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Surface Coating Technique of Northern Black Polished Ware by the Microscopic Analysis

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Abstract

An organic substance has been identified in the top layer of Northern Black Polished Ware (NBPW) excavated from the Wari-Boteshwar and Mahasthangarh sites in Bangladesh. NBPW is the most distinctive ceramic of Early Historic period and the technique of its surface gloss acquired numerous theories. This particular paper is an analytical study of collected NBPW sherds from these two sites including surface observations using binocular and scanning electron microscopes and Thin Section Analysis of potsherds. Thin section analysis identified two different layers of coating on the surface of the NBPW. One layer is a 'slip' (ground coat) and the other is a 'top layer or top coat '. The slip was made from refined clay and the top layer was derived from organic substance. Microscopic analysis confirmed the solid and non-clayey characteristics of the top coat.

Introduction

The present research aims to elucidate the characteristics of the glossy, black surface coating of the famous archaeological pottery of South Asia called NBPW (Northern Black Polished Ware). This research proceeded in two directions: it started with a review of the literature regarding the information about NBPW and previous research about the coating technique used in NBPW, thereafter; it proceeded to a scientific analysis using two fundamental techniques: first, surface observation in binocular and SEM and second, making thin-sections observation in both an optical and SEM.

Information about NBPW

NBPW was potted on a fast wheel and is made of fine-grained clay and with little tempering material: it has a highly glossy surface which can easily be distinguished by the fine quality of its manufacturing technique (Haque *et al*. 2001: 11-40). T.N. Roy (1983) had divided the fabric of the NBPW into five main groups (Agrawal, 2009).

NBPW has been discovered in various regions of Bangladesh, India, Pakistan, Nepal and Sri Lanka. The northernmost site of NBPW is Udegram in Pakistan, the southernmost site is Anuradhapura in Sri Lanka, the westernmost site is Prabhas-Pathan in India and the easternmost site is Wari-Bateshwar in Bangladesh (Haque *et al*. 2001: 11-40). NBPW has been excavated from two early historic sites in Bangladesh, called Wari-Bateshwar and Mahasthangarh. NBPW from the Mahasthangarh site was dated to *c*. fourth century BCE to first century A.D (Alam, and Alam, 2001: 343). The forms of NBPW found at Mahasthangarh include the dish, cup (with or without lip), bowl and beaker (Fig. 1). Most of the examples of NBPW excavated from the

Mahasthangarh site are black, but they also show red, silver and golden colours (Alam, and Alam, 2001: 343).The time period for the Wari-Bateshwar site has been set at between *c*. 700 BCE and 100 BCE, or 50 C.E for the sub continental site (Haque *et al*. 2001: 11-40). The examples of NBPW excavated from the Wari-Bateshwar site are (for the most part) dishes, bowls and spouted jars, all off which possess black and grey cores: their surfaces are commonly a lustrous black colour, however light chocolate, light silver and light red sherds were also found (Haque *et al*. 2001: 11-40). A series of recent radiocarbon dating results from Ayodhya in Uttar Pradesh, India suggest that the NBPW phase could, go back to as early as *c.* 1000 BCE (Singh, 2008: 260).

Figure 1 NBPW excavated from the Mahasthan area, Mahasthangarh Museum, Mahasthan, Bogra district, Bangladesh.

NBPW does not include any large and heavy forms such as storage jars or globular pots. This pottery was a highly valued, deluxe ware, mostly intended for the elite of the society. This is indicated by the limited number of forms discovered and by fragments of specimens (repaired with copper rivets, fillets, or pins). This finding shows that the broken NBPW was not usually discarded; it was continued to be used after being repaired with copper ware as the cost of repair was less than the cost of production and import (Rahman, 1998: 75-93). The gloss of surface coating used in the production of NBPW has been addressed through several hypotheses though there is hardly any unanimity about it (Agrawal, 2009).

Past Scientific Study regarding NBPW

Since 1946, many scientists in India (and in other countries) have been investigating techniques of NBPW fabrication and have developed three or four theories regarding the composition of its lustrous black slip and its surface dressing techniques. Among the many hypotheses regarding NBPW, the two main hypotheses have either iron or carbon as the main ingredient responsible the surface glossiness. In the last 65 years, many researchers; including Sana Ullah (1946), B.B. Lal (1956), K.T.M. Hedge (1966, 1976, 1978), H.C. Bhardwaj (1973, 1979), Mitchell (1979), K.J.S. Gillies & D.S. Urch (1983) and Robert Harding (2004) have proposed hypotheses regarding the black gloss coating found on NBPW. Sana Ullah (1946) and K.T.M. Hedge proposed that the black colourations of NBPW are due to iron compounds present

in the material, whereas B.B. Lal (1955-1956), H.C. Bhardwaj (1979) and Mitchell (1979) claimed that carbon is the dominant black colourant in NBPW (Gillies and Urch, 2007: 29-44).

The examination of NBPW (bichrome and monochrome group) excavated from Rajgir, India by Robert Harding (2004), found that the examined samples had two slips, with the upper surface being approximately one micron in thickness. The upper coating was observed to be thinner where an edge was exposed; it was also indicated by the presence of air bubbles on the sherd surface. He also suggested that the extreme thinness of the top coat implies a very fine suspension in liquid that was either wiped on or into which the pot was dipped. Harding also noted that iron is present at significantly high levels in all of the sherds, irrespective of the colour of the sherd, and at higher levels than in the underlying material (Harding, 2004: 30-34).

