An Experimental Ipswich ware Kiln

By Keith Wade, Jnana Emmett and Alice De Leo

On behalf of Suffolk County Council Archaeological Service

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Contents

Background to the project

Experiments were conducted to build and fire a reconstructed Anglo-Saxon kiln to produce replica Ipswich ware pots.

This activity was part of the *Rendlesham Revealed* community archaeology project, led by Suffolk County Council Archaeological Service and funded by The National Lottery Heritage Fund, thanks to National Lottery Players.

Leading the experiments were Keith Wade, retired county archaeologist and specialist in the Anglo-Saxon archaeology of Ipswich; and Duncan Allan, Trustee of the Hands on Heritage experimental archaeology site, based in Tunstall Forest in east Suffolk.

Volunteers from the Anglian Potters were involved, conducting research and experiments to make replica pots and construct and fire the kiln. Jnana Emmett brought invaluable expertise and experience of wild clay and constructing cob kilns, driving the project forward and contributing to its success.

The project's main aim was to use historical methods to construct a kiln based as closely as possible on the archaeological remains excavated in Ipswich, to produce replica Ipswich ware pots using clays and sands that would have been available to potters in Ipswich in the Anglo-Saxon period. Based on other experimental kiln firings, such as the Roman reproduction kiln as part of the Aylsham Roman Project, it was expected that the firing would take from 9 to 20 hours to reach 800-900°C and an overnight firing was planned. The kiln was built in July and August 2022 with an initial firing on 13-14th April 2023 and a second firing on 16-18th August 2023.

Specific Research Aims

It was hoped that the project would address a series of questions:

<u>Processing of the clay/making pots</u>

- was London Clay used?
- how was the clay processed?
- were additives required to make it useable?

<u>Building and operating the kiln</u>

- Which clay is best for the kiln build?
- Was it easiest to use cob blocks for the build?
- How long does the kiln have to dry before firing?
- Once the pots were stacked in the kiln, how was the oven sealed over: a clay dome or turf?
- What fuel is needed to fire the kiln (type of wood, quantity)?
- Can the firing temperature reach 900°C?
- Can a reduced grey fabric be achieved by restricting oxygen at the end of firing?

The Archaeological Evidence

Ipswich Ware

Ipswich ware was mass produced in Ipswich from *c.*690-870 AD. It was fired in kilns; the archaeological remains of two such kilns have been excavated in the town. The main area of kilns in the north-east corner of the town was adjacent to a stream and sources of clay (Reading Clay and London Clay). There were two main fabrics: sandy and 'pimply'- the difference being that the 'pimply' has larger quartz sand grits which result in a pimply effect on the surfaces.

Ipswich ware pots are baggy with simple out-turned rims (Fig.1). The walls are relatively thick, sometimes a little uneven and often showing 'girth' grooves. Bases of cooking pots and pitchers are sagging. A slow wheel or turntable is thought to have been used to make the pots. The body of the pot was built up in coils and finished on the turntable. The pot was then removed by cheese wire and once dried enough the heavy base slab was trimmed to form a sagging base. It is nearly always grey in colour, presumably reduced by controlling oxygen entering the kiln at the end of firing. It is thought that the pots were fired at approximately 900°C.

The Kilns

The plans of only two Ipswich ware pottery kilns have been recorded through excavations in Ipswich: one at St Stephen's Lane in 1989 (Blinkhorn 1989) and the other at Stoke Quay in 2012 (Poole 2020).

St Stephen's Lane Kiln (Fig.2)

This single flue, up-draught kiln, sunk into the ground, was well preserved, with only the stokehole, the north-east corner of the oven and the upper part of the dome missing. The lower part of the oven was divided into two flues by a separating spine wall of clay which stopped short of the north wall and from which arches sprang to form the flat, perforated firing platform, approximately 50cm above the floor of the oven.

Two arches remained in situ at the north end of the east flue, and the confused remains of several others were found collapsed into the layer below. One intact and one collapsed arch were found in situ in the west flue, with evidence of the missing arches in the form of scars and protuberances on the central spine. No trace of these arches was found in the bottom of the west flue, and they must have been removed before the end of the life of the kiln.

The kiln oven walls survived to a height of c.50cm above the platform, narrowing from c.80cm wide at the firing platform level to 50cm at its greatest surviving height. The oven was probably capped with a removable roof and some sort of simple chimney.

Impressions left in the clay show that it had been built using arches of withies as formers for the flues, arches and roof, with the non-removable walls of the oven packed against the sides of the pit.

The kiln oven measured 1.2m long by 0.8m wide and was set 80cm into the natural subsoil. Allowing for 40cm of topsoil, this would make it set 1.2m below ground level. The stoke pit was roughly circular and 2m in diameter.

The Stoke Quay Kiln (Fig.3)

This well-preserved kiln was aligned in a north-westerly to south-easterly direction with the stoke pit on its north-western side. The lower chamber survived in its entirety, together with a substantial part of the upper chamber, in total a height of 0.6m. The inner end of the flue survived to its vault. The

structure was key-hole shaped with a circular firing chamber, 0.9m in diameter internally, with vertical-sided walls, surviving to a height of 0.65m, and a linear flue, which survived for a length of 0.3m extending westwards from the kiln chamber. The flue measured 0.5m wide, narrowing to 0.3m at its junction with the kiln chamber.

The clay fabric used to construct the kiln was a fine sandy yellow clay, containing moderate to frequent rounded quartz sand (c.0.3-0.8mm in size) together with a low density of flint gravel and pebbles up to 30mm. It had been fired to an orange-red colour under oxidising conditions, but much of the surface was fired dark grey to black.

Within the oven was a pedestal, 60cm in diameter at the base increasing to 70cm at the top, in the form of a hollow drum with flaring fluted walls, filled with loose gravel and sand before being capped with a flat clay plate, 70cm in diameter and 38mm thick, creating a single mushroom-shaped structure. The pedestal was constructed from tapered wedge-shaped blocks set side by side and built up in layers with vertical wattles embedded into its outer face. A narrow gap of c.0.1m was left between the pedestal / plate and the kiln walls to allow the heat to circulate to the upper chamber.

The kiln and flue walls and floor were built as a single continuous structure in the same yellow sandy clay. The floor was relatively thin, measuring between 35 and 55mm thick, abutting the base of the pedestal and thickening to c.100-150mm in the main oven walls, but in the flue the clay was frequently 200-250mm thick. The walls survived to a height of 0.55-0.62m, of which c.0.15m extended above the level of the pedestal.

Preserved within the walls was a series of vertical wattle impressions in the exposed surface, running the full surviving height of the walls. In some cases, the wattles were entirely enclosed in clay from the middle to the base of the wall (and show they were complete round wood, not split poles).

It is possible that the wattles were bent over to create the framework for a dome, but this was probably a temporary construction, allowing the kiln to be loaded and emptied through the top.

The walls were constructed of individual sub-rectangular blocks of clay laid in rough horizontal courses and bonded together, with rough internal bonding faces surviving on both vertical and horizontal joints between blocks.

Lying to the west of the kiln chamber, the slightly elongated oval stoking pit measured 2.1m by 1.2m and was up to 0.90m deep with the slopes of its western end considerably shallower than its other sides, probably in order to allow easier access. The base of the pit corresponded to that of the underside of the flue walls suggesting that it was dug at the same time as the construction pit for the kiln.

The Fuel

Charcoal analysed from the two excavated kilns showed that oak was the main fuel with small amounts of buckthorn, hawthorn, alder and hazel roundwood.

