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# Painted Pottery from East Macedonia, in North Greece: Technological Analysis of Decorative Techniques

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ABSTRACT - *Neolithic pottery from East Macedonia displays a considerable variety of surface finishing, ranging from through burnishing, painted, applied, incised, excised and impressed decoration. Methods of surface treatment, although widely used as the main criterion for the classification of ceramic wares, have received little attention. Pottery is usually described in terms of decorative motifs, colour variation or colour combination, but the technological processes responsible for these effects are, in most cases, ignored. The usual assumption is that similar results can be obtained by means of similar technological processes. This assumption is questioned by the present work, on the basis of a study of a large sample of painted ceramics from East Macedonia covering the whole of the Neolithic period. The material has been studied macroscopically and microscopically (polarising microscope and scanning electron microscope). A number of refiring tests were also carried out. The analysis so far indicates that there was great variation firstly, in the raw materials and techniques used by the potters for the production of painted motifs, and secondly, in the conditions prevailing during firing.*

IZVLEČEK - *Neolitska keramika iz vzhodne Makedonije kaže veliko raznolikost pri obdelavi površine, ki obsega tehnike okraševanja, kot so loščenje, slikanje, apliciranje, vrezovanje, izrezovanje in vtiskovanje. Čeprav se metode obdelovanja površine na široko uporabljajo kot glavni kriterij za klasifikacijo keramičnih posod, jim niso posvečali veliko pozornosti. Keramiko običajno opisujejo glede na motive okraševanja, barvo ali barvne kombinacije, večinoma pa prezrejo tehnološki proces, s katerim so izdelovalci dosegli omenjene učinke. Običajno domnevajo, da s podobnim tehnološkim procesom dobimo podoben učinek. V članku to predpostavko postavljamo pod vprašaj na osnovi raziskave velikega vzorca slikane keramike iz vzhodne Makedonije skozi vse neolitsko obdobje. Material smo raziskovali makroskopsko in mikroskopsko (polarizacijski mikroskop in vrstični elektronski mikroskop (SEM)). Opravili smo tudi številne teste s ponovnim žganjem. Analize zaenkrat kažejo, da gre za veliko raznolikost tako v surovini kot v tehnikah, ki so jih lončarji uporabljali za slikanje motivov. Velike razlike pa smo našli tudi v načinu žganja.*

KEY WORDS - *Neolithic Macedonia; painted pottery; technological analysis; firing of pots; petrographic study; chemical analysis; SEM; refiring test*

## INTRODUCTION

East Macedonia is the area between the Strymon and Nestos Rivers, in Northern Greece (Fig. 1). The earlier Neolithic levels excavated so far are dated to 5500–5200 BC (the late Middle Neolithic period). This phase is represented by the lower levels of the site of Limenaria on the island of Thassos (*Malamidou and Papadopoulos 1993*), as well as those of Sitagroi (Sitagroi I: *Renfrew et al. 1986*) and Dimitra (Dimitra I: *Grammenos 1997*). Late Neolithic I, dated to ca. 5200–4800 BC, is represented by Sitagroi II, Dimitra II, Dikili Tash I (for Dikili Tash see *Treuil 1992*) and the lower levels of Krioneri (*Malamidou 1997*) and Promachon-Topolnitsa (*Koukouli et al. 1996a*). Late Neolithic II, starting around 4800/4600 BC, is represented by Sitagroi III, Dimitra III, Dikili Tash II, Paradeisos (for Paradeisos see *Helstrom 1987*), the upper levels of Krioneri and Promachon-Topolnitsa, and the site of Kastri in Thassos (*Koukouli 1972*). The end of this phase is estimated to be around 3800 BC. Apart from the excavated sites mentioned so far, ceramic material attributable to the Late Neolithic has been found, through surveys,

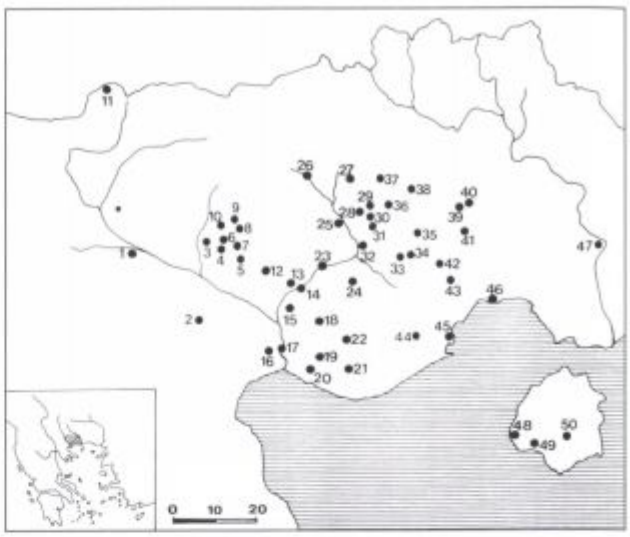


***Fig. 1. Map of East Macedonia and Adjacent areas showing the Neolithic sites discussed in the text: 1. Kastri Srimonikou, 2. Zervochori, 3. Monovrisi, 4. Chriso, 5. Toumba, 6. Fakistra, 7. Prof. Ilias Pentapolis, 8. Gradiskos, 9. Agio Pneuma, 10. Neo Souli, 11. Promachon, 12. Tholos, 13. Airi Bairi, 14. Dimitra, 15. Fidokoriphi, 16. Krioneri, 17. Hill 133 Amfipolis, 18. Mikro Souli, 19. Galipso, 20. Lakkovikia, 21. Akropotamos, 22. Podochori, 23. Agista, 24. Nea Bafra, 25. Megalokabos, 26. Maara Cave, 27. Petrous, 28. Bournar Basi, 29. Milopotamos, 30. Zoodochos, 31. Kalos Agros, 32. Sitagroi, 33. Sikia, 34. Kalabak Tepe, 35. Doxat Tepe, 36. Arkadikos, 37. Xiropotamos, 38. Kalifitos, 39. Kirgia A, 40. Kirgia B, 41. Kefalari, 42. Dikili Tash, 43. Polistilo, 44. Sibolo Cave, 45. Nymphs Cav., 46. Kara Orman, 47. Paradisos, 48. Maries Cave, 49. Limenaria, 50. Kastri.***

at a large number of tell sites (i.e. Polystylo, Mikro Souli, Podochori, Toumba etc., see Appendix D in *Grammenos 1991*).

Most of the East Macedonian settlements are located in the well-drained fertile plains of the region. Common to all sites is their proximity to a water source, which is usually a river or lake (*Andreou et al. 1996)*. Since most of the excavations are small-scale operations, information on the layout of the settlements is scarce. An exception to this is the site of Dikili Tash, where a number of parallel, rectangular houses with internal ovens and platforms, an abundance of pots, stone and bone tools have been revealed by the recent excavations (*Koukouli-Chryssanthaki et al. 1996b*). The houses, separated by small lanes, are dated to the LN II period. A very clear picture of the organisation of the Neolithic household is also offered by the architectural remains of the LN I strata of the same site (*Koukouli-Chryssanthaki et al. 1996b; Treuil and Tsirtsoni 2000*). Furthermore, important data on the organisation of a Middle Neolithic settlement have been obtained through the recent excavations at the site of Limenaria (*Malamidou and Papadopoulos 1993*).