Some scholars, including D.P. Agrawal, S. Kusumgar, and D. Lal, mentioned that the black gloss of the NBPW may have resulted from some sort of post-firing technique in which the kiln-hot pottery was coated with an organic liquid (Sinha, 1997:89-101). The chemical report suggests that the black glaze is achieved by applying a substance with, certain chemical properties to the black-slipped surface of the pottery (Sinha, 1997:89-101). H.C. Bhardwaj has attempted to isolate the slip from the core by chemical analysis and has suggested that the slip might have been created by the application of a well-levigated emulsion of refined clay and organic liquid (plant juice) to the dried pots. After the slip had dried, the pots were fired under reducing conditions. The organic matter in the slip was carbonized without burning out, resulting in a uniformly lustrous black surface (Sinha, 1997:89-101).

Practical experiments regarding NBPW have been undertaken by many scientists, including A.N. Khanna at Kangra (Himachal Pradesh, India), G.C. Singh at Nizamabad (Azamgarh, Uttar Pradesh, India) and K.T.M. Hedge (Baroda University, India). At Kangra, it is evident that the slip, burnishing with cloth, firing in a sealed iron barrel with pieces of heartwood of resinous pine (Chir) and the reducing atmosphere of firing are collectively responsible for the luster of the black pottery (Bisht, 2004: 75-83).

On the other hand, in the Nizamabad experiment, it is the slip 'Kabiz' which is comprised of iron-rich soil, bark of the mango tree, bark of the babul tree (another name for the Indian herb tree, *Acacia arabica*), leaves of bamboo (if greenish tinge is required), leaves of arasa (*Ficus religiosa*), caustic soda, and reh juice is coated on the sun-dried pot. Next, there is an application of mustard oil and polishing with a dry cloth. Firing is carried out in an inverted pot which is filled with the dung of goats (responsible for smoke); cow dung cakes are used both to cover the pots and achieve the required temperature. Both of these techniques result in lustrous black polished pots similar to NBPW (Bisht, 2004: 75-83).

In the experiments of K.T.M. Hedge, a thin red slip glaze made of red ochre, clay, and sajjimatti is applied (sajjimatti occurs as a superficial incrustation on alluvial soil during the summer month in the Ganges valley region, sajjimatti forms an easily-visible layer of glistening, white, crystalline salt; its main components are 15- 20% sodium carbonate, 10- 15% sodium bicarbonate, 50- 70% silica, and 5% lime). Then, he baked the pottery in a sealed jar filled with cow dung and goat droppings at 800^{o}C- 1000^{o}C for 12 hour. By using this process, he was able to reproduce a specimen very similar to NBPW (Hedge, 1978: 154).

Sites and Research Materials

This study focuses on the monochrome type of black surface coating of NBPW samples found in this pottery group. To this purpose, total 27 pieces of NBPW potsherd were collected from excavated sites in North and North-East Bangladesh. Including these, 17 pieces of NBPW potsherd were collected from the early historic site, called Wari-Bateshwar in the Narshingdi district, situated 55 km north-east of Dhaka, 10 additional NBPW potsherds were collected from another early historic site, called Mahasthangarh in the Bogra district, Northern Bangladesh (Fig. 2).

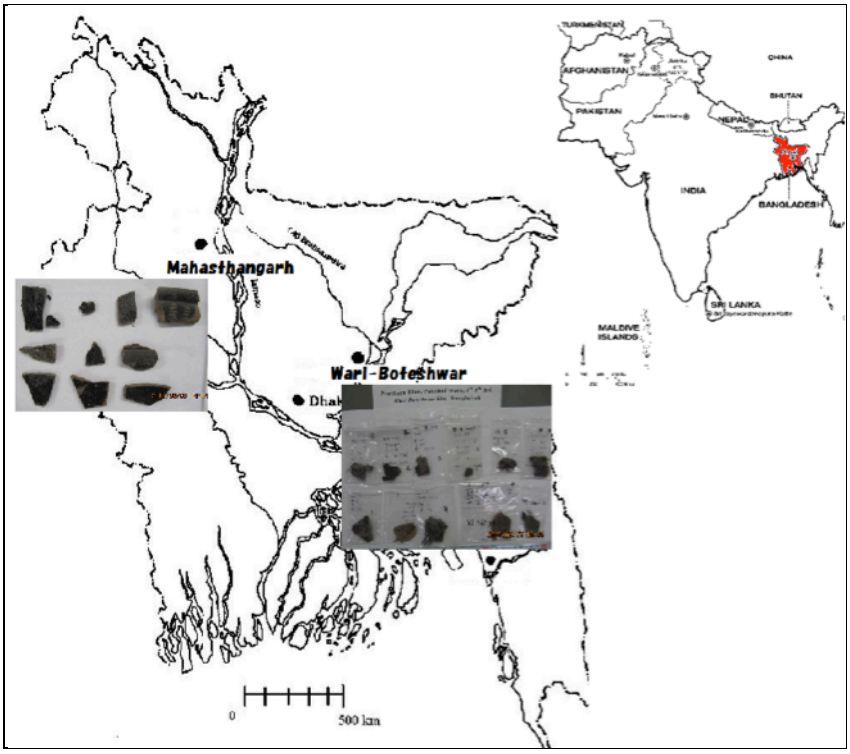

Figure 2 Map showing the two archaeological sites in Bangladesh, called Wari-Bateshwar and Mahasthangarh. NBPW potsherd samples were collected from these two sites.

Sites: Wari and Bateshwar are two adjacent villages under the jurisdiction of the Belabo police station in Narshingdi district. The soil of the entire area is red and contains pebble. Wari and Bateshwar stand on relatively flat ground, which is considerably higher than the surrounding area. There exists marshland between the two villages to their north, north-east, east and south-east. The confluence of the *Arial Kha* river and Brahmaputra river is 5 km north-east of Wari. The shrunken and nearly-dry channel of the river *Koira* borders Wari in the north. *Sitalakhya*, another major river in the vicinity, flows some 35 km west of Wari and Bateshwar (Jahan, 1999: 207-216).