The Clay

London Clay and Reading Clay, which outcrop on the east side of Ipswich town centre (Fig.4) were certainly used in medieval and later potteries in that area and must have been used to produce Ipswich ware and the later Theford wares (c.870-1150 AD). A medieval pottery kiln has been excavated along Fore Street and a floor tile kiln in Grimwade Street. In Victorian times, Reading Clay was being used to make red bricks at Back Hamlet and London Clay was being used at Argyle Street,

St Helen's and Back Hamlet, Ipswich (Markham 1976, 26). The cliff face on the west side of Alexandra Park marks the extent of clay extraction. Anglo-Saxon structures such as ovens, hearths and floors excavated in Ipswich are usually made of yellow clay, presumed to be brickearth and/or boulder clay, which is also available near the town centre.

As permission to extract clay from east Ipswich was unlikely, sources further afield were found. A ton of London clay was donated by Tarmac from their quarry near Colchester, and a ton of brick-earth was supplied by the Bulmer Brick and Tile Company from their pit near Sudbury. Sand was obtained from a nearby pit in Tunstall Forest.

The Experimental Kiln Reproduction and Replica Pottery

Reproducing Ipswich ware Pots

London Clay was the primary material used to make the replica pots. Two methods were tried in processing the clay: a wet method and a dry method. In the wet method the clay was submerged in water in a bucket, however the clay did not absorb any water and remained in lumps. The dry method involved breaking the clay into small lumps, of c. 1cm, with a mallet and drying in the sun for 2-5 days and then submerging under water in a bucket. This was successful in that the lumps slaked (absorbed water) quickly. The wet slurry was left to settle for a few days, after which the water was taken off with a sponge and the liquid clay was left to dry for a minimum of 5 days before it was plastic enough to be malleable and useable. Presumably, the Anglo-Saxon potters would have used small settling ponds or barrels to do this.

The volunteer potters found that the London Clay was difficult to use unless sand was added to make it workable. Even then it was very sticky, and pots made with it needed slow drying to avoid cracking. London Clay holds a lot of water in its structure, which indicates that the particles are very fine with minimal silt or inclusions. All the pure London Clay pots failed by cracking in the drying or firing process. Following the difficulties in using the London clay, the volunteer potters experimented with different mixes. A 50:50 mix of London clay and brickearth was much easier to work, being not so sticky, more responsive and stable.

The clay was wedged up well before potting (about 11.5Kg of clay was wedged with about 1Kg of fine sand). A thick base was made on a spinner/turntable and left to firm up overnight. Coils were then made, about 1.5cm thick, hand rolled on a wooden board. The coils were then applied to the leather hard base and smoothed before adding the next coil. No water or slip was necessary for the subsequent coils. The clay was firm enough to hold its shape and some pots were made in one day, or up to 10 hours over several days, depending on size.

Various wooden tools were used to scrape off surplus clay and form the flared rim. The following day it was much easier to smooth the surface with a spatula and fingers. The characteristic "throwing lines", also called girth grooves, often visible on Ipswich ware pots could also be made using wet fingers of one hand, whilst moving the wheel with the other hand. However, this was not very successful as it was not possible to spin the turntable fast enough to replicate the even girth grooves. Maybe it could be achieved with further practice; the volunteer potters suspected that potters in the Anglo-Saxon period may have had the wheel turned by someone else or the use of a kick wheel, allowing the potter to use both hands to achieve the regular finish.

The pots were removed from the turntable with a cheese wire and then upturned to allow the 'knife

trimming' to form the sagging base. They were then left to dry; the duration varied by volunteer potter, most were dried for up to 6-10 months over winter for the first firing, and the pots for the second firing were made within 3 months.

The volunteer potters also ran pottery making sessions with local children from Rushmere Hall Primary School, teaching them how to make coil pots. The pots varied in quality and size; they were fired in the kiln during the first firing.

The Kiln Reconstruction

The two excavated kilns are only superficially different. They were both single flued up-draught kilns set into the ground with ovens and stoke pits of similar sizes and with firing platforms for the pots.

It was decided to build the oven structure and its pedestal and firing platform using pre-made clay lump blocks like the kiln excavated at Stoke Quay (Poole 2020, 59-67). For ease of construction, blocks on their side were to be used to span the pedestal and oven walls instead of arches constructed around withies (Fig.5).

The kiln was sited in a clearing in the forest, far enough away both from trees and their root system, so as not to pose a fire hazard. The oven pit (2mx1m) and adjoining stoke pit (2m diameter) were dug out to a depth of 0.5m, on 6th-7th July 2022, keeping the upcast soil nearby for later use as insulation around the kiln (fig.6). At the same time the building blocks, 45x20x10cm, were made by puddling brickearth with added sand and straw (Fig.7), packing into simple wooden moulds, dusted with sand to prevent sticking (Fig.8), turned out (Fig.9) and put onto drying tables (Fig.10) for 2 weeks.

On 20th July and 4th August 2022, the kiln oven, flue, and central spine/ pedestal walls were built with the clay lump blocks, cemented with wet clay (Fig.11) and the floor was then covered with 4cm of clay. After filling the void of the central pedestal with soil the 'arches' were built between the pedestal and oven walls by laying blocks on edge (Fig12). The walls of the oven were then raised by another layer of blocks and a barrel vault flue arch constructed in wet clay over a straw former. (Fig13).

The structure was then left to dry covered under a tarpaulin (Fig14). The intention was to fire the kiln in the Autumn, but the unusually dry summer posed greater health and safety risks relating to fires in the forest, and it had to be delayed until Spring 2023.

The First Kiln Firing 12th-14th April 2023

On 6th April 2023, a small fire was lit in the kiln flue to dry the structure before stacking with pots (Fig. 15). Rectangular tiles of London Clay, *c*.20-30cm by 20cm and 2-3cm thick, were made to construct the dome over the pots (Fig.16).

Stacking the pots

On 12th April 2023, the firing platform was tumble-stacked with 100 pots of varying sizes (Fig.17), from small children's pots to large urns, the Ipswich ware replicas. Test bars were placed at the front and back of the kiln to record the variation of firing temperatures. The pots were tumble stacked, both upside-down and upright, in 3 or 4 layers, with the largest on the bottom and smaller pots inside larger ones.

Building the Dome

The stacked pots were covered with hay on which were laid the slabs of London Clay (Fig.18), made the week before, but still slightly flexible. They were laid in overlapping concentric layers over the pots, from the bottom up, with a wet clay mix used to mortar them together and fill in any gaps. Three air holes were exposed, which could be blocked and unblocked to control the temperature during the firing. Two small holes were made for Thermocouple probes to record the kiln temperature, one at the front and one at the back.

Wood for Firing

The wood sourced locally was mainly Ash from trees dead for some years from Ash die-back plus hazel faggots and gorse.

Firing the Kiln

The kiln firing began at 11am, 13th April 2023 (Fig.19). The temperature was raised slowly for the first 5 hours. The fire drew using mainly split hazel branches (smaller hazel sticks and gorse did not burn well).

At 16.15 it had reached 225°C at the front and the hay was smouldering (Fig.20).

At 17.30 and 300°C the dome tiles distorted and cracked and some repairs with clay mortar was needed, and turf was placed around the base of dome where cracks were also appearing.

The temperature plateaued at c.500°C then rose again but it was a struggle to keep the temperature rising. More air holes were opened in the dome to try and increase the air flow and increase the temperature, which was partially successful. Raking out of embers was needed at regular intervals.

At 1.15am, the temperature had reached 653°C at the front and 586°C at the back. As there was insufficient wood left to raise the temperature over 700°C the kiln was closed and covered to reduce air flow and encourage reduction of the pottery fabrics. The flue was filled with as much wood as could fit and then blocked with turf. The dome was blocked with wet clay mortar and soil. At this point thermocouple 1 at the front was broken. The operation was finished by 2am.

At 7am, on 14th April, the surviving thermocouple at the rear of the oven recorded 415°C. At 1pm small holes were made in the dome to encourage it to cool, and turf removed from the bottom of the dome and flu. At 2pm it had cooled to 186°C.