A characteristic of the Neolithic pottery from East Macedonia is the great variation of painted vessels. Late Neolithic pots in particular, when compared with contemporary material from Central or West Macedonia show a much greater variation and elaboration in the colour of the motifs and the surface of the vessels, as well as in the decorative patterns and the forms of the pots (*Grammenos 1997*). Despite this, the methods of surface treatment have received little attention. The usual assumption is that similar results can be obtained by similar technological processes. This assumption is questioned by the data discussed in the present work. In fact, study of the ceramic material from a number of East Macedonian sites has shown that a great variety of raw materials and techniques, some of which are rather complicated, were used by the Neolithic potters to decorate their pots.

Data for the present work were obtained through the macroscopic examination of a large sample of ceramics, the microscopic examination of 51 thin sections, the refiring of 75 sherds, and the chemical analysis of 9 samples[1]. The presentation of the data will follow a chronological order: material from the Late Neolithic I phase will be presented first, followed by the LN II data.

## LATE NEOLITHIC I

During the early part of the Late Neolithic (LN I) a whole new range of painted wares emerge. These vessels, amounting to 10%–12% of the ceramic assemblage, are mainly painted with a brownish pigment on a buff-coloured surface. Despite their rather limited appearance, vessels display a great variation in the colour of their pigment, background and fabric. Thus a number of wares have been identified by researchers to classify the material: brown-on-cream, brown-on-buff coloured surface and brown-on-white slip (*Keighley 1986; Grammenos 1997*). Except for

1 Chemical analysis and examination with the Scanning Electron Microscope (SEM) was conducted by Dr. V. Kilikoglou (Laboratory of Arcahaeometry Institute of Material Science NCSR "Demokritos", Athens)

the vessels decorated with dark pigment on a clear-coloured surface there are, in minor quantities, pots decorated with red or purplish-brown pigment on a red-coloured background (orange-on-orange and red/brown-on-red ware respectively: *Keighley 1986. 353*). Still, these wares are considered very general and many sherds could not be assigned to any category, due to their colour variation (*Keighley 1986. 354-357; Grammenos 1997.Cat. 12 in Tab. 1*). It will be argued in the following paragraphs that this polymorphy of painted vessels results from the variety of techniques and raw materials used by the potters to decorate the pots.

Another criterion used by researchers for the classification of the material is the decoration of the vessels. Fragments with very thin linear motifs were assigned to the brown-on-cream and red/brown-on-red ware (Akropotamos style: *Keighley 1986.352-353; Grammenos 1997.Categs. 2,6,7,8,9 in Tab. 1*). Motifs are in narrow lines, about 3-4 mm wide, and there is a rich display of spirals, concentric circles, parallel lines and ladder elements (*Keighley 1986. 352*) (Fig. 2). All examples are made from fine-textured fabrics. Brown-on-buff or brown-on-white sherds are reported as being decorated exclusively with motifs of broad thickness (6-9 mm). Among the design characteristics are thick wavy lines, parallel lines, concentric circles, thick arcs etc. (*Keighley 1986.354-356*) (Fig. 3). The fabric of these vessels can vary from fine to medium-coarse textured.

Recent research, however, has shown that the distinction of the vessels according to the width of their motifs is over-simplistic and conveys a biased picture of the material (*Tsirtsoni 2000*). Vessels can have their entire surface decorated either with bold or thin-lined motifs (Figs. 2.1, 5). In other cases, however, a single vessel can combine both types of decoration (Fig. 2.2). In the present work, the term "Akropotamos style" will be used to describe the thin lined motifs, but it should be kept in mind that the results of the vessels with Akropotamos style decoration may be applicable to vessels with bold motifs and vice-versa.

## Vessels decorated with a brown pigment on a grey/buff-coloured background

Two elements are of importance for the decoration of these vessels. Firstly, the colour of the pigment, and secondly, the colour of the background bearing the decoration.

The pigment is basically dark brown, but colours vary from light brown to black. Research for the present work has shown that in the production of the dark colour of the decoration two different methods were used:

α. Vessels were painted with an iron-based pigment that acquired a dark colour by being fired in reducing conditions (iron reduction technique). This complex technique can be summarised as follows: during firing, both the decoration and the body of the vessels turn black as they are fired in a reducing atmosphere. Under these conditions the sintered, iron-based pigment will retain the dark colour, in contrast with the body which, by being more porous, is re-oxidised (*Farnsworth and Simmons 1963.391*). It is the first time that this technique has been identified in Neolithic East Macedonian pottery.

β. Vessels were painted with a manganese-based pigment, a material that can produce a dark colour irrespective of firing conditions. In comparison to the iron reduction technique, the use of a manganese-based pigment is a rather simple technique.

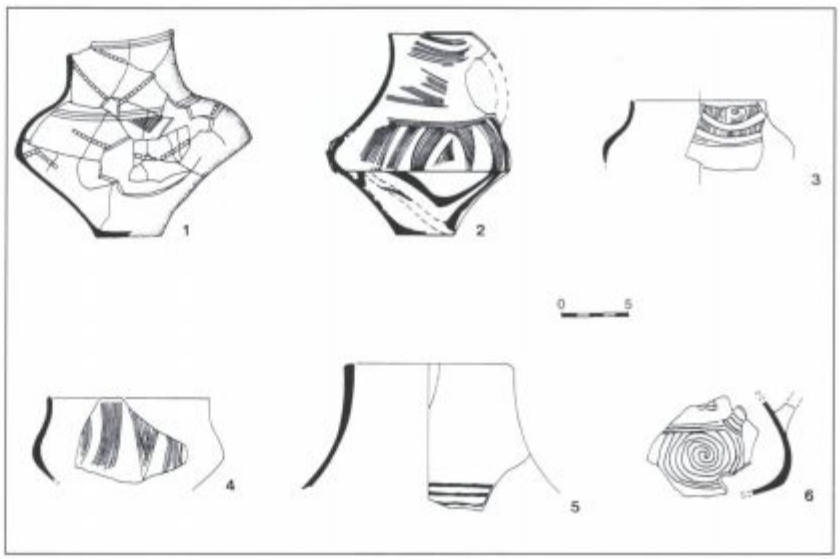


***Fig. 2. Late Neolithic Painted Vessels: 1. Brown-on-cream from Dimitra (*Grammenos 1997.Fig. 10.88*); 2. brown-on-cream from Dikili Tash (*Tsirtsoni 2000.Fig. 4*); 3. red/brown-on-red from Sitagroi (*Keighley 1986.Figs. 11.12, 8*); 4. red-on-red from Dimitra (*Grammenos 1997.Fig. 21.320*); 5. brown-on-cream from Sitagroi (*Keighley 1986.Figs. 11.12, 6*); 6. red-on-red from Dimitra (*Grammenos 1997.Fig. 21.313*).***