Systematic archaeological exploration at the site was carried out in 1998-99 season by the supervision of Shahnaj Husne Jahan and subsequently a number of excavations conducted at the site since 2000 (Jahan, 2010). A small-scale trial excavation of this site began in 2000 (February 4th - April 24th) which was carried out by The International Centre for Study of Bengal Art (ICSBA). This excavation discovered significant artefacts, including NBPW. The discoveries made during the excavation place the active period of Wari-Bateshwar in the early historic period (Haque et al. 2001: 11-40). Excavation work at the Wari-Bateshwar site is still being carried out under the supervision of archaeologist Dr. S. S. Mostafizur Rahman. Various types of archaeological antiquities are being recovered at every phases.

The Mahasthangarh site is located in Mahasthan village in the Bogra district, in northern Bangladesh. During early history (*c.* 500 BCE to 550 CE) and the early medieval periods (*c*. 550 CE to 1200 or 1300 CE), Bogra district was a part of the kingdom of *Pundravardharna* and a part of the *Gauda* empire. According to a legend, *Pundravardhana* was the country of the *Pundras*. The early historic and early medieval sites of this district are situated on the red-bed *Barind* tracts, which are slightly elevated terraces on the alluvium. This area is higher in elevation than the surrounding plains and forms a distinct (and relatively flood-free) physiographic unit. The elevation of the district ranges from 15 to 25 m above mean sea level. The plains are dissected by erosion, the ridge tops between the depressions are almost level, and the valley sides and floors have been terraced to allow cultivation. The ridge tops, which preserve evidence of human occupation in the early historic and early medieval periods, have been designated 'sites'. Most of the ridge tops were occupied by human groups during the early historic and early medieval periods. The majority of the sites consist of a mound which contains burnt-brick structures representing a *stupa*, temple, *vihara*, or other structures. The term 'site' has been used in a broad sense and includes the mounds that lie within it. The size of the sites in the Mahasthan area has been calculated on the basis of the area over which artefacts are found to be distributed. As most of the sites of the Mahasthan area are covered by modern occupation, the distribution area of artifacts and therefore the size of sites could not be measured precisely. During exploration, 135 sites were found in an area of 2920 km^2 in the Bogra district (Rahman, 2000:17-95). Mahasthan is one of these sites; potsherd samples were collected from Mahasthan. Mahasthan citadel is situated in the village of Mahasthan and is surrounded by the *Karatoya* river on the east and a moat on the other three sides. This moat is locally known as *garh*. No archaeological remains prior to the late fourth century BCE have been recovered from the region of Mahatshangarh, which suggests that the initial population selected this area and quickly built up the site, possibly as a trading centre, given its favorable location on the bank of the *Karatoya* river (Smith, 2001: 61-73).

The archaeological site in the Mahasthan area was discovered by Sir Alexander Cunningham's surveys in the 1879. A framework for Mahasthan history was established in 1929 through a survey of written sources, at a time when regular excavations were starting at the site under the direction of K.N. Dikshit (Archaeological Survey of India), 1929- 1930 and 1934-1936, sketch plan published by P.C. Sen. No final report on the ASI excavation was ever issued (Salles and Alam, 2001: 1-18). In 1960-1961, official excavations were conducted by the Pakistan Department of Archaeology and Museums. Short soundings were also made in the year 1965 and 1966. Since, 1988, the Directorate of Archaeology of Bangladesh has conducted several seasons of excavation, conservation and restoration. Unfortunately, most of the results of

over fifty years of research regarding Mahasthan remain unpublished (Salles and Alam, 2001: 1-18). A joint French-Bangladeshi venture excavation was carried out from 1993- 1999 in the Mahasthangarh area; the first interim report was published in 2001 (Salles and Alam, M., 2001: 1-18).

Research Materials: The analyzed potsherds are included in the monochrome type of NBPW and collected from the excavation sites at Wari-Bateshwar and Mahasthangarh. In this paper, potsherds from Wari-Bateshwar and potsherds from Mahasthangarh are referred to by the abbreviations 'WB NBPW' and 'MAH NBPW'. The primary characteristics of the collected potsherds of WB NBPW by visual observation showed that they possess an internal and external surface coating which are black and glossy (Fig. 3, WB NBPW No. 8) and the body surface is very smooth. Core is deep ash colour. Gray colour body surface is visible where the coating is damaged.

Figure 3 External and internal surface of WB NBPW potsherd.

The other visual information's are listed in Table 1.

Table 1 Collected NBPW potsherds of Wari-Bateshwar site and characteristics

No.	Shape	Size	Description
1	Rim part of a dish	3 .5×5 cm (approx.), 7mm in thickness	excavated from the depth of 156 cm., thick body texture, glassy and smooth surface possess coating in inner and outer surface, reddish colour coating is visible where the black coating is absent
2	Neck part of a bowl	3×3 cm (approx.), 3.8 mm in thickness	Intact potsherd, thin body texture, smooth surface possess black coating in inner and outer surface, simple circular band is present in the neck area.
3	Body part of a bowl	5×2.5 cm (approx.), 4.7 mm in thickness	Damaged potsherd, body texture is thick, black colour coating is partly present in both inner and outer surface of the potsherd.
4	Rim part of a small bowl	4×2 cm (approx.), 3.75 mm in thickness	Intact potsherd, excavated from the depth of 128 cm., black colour coating is present in both side,

