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An Investigation into the Firing of Nabataean Pottery

Introduction

This paper presents part of a project aimed at investigating the methods of manufacture of fine Nabataean pottery (Mason and 'Amr 1990; 1992a; 1992b; 1993). The project was carried out jointly by the Department of Antiquities of Jordan and the British Institute at Amman for Archaeology and History who have funded the project along with, initially, Yarmouk University and later on the Wainwright Fund of the Oriental Institute at Oxford.

The part under discussion here is the building and firing of an experimental pottery kiln, carried out in 1990 and 1992 at Jarash. The experimental structure was based on the plan of a kiln excavated at Zurrāba, to the east of Petra, in 1980 (Zayadine 1981: 350-351; 1982: 380-382; 1986: 185-187). It was meant as a 'research tool' to investigate the effects of firing on pottery made from clay thought to have been used by the Nabataean potters (Mason and 'Amr 1990: 287-290).

The Zurrāba Kilns

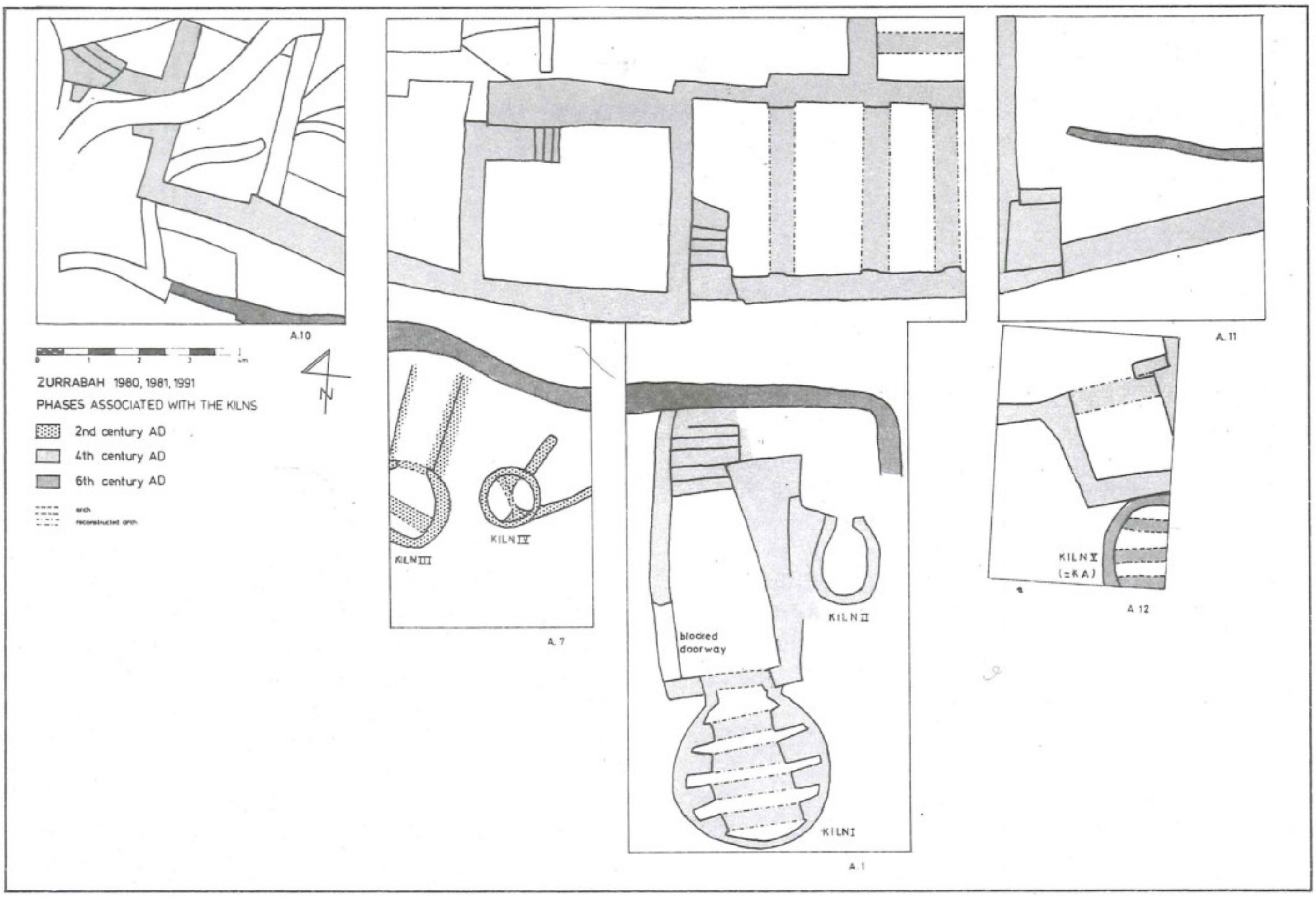
To date, five pottery kilns ranging in date from the second to the sixth centuries AD had been uncovered at Zurrāba ('Amr 1991) (FIG. 1). When the project was started in 1990, however, only two kilns (Kilns I and II) were available for inspection, as Kilns III and IV had been re-buried in 1980 and Kiln V was discovered in 1991. Kiln I was chosen as the model for the experimental kiln as it is the larger and more complex of the two kilns.