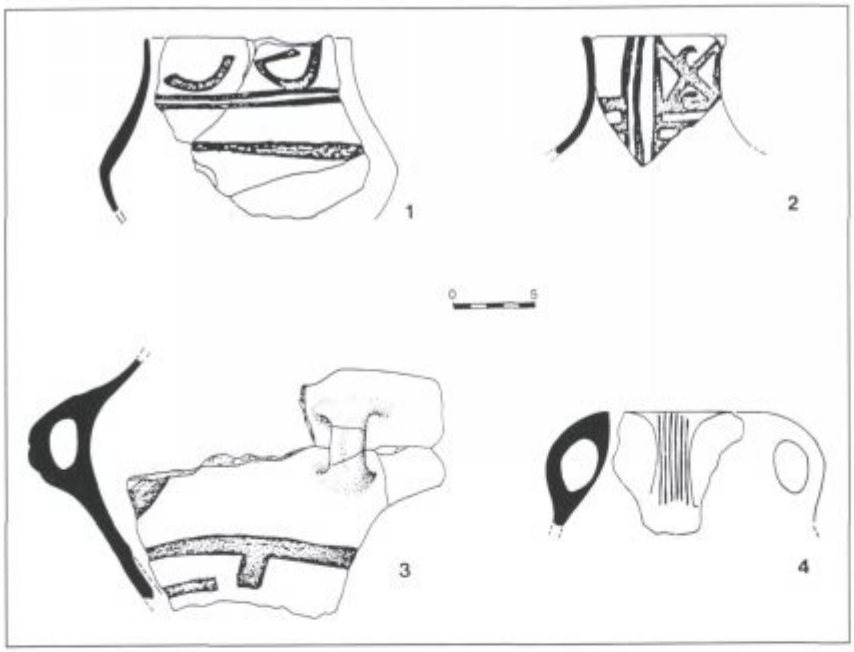


***Fig. 3. Late Neolithic Painted Vessels: 1. brown-on-grey from Dimitra (*Grammenos 1997.Fig. 20.304*); 2. brown-on-grey from Dimitra (*Grammenos 1997.Fig. 20.308*); 3. brown-on-grey from Dimitra (*Grammenos 1997.Figs. 21.310*); 4. vessel decorated with a post-firing organic coating from Dimitra (*Grammenos 1997.Fig. 20.306*).***

As for the whitish background, various raw materials such as kaolin or calcareous based slips were used by the early Late Neolithic potters (see the section below). In other cases, vessels remained unslipped, but acquired a buff-grey coloured surface through the control of the firing atmosphere.

### *Iron-based pigment*

We can begin our presentation with the data on the iron reduction technique. The data were obtained through refiring tests, chemical analysis and macroscopic examination of the material.

The refiring of 30 sherds with brown motifs (20 Akropotamos-style, 10 with bold motifs) was carried out in a Labertherm furnace in an oxidising atmosphere from 25°C to 900°C (Tab. 1). After refiring, the bold motifs (Munsell soil colour notations 10YR 3/1; 10YR 3/2) of four sherds from the sites of Mikro Souli and Podochori acquired a clear red colour (Munsell soil colour notations 2.5YR 4/8: see Fig. 4). In the remaining sherds the motifs retained their dark colour. According to the characteristics described above, it appears that the decoration of the four vessels from Mikro Souli and Podochori was produced through the iron reduction technique. The change of colour, from brown to red, indicates that the iron-based pigment was not thoroughly reduced. For a successful result, two variables must be controlled by the potters: first, the quality of the pigment, and second, the firing conditions.

The preparation of fine-textured pigments is very important because coarse and grainy pigments are difficult to vitrify (*Aloupi and Maniatis 1990*) and during the oxidising phase of firing they will re-oxidise more easily than the fine textured ones. At the same time, the pigment must be applied in thick layers, since such layers sinter more effectively than the thin ones (*Jones 1986. 765*). Equally important for the vitrification of the pigment is the control of firing conditions, mainly temperature and duration of firing. The duration of reducing conditions is also of great importance. Analysis of two of the refired sherds (one from Mikro Souli and one from Podochori) showed that their pigment is fine textured, but it remained porous since it was thin (5–10 μm), and the firing temperature (800°C–850°C) and perhaps the duration of firing were not enough for its complete vitrification.

As for the twenty-six sherds retaining their dark motifs after refiring in oxidising conditions, the results of the refiring test are not conclusive. The sherds were either decorated with a manganese-based pigment, or with a thoroughly reduced ferruginous material.

Mikro Souli and Podochori are situated in the western provinces of East Macedonia, not far from Dimitra. Macroscopic examination of the painted vessels from Dimitra indicates that the iron reduction technique was also used there: quite often the brown motifs of brown-on-buff or brown-on-white pots are, in places, red. At Dikili Tash, a site further east, similar features have been noticed both on vessels with broad motifs (Fig. 5) and on those with the Akropotamos-style decoration. Since manganese based pigments do not shade to red or brown (*Farnworth and Simmons 1963.394*), it has to be concluded that the vessels were decorated with an iron-based pigment fired in reducing conditions.

The discoloration of the motifs can be attributed to local draughts of air that did not permit the maintenance of fully reducing conditions. The non-uniform thickness of the pigment material may also be responsible for such features. Motifs, mainly the bold ones, are quickly executed, and often the relief of the decoration is varied on a single vessel. As already mentioned, thicker layers can retain their colour better than thin.

### *Manganese-based pigment*

The brown-black pigment was also produced through the application of manganese-based materials. $MnO_2$ was identified by the chemical analysis of four sherds with Akropotamos style motifs (two from Dikili Tash and Mikro Souli, respectively: see Tab. 1). Similarly, Gardner has identified the brown pigment of the Akropotamos style sherds from Sitagroi, as an iron oxide-manganese based material (*Gardner 1980. 109*). The use of manganese pigment for the production of the bold brown-black motifs of the East Macedonian sites is not documented, but on the basis of the discussion in the previous section it cannot be excluded.

Pure manganese coatings do not ordinarily contain sufficient fluxing materials to sinter or vitrify, and so if they are applied to the surface of the vessels they will be fugitive. But the brown-black motifs of the Neolithic vessels have been permanent. According to Shepard (*1976.42*) the successful bonding of a manganese pigment could be due to the following reasons: (1) polishing, (2) the presence of impurities, mainly clay, (3) protection by a post-firing coat (lacquer-like substances or resins of various plants). The use of a post-firing, protecting coat is not reported from any Neolithic site. The burnishing lustre of the Late Neolithic I vessels varies from good to poor. It seems, however, that the durability of the dark pigment of the vessels should be attributed mainly to the presence of clay. The sherds analysed in the present study (including the LN II black-on-red ware: see section below) were painted with an extremely fine-textured material containing $MnO_2$, $Fe_2O_3$ and high amounts of alumina (that is, a clay-based material). Although iron was most probably naturally present in the clay used for the preparation of the pigments (i.e. a ferruginous clay), manganese-ore had to be added by the potters.