			smooth surface
5	Rim part of a bowl	2.5×3.5cm (approx.), 4.2 mm in thickness	Intact potsherd, excavated from the depth of 128 cm. thin body fabric, glassy and smooth surface, reddish colour coating is visible where the black colour is absent.
6	Body part of a bowl	5 × 2.5 cm (approx.), 4.7 mm in thickness	Damaged potsherd, excavated from the depth of 89 cm. thin body fabric, surface is scratched, black coating is present in the both side.
7	Rim part of a bowl	4 × 3.5 cm (approx.), 7.4 mm in thickness	Damaged potsherd, excavated from the depth of 176 cm. thick body fabric, black coating is present in both side.
8	Rim part of a bowl	4 × 7.5 cm (approx.), 6.2 mm in thickness	Intact potsherd, thick body fabric, smooth surface, black colour coating is present in the both side.
9	Body part	6 × 6 cm (approx.), 10.3 mm in thickness	Damaged potsherd, excavated from the depth of 176 cm. thick body fabric, black color coating is present in the both side.
10	Rim part of a bowl	3 × 1.8 cm (approx.), 3.72 mm in thickness	Intact potsherd, smooth surface, black coating is present in the both side.
11	Broken body part of a bowl	3.5×5.5cm (approx.), 10.3 mm in thickness	Intact potsherd but overlapped by clay, thin body fabric, black coating is present in both side,
12	Rim part of a bowl	3 × 5 cm (approx.), 4.6 mm in thickness	Intact potsherd, fine and thin body fabric, black coating is present in the both side.
13	Broken body part	4 × 3.5 cm (approx.), 5.0 mm in thickness	Intact potsherd, thin body fabric, black coating is present in the both side.
14a	Rim part of a bowl	2.8×4 cm (approx.), 3.3 mm in thickness	Intact potsherd, thin body fabric, black coating is present in the both side.
14b	Body part of a bowl	2.1×2.4cm (approx.), 2.5 mm in thickness	Intact potsherd, smooth surface, thin body fabric, black coating is present in the both side.
14c	Body part of a bowl	1.9×2.3cm (approx.), 3.35 mm in thickness	Damaged potsherd, thin body fabric, coating is present in the both side.

15	Lower part of a dish on stand	5×5.5 cm (approx.), 5.58 mm in thickness	Intact potsherd, thick body fabric, black coating is present in both inner and outer surface.
16	Rim part of a bowl	4×6 cm (approx.), 5.1 mm in thickness	Intact potsherd, thick body fabric, black coating is present in the both side, circular band is present in the lower part of the rim.
17	Rim part of a bowl	6×4.8 cm (approx.), 3.4 mm in thickness	Intact potsherd, thin body fabric, black coating is present in the both side.

The collected potsherds of MAH NBPW showed that they possess black coatings on both the internal and external sides (Fig. 4, MAH NBPW No. 2) and when freshly broken, they create straight, sharp fractures. Core is deep ash colour.

Figure 4 External and internal surface of MAH NBPW potsherd.

Visual information's are listed in Table 2.

Table 2 Collected NBPW potsherds of Mahasthangarh site and characteristics

No.	Shape	Size	Description
1	Body part	2×1.9 cm (approx.), 3.0 mm in thickness	Intact potsherd, core was deep ash colour. Both the surface was coated, smooth, glossy and black in colour. Gray colour body surface was visible where the coating was damaged
2	Body part	3.9×4.5 cm (approx.), 4 mm in thickness	Intact potsherd, thin body fabric, surface is smooth, black coating is present in the both side

3	Body part	3.5×4.7cm (approx.), 3.9 mm in thickness	Intact potsherd, surface is smooth, black coating is present in the both side
4	Body part	2.6×2.9cm (approx.), 5.6 mm in thickness	Intact potsherd, thick body fabric, smooth surface, black coating is present in the both side
5	Body part	3.6×4.2cm (approx.), 3.7 mm in thickness	Intact potsherd, smooth surface and thin body fabric, black coating is present in the both side
6	Body part	2.1×2.2cm (approx.), 2.9 mm in thickness	Intact but very small potsherd, black coating is present in the both side.
7	Rim part	2.9×3.5cm (approx.), 4.7 mm in thickness	Damaged potsherd, thick body fabric, black coating is present on the both side, ash color surface is visible where the black coating is absent.
8	Body part	2.5×3.1cm (approx.), 4.7 mm in thickness	Damaged potsherds, thick body fabric, ash colour surface is visible where the black coating is absent.
9	Body part	2.5×3.6cm (approx.), 4.6 mm in thickness	Intact potsherd, thin body fabric and scratched surface, coating is present in the both side.
10	Rim part	4.7×5.1cm (approx.), 4.0 mm in thickness	Damaged potsherd, thin body fabric, smooth surface, coating is present in the both side.

Research Method

Analytical study was carried out using four methods including experiments, these are:

Surface observation by binocular microscope: the surfaces of the NBPW potsherds were analyzed using a binocular microscope (Olympus SZH10).

Surface observation by SEM: the surfaces of the NBPW potsherds were analyzed using a scanning electron microscope (SEM) (HITACHI, Miniscope TM-1000).

Microscopic examination of thin sections: thin section studies can be extremely useful in determining the method of surface coating technique of pre-historic pottery. So, thin-sections were prepared for optical and scanning electron microscope (SEM) observations which were prepared by using the 'polished-thin-section method'.

Polished thin section method and preparation process: In Japan, this method was first introduced by Masaharu Nagashima. After some years, Dr. Fumio Okada invented a new method for thin-section preparation (Okada, 2000:135), which was used in this paper for the analysis of the collected NBP potsherds. This method is advantageous for the following reasons: (a) it requires

little experience; (b) it is relatively inexpensive; (c) it requires little variation in technique for different types of material; (d) the prepared thin-sections are clear for identifying the surface coating, including the base coat and top coat, with the quality of the used clay; and (e) the prepared thin-sections can be stored for many years at normal room temperature. Thin-sectional microscopic specimens can evaluate the making technique, the quality of the used clay, and the characteristics of the applied slip and coating.