Kiln I was dated to the "Roman period", more specifically late third or early fourth century AD (Zayadine 1982: 386; 'Amr 1991: 320), thus placing it slightly later than the "classical" Nabataean fine wares. Because the experimental kiln was regarded as a research tool, its use was justified especially since the Nabataean pottery tradition continues well past the date of Kiln I at Zurrāba ('Amr 1991: 315-318, 321).

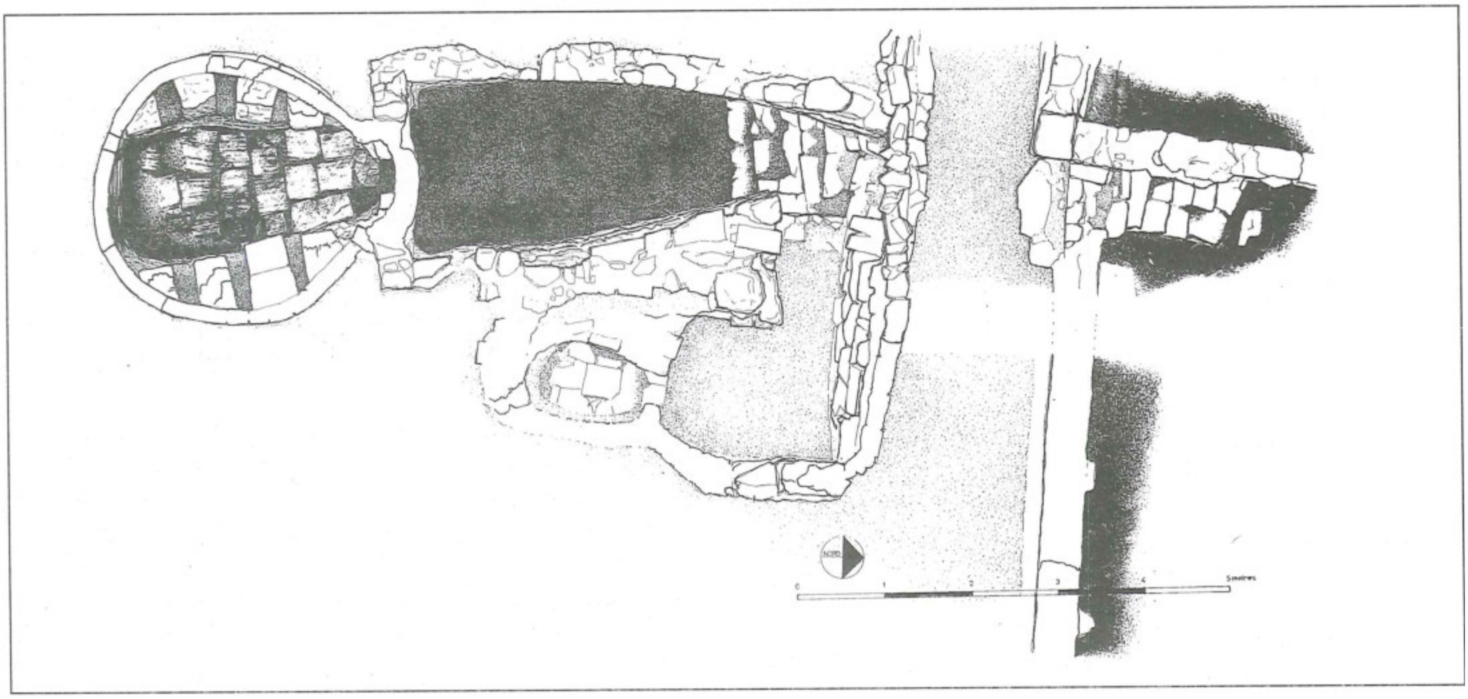
A problem in kiln studies is the variety of terms applied to the kiln components. In this paper, the terms defined by Swan (1984: 29-32) will be used. Thus the *stoke-hole* is the opening through which the fuel is introduced, the *combustion-chamber* is where the fuel is burnt, in the combustion-chamber are built *supports* for the *raised oven-floor*, above which is the *superstructure* defining the *oven*, in which the pots are stacked for firing.