| Sample studied macroscopically | Thin sections | Refired sherds | Chemical analysis and SEM |
|---|---|---|---|
| Akropotamos LN | | 7 (5 Akropotamos 2 Bold br. decor) | |
| Dikili Tash LN | 31 (23 undecorated 2 Bl/red 1 Bl/white 5 Graphite) | 17 (5 Akropotamos 2 Bold br. dec.) 9 Graphite 1 "Bitumen" | 3 (2 Akropotamos 1 Br/white) |
| Dimitra LN | | 4 (2 Bl/red 2 Graphite) | 1 Bl/red |
| Galipsos LN | 2 Bl/red | 6 (2 Akropotamos 1 Polychrome) | |
| Kalambaki LN | 4 (2 Bl/red 2 Graphite) | 5 (3 Bl/red 2 Graphite) | |
| Kalifitos LN | | 1 Graphite | |
| Mikro Souli LN | | 2 Bold br. decor | 3 (2 Akropotamos 1 Bold br decor) |
| Nea Bafra LN | 2 Bl/red | 5 (2 Bl/red 3 Graphite) | 1 Bl/red |
| Podochori LN | | 2 Bold br decor | 1 Bold br decor |
| Promachon-Topolnitsa LN | 10 (3 Akropotamos 1 Graphite 1 "Bitumen" 2 incised décor 1 black topped 2 undecorated) | 6 (3 Graphite 3 "Bitumen") | |
| Sitagroi MN and LN | | 10 Graphite | |
| Toumba LN | 2 Bl/red | 10 (5 Akropotamos 2 Bold br decor 2 Bl/red 1 bichrome) | |

***Tab. 1. The ceramic material and the analytical methods employed in the present work.***

### *Buff-grey background*

The background of the LN I painted vessels ranges in colour from grey-cream, white, very pale brown or buff. Such colours can be produced either by the application of a slip or by controlling the firing conditions, both of which methods were often used in combination by the East Macedonian potters to produce their painted pots.

The clay fabric of the Akropotamos-style vessels is cream-grey, very light brown, or reddish-yel-

***Fig. 4. Sherds from Mikro Souli and Podochori decorated by the iron reduction technique. After refiring, in an oxidising atmosphere at 900°C, the brown motifs acquired a clear red colour.***

low. In the first case, the motifs appear to have been applied to an unslipped, carefully burnished surface. Vessels made from very light brown, or reddish-yellow coloured materials usually have a thin, cream-beige slip. In most of the cases the slip is worn out, being preserved only in small spots. Gardner, in her analysis of the Sitagroi material, identifies this white layer as kaolin slip (*Gardner 1980.109*). Twenty Akropotamos-style sherds with cream-grey and very pale brown fabric (the colour of surfaces and fabric ranging from Munsell soil colour notations 10YR7/2 and 7/3, 7.5 YR 7/2 to 10YR 6/3) were refired, for the present study, in oxidising conditions at 900°C (see Tab. 1 and the previous section on iron deduction technique). After refiring, their fabric acquired a reddish-yellow colour (Munsell soil colour notations 7.5 YR 7/6 and 6/6 and 5YR 6/8) indicating that the grey, very pale brown fabric was produced by firing the pots in conditions that did not permit their full oxidation. Furthermore, refiring showed that all sherds had a thin, whitish, matt slip, except for two sherds which were only burnished. Similar results were obtained after refiring ten sherds with bold brown motifs on a buff, very light brown background. All sherds acquired a clear reddish-yellow colour. Five were covered with a thin slip, which macroscopically appears similar to that applied on the Akropotamos-style vessels. Four sherds with Akropotamos-style decoration (two from Dikili Tash and two from Mikro Souli) were analysed by V. Kilikoglou. Three were covered with a calcareous-rich slip, ranging in thickness from 10–20 μm. The fourth calcareous slip was thicker, reaching 30–40 μm.

The whitish slip, even when well preserved, is usually thin and cannot conceal the reddish colour of the fully oxidised body. It seems then that despite the use of a slip, firing the vessels under conditions which did not permit their full oxidation was important for the successful production of a cream-grey, very light brown background. Chemical analysis of four of the refired sherds showed that the pigment used for their decoration is manganese-rich (see previous section on manganese-based pigments). Thus, firing in non-oxidising conditions was not aimed at the production of the dark motifs, but at the production of the desired background of the decoration.

***Fig. 5. Brown-on-buff vessel from Dikili Tash. Both motifs and background are, at places, red. This discoloration can be attributed to local drafts of air that did not permit the maintenance of fully reducing conditions.***

### Vessels decorated with a red pigment on a red-coloured background

Pots with red, red/brown motifs on a red coloured surface (orange-on-orange and red/brown-on-red wares) are present, although in minor quantities, in Late Neolithic I levels (Figs. 2.3, 4, 6). For the production of the red motifs an iron-based pigment was used which acquired a clear red colour by firing in oxidising conditions. Under the same conditions the fabric of the vessels turned red and was used as the background of the decoration.

Vessels with red/brown (orange-on-orange and red/brown-on-red wares) and dark brown decoration (brown-on-cream, brown-on-buff and brown-on-white wares) have comparable motifs (thin or bold lines), similar forms and fabrics (*Keighley 1986. 353; Grammenos 1997.39–41*). They differ mainly in the colour of their decoration. Based on this, someone could propose that the red/brown motifs were the result of firing accidents: potters were aiming at the production of brown-on-buff effect, but since they could not control the firing conditions, produced the red-on-red vessels. Although this may be the case for a few vases, it seems that the clear red colours of most of the red, red/brown-on-red vessels should not be attributed to firing accidents.

Sometimes, iron-based and manganese-based pigments were combined by the potters to produce a polychrome effect (red and black motifs on a red background). Such vessels are rather rare: a few sherds have been found at Dimitra, Toumba, Galipsos, and Promachon-Topolnitsa (*Grammenos 1997; Koukouli et al. 1996a*). Some of these sherds (from Dimitra, Toumba and Galipsos) were examined under stereoscopic microscope. In all cases the red and black pigments appear to have comparable relief. This seems to exclude the use of the iron reduction technique, in which, by varying the thickness of an iron-rich pigment and changing from a reducing to oxidising atmosphere, a dichromatic effect can be produced (*for a theory on this see Jones 1986.765*). Support for this conclusion lies in the fact that after refiring (in the same conditions as the vessels with brown-black motifs) the motifs of two sherds from Toumba and Galipsos did not lose their original colours.

### Vessels decorated with an organic material applied after firing

Such vessels have been found in the recent excavations of Promachon-Topolnitsa, a site on the Greek-Bulgarian border (*Koukouli et al. 1996a.753*). The decoration, which consists of stripes, wavy lines or groups of parallel lines, was executed with a soft, thick, black-coloured material, which adheres well to the surface of the pots.

Three decorated sherds were refired, in an oxidising atmosphere at 320°C for 30 minutes. After firing, the motifs were still present, but assumed a very pale grey colour. After firing at 450°C for 30 minutes, the decoration disappeared (Fig. 6; *Yiouni et al.1994*). Since this temperature is low (far below the temperature-range at which ceramics are fired), it can be concluded that the black colouring material was an organic coating applied after the original firing of the vessels. Macroscopically, the material appears as bitumen, but this has to be verified by further analysis[2].

***Fig. 6. Refiring of sherds from Promachon-Topolnitsa decorated with an organic coating. In the clear coloured chips of two of these sherds the organic material disappeared after refiring at 450°C, for 30 minutes. The pink-red slip of the third sherd was not affected by the firing.***

2 Bitumen is either an originally mineral pitch or any of several hard or semisolid materials obtained as asphaltic residue in the distillation of coal tar, wood tar, petroleum etc.