The potsherds to be used for thin sections were divided into several pieces (approximately 2.5-4.0 mm in measurement). The potsherd samples were then embedded in epoxy resin (Adeka resin, mix the epoxy base agent and the hardener in a 5: 2 weight ratio). Next, the surfaces of the embedded samples were ground flat and polished with wet-type sandpaper. The upper surfaces were observed with a stereoscopic or metallurgical microscope, and the samples were attached to the slide glass with epoxy resin. The other side of the sample was ground and polished until it was approximately 20 μm in thickness. Then, the prepared slide was observed using the optical microscope and SEM (Fig. 5). All of the microscopic analyses were carried out in the laboratory of the Art Research Institute at the Kyoto University of Art and Design in Kyoto, Japan.

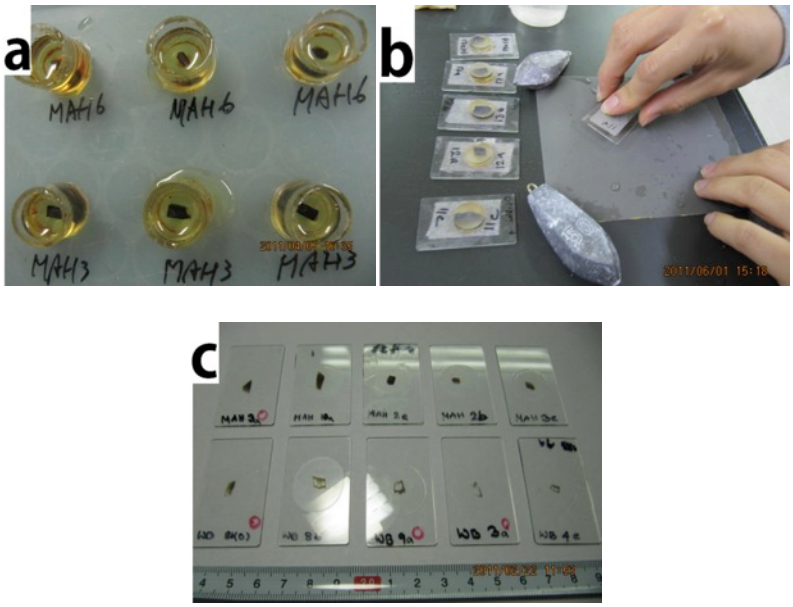

Figure 5 (a) Potsherds embedded in resin; (b) Sanding the sample using waterproof abrasive paper; (c) Slides complete for microscopic observation.

Experiments: experimentation is one of the analytical methods for the present study. According to the microscopic analysis of the NBPW potsherds, a short experiment was undertaken to discover the application process of the surface coating of NBPW. Initially, test pieces were prepared from the clay, which was collected from the NBPW level at the Wari-Bateshwar site. Next, a ground coating was made from refined clay applied to the surface of the test pieces and polished. Next, test pieces were fired at 800°- 1000°C in an electric kiln. Last, different types of organic substance were applied on the surface of the individual test pieces; thin sections were then prepared for microscopic analysis.

Microscopic Observation Results

Surface Observation by Binocular Microscope

All the collected potsherds of WB and MAH NBPW exhibit a black coating on the internal and external surfaces and have very smooth surfaces. Close observation found that black color scattered spot was present in certain places of the surface coating which may be the cause of surface gloss [Fig. 6a, WB NBPW potsherd No. 8]. In one potsherd (WB 16), binocular microscopic observation shows that, the surface coating possesses two colours, reddish and a black. The reddish-coloured surface is visible where the black colour is damaged [Fig. 6b & 6c]. The potsherds were cleaned with water after excavation this may explain the loss of glossiness on parts of the surface.

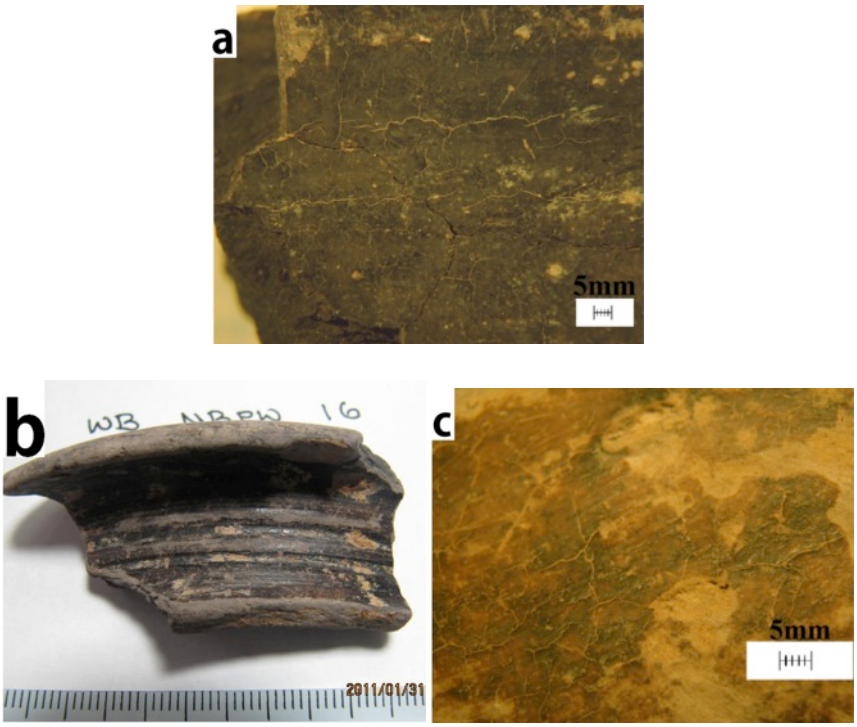

Figure 6 (a) Surface observation by binocular microscope, WB NBPW potsherd no.8; (b) External surface of potsherd No 16; (c) Surface observation in binocular microscope, a black colour is visible on the reddish coloured surface coating.