Kiln I is a simple updraught kiln, with the combustion-chamber directly below the oven. This principle is common in kilns of the area since the Bronze Age and is still seen in modern kilns. The plan of Kiln I is unique, however, in that the combustion-chamber is almost rectangular in shape, measuring 1.15-1.35 x 3.0m with a height of around 1.0m, paved with bricks, while the oven is circular (the oval shape described in Zayadine 1982: 380 is actually a distortion due to the position of the entrance at the northern side) with an average diameter of about 3m (FIG. 2). Four heavy arches spring from the long sides of the combustion-chamber and would have supported a dome defining the oven. The spaces between the arches would have acted as flues for pulling the hot gases from the combustion-chamber into the oven. The plan of this kiln should not be confused with the "central corridor with cross walls and cross flues" kilns (Cuomo di Caprio 1978/9: Class I/d), where "the arches supported the floor" (Schaefer and Falkner 1986: 421). No traces of the oven-floor or its supports were found. The opening of the kiln faces north, and is a corbelled stone arch protected by brick insulation, which would have acted both as a stacking and stocking hole. This arch is the only stone element in the kiln structure, which is otherwise built of brick.

A passageway accessible from the north by a flight of steps leads to the opening of Kiln I. This is due to the fact that the combustion-chamber and part of the superstructure were dug into the ground — i.e. into earlier deposits, a common solution for additional insulation (see for example Adams 1961: 33, 37; 1962: 65, 66; 1986: 31-32; Golvin *et al.* 1982: 42, 43, 47, 66; Coulson and Wilkie 1986: 66; Anderson 1987: 42). The floor of this passage is paved with stone and its side walls are also of



1. Schematic plan of the excavations at Zurrāba.



2. Plan of Kiln I at Zurrāba (drawing by Jacques Rougetet, courtesy F. Zayadine).

stone, none of which show traces of firing, so it could not be assumed that any part of this passage acted as an external combustion-chamber.

The Experimental Kiln Construction

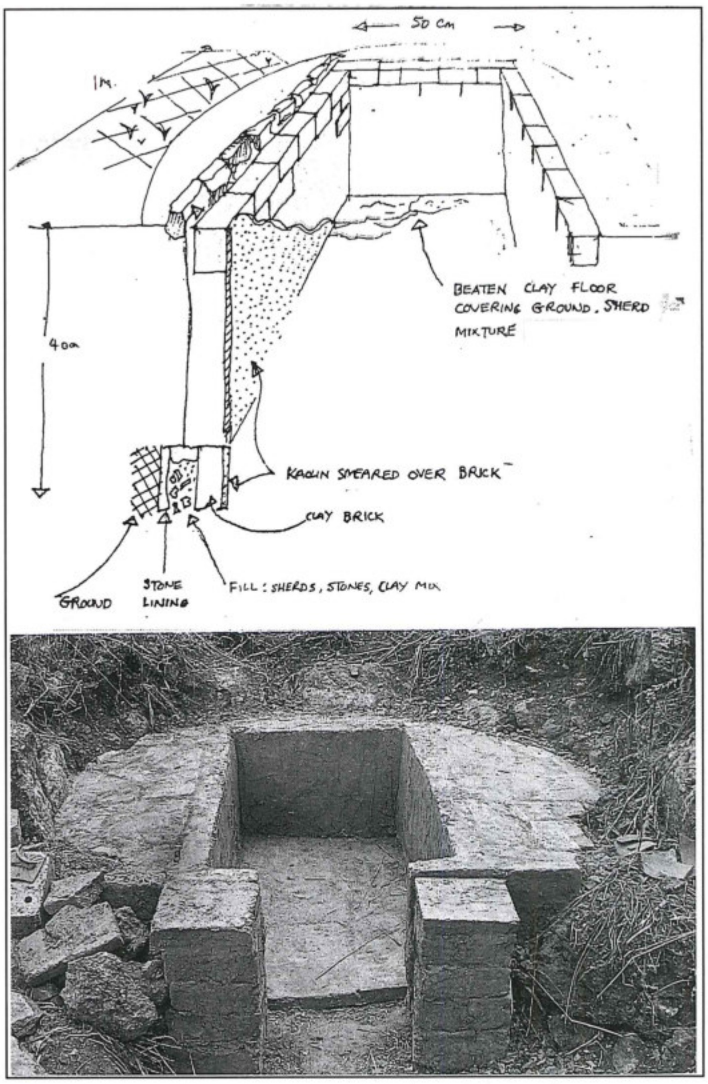
The kiln construction took place at Jarash, where the Department of Antiquities kindly offered us some space in a secluded area in the northwestern sector of the city. The area was an agricultural field prior to its acquisition by the Department, and we were assured that at least the top metre was disturbed by modern agricultural activities.