Similarly decorated vessels were also identified among the ceramic material from two other settlements: Dikli Tash and Dimitra (Fig. 3.4; *Yiouni 2001*). These are the first documented instances for the use of this technique in Macedonia. It is very probable, however, that this practice was more widespread. Sherds from the Late Neolithic Servia (in West Macedonia) are decorated with a colouring material which, according to the excavator's description, has the characteristics of an organic coating applied after firing (*Yiouni 2001*). It should also be pointed out that the scarcity of this type of decoration might not reflect the original distribution of this ware. Taphonomic processes or the vigorous cleaning of the sherds can easily destroy the post-firing application.

Vessels with similar decoration have also been found at two Bulgarian settlements situated north of Promachon: Damyanitsa and Balgarcevo (20 and 80 km respectively to the north: *Grabska-Kulova 1993; Pernicheva 1995*). Analysis of one sherd from Damyanitsa showed that the colouring material was bitumen (*Wagner and Graf 1993*). Deposits of bitumen exist in the area around Damyanitsa, but Wagner and Graf cannot exclude the possibility that the material was obtained as a residue in the distillation of organic substances.

**Firing of Late Neolithic I painted pottery**

According to the discussion so far, it is clear that firing played a major role in the final appearance of the LNI painted vessels from East Macedonia. By controlling the firing conditions, potters could modify the colour of the motifs and/or the background of the decoration. In the present section we will try to reconstruct the firing techniques used by the potters on the basis of the macroscopic examination of the material, the estimated firing temperatures of the analysed sherds and the available remains of firing structrures.

Starting our discussion with the vessels decorated with brown motifs, it is easy to conclude that these vessels were not fired in open firings. In such a procedure the positioning of fuel and vessels before firing can affect the flow of air (*Rye 1981.98*), but during firing it is very difficult to control the atmosphere and to change it at will from oxidising to reducing. It is true that the control of the firing conditions by the LN I potters was not very strict and the changes in atmosphere were not always successful, but still the overall appearance of the vessels is not compatible with an open firing.

So vessels were fired either in pits (where fuel and vessels are not separated), or in kilns (where fuel and vessels are separated). When pits are simple depressions in the ground they do not offer any significant advantages compared to open firings. More sophisticated structures, however, such as a circular wall or a three or four-sided enclosure, are known ethnographically. The fuel and vessels are often placed in alternating layers, and air access may be provided by holes in the walls at or near ground level and by passages let through the setting (*Rye 1981. 98*). Thus, pits may achieve higher temperatures and sustain them longer than open firings. Moreover, pits provided with an air inlet offer better control since air can be excluded easily during firing (*Shepard 1976.216–217*). In a kiln firing, of course, the firing atmosphere and the rate of heating can be controlled more effectively.

Macroscopic examination of the painted vessels indicates that they were, most probably, fired in pits. The basic indication for such a firing is the discoloration of their motifs. The change in colour, on a single vessel, from brown to red is compatible with a pit firing because it suggests that the firing conditions were not strictly controlled, as would have been expected in a kiln firing. Moreover, the painted vessels have often grey-coloured, smoked areas, a feature suggesting that, during firing, the vessels were not separated from the fuel. The available estimated temperatures of the analysed sherds are also within the range attained by pit firings. As can be seen from Table 2, the mean temperature is 850°C, although some vessels were fired at even higher temperatures (1000°C–1100°C).

So far, the discussion has been restricted to the data obtained from the analysis of fired ceramics. But what do we know about the firing structures themselves? An oven from Dikili Tash, similar in shape to the domestic ovens from the site, has been identified as a structure used for firing vessels since it contained a number of pots mixed with charcoals (*Seferiades 1983.643, Fig. 6*). In this case, vessels and fuel were placed in the same chamber. Re-examination of the data, however, and comparison with the architectural remains from the recent excavations of the site question this interpretation (*Tsirtsoni 2000*). According to the new interpretation, it appears that the vessels were not standing on the floor of the oven, but on a near-by clay platform (a common feature accompanying the ovens at the site of Dikili Tash). Another structure that could have been used for firing pots was found at Krioneri. A cylindrical

| Site/Ware | Temperature Range (°C) | Scientific Method of Estimation |
|---|---|---|
| Dikili Tash 1 Akropotamos-style | 800–900 | Scanning Electron Microscope (V. Kylikoglou) |
| Dikili Tash 2 Akropotamos-style | 1100 | " |
| Mikro Souli 2 Akropotamos-style | 1050–1080 | " |
| Mikro Souli 3 Akropotamos-style | 800–900 | " |
| Mikro Souli 1 Bold. Br. Décor | 850 | " |
| Podochori 1 Bold. Br. Décor | 800–850 | " |
| Dimitra 5 sherds of Akropotamos-style | 750–850 | X-Ray Diffraction (Kessissogloy and Mirtsou 1997) |
| Dimitra 2 sherds of Akropotamos-style | 900–950 | " |

***Tab. 2. Firing temperatures of Late Neolithic I painted vessels.***

pit (1 meter in diameter), with an opening at the side (0.40 m wide), was dug by the Neolithic inhabitants at the edge of the settlement (*Malamidou 1997.515, Fig. 5*). It contained some undecorated sherds mixed with ashes and charcoal. The interior of the pit was burned, whereas the opening was blocked with stones and earth. Although the contextual data are not fully conclusive for the use of this pit for firing pots (i.e. absence of whole vessels inside the pit and lack of pottery wasters in the surrounding area), theoretically it could have provided the conditions needed for the reduction of the iron-based pigments.

The contemporary vessels decorated with red motifs (orange-on-orange and red/brown-on-red ware) could also have been fired in similar structures, although an open firing cannot be excluded. The same can be proposed for the vessels decorated with an organic coating applied after firing.

## LATE NEOLITHIC II

Vessels painted with a dark brown or red pigment (brown-on-cream, brown-on-buff, brown-on-white, orange-on-orange and red/brown-on-red wares) continued to be produced, although in decreasing frequency, in Late Neolithic II (Tab. 3). This phase, however, is characterised by the presence of two distinctive wares: the black-on-red and graphite decorated vessels.

Black-on-red ware is characteristic of the East Macedonia, since it is restricted mainly to this region. Appearing sporadically in LN I (*Grammenos 1997.Tab. 1; Keighley 1986. 358*), black-on red vessels are more common in LN II (Tab. 4). In Central and West Macedonia black-on-red vessels are sporadically present (*Grammenos 1991.126*). In Thrace, this ware is found at the settlements of Paradeisos (*Hellstrom 1987*) and Paradimi (*Bakalakis and Sakellariou 1981*), being rare at Makri (*Efstratiou 1991.600*).