Surface Observation by Scanning Electron Microscope (SEM)

All the collected potsherds of NBPW were observed by SEM and that results showed that the place of high reflectivity of the electron image was a plain smooth coating (Fig. 7a & 7b). The place of low reflectivity of the electron image showed another coating (top coat) on the smooth surface, and there were many cracks in it. Below the plain smooth surface, rough body clay was visible (Fig. 7a).

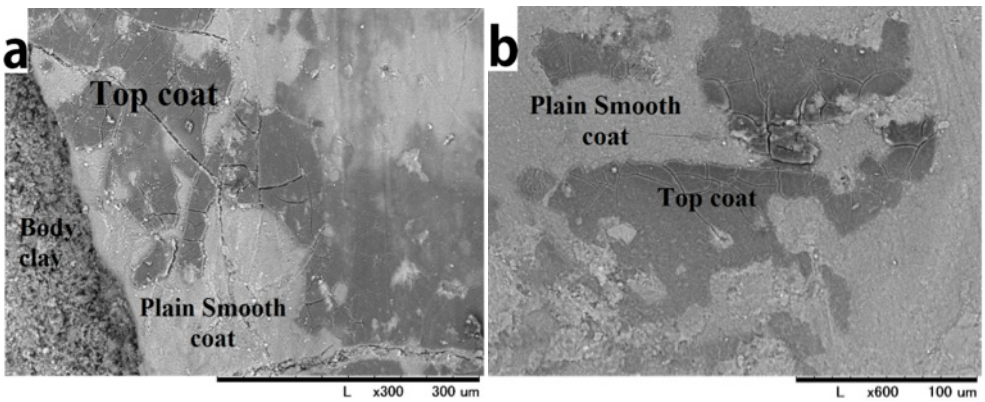

Figure 7 (a) Surface observation by SEM, WB potsherd No. 16, body clay adjacent plain smooth coat (the place of high reflectivity) and top coat (the place of low reflectivity) is identified; (b) Surface observation by SEM, MAH potsherd No. 6, plain smooth coat and top coat is identified.

Thin Section Observation by Optical Microscope and SEM

A total of 200 glass slides were prepared from the NBPW potsherds to allow thin section observation. Among these, 100 glass slides were prepared from the 17 pieces NBPW potsherds from the Wari-Bateshwar site; other 100 glass slides were prepared from the 10 pieces of NBPW potsherds from the Mahasthangarh site.

All the thin section (made from WB and MAH NBPW) observation shows that, two staged surface coating is present on the potsherds surface; ground coat and top coat. Ground coat which is visible on the body surface is made from clay. Observation shows, the body clay and the clay particles of the ground coat are different. This ground coat is made from fine clay that is free from large mineral particles and uniformly applied to both the internal and external sides of the pottery. This refined clay made surface coat (ground coat) should be called as 'slip' (Fig. 8a). Applied slip is approximately 15-25 µm in thickness. The colour of the slip is deep brown and contains many horizontal cracks in it.

Next, the top coat is found on the thick slip and present on the both side of the potsherd (Fig. 8a). This coat is black in colour, and looks different from the ground coat or slip. This top coat is very thin, approximately 2-4 µm (Fig. 8a & 8b) and has many vertical cracks in it (Fig. 8b).

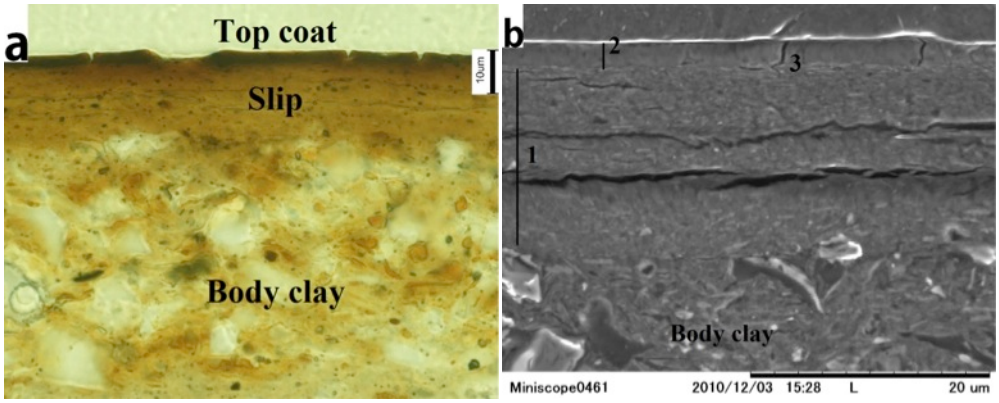

Figure 8 (a) Thin section observation of the WB NBPW in an optical microscope, thin black

colour top coat is visible over the surface slip; (b) Observation by SEM, slip (1), top coat (2), cracks in top coat (3) is visible.

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A yellow-coloured, condensed mud was piled on the surface of the some collected potsherds; it was very sticky and difficult to clean during the preparation of the thin section (Fig. 9a). In the thin section observation, this condensed mud is visible as a yellowish layer above the first layer or top coating: it possesses the same characteristics as the body clay and glitters in the polarization image taken by an optical microscope (Fig. 9b & 9c). Thin section observation also identified a detached top coat from the ground coat or slip (Fig. 9b & 9c].