All the bricks for the structure were hand-made using clays from the Sākib area on the Jarash-'Ajlūn road. These were a blue marl and a yellow plastic which we mixed with crushed sherds and sand for making the bricks. Ash and lime were added to these clays and used as mortar.

The kiln was built with unfired bricks, dried for at least two weeks before using in the construction. "Pre-firing" of the kiln was done at two stages, first upon the completion of the combustion-chamber, then when the structure was completed. These firings were done using dry grasses and scrap wood with no pottery in the kiln and were meant to test the structure. It is also quite natural to assume that the most appropriate firing for the bricks would be that of the kiln itself (for ethnographic examples of kilns built of mud brick which fires *in situ* see Nicholson and Patterson 1989: 73 and Golvin *et al.* 1982: 48-50; while Melkawi *et al.* 1994: 451 report seventh century AD examples of the same practice).

Initially it was decided that the reconstructed kiln be half the size of Zurrāba's Kiln I, so the bricks were made accordingly. Thus bricks for building the walls were made approximately 20 x 10 x 10cm, and bricks for the arches measured approximately 20 x 20 x 3cm. Due to practical reasons, however, the kiln was moved to another spot in the same area and it was decided to build it a third of the original size. This change in plan meant we had to accommodate the half size bricks to a third size kiln, which affected only the number of arches that could be accommodated.

A pit was dug into a bank for the combustion-chamber, approximately 1.10m long, 50cm wide and 40cm deep. It was decided that the passageway in front of the original kiln was not basic for the structure. The pit was lined with sherds and clay and the combustion-chamber floor and walls were built with bricks. The interior was lined with the blue marly clay from Sākib, which proved more refractory than the plastic yellow during experimental firings in an electric kiln at the Ceramics Department, Yarmouk University. The area around the top of the combustion-chamber walls, in a circle of 1m diameter, was consolidated with stone and clay



3. The combustion-chamber of the experimental kiln.

to support the weight of the superstructure arches (FIG. 3).

No traces of the original oven-floor or its supports were detected for Kiln I at Zurrāba, despite close inspections of the combustion-chamber by us, Kenneth Russell and Robert Schick. Therefore it was decided that the support could not have been a "tongue" — which would have been connected to the back wall where its subsequent removal would have been detectable — nor a central pillar/core, which would have left a definite mark on the floor.

Initially seven pillar supports were erected along the walls of the experimental kiln combustion-chamber, onto which three shelves were placed, these had a series of holes in them to allow the upward flow of the gases. The pillars were later replaced with three small arches spanning the combustion-chamber, which proved more stable (a solution suggested by Zayadine 1982: 380 and later presented by Kiln V at Zurrāba, 'Amr 1991: 315). On a visit to Zurrāba in June 1992, Zbigniew Fiema noted rough sections in the brickwork of the combustion-chamber walls of Kiln I, directly below the superstructure arches. These may have been the remains of arches that were broken off when the kiln was reused for purposes other than firing pottery, such as storage.

For stacking the pottery in the experimental kiln, tiles were placed above the combustion-chamber arches instead of the shelves. Many over-fired tiles were recovered at Zurrāba but not a single piece which may represent a shelf with circular holes was found there.