Graphite, the mineral form of carbon, has an early appearance in the East Macedonian region. Grey lustre and grey-channelled wares are present in the late Middle Neolithic and early Late Neolithic (Sitagroi I and II levels). These vessels are covered by graphite, which produces a smooth, glittering and "soapy" surface (*Keighley 1986.346*). Graphite, painted and excised with graphite (vessels combining painted and excised motifs) are characteristic of the LN II levels. They are present at all East Macedonian settlements, increasing in frequency as we move eastwards. At Dimitra, for example, such vessels amount to 5%–17% of the decorated pottery, but they are far more common at Sitagroi and Dikili Tash, where they comprise 75% or more of the decorated pottery (Tab. 4). In Thrace, graphite-decorated

| Site/Ware | Temperature Range (°C) | Scientific Method of Estimation |
|---|---|---|
| Dimitra 8 Bl/Red sherds | 900–950 | X-Ray Diffraction (Kessissogloy and Mirtsou 1997) |
| Dimitra 1 Bl/Red sherd | 750–850 | " |
| Dimitra 1 1 Bl/Red sherd | 850–950 | Scanning Electron Microscope (Kilikoglou) |
| Dikili Tash 3 1 Bl/White sherd | 1000–1100 | " |
| Nea Bafra 1 1 Bl/Red sherd | 850–950 | " |

***Tab. 3. Firing temperatures of black-on-red and related Late Neolithic II painted vessels.***

vessels are common at Paradeisos and Paradimi, but rare at Makri (*Efstratiou 1991.600*). Only sporadic examples are reported from a few Central Macedonian sites (*Heurtley 1939.133, no. 128–9*). In contrast to the black-on-red pottery, which has a very limited spatial distribution, graphite decorated vessels are characteristic of the Gumelnitsa-Karanovo VI cultural complexes of Bulgaria and Romania (*Demoule 1993.382*).

**Black-on-red**

The black motifs were painted either on the clear red, fully oxidised surface of the pots, or on an iron-based slip. The complex decoration of the vessels has been divided into two styles, I and II. Style I, displayed on a wider range of vessels, consists of various curvilinear and rectilinear patterns, various filled motifs (rectangles, triangles) and combinations of all three (*Evans 1986.400*) (Figs. 7, 8). Style II consists of broad curvilinear lines which often give a floral appearance (Fig. 9). Black-on-red vessels are usually open, large-sized pots with rounded or flaring walls. Jars are also present.

All the analyses so far show that the black decoration was executed with a manganese-based pigment. This material decorated the vessels from Sitagroi and Dikili Tash (*Gardner 1980.123; Courtois in press*). Similarly, manganese has been identified in the chemical analysis of two black-on-red sherds from Nea Bafra and Dimitra (Tab. 1).

During the macroscopic examination of the pottery from East Macedonia an interesting feature was noticed among the black-on-red pottery from Dimitra and Krioneri. Black-on-red vessels sometimes have a milky-white, transparent layer, which was applied on top of the painted decoration. Traces left on the surface of one sherd from Dimitra which was not carefully covered with this material, indicate that the transparent slip was wiped in various directions with a soft material (probably cloth). Furthermore, whereas the white layer is micaceous, both the red slip and the black pigment are free from mica. Chemical analysis of this sherd, showed this thin (3–5 μm), fine-textured layer was applied before the firing of the vessel.

It is the first time that such a practice has been reported for a Greek Neolithic ceramic material. Perhaps it was restricted to sites near the river Strymon (both Dimitra and Krioneri are situated there), since it seems to be absent from settlements further east (i.e. Dikili Tash). What are the reasons for the application of this extra layer? Colour contrast and the reduction of porosity should be excluded as possible explanations as the material was applied to slipped and painted surfaces. Nor can it be proposed that it was used to protect the black pigment, since chemical analysis of the sherd from Dimitra showed that the colouring material is not a pure manganese coating, but a clay-based solution enriched with manganese. One probable explanation is that, by applying this extra layer, the potters could rapidly produce a lustrous surface. Black-on-red vessels are often open, large-sized pots. Burnishing these pots is more time-consuming than simply covering their surface with a liquid suspension.

**Graphite decorated pottery**

Graphite is also applied on large vessels with flaring or carinated walls (*Evans 1986.398*). Closed pots, often smaller in size, were also painted with graphite. The decorative style varies from rather simple lines to various complicated combinations of straight or curvilinear motifs: spirals, meanders, circles, triangles and lozenges (*Evans 1986.397*) (Figs. 10.1, 3, 4). In the vessels excised with graphite, painted motifs are combined with excised linear patterns filled with white or red-coloured paste (Fig. 10.2).

Graphite is a soft, grey, laminar form of pure carbon occurring in high-grade metamorphic rocks as a final product of the carbonisation of organic substances. Due to its silvery appearance graphite pigment can be relatively easily recognised by macroscopic examination. So far, this material has been identified, by X-ray diffraction, on specimens from Karanovo in Bulgaria, Dikili Tash and Sitagroi in East Macedonia

| Site | Graphite Painted (% of decorated pottery) | Black-on-Red (% of decorated pottery) | Vessels with dark brown motifs (% of decorated pottery) |
|---|---|---|---|
| Dikili Tash | 75% | 1–5% | – |
| Sitagroi | 79% | 21% | – |
| Paradeisos | 90% | 10% | – |
| Krioneri | 15% | 60% | 15% |
| Dimitra | 5–17% | 28–58% | 52–9% |

***Tab. 4. Relative amount of black-on-red and graphite decorated vessels. (*Data from Demoule 1993; Evans 1986.Tab. 2.1; Hellstrom 1987; Malamidou 1997; Grammenos 1999.Tab. 1*).***

(*Jones 1985.768, Tab. 9.6a*). In her study of the material from Sitagroi, Gardner concluded that two different methods were used for the execution of the decoration: graphite was either rubbed on the surface of vessels (like a crayon), or it was applied, with a brush, in a liquid suspension (*Gardner 1980.124; Evans 1986.397*). These differences must have been dictated to a great extent by the nature of the raw material. If it is pure, graphite can be used as a crayon. Otherwise, it has to be refined before it can be used for decorative purposes (*Yiouni 2001*). A refiring test carried out for the present study indicates that pure graphite was rarely used by Neolithic potters. Thirty sherds with graphite decoration from a number of East Macedonian sites (Tab. 1) were refired at 850°C, in an oxidizing atmosphere. The maximum temperature was retained for 30 to 60 minutes. Apart from two sherds (both from the site of Promachon) unaffected by the firing, in all other cases the pigment appears as a white residue, occasionally preserving some metallic sheen. Since graphite is burned at rather high temperatures, it seems that the colouring material of the refired vessels was not pure graphite.