Opening the Kiln

At 2.15pm the kiln was slowly dismantled to reveal the pots (Fig.21) and the thermocouple was removed with a last reading of 177°C. All the pots had survived with only one broken horizontally across the body and one or two had small cracks. They had been fired enough to a change colour: pinkish especially at the front and a greyish, light colour at the bottom and back of kiln, where the temperature was hotter.

The porosity of the pots was tested. One pot was filled with water for half an hour; the pot kept its form suggesting the temperature was hot enough to achieve the chemical change from clay to ceramic, however the pot was still porous and did not match the hardness of the archaeological pottery. A break test on two of the test strips showed the one at the front of the kiln broke at 5.8kg and the one at back at 5.15kg.

The Second Kiln Firing, 16th-18th August 2023

Modifications

Modifications were made to the kiln structure to raise the height of the permanent walls, and so reduce the size of the temporary dome needed, and to improve airflow in the flue. On 26th July clay was mixed and additional bricks made using a mould with bevelled sides specifically to raise the kiln walls, like blocks in an igloo (Fig.22) and a clay cap was made to top off the dome when constructed (Fig.23).

On 3rd August the tapered clay bricks were used to raise the kiln wall by one course with the bricks sloping inwards (Fig.24).

A new flue arch, 30 cm high by 210cm wide, was built with its underside level with the underside of the kiln floor and sloping downwards slightly towards the front. It was constructed on a former (two bundles of reeds and a piece of sacking), supported at the kiln end on a brick which could be pushed out of the way allowing the bundles to drop and then be removed easily.

On 16th August London and Brickearth clays were mixed with sand and horsehair by treading with bare feet, to be used for coils in the dome construction.

Holes were drilled through the kiln walls and two pyrometers were placed at the front of the kiln and one at the rear. A little witness cone shelter was placed at the rear of the kiln, along with the four test strip containers, two at the front, two at the back for comparison. The pots were then stacked into the kiln. An initial layer of pots was laid upside down forming a cover over the vents in the firing platform. Two large pots, one rim down and one rim up, were placed in the centre to form a central column. The remaining pots were then stacked above and covered with a layer of hay. The dome was constructed using large coils of the clay-sand-horsehair mix. There were coiled up to make the sides. When about two thirds complete the dome began to feel unstable and was left to firm up. The top was made separately with 11 vent holes strategically positioned to control the airflow using clay caps. The pre-made top piece (cap) was then put in place (Fig.25).

Firing

The kiln was fired in several phases. This started with a candling phase to allow the dome to settle and dry, (driving out moisture) at about 8.30pm and continued until 11pm, with a small fire of ready chopped kindling outside the kiln mouth, keeping the temperature below 100 degrees. The kiln was then left overnight until candling recommenced at 5.40am and continued until 8am, by which time the temperature was 139°C at the front and 161°C at the rear and the hay had caught fire.

The fire was then moved into the full depth of the flue (Fig.26) and steady stoking raised the temperature to 550°C over the next 5 hours. The 11 vents with their covers proved very effective for controlling airflow through the kiln.

At 1pm the first riddling and removal of embers was needed, and after that the temperature rose much more slowly, at about 50°C per hour (Fig.27).

After reaching 800°C at 6pm, the fire mouth kept getting blocked with embers and regular riddling was required with full safety equipment worn. Fallen pine branches from the surrounding forest were then used to lift the fire temperature to 880°C at 9pm.

At this point the flue and vents were sealed. Bricks were used to seal the kiln mouth, and wads of stiff previously mixed clay were used to seal the vents. This worked well but the use of dry bricks cemented with wet clay, meant that joints opened up as they baked and it was impossible to fully seal making a reduction firing unlikely.

The pyrometers showed that the front of the kiln, with no direct vent to the fire chamber, tended to be cooler than the rear which was above a vent. However, they had levelled up at the end of the firing. The witness cones showed a temperature 100 degrees higher (c. 975°C) than was shown by the pyrometers (880°C) for some reason.

Stoking

Round wood from dead ash trees was used for the firing. Shorter 30cm lengths which had been cleaved were best for the early firing but 1.5-2m lengths were ideal for feeding into the kiln later. The best size was 6.5cm diameter. The 8cm diameter pieces were too big and ideally would have been split but the wood was already dry making it difficult.

A block was placed about 50cm away from the kiln mouth to rest the ends of the wood on to lift it away from the embers and ash. As with the first firing, ash and charcoal accumulation in the flue was an issue, in a kiln with no grate and ash pit. The wood at the bottom, resting on the embers, is starved of oxygen and the ember pile grows up at the back of the fire mouth tunnel to block it. This required regular riddling and removing. A pair of Raku tongs was used to riddle the embers and draw some of them out and a long hoe used to reach to the back of the kiln mouth tunnel and clear it. The ashes were raked out into the stoke pit and doused with water. The safety gear of gloves, sleeves and apron was essential in this process.

Opening

The next morning (18th August) the kiln was still too hot (400°C) to open and was left to cool for a further 24 hours. At 10am on 19th August, the pyrometer still showed a temperature of 108°C after 37 hours of cooling and a heavy rain shower. A small gap was opened in the kiln mouth, and a chink in one of the vents, then other vents were gradually opened until the temperature had fallen below 100°C. By gripping through the vent holes (while wearing insulated gloves) chunks of the dome were lifted off revealing the pots with a layer of hay ash upon them (Fig.28). The pots had a good sooty terracotta colour but not a black (reduced) firing (Fig.29).

Discussion and Conclusions

1. The clay used for Ipswich ware

The volunteer potters found that London Clay needed additives to make it more workable of which sand is the most important. Mixing with other clay also helped. On its own, the clay was found to shrink up to 15% on drying leading to cracks in pots on drying/firing. This was also a problem in the first firing where the dome was made of London Clay slabs rather than brickearth and shrinkage during firing produced gaps which needed plugging with wet clay.

However, London clay varies over small distances and the clay from the Colchester quarry may not have had the same handling qualities as the clay dug in Ipswich for Ipswich Ware. For example, a small sample of London clay from the Bulmer Brick and Tile works proved much easier to use.

The major study of Ipswich ware (Blinkhorn 2012) does not clarify the situation in terms of the clay used. However, the variability of fabric found in the thin section and chemical analysis might be best explained by the use of more than one clay mix, which could have varied slightly with each batch, and this was a possibility raised by Blinkhorn (2012, 18).

Following the difficulties in using the London clay, the volunteer potters experimented with different mixes. A 50:50 mix of London clay and brickearth was much easier to work with being not so sticky, more responsive and stable.

London Clay was used in the London area for pottery and brick making and was the subject of a recent study (The London Clay Project) by the artist Maja Quille (https://majaquille.com/london-clay-project). In her webpage she quotes from two experts.

The Principal Research Fellow in ceramic analysis in the Dept of Archaeology at UCL, said:

"The London Clay is rich in smectite which makes it very plastic/sticky and not the best for ceramic production. It also has a high shrink-swell capacity, meaning that pots can shrink and crack upon drying. Nevertheless, it might have been mixed with a plastic 'temper' to counteract the plasticity. The shrink swell capacity can also be modified in this way or by mixing with another clay source.'"

An expert on nanofossils and London Clay said:
"London Clay was used for pottery, but I think Reading Formation and brickearths were preferred because there is so much pyrites and selenite in London Clay. The former two are known to have been used by major industries in the London area. Highgate Wood, a site of a major industry, may have used London Clay."

In conclusion, it seems likely that London Clay was mixed with the Reading beds clay (and sand). As the London Clay sits stratigraphically on top of the Reading beds, both could have been easily mined in the same location, close to the potteries in the south-east of the town. The need to add sand to the clay most likely explains the two fabrics: sandy and pimply (which has some larger quartz grains). Either two sources of sand were used or one source with some potters sieving out the larger sand grains.