After the combustion-chamber was completed and a fire lit in it to harden the bricks, the superstructure arches were built around formers (FIG. 4). Only three instead of four arches were built as we had to adapt the half-size bricks to the third-size kiln (see above). The arches were placed 10cm apart to allow for the flues. The dome was built around the arches, leaving gaps (exhaust-vents) at the top to allow the flue gases to escape. An entrance was constructed at the front (north side) and corbelled resembling the original, in brick instead of stone (FIG. 5). Finally the dome was coated with a thick insulation layer of clay.

Choice of Experimental Fuel

Many different potential fuels would have been available to the Zurrāba potters. Of these, hard woods are the most unlikely candidates as they would have been too valuable

4. Building the superstructure arches.

5. The completed experimental kiln.

for burning in the given environment. Additionally, the tons of ash excavated at Zurrāba contained almost no charcoal (although almost complete absence of charcoal had been reported for wood firings, Hartley 1961: 3 postulated that may be due to "the oxidizing nature of the firing", compare Bryant 1978/9: 20 who reported large amounts of charcoal resulting from reducing firings). At any rate, both the 'pre-firing' of the experimental kiln using scrap wood, and the first firing using pine produced large amounts of ash and charcoal that proved difficult to deal with, as they occasionally choked the combustion-chamber and in the absence of an ash pit — no evidence for which was found at Zurrāba — the raked out embers made very uncomfortable work conditions despite the use of a long iron rake (see also Bryant 1978/9: 21; Mayes 1961: 14 Code Letter I).

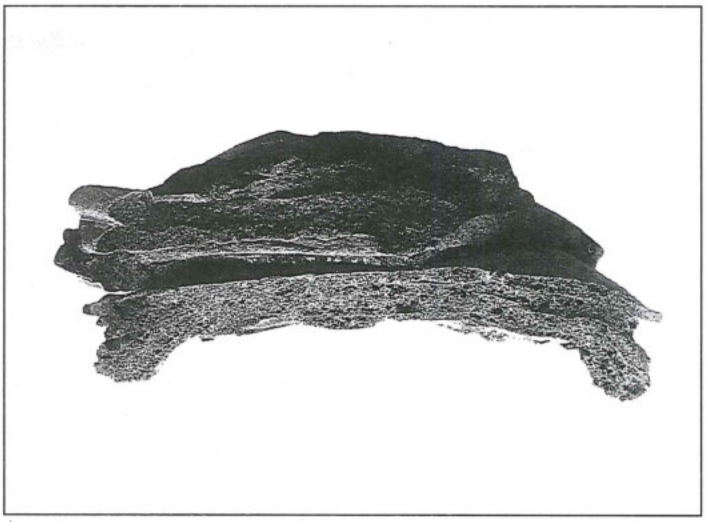
Considering that modern "Hebron tradition" potters use waste products such as saw dust and wood chips, the outer shells of old car batteries and dirty engine oil or diesel oil ('Amr 1987: 43) or even rubber tyres (Rye 1981: 103; see also Golvin *et al.* 1982: 74), waste material should be investigated. Near Eastern commercial —

rather than household — potters closer to nature seem to choose agricultural waste (see for example Golvin *et al.* 1982: 54; Nicholson and Patterson 1989: 77; Peacock 1982: 25, 31, 41). At Zurrāba, the only charred plant remains that appeared frequently were olive pips (Zayadine 1982: 384). Today, much of the agricultural land of Wādī Mūsā is planted with olive trees and although their owners take the olives to Ṭafīla for pressing, there is evidence for the existence of an ancient olive press system only a few hundred metres west of the Zurrāba pottery workshop (Zayadine 1982: 384, 559), but unfortunately the remains are too disturbed to allow for dating. Strabo's claim that the Nabataeans did not use olive oil was negated by the discovery of a first-second century AD olive press at Khirbat adh-Dharīḥ (Villeneuve 1990: 369), and there is historical evidence for the use of olive pressings in firing pottery kilns in Roman Palestine (Vitto 1986: 54). This makes olive pressings, which is still widely used for fuel in Jordan, an almost certainty for fuel used by the Zurrāba potters. The wild bushes for fuel postulated by Zayadine (1982: 380) would have produced even more ash for choking the combustion-chamber and most probably would have less calorific value, but they may have supplemented the olive pressings firing. Other fuels such as animal dung cannot be dismissed and mixtures of fuels may have been used.