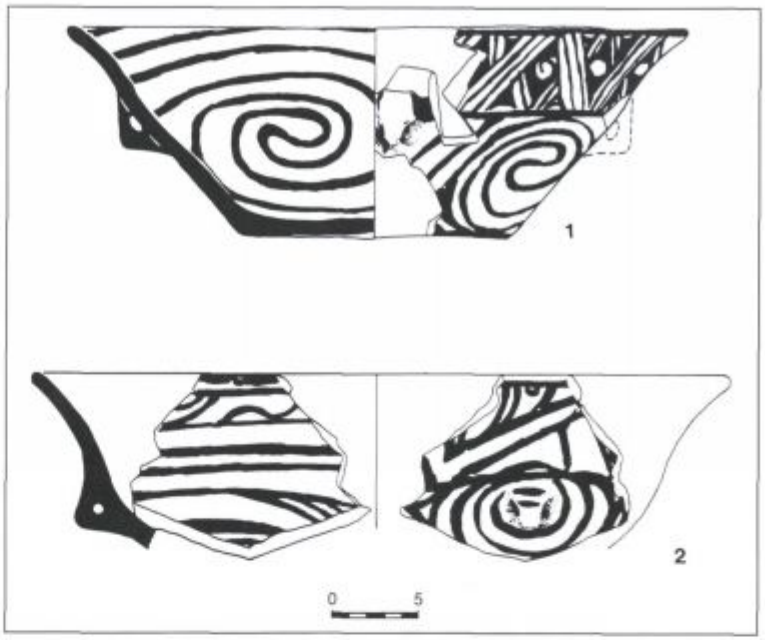


***Fig. 7. Black-on-red vessels from Sitagroi (*Evans 1986.Fig.12.8*).***

Graphite decoration occurs mainly on black or dark brown-coloured surfaces (*Evans 1986.397; Seferiades 1983.653*). Thus, the silver colour of the pigment is more pronounced. The dark coloured background was not achieved by the application of a slip, but through the control of firing conditions. This conclusion is based on the following observations: the black colour of the surface(s) extends deep into the vessel's cross-section; in other cases the entire cross-section is dark. Furthermore, after refiring in an oxidising atmosphere, all sherds (30) acquired clearer surfaces and cross-sections.

The linear patterns of the vessels excised with graphite are filled with a white or red-coloured paste. At Sitagroi both calcium carbonate and kaolin were used as a white infill, the red paste being ochre (*Gardner 1980.128*). Potters from Dikili Tash were using a paste rich in calcium oxide (CaO), sometimes containing white mica (*Courtois in press*). These materials were most probably applied after the original firing of the vessels (*Gardner 1980; Yiouni 2001*).

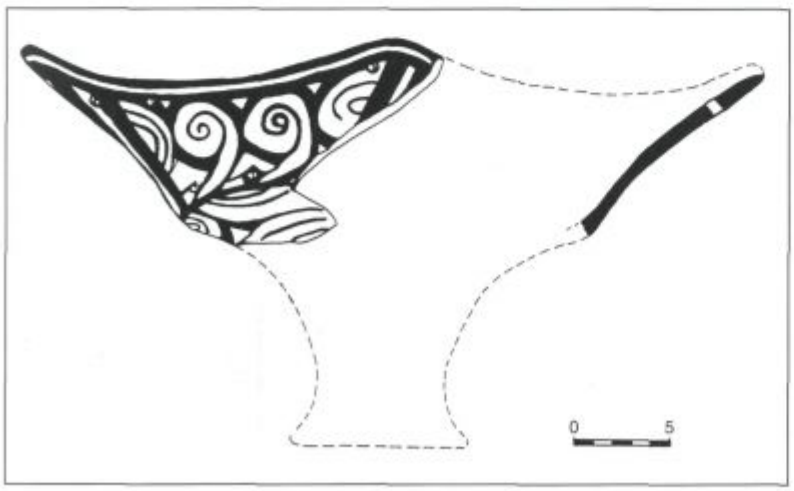


***Fig. 8. Black-on-red vessel from Dimitra (*Grammenos 1997. Fig. 30. 457*).***

So, the production of graphite-decorated vessels required a combination of various techniques. Extreme examples of this practice are the pots combining graphite painted patterns, with excised motifs, the production of which can be summarised as follows: first the potters painted the motifs, and with a sharp tool produced the excised patterns. The painted sections of the pots were burnished. During firing, the vessels acquired a dark-coloured background, and after firing, the paste filling the excised motifs was applied.

## The firing of Late Neolithic II painted vessels

In her study of the Sitagroi material Gardner, distinguished two groups (Type I and II) of graphite decorated ware (*Gardner 1979*). Type I is found north of the Rhodope Mountains, and Type II, south of the mountains, on the Drama Plain in east Macedonia. According to Gardner, pots from the southern region (Type I) were fired at rather high temperatures (1000°C or even more, according to refiring tests) and the quality of their pigment is very good (grainy, with a crystalline metallic sheen). In contrast, vessels found in Bulgaria were painted with a thin, fugitive pigment, and were low fired (lower than 750°C, according to Garner's refiring tests).

Subsequent research on graphite-decorated vessels from Greek Neolithic sites does not support Gardner's conclusions. The estimated firing temperature of two sherds from Dikili Tash is lower than 750°C (*Maniatis and Tite 1981.57–9*). Both vessels were fired in non-oxidising conditions. Kessissoglou and Mirtsou reached the same results after the refiring of a number of sherds from Dimitra (*Kessissoglou and Mirtsou 1997.89, Tab. 1*).

As mentioned above, thirty sherds from a number of east Macedonian Neolithic sites were refired by the author. In most cases the graphite pigment was burned off when fired at 850°C, or even at lower temperatures. The fabric of the sherds was also affected, since seven sherds (from Nea Bafra, Sitagroi and Dikili Tash) were vitrified. Graphite-decorated vessels were most probably manufactured from non-calcareous clays and, in contrast with the refiring test, were originally fired in a non-oxidising atmosphere. Since the firing of non-calcareous clays in reducing conditions lowers (by 50°C) the temperatures at which vitrification starts (*Maniatis and Tite 1981.61*), it is quite probable that some of the sherds were originally fired at temperatures lower than 850°C. Thus the analyses of the graphite-decorated pots suggest that these vessels were regularly fired in a non-oxidising atmosphere at rather low temperatures. A pit firing could facilitate the production of black coloured surfaces because of the ease of excluding air. It should be pointed out, however, that open firing of the vessels cannot be excluded.


***Fig. 9. Black-on-red vessel from Sitagroi (*Evans 1986.Fig. 12.9.3*).***

Instead, open firing can easily be excluded for the contemporary black-on-red ware. These vessels have clear red-coloured surfaces and cross-sections. When tapped, they produce a clear, crystalline, sound. These characteristics indicate that the pots were thoroughly fired in oxidising conditions at rather high temperatures. Indeed, the estimated firing temperature from a number of analysed sherds is around 900°C (Tab. 3). An interesting feature of the black-on-red vessels is the rarity of smoked areas on their surfaces. According to these characteristics, an open firing can be excluded, but is it possible to propose that these vessels were fired in kilns?

Kilns represent a major advance toward ensuring success in firing pots. Updraft kilns are simple, enclosed firing chambers in which the heat moves upward from underneath the pots and is then vented outward. While many types of complex kilns exist, simple ones used by traditional potters usually have open tops through which the kiln is loaded. The maximum temperatures these kilns attain usually range from 900°C to 1000°C (*Rice 1987.160*). Apart from sustaining temperature as long as is needed, the other main advantage of a kiln firing is that both the atmosphere and the rate of temperature rise can be controlled (*Rye 1981.98*).

The remains of structures that could be interpreted as kilns are absent from the Greek Neolithic sites. Taking into consideration the limited scale of the excavations, this absence is not a sound argument against the existence of kilns. Turning to the fired vessels themselves, it can be seen that the consis-

tency of high firing temperatures and the control of the firing atmosphere are compatible with kiln firing. The technology of the vessels is also supportive of such a firing. As mentioned above, black-on-red vessels are often large and have complex shapes (Figs. 7, 8, 9). Furthermore, black-on-red vessels were regularly made from extremely fine-textured fabrics (*Renfrew et al. 1986.155*). Firing such vessels can be very risky. In a kiln firing, however, pots can be heated slowly and evenly to complete the drying process. The need for temper in the clay is not so great because, the rate of shrinkage is more controlled (as the rate of temperature rise can be controlled). In contrast, graphite decorated vessels were regularly made from medium to coarse-textured fabrics (*Renfrew et al. 1986.158*). Such fabrics facilitate the building and drying of large, complex forms and can withstand abrupt changes in firing temperature.