2. Was Ipswich ware coiled or made on a wheel or both?

The volunteer potters made exceptionally good replicas of Ipswich ware pots using the coil method. In fact, some of the resulting pots looked more 'polished' than the originals (Fig.30 and Appendix) but this probably reflects the amount of time which the potters spent making them. The Middle Saxon potters were mass producing pots for everyday use, presumably of low value, and a rustic look was clearly acceptable.

The 'girth grooves' commonly found on Ipswich ware pots are usually seen as the product of turning on a wheel and it seems likely that they used a kick wheel and not just a turntable, especially to produce the rims.

3. Time investment

The experiment emphasised the significant time investment involved in the whole process: digging out clay for the kiln construction and potting, processing the clay for use, building the kiln, and making the pots, gathering suitable wood for the firing, etc. However, once built, kilns can be used many times, if they are covered over the winter to prevent rain and frost damage. This was successfully tested with the reconstructed kiln, which was covered over the 2022-23 winter (Fig.31) and fired multiple times following some minor repairs.

4. Loading the kiln

Being a community project and involving school children, the type and size of the pots were not consistent. It seems likely that a commercial potter would plan the kiln load and have a size range and number in mind to fill the kiln efficiently.

5. The Kiln Dome

Based on this experiment it would seem necessary to build a well-made dome over the pots to reduce heat loss if aiming for 900°C. This would seem to rule out turf. The first kiln firing had a shoddy clay dome which partially collapsed, and the kiln temperature did not exceed 525°C. Whereas the second firing with its superior coil-built dome and stoppable air vents managed 800 to 975°C.

6. The replica pots (see Catalogue)

Neither firing achieved a reduced (grey) fabric which is the norm for Ipswich ware (although there are many examples of buff and even some orange-brown colouring from the excavations). Although, in both firings, attempts were made to stop air entering the kiln on close-down, it wasn't very successful.

7. Fuel

Although oak was not used in the firings, the seasoned ash which was used had a similar calorific value. A large pile (1 cubic metre) was used in each kiln firing. Other woods, such as pine or gorse can be used to raise the temperature more quickly.

Recommendations

1. The kiln proved robust and will be used for firings in the future. It would be useful to monitor how much repair is necessary over time to give an idea of the longevity of such kilns.
2. An attempt should be made to examine and sample London and Reading Clay from south-east Ipswich and make further reproduction pots.
3. Thin sections could be made of the reproduction pots for comparison with the results of The Ipswich Ware Project.

Acknowledgments

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Fig.1. Ipswich ware cooking pot waster (left) and spouted pitcher (right).

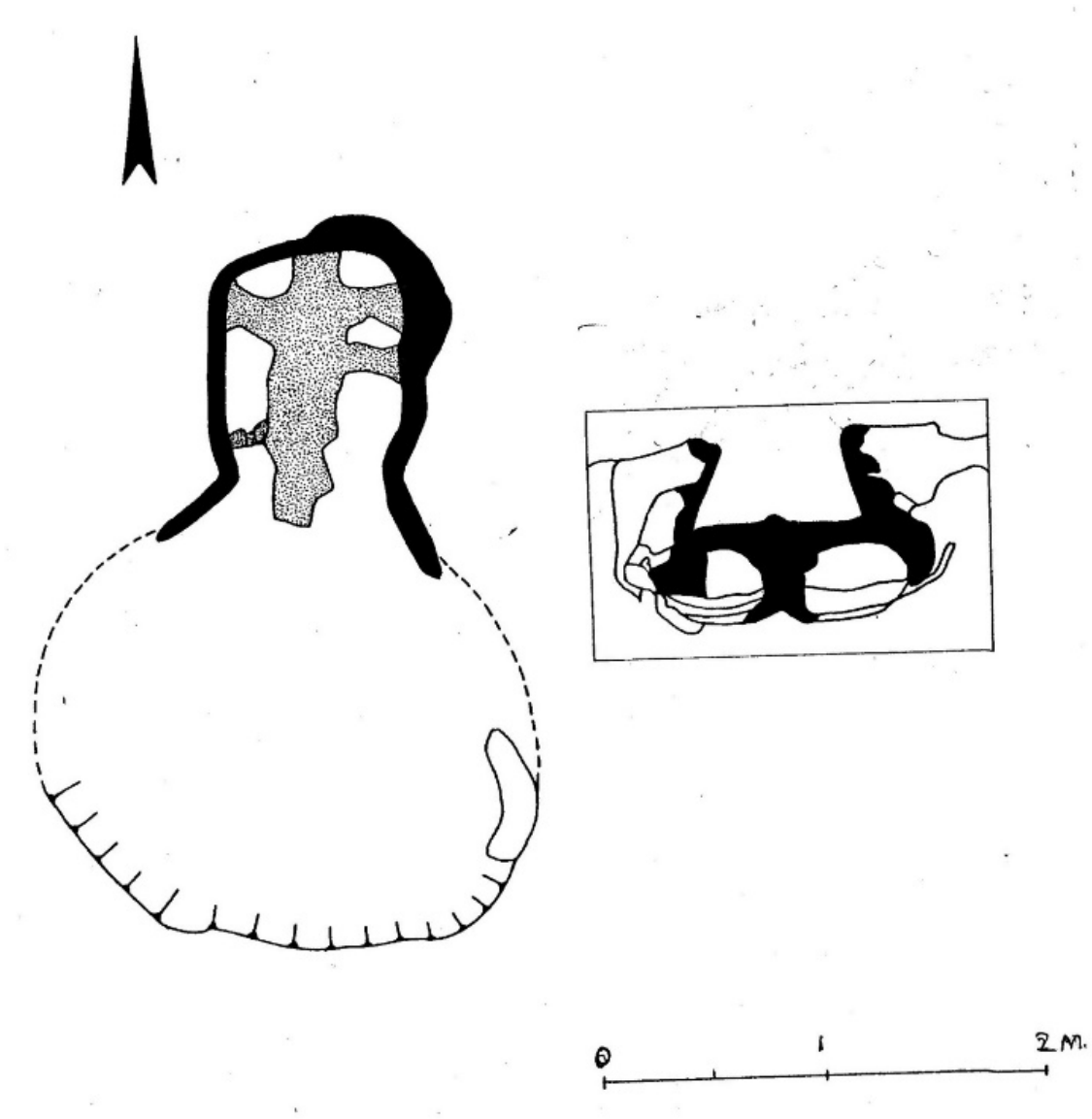


Fig.2.The St Stephen's Lane Ipswich ware kiln plan and section.