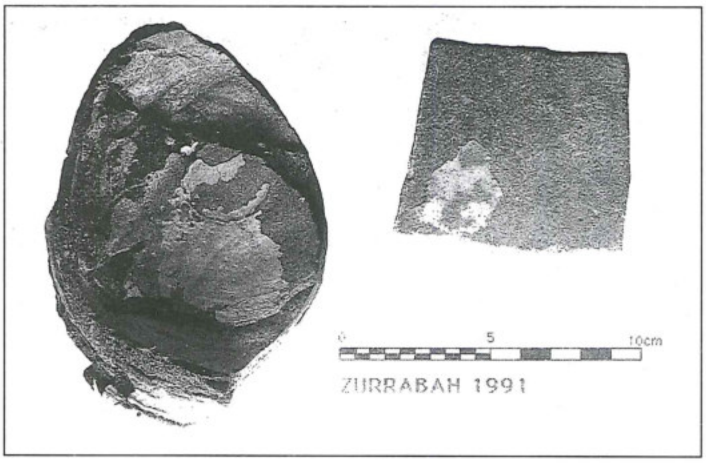
Saggering and Stacking the Pottery

The Zurrāba excavations produced exceptional examples of over-fired wasted stacks, where sometimes over thirty bowls had melted and fused together in one mass (Zayadine 1982: 563 PL. CXXXIX; 1986: 188). Close examination of some of the waster stacks gave the impression that the bowls "melted down" rather than "up", i.e. they seem to have been stacked right way up rather than upside down when the melting occurred, with parts of the rims sometimes giving the impression of having melted through something, e.g. a fracture in the oven-floor. In many cases parts of the rims had melted "lower" than the bases (FIG. 6). Additionally, a frequent occurrence were small rhomboid clay shapes stuck to the bottoms of stacks (FIG. 7). These were made of a coarse (more refractory?) clay and occurred in deposits from all phases. Most probably they served to stabilize the stacks of round based bowls. A consistent observation is that the bowls were stacked on top of each other with no separators.

No clear evidence for saggers was found. However, plain coarse large bowls or pipes — sherds from many of which were found — may have served as saggers (see for example Golvin *et al.* 1982: 51). Saggering is a simple, though space and heat consuming, method for producing well oxidised wares, but it is not necessary if a clear oxidising fire can be maintained and the flames kept away from contact with the pots (Billington 1962: 163). The numerous over-fired pots and stacks from Zurrāba seem to indicate unprotected firing, still we decided to wait for the results from our first firings to make a decision on the matter.



6. A stack of wasted bowls from Zurrāba with the rims melted lower than the bases.



7. Rhomboid coarse ware pieces from Zurrāba, sometimes found stuck to the bottoms of stacks of wasted bowls.

The Experimental Firings

By April 1992, the kiln had been fired five times, excluding the pre-firings (see kiln construction above). The first "loaded" firing used pine — which happened to be abundant at the time — in order to familiarise ourselves with the kiln and observe its firing characteristics. We were encouraged by the superb "pull" and the 850°C reached over six hours. On the other hand, the problem of ash and the frequency of stoking convinced us to turn over to the olive pressings.

The other four firings used olive pressings as the basic fuel. During all the firings the opening of the oven was bricked up. The kiln was left to cool for at least three days after each firing before it was unloaded, after which time the embers and combustion-chamber floor were still too hot to handle. A brief description will be given of these firings.

First Olive Pressings Firing: 30 November 1990. There was almost no breeze throughout the firing, dry warm weather. Dry pressings from the 1989 season were used. In order to help the fire become established, pine cones and twigs were used in association with the pressings in the initial phases so that a good bed of hot ash developed. Some time was taken over this stage. It was noted that lumps burnt more efficiently than loose pressings, which tended to cover unburnt fuel thus preventing further combustion. An estimated temperature of 800+°C was reached over four hours (recorded by cones). The stoking was *extremely* relaxed compared to the pine firing. Ashes filled almost two thirds of the combustion-chamber, no raking was necessary but some poking was done to get air to the unburnt fuel. The vessels had patches of strong reduction especially where not protected by stacking. No over-fired wasters but there were a few heat spalled vessels.

