we do have derives from Kilns 8 and 9, where oak heartwood dominated the charcoal assemblages, accompanied by alder stems, oak and gorse/broom twigs. The wood showed no evidence of coppicing, suggesting that fuel was gathered from natural woodland (Gale 1995).
[75] Barley 1964, 177.
[76] See note 72.
[77] Bryant 1977, 121.
[78] Brookes and Mainman 1984, 70.
[79] Ibid, 68.
[80] Ibid, 68–9.
[81] Brooks and Mainman 1984.
[82] Ibid, 67–8.

[83] Aspinall 1977; Brookes and Mainman 1984, 67.
[84] Aspinall 1977, 13.
[85] Buxeda I Garrigós et al 2001; Golitko et al 2012.
[86] Vince 2006, 10.
[87] Dunning 1959, 34; Kilmurry 1980, 176–95.
[88] Dunning 1959.
[89] Vince 1993, 161.
[90] Ibid, 156, 160.
[91] Rogerson and Dallas 1984, 118; Dallas 1993, 60; Leah 1994, 84.
[92] Dallas 1993, 68; Leah 1994, 1, 84.
[93] Nailor 1984.
[94] Hebditch 1967–8.
[95] Jarvis 1997; Young et al 2005, 77.
[96] Abbott et al 2005.
[97] Aitken et al 1983.
[98] Wade 1976.
[99] Williams 1974
[100] Kilmurry 1980, 63–6.
[101] 'Natural tempering' is a commonly-used term, but a fallacy. Adding temper is an intentional act and claiming that clay is tempered makes a definite statement about a potter's behaviour (Rye 1981, 31). Naturally occurring inclusions are known as 'intrinsic' or 'incidental' inclusions (Freestone 1995, 111).
[102] Kilmurry 1980, 44–5.
[103] Rogerson and Dallas 1984, 34.
[104] Miles et al 1989, 186.
[105] Ixer 2013, 139–40
[106] Kilmurry 1980, 65–67.
[107] Symonds 2003, 75.
[108] Young et al 2005, 42.
[109] Ford 1998–9, 20.
[110] Goodwin 2013, 44.
[111] Ford 1998–9, 20.
[112] Miles et al 1989, 205–12.
[113] Ford 1998–9, 18–9.
[114] Kilmurry 1980, 87.
[115] As was the case for Newark Torksey-type ware (Abbott et al 2005, 6), Lincoln Late Saxon Sandy ware (Young et al 2005, 44), Lincoln Kiln-type Shelly ware (Miles et al 1988, 199, 205; Williams 1988), Stamford (Kilmurry 1980, 207) and Lincoln Late Saxon Shelly ware (Young et al 2005, 61).
[116] Dunning 1959, 44; Barley 1964, 177; Vince 1993, 156.
[117] McCarthy and Brooks 1988, 160; Rogerson and Dallas 1984, 118.
[118] As Thetford's regime is paralleled with Torksey's Kiln 2 one might argue that Dunning was correct and that Torksey ware did emerge from Thetford. However, none of the Torksey kilns bear any resemblance to those so far excavated in Thetford. Moreover, the distinctive flat bases, common to both industries, are a late 9th/early 10th-century occurrence at Torksey, but an 11th-century phenomenon at Thetford (Rogerson and Dallas 1984, 126).
[119] Blinkhorn 2013, 165.
[120] Dunning 1959, 71.
[121] Hurst 1976, 318; Kilmurry 1980, 195.
[122] Blinkhorn 2013, 160.
[123] Ibid.
[124] Ibid.
[125] Ibid, 162–5.
[126] Using the original Stamford dates provided in Jordan et al (1994, 191–2), recalibrating using OxCal v4.2 returns a date of 1300±80BP cal AD 598–942 and 1140±70BP cal AD 695–1021, 95.4% confidence, for samples HAR-2274 and HAR-2275, respectively.
[127] Garmonsway 1972, 75–7.
[128] Adams Gilmour 1989; Young et al 2005, Appendix 1.

[129] Adams Gilmour 1988, 152, 160; Young et al 2005, 73, 99.
[130] Carver 2010, 92; Ford 1998–9.
[131] Dodd et al 2013, 102.
[132] Hadley in press.
[133] Lane 2007.
[134] McLeod 2014, 132–58.
[135] Hadley and Richards in press.
[136] Sawyer 1998 196–7; Stocker 2000, 189–91.
[137] Blackburn 2011, 207–64; Hadley and Richards 2013.
[138] Blackburn 2011, 208.
[139] Eg in AD 880–85, Garmonsway 1972, 76–8.
[140] Hadley and Richards 2013, 12.
[141] Stocker 2000, 191.
[142] Ibid.
[143] Mainman 1990, 427.
[144] Stocker 2000, 190–2.
[145] Everson and Stocker 1999, 226–8
[146] Sawyer 1998, 246–52.
[147] Vince 2003, 241, 281; Vince and Young 2009, 397–401.
[148] Ibid.
[149] Young et al 2005, 77.
[150] Ibid.
[151] Ibid, 14–15.
[152] Abbott et al 2005.
[153] Eg Vince 1991.
[154] Vince 2005, 233–4.
[155] White 2012.
[156] Ibid, 63.