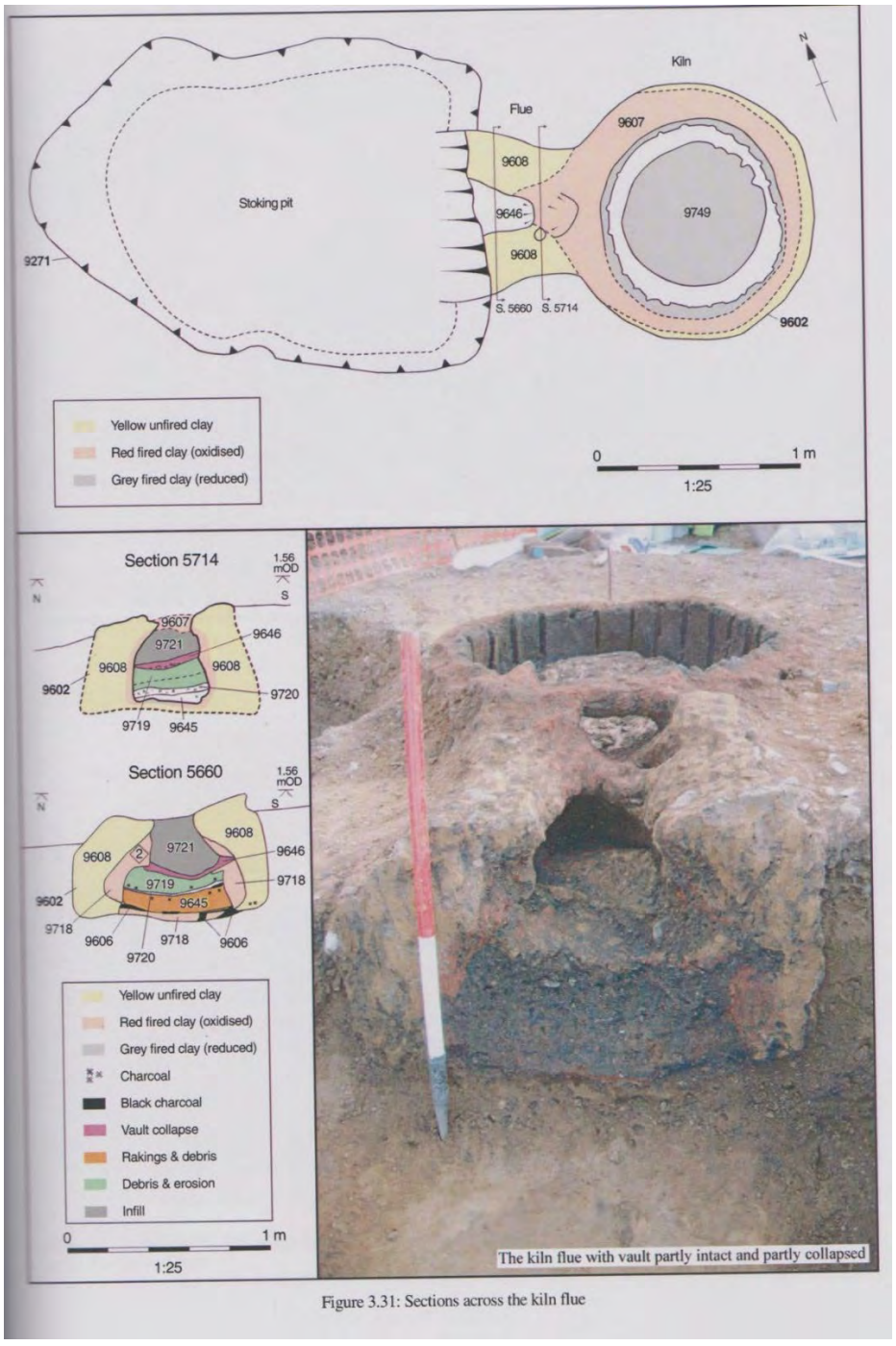


Figure 3.31: Sections across the kiln flue

Fig.3. The Stoke Quay Ipswich ware kiln plan and section. (from Brown *et al* 2020)

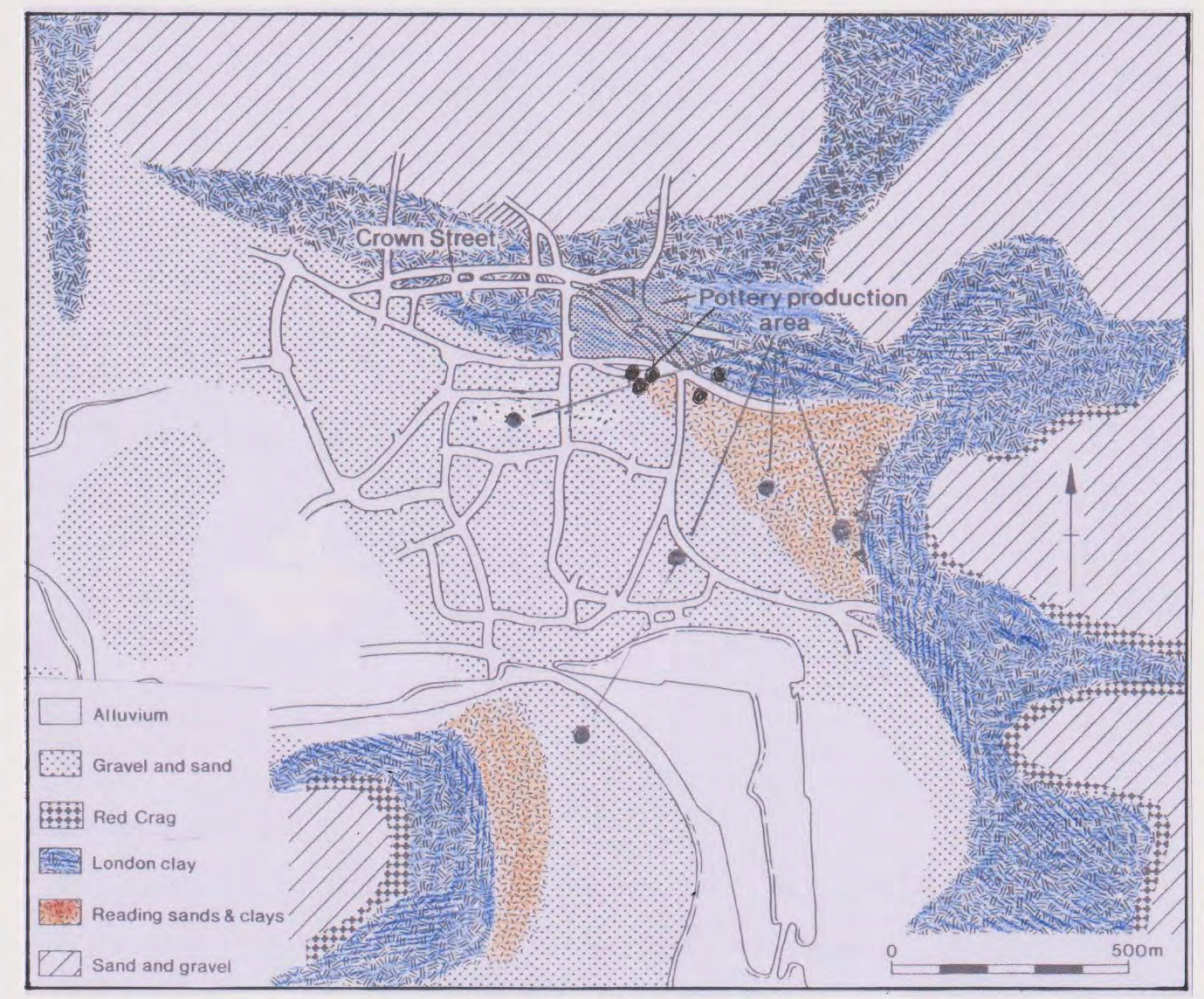


Fig.4. Ipswich surface geology showing London Clay and Reading beds and Anglo-Saxon and later pottery production sites.