Second Olive Pressings Firing: 21 June 1991. There was little breeze throughout the firing, dry hot weather. Dry pressings from the 1989 season were used. The behaviour of the olive pressings at the beginning was the same as the first firing. A top temperature of 800+°C was recorded (by cones). An attempt at full oxidation was carried out at the end of the firing for twenty five minutes using dry palm branches which well oxidised the bowls. A heat variation from front to back of approximately 100°C was estimated.

Third Olive Pressings Firing: 5 November 1991. There was varying breeze with a few gusts of wind. A mixture of old and new olive pressings shaped into cakes were used. By now we were familiar with the initial behaviour of the olive pressings. Dry olive leaves were used to invigorate the fire from time to time. An estimated top temperature of more than 850°C was reached over 5hrs 50mins. This was the first firing with a full load, 75 vessels of varying forms and sizes were stacked. We experimented with flues to try to even out the heat. Some bowls had reduced portions where not protected in the stack (FIG. 8). One bowl, made of Jarash clay, was an over-fired waster (it was placed at the back of the kiln). The temperature variation between the back and front was noticeable.

Fourth Olive Pressings Firing: 15 March 1992. The kiln was soaked through with water due to the prolonged wet weather. A fire was lit a few days earlier for several hours but the kiln was still very wet. A fire with twigs was lit for two hours before stacking the pots but still the kiln was wet. There was some breeze, cool weather, a few rain drops towards the end of the firing. New olive pressing cakes were used. There was a full load, again of 75 vessels. We decided to sagger some vessels in large fired bowls. The fire was started a bit too rapidly, reaching 300°C in the first hour which resulted in the shattering of some of the bowls. There was much more smoke than experienced in the preceding firings and the kiln consumed significantly more fuel, certainly as a result of the excess water in the fabric. A temperature of 850°C was reached over five hours, occasionally rising to 860°C (readings from one thermocouple placed at the centre back). Cones were placed at several positions in the front, centre, back, top and bottom. The kiln was left to soak at the top temperatures for one hour. The firing was finished off with a load of dry palm leaves. Flues were left open throughout. The pottery was well oxidised with the exception of one small vessel that was covered in soot. One saggered bowl showed signs of over-firing, another one was shattered (although probably during transport in the saggers rather than from heat). Nine vessels were shattered by the initial rise in temperature, all at the back. There was an estimated variance of about 100°C between the front and back of the kiln.

General Considerations and Conclusions

The Kiln Structure

The structure fared very well after almost three years of exposure and six firings. One large crack appeared at the back during the first firing, most likely caused by thermal stress. It was repaired, reappeared in the second firing, then did not seem to give problems after the second repair. Repairs also had to be made to the outside insulation layer after the winter storms of 1990/91 then 1992. The latter also caused the wear of part of the pillars in front of the stokehole. One of the pillars initially supporting the oven-floor collapsed during the second firing. All of the shelves used on top of these pillars had to be replaced after each firing (three of them collapsed during firings). The combustion-chamber arches fared better and only once a spanning brick collapsed during firing, most bricks could be re-used. No damage occurred either to the superstructure arches or dome.

All the inner surfaces were good, having fired to a light pink, however under the insulation layer the bricks were still green to about a quarter of their thickness. This seems usual in low fired kilns (see Mayes 1961: 7).

The variation in temperature seems normal in up-draught pottery kilns with the combustion-chamber directly below the oven. Nicholson and Patterson (1989: 84) report a variation of 100-150°C between different parts of a kiln 4.50m in diameter and 3.40m high, although larger kilns are supposed to have better heat distribution than smaller ones (David Killick, pers. com.). Similar variations have been reported for updraught kilns with external combustion-chambers and slightly larger size (Mayes 1961: 11).

The pull of the flue is satisfactory. One difficult feature is the stacking, due to the size of the opening. The original at Zurrāba, however, is of a size through which a man could easily go through on his knees, over the oven-floor.