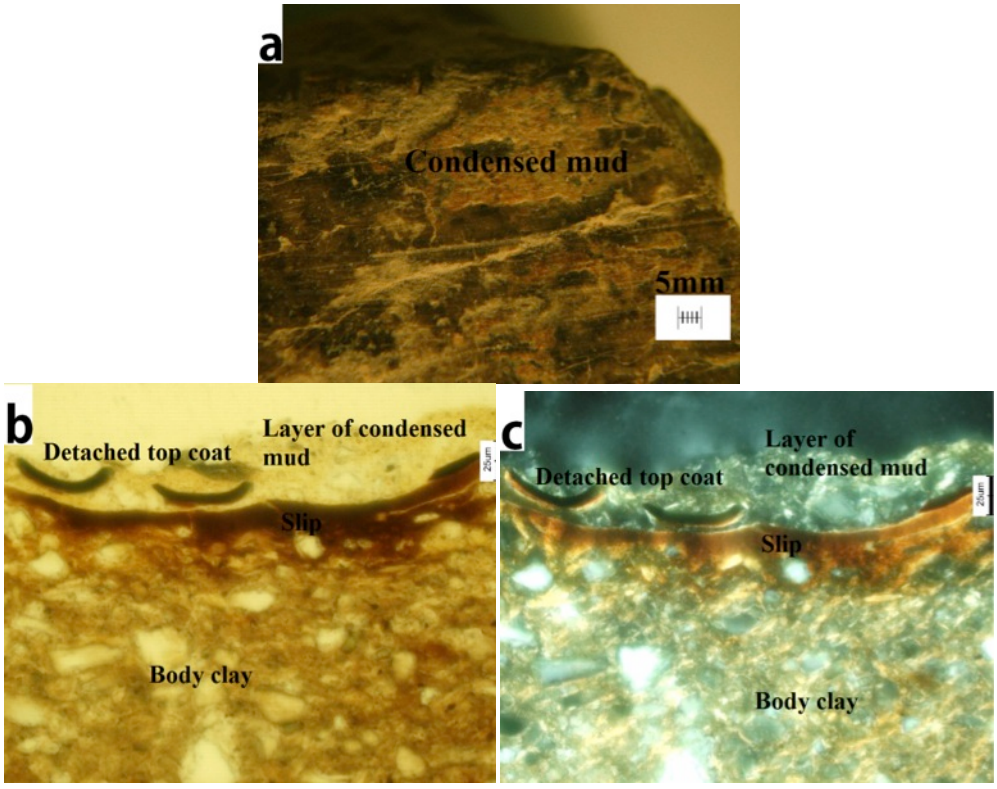

Figure 9 (a) Observation by binocular microscope, condensed mud is visible on the external surface of the WB potsherd; (b) Thin section observation by optical microscope, condensed mud is visible on the top coat, WB potsherd; (c) Polarization image of the same thin section, upper condensed mud is glittering like the body clay.

Discussion

Analysis carried out by optical and scanning electron microscopes identified that collected NBPW potsherds possess two layer of surface coating; one is a ground coat or first layer of coating and the other is top coat or second layer of coating. The ground coat is made from highly refined clay, at a minimum of 15- 25 µm in width and has horizontal cracks. Robert Harding's research (2004) concludes that 'all the examined samples have two slip, with the upper surface

being about a micron in width…' (Harding, 2004: 30-34). Recent research has identified that the ground coating is made from clay and is called 'slip'. The optical microscopic observation of thin section showed the reddish colour slip, there possibly clay is containing high level of iron. On the other hand, top coat is black colour and soil was not being found in the top coat. Optical microscopic and SEM observation shows pure (solid) characteristics. That's why this study proposes the top coating of NBPW was not made from any clayey material. This top coating is approximately 2- 4 μm thick and possesses many vertical cracks, which can be indication of an organic source. The result of microscopic analyses deduces, the top coating did not originate from clay-like material and this is not a 'slip'.

The using of plant juice on dried pots is also mentioned in the sacred Hindu text *Shatapatha Brahmana*, a text written in Sanskrit *c*. 800 BCE (Bhardwaj and Sinha, 1969: 188-192). H.C. Bhardwaj (1969) suggested that the 'slip might have been obtained by the application of well levitated emulsion of refined clay and organic liquids (plant juice) over the dried pots. After the slip was dry, the pots were fired under reducing condition. The organic matter in the slip carbonized without burning out, resulting in a uniform lustrous black surface' (Bhardwaj and Sinha, 1969: 188-192). However, in the present research, two separate layers of coating are found in the thin section observation, which suggests that, the ground coat and top coat were originated from separate origin and present one upon another. According to practical experiment, first we had applied fine clay made slip on the surface of the test piece, then organic substance like oil mixed pine tar had applied on the surface. Finally, whole process properly dried and fired at 800ºC. Firing results shows the organic substance burned out without carbonize. So practical experiment proved, if organic substance was applied on the surface before firing that will be not exist after firing (Fig. 10).

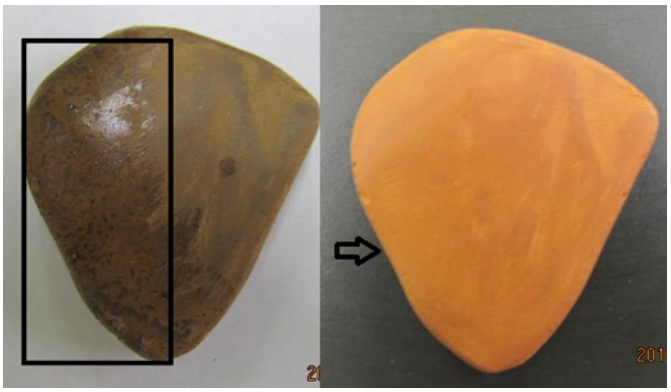

Figure 10 Organic substance was applied on the surface of the test piece before firing and not exists after firing at 800ºC.