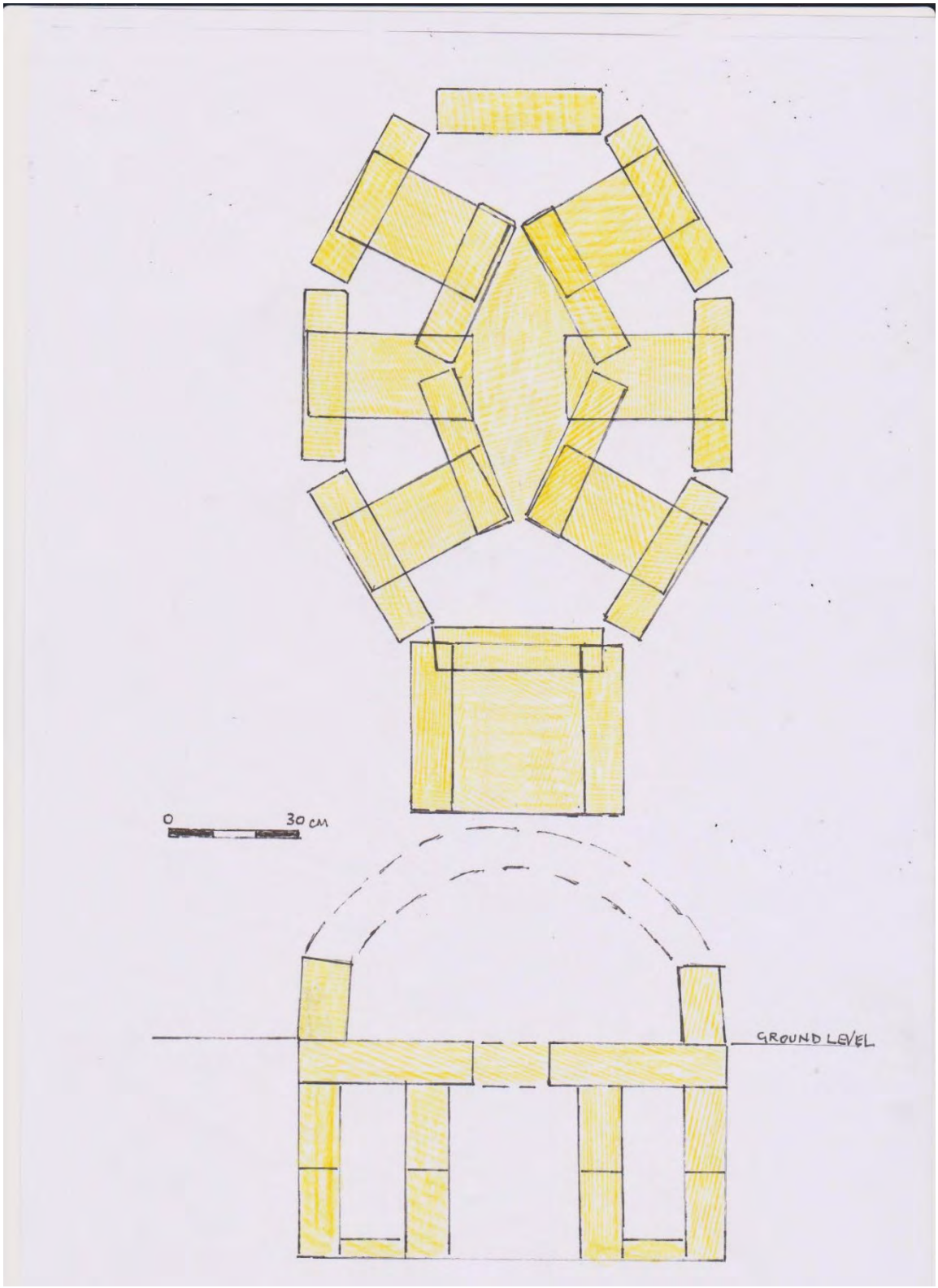


Fig.5. Design for the Ipswich ware kiln construction.

Fig.6. Digging out the footprint of the kiln and stoke pit.

Fig.7. Puddling the brickearth with straw

Fig.8. Packing the cob into wooden moulds.

Fig.9.Turning out the cob blocks

Fig.10. Blocks laid out to dry.

Fig.11. Building the walls of the kiln

Fig.12. The ‘arches’ laid to form the firing platform.

Fig.13. A further course of wall oven and the flue arch added.

Fig.14. The kiln covered for winter 2022-23.

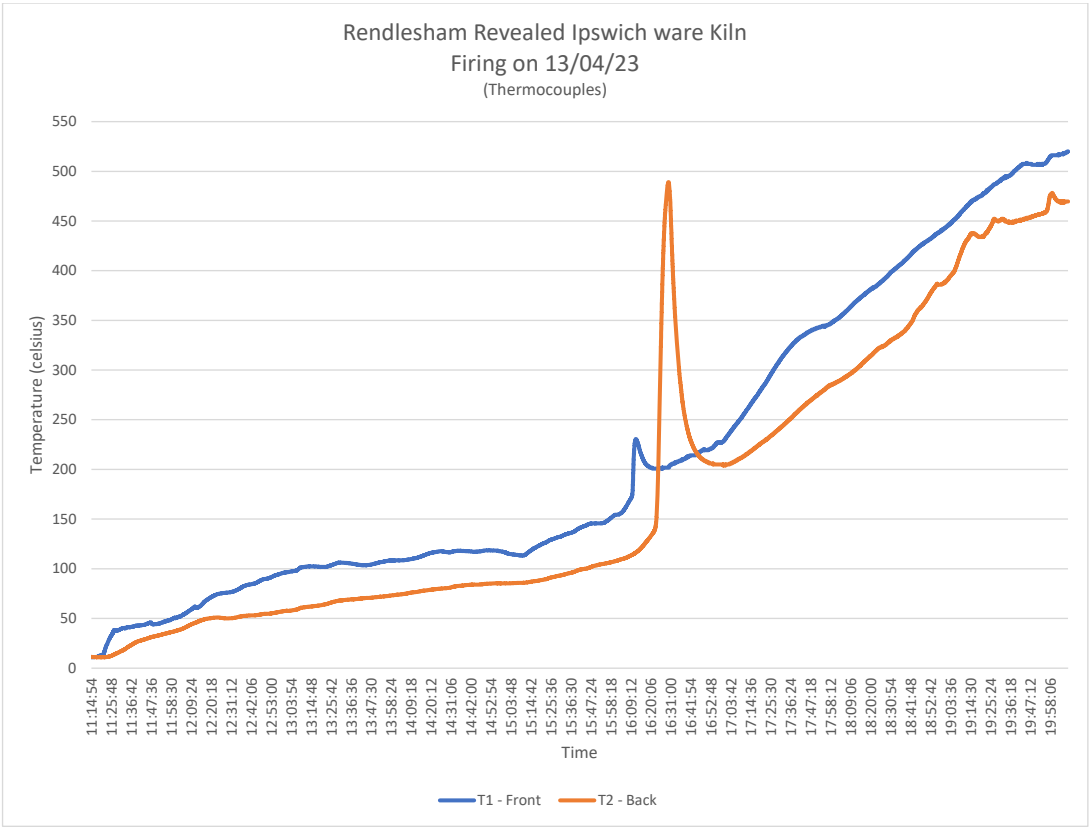
Fig.15. Drying out the kiln

Fig.16. Making slabs of London Clay to construct the kiln dome

Fig.17. Stacking the pots

Fig18. Slabs for the dome being laid on the hay above the pots.