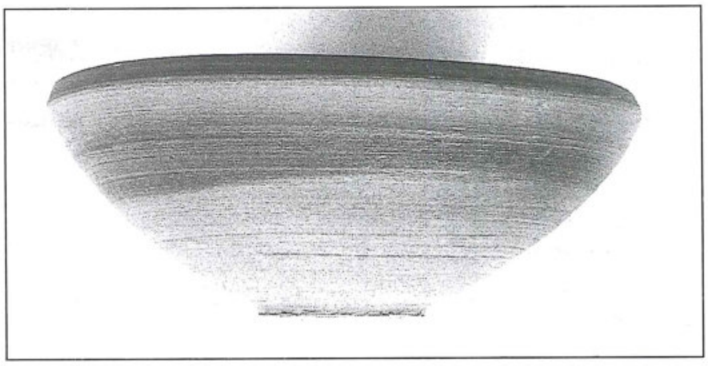
The Olive Pressings

The kiln was fired using two different seasons of olive pressings waste. It was observed that with age the pressings consolidated into dry lumps, which burnt well. New pressings with higher moisture content required fairly hard compression to consolidate into 'cakes'. Some were pressed into brick moulds while others were simply rolled into balls. After the pile of pressings was exposed to the heavy rains of 1991/92, it was easier to produce the blocks, but they required a very long drying period.

The pressings release a strong heat, burning with a yellow flame that breaks into a green/blue flame, and temperatures in excess of 800°C could be reached without much effort. During the earlier stages of firing and until a bed of embers is established, it releases a good deal of unwanted gases which slows the heat rise down (more so in the case of fresh pressings, the workers at the olive press where we obtained the pressings said they use pressings from the previous season for their heaters). This slowing down in heat rise, however, was to some extent advantageous since the amount of wasters was almost eliminated. The main problem seems to be the partially reduced vessels by the end of the firing, which is most probably due to the clay composition (see the assessment of the resultant pottery below). Several solutions may exist which have not been exhausted yet. Saggering is one of the less likely to have been used by the ancient potters. It should be kept in mind that some of the reduced rings around the rims of the bowls closely resemble grey rings found on the exterior rims of some Nabataean open vessels (see FIG. 8).

The Resultant Pottery

The clay from which the pottery was made showed special properties and requirements (Mason and 'Amr 1990: 289-300). To start with, the resultant red colour upon firing is, as expected, due to the amount of iron oxide present in the clay. The pots were made using the green clay at 'Ayn aṭ-Ṭīnah, which has an average *elemental* iron content of over 5% (pre-levigation content, 'Amr



8. A bowl with oxidised body and reduced rim where not protected by

1987: 307). Shepard (1980: 150) states that, generally, red colour will result from an *iron oxide* content of greater than 3%.

X-Ray Diffraction analysis carried out at the Geology Department of the University of Jordan showed the clay to be composed of kaolinite and a mixed layer of illite and smectite.[1] Smectites are a major component in soils of arid regions (Rice 1987: 48). Their characteristics dominate the clay properties that we had to come to terms with, starting with the high plasticity and shrinkage (Rice 1987: 44, 49), thus the possibility of throwing very thin sections and the required extremely slow drying in order to avoid cracking (Mason and 'Amr 1990: 295, 297-298). During firing, the required slow start is due to the fact that smectites give up much water between 100-200°C (Rice 1987: 87, see the fourth olive pressings firing above for explosions due to an impatient start). Finally, an explanation for the tenacious reduced patches on the pots could be found in the fact that smectites strongly retain organic material in their structure and carbon is not readily given up in firing (Rice 1987: 88). Here it should be noted that carbon can have an effect on the iron content present in the clay, which acts as a flux thus raising the temperature on the pottery surface (Franken and Steiner 1990: 84-85).

Other analyses carried out at the Chemistry Department of the University of Jordan showed the clay to have surprisingly high base exchange as well as high adsorptive capacity, both characteristic of smectites as well (Rice 1987: 48, 60).

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[1] Since the presentation of this paper, extensive analyses of the clay from 'Ayn aṭ-Ṭīnah formed major sections of two post-graduate research projects at the Departments of Chemistry and Geology, University of Jordan (Baker 1993; Abu Dayyeh 1993).

tinuous support, turning hard work into a pleasurable experience. All the staff at the Jarash Antiquities Office were extremely generous throughout the long period of the project. Hazem Zobi and Rula Attalah came to the rescue several times when equipment failed. Thanks also to Mohammad Sadooq Melkawi who helped with the kiln construction, and Giovanni Caravaggio who helped with the test firings. Joseph A. Greene, Roland-Pierre Gayraud and Estelle Villeneuve provided some of the reference material.

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