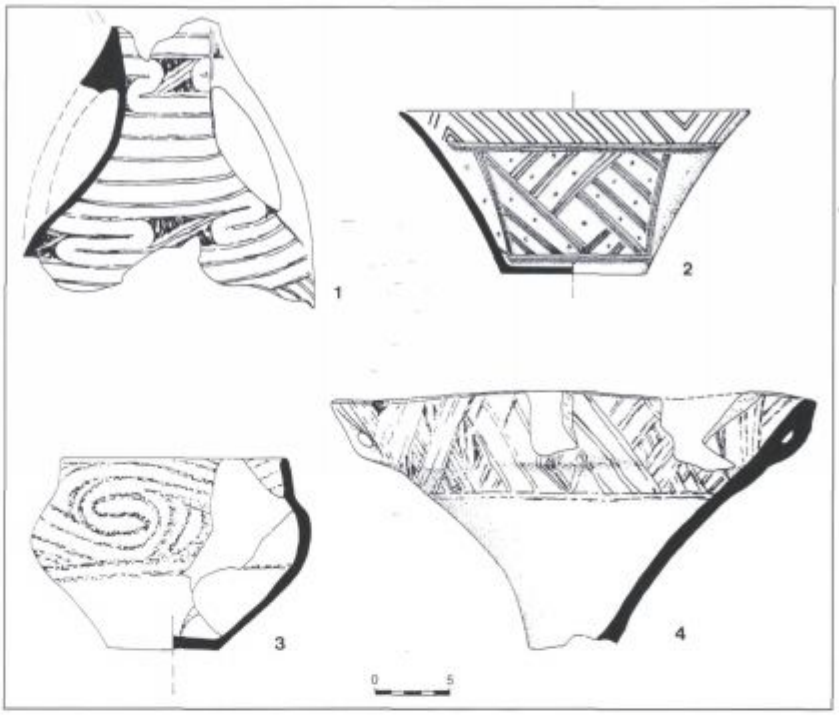


***Fig. 10. Graphite decorated vessels: 1. and 4. from Sitagroi (*Evans 1986. Figs. 12.5, 1 and Fig. 12.4*); 2. excised with graphite from Dikili Tash; 3. from Dimitra (*Grammenos 1997.Fig. 19, 267*).***

## CONCLUSIONS

During LN I there was great variation in the methods and raw materials used to decorate pots. Dark brown, the preferred colour of decoration, was produced either through the use of manganese-based materials or through the reduction of iron-based pigments. More rarely, the dark motifs were produced with an organic material applied to the surface of the vessels after firing. Manganese-black and the iron reduction technique are widely known in East Macedonia. In contrast, the post-firing organic coating, despite its sporadic appearance at Dikili Tash and Dimitra, is characteristic mainly of the site at Promachon-Topolnitsa (a site divided by the Greek/Bulgarian border) and the neighbouring Bulgarian site of Damyanitsa (being rare at Balgarcevo).

The grey-buff colour of the background of the decoration was produced either through the application of a slip (kaolin or calcareous material) or by firing the vessels in non-oxidising conditions. Since in many cases the slip was very thin, the manipulation of firing conditions was imperative for the achievement of the desirable grey-buff colour. Red motifs, less common than the dark brown, were produced by the application of an iron-based pigment fired in oxidising conditions.

In all cases, the manipulation of firing conditions was decisive for the successful appearance of the decoration. The reduction of iron-based pigments, in particular, is a complex method requiring the careful preparation of the colouring material and organisation of firing conditions (control of atmosphere, temperature and duration of firing). These vessels were fired in pits, most probably provided with an air inlet (as the structure excavated at Krioneri). The discoloration of motifs from brown to red indicates that the potters were not always successful in their attempts.

Characteristic of LN II are black-on-red and graphite-decorated vessels. Although these wares have many similarities in vessel form and decoration, they have pronounced differences in the fabric used for their manufacture, the raw materials used for decoration and the firing sequence.

Graphite-decorated vessels were made from medium to coarse-textured clays which could not withstand firing at high temperatures. In contrast, the fine-tex-

tured fabrics of the black-on-red vessels were regularly fired at rather high temperatures (around 900°C). This means that, for each ware, there existed specific recipes of clay fabrics, and potters systematically collected raw materials that would produce the desired results. The same is true of the earlier LN I painted vessels, since potters collected clays that could acquire, by being fired in slightly reducing conditions, a grey-buff colour. In the LN II period, however, there was a strict dichotomy between the clay fabrics used in the black-on-red and graphite decorated vessels.

Completely different raw materials were also used for the decoration of these two wares: manganese-based pigment and an iron-rich slip for the decoration of the black-on-red vessels. The graphite-based pigment was often combined with a variety of post-firing pastes (ochre, kaolin or calcareous-based paste). It is interesting to note that manganese and graphite are common in the mountains surrounding the Drama Plain and that very often they are found in juxtaposition[3]. Despite this, the black background of the graphite-decorated vessels was produced through the manipulation of firing conditions and not by the application of a manganese-based slip. A pit or even an open firing could provide the conditions for the successful firing of graphite-decorated vessels. A kiln firing is proposed for the black-on-red vessels. Due to the complexity of firing techniques this proposal must be considered as preliminary and has to be confirmed by future research. It is undeniable, however, that the firing sequence of black-on-red vessels was carefully organised and strictly controlled.

Given the basic differences outlined above and taking into consideration that the whole technological sequence is very complex, it could be proposed that these two wares were not manufactured by the same potters changing at will from one ware to the other (*see also Courtois in press*). As can be seen from Table 4, both wares are present at all east Macedonian sites, but their distribution follows an opposite pattern. Graphite-decorated vessels are rare at Krioneri and Dimitra (that is, in the western part of east Macedonia), but increase dramatically in frequency as we move eastwards. In contrast, black-on-red vessels are more common at the western sites. In the western region, vessels decorated with dark brown motifs are also present. At Dimitra, in particular, such vessels are extremely common in the early levels of LN II (amounting to 52% of the decorated pottery). Black-on-red and vessels with dark brown motifs have many similarities in the texture and colour of the clay fabrics used for their manufacture.

It should be stressed, however, that the pattern of production of the Late Neolithic painted wares may not has been so simple (that is, the production of black-on-red in the west and of graphite decorated pots in the east) as appears from the data presented above. It has already been seen that the black-on-red decoration of the vessels from Krioneri and Dimitra was sometimes covered with an extremely thin (3–5 μm), whitish slip. This feature seems to be absent further east. A research program combining the petrographic and chemical analysis of a large sample of ceramics and raw materials is needed to better define the organisation of the production of the Late Neolithic painted vessels from east Macedonia.

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3 Dr. I. Chatzipanagis (Institute of Geological and Mining Research, Thessaloniki), pers. comm. 1998.

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