Fig.19. The first firing underway



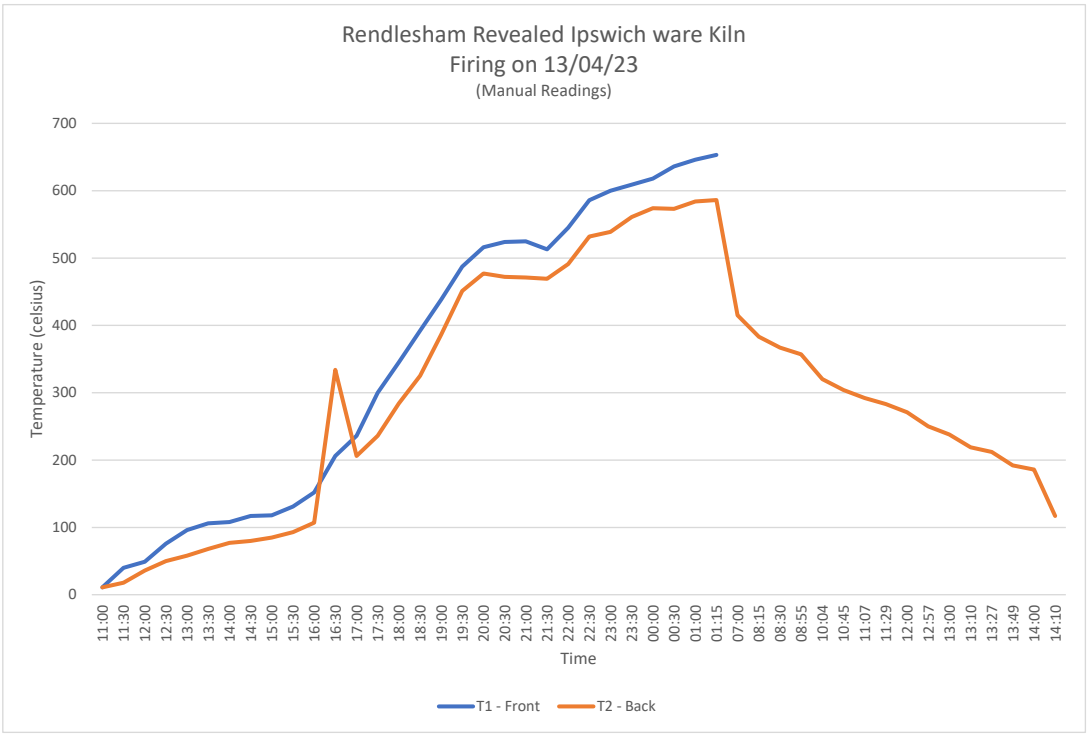


Fig.20. Kiln first firing: temperatures achieved over time. Thermocouple data is shown in the top graph, which only recorded the first 8 hours. Manual readings are shown in the bottom graph. One of the pyrometers (T1) was damaged and stopped recording. The peak in both graphs is the hay catching fire.

Fig.21. First firing: Opening the kiln.

Fig.22.Making the tapered blocks to raise the kiln oven walls one course

Fig.23. The pre-made cap for the dome.

Fig.24. The oven walls raised by one course sloping inwards and the pots stacked..

Fig.25. The dome awaiting the pre-made cap and showing the air vents

Fig.26. Second firing underway

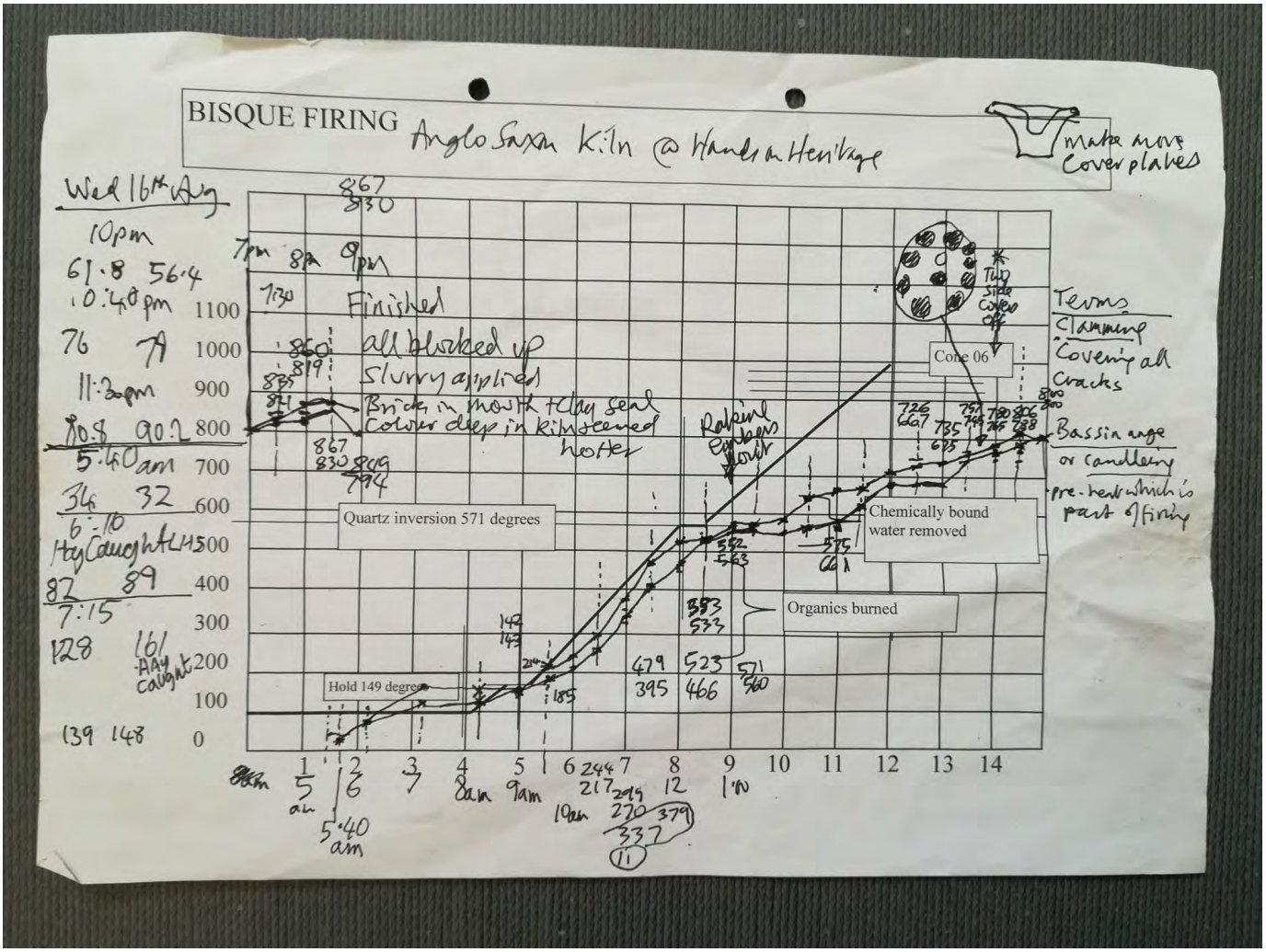


Fig.27. Second firing: kiln temperatures over time

Fig.28. Second firing: Opening the kiln.

Fig.29. Pots from the second firing.

Fig.30. Ipswich ware reproduction pot (Jnana Emmett) showing the way the London clay cracks due to diferential shrinkage between inside and outside - the cracks do not go all the way through. Fired to 950 degrees in an electric kil. This problem was solved by adding more sand.

Fig.31. The shelter for the winter of 2022-3.

Appendix A: Anglo-Saxon kiln & pot project – Catalogue of pots, clay mixes and outcomes by Jnana Emmett

Introduction
This work is a contribution to the Rendlesham Revealed "Being Anglo-Saxon: an experimental archaeology kiln project"

Aims:-
To learn how to make usable pots from the local clay (called London Clay)
To create reproduction forms based on Ipswich ware
To fire them in a reproduction Anglo-Saxon design kiln using local wood.

The London clay is widely available on the surface in the area and it is assumed that the Anglo-Saxons would have used it for their pots – but we quickly found that it is difficult to use, as it either cracks when it's drying, or when it is fired. It is reluctant to dry, but has to be dried thoroughly before being prepared, it is extremely sticky and sticks to everything. Potters get to know how to work with their clay and develop a recipe of added ingredients – usually proportions of sand, ground up pre-fired clay (grog) and animal dung. It is hard for potters to interpret the scientific thin section analysis that has been done on the archaeology and map that into a recipe. We did not know which kind of sand they used, or in what proportion, and it was unclear whether they used grog – and some did have evidence of added vegetable fibre which probably would have come from locally available animal dung at the time but is now harder to source.

The catalogue of pots that follow are made from a range of recipes – different proportions of sand, London Clay and local brickearth. The fired strength of a range of the recipes has been measured.