The second experiment was carried out to reproduce the glittered surface of NBPW. Different types of organic material, including vegetable oil mix pine tar (heated at 100^{o} C temperatures on a hot plate for 5- 10 minutes), tung oil (heated at 120^{o}C temperatures in an oven for 24 h), and raw vegetable oil were applied separately on the surface of the post-fired test pieces. Result shows that, after applying several times vegetable oil mixed pine tar could form a layer on the surface (Fig. 11a); other organic material (tung oil and raw vegetable oil) was penetrated into the surface.

This study includes third experiment that also reproduce of NBPW. A fine-grained clay slip was applied on the dried test pieces and then polished the surface. Test pieces were fired at 800ºC and were impregnated with the dried leaves of maple tree (*Acer palmatum*). Results show that, impregnated test piece is look alike the NBPW and achieved the same glittered surface as NBPW possessed (Fig. 11b).

The experiment result suggests that NBPW was possibly impregnated with leaves and barks of resinous tree or the organic substance was applied on the post-fired pottery surface. Thin sections were prepared from the experimental test pieces. Thin section observation shows, it (oil mixed pine tar applied test pieces) has possess thick and transparent colour surface coating which is not similar with the NBPW (Fig. 11c). Next, thin section observation shows, it (impregnated test pieces) has possess the same thin top coating like NBPW (Fig. 11d).

From the above discussions following may described about the technique for the surface coating of NBPW, *first,* a fine-grained clay slip was applied to the naturally dried pot and then polished or burnished. *Second,* the pottery was dried (as necessary) and fired. *Third,* impregnate the fired pottery with dried leaves and barks or the surface of the pots were coated with oil. The extreme thinness of the top layer/coat suggests that [Fig. 11d], it is not possible to achieve such thin layer by applying organic substance over the surface other than impregnation.

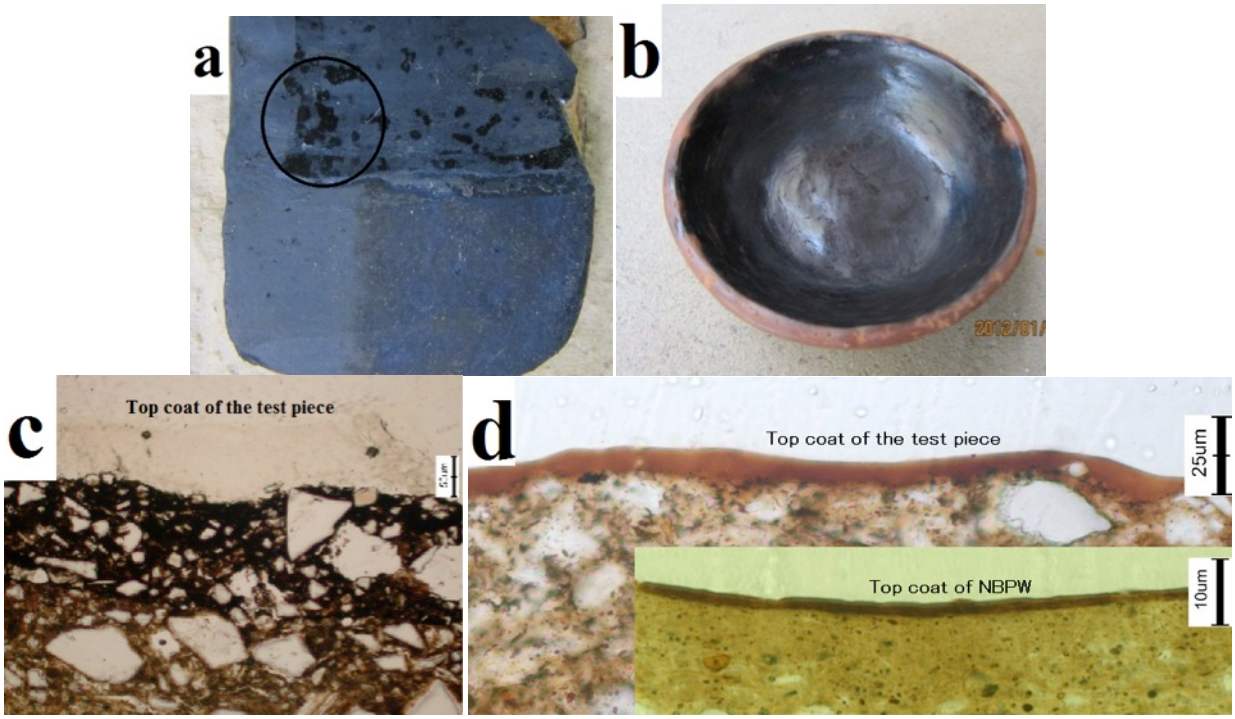

Figure 11 Experiment on the reproduction of NBPW and thin section observation; (a) organic substance applied test piece; (b) impregnated test piece; (c) thin section made from the organic substance applied test piece; (d) thin section of impregnated test piece (upper part) and thin section made from NBPW (lower part).

One is very significant point always be kept in mind for the conservation of such kind of archaeological pottery, extruded washing should be prohibited. The microscopic analysis is point out, top coating of all the collected NBPW potsherds were scattered on the surface and may be that is one of reason for rough washing after excavation. That's why, for washing any

archaeological potsherds should be very careful, otherwise there may be chance to damage the surface coating and thus, become unavailable for use in further research.

Conclusion