All the pure London clay pots failed

As soon as sand or brick clay was added, the workability improved and pots have been fired successfully – and I went on to try cooking in several of them with the help of the Hands on Heritage project team – and they all survived the initial cooking session over wood embers. The mix of 20% sand with London clay proved to be the strongest, and the mix of London clay and sandy brickearth was much easier to work with, but not as strong. Even the strongest mix was much weaker than the test strips of commercial terracotta which were fired together in the same kiln. Tests like this can be time consuming and endless, I'm sure there are many recipes yet to explore and test.

The other variable was our making skills – I had done coiled construction before but my skills improved considerably during this project – I was wet processing the clay so initially I was trying to make with clay that was too soft and the clay tended to have a will of its own, and was hard to discipline to match the forms in the archaeology - especially the biconic form so beloved by the Anglo-Saxons. I enjoyed exploring the stamped decoration, and working out how to shape bosses and shapes in the surface of the pot.

The Ipswich Ware has a strange construction detail – it looked like they were made with a thick base hollowed inside, then when leather hard the base was trimmed with a wire (or possibly a horse tail hair equivalent) All my attempts to replicate this led to too much thick and thin section and cracking.

The London clay has been extensively researched and has four different clay minerals, one of which has the property of holding onto water and being reluctant to release it, which leads to uneven drying and cracking.

	Description		Outcome	Photo
A	Pure London Clay Ipswich ware style honeypot form Coiled cut-bottom pot	Wt:1.015kg W :15cm H :12.5cm Fired in HoH kiln 2nd firing	Unusable – many cracks on base One of the first four made when learning about the London clay	
B	Pure London Clay Ipswich ware style honeypot form Coiled cut-bottom pot	Wt:1.015kg W : 15.2cm H : 12.2 cm Fired in HoH kiln 2nd firing	Unusable Many cracks on base Second one of the first four made	
C	Mix LC plus sand Bowl Thrown – with inclusions	Wt:735g W :16.2cm H :8.3cm Fired in HoH kiln 2nd firing	Thinly thrown – a sound pot – no cracks but big inclusions	
D	Pure LC Bowl Coiled London clay plus sand	Wt:0.808g W :16.7cm H :8.1cm Fired in HoH kiln 2nd firing	Unusable Cracked inside in a ring around the base	

E	Mix London clay plus 20% sand Ipswich Ware style honeypot form Hand coiled	Wt:1.365 W :16.8cm H :16.1cm From first firing – low temp - approx 700 degrees	Fine vertical crack on rim It sounds cracked	
F	Mix London clay plus sand Bowl Hand coiled Burnished with brushed slip decoration	Wt:940g W :17.2cm H ☹.5cm Fired in HoH kiln 2nd firing	Good sound bowl	
G	Mix London clay plus sand Bowl - Thrown. Decoration impressed with sharp edge of wooden tool	Wt:636g W :7.4cm H :15.7cm Fired in HoH kiln 2nd firing	Well fired – one fine crack on outside of base Chip on rim from firing	
H	Mix Bulmer LC & brickearth Cooking pot	Wt:1.18kg W :23cm H : 11cm Fired in HoH kiln 2nd firing	Good quality well fired Hand coiled Ridged deco Cooked with - on wood fire embers – it survived.	
I	Mix2/3 LC +1/3 Brickearth + chaff Cooking pot Chaff added to see if it improves tolerance to cooking	Wt: 636g W :7.4cm H :15.7cm Fired in HoH kiln 2nd firing	Good quality well fired Cooked with - on wood fire embers – it survived.	

J	LC Pure from residue at bottom of bucket Thrown - thin	Wt: 520g W :14.8cm H : 8.7cm Fired in HoH kiln 2nd firing	Smelly sulphate Crack on inside – possibly usable (Sulphate smell from 24hr soak in water)	
K	Mix 2/3 LC + 1/3 Brickearth, + chaff	Wt:1.065kg W :17.9cm H : 9.5cm Fired in HoH kiln 2nd firing	Nice bowl – good size – ridged deco made with wooden tool	
L	Mix Bulmer LC + B Hand coiled cooking pot	Wt:1.515g W :21cm H :12.3cm Fired in HoH kiln 2nd firing	Sound cooking pot – smooth finish – finger groove decoration Cooked with - on wood fire embers – it survived.	
M	LC + B + chaff Coiled Thin	Wt: 658g W :16.3cm H : 8.5cm Fired in HoH kiln 2nd firing	Sound pot but warped Crescent moon decoration with wodden stamp	
N	LC + clay sample from Norfolk	Wt: 756g W :16.2cm H : 7.5cm Fired in HoH kiln 2nd firing	Thrown cooking pot Really good finish – lovely feel. The Norfolk sample was from a clayey bit in a ploughed field	

O	Mix 1/3 LC and 2/3 sample clay from Norfolk Hand coiled cooking pot	Wt:1.680g W :21cm H : 11.5cm Fired in HoH kiln 2nd firing	Lovely smooth sound pot Cooked with - on wood fire embers – it survived.	
P	Orwell shore clay Ipswich ware style honeypot Cut base	Wt: 864g W :14.9cm H : 12.8cm Fired in HoH kiln 2nd firing	Very small crack on base underneath – doesn't go through	
Q	Clay sample from Old Felixstowe Hand coiled cooking pot	Wt:1.755kg W :24cmcm H : 12.3cm Fired in electric kiln – orangey colour	One of the first coiled pots – before the project's clay was available. Possibly a weak clay but cooked ok on wood embers and intact	
R	Clay sample from Orwell shore Hand coiled cooking pot	Wt:1.375kg W :20cmcm H : 11.2cm Fired in electric kiln – orangey colour	The second coiled pot – made before the project's clay was available. Cooked ok on wood embers – and is intact	
S	Water pot Orwell Shore clay With large commercial grog	Wt:3.27kg W :22.5cm H : 22 cm Fired in HoH kiln 1st firing	Large coiled pot Finger groove decoration Burnished Small blown blemish on the side – possible inclusion	

T	Urn with 8 bumps and scribed and stamped decoration	Wt:2.55kg W :23.8cm H : 19.5cm Fired in HoH kiln 2nd firing	LC plus 30% sand plus grog. Coiled. First attempt at pressing out bumps Flame marks from firing	
U	Coiled pot Stamped decoration Expressed and impressed bumps and arched forms	Wt:1.88kg W :21.5cm H : 17cm Fired in HoH kiln 2nd firing	Shrinkage cracks all round the base inside – they don't go all the way through, sound on the outside and the pot rings well	
V	Coiled pot Stamped decoration Mix of Felixstowe Ferry and Old Hall bore hole clays – fired a light terracotta	Wt:2.59kg W :22cm H : 20.4cm Fired in HoH kiln 2nd firing This clay mix didn't pick up surface colouring from the firing.	Sound pot Classic form – turned out more globular that the intended boconic. Finger groove decoration. The throne lid is a humerous addition	
W	Brew Pot with spout and handle. Coiled. One of my early pots – so still learning coiling skills. Tool formed decorative bands	Wt:6.39kgg W :31cm H : 28.5cm Fired to 1000 degrees C in electric kiln as it had been made in summer last year and had been too many months waiting to be fired	LC and sieved sand. 14kg of clay used to build it. Cut base – which cracked on outside. Pot has good ring, so sound. Many typical London Clay shrinkage cracks.	

X	27 test pinch pots made over the 18 months with different clay mixes.	Wt:58g to 150g W :4.2cm to 7.2cm H : 4.3cm to 7.7cm Some fired in saggar in electric kiln – hence darker colour. Some fired in HoH kiln 2nd firing	Some were made before any of the larger pots to test combinations of added sand and grog. Some made with leftover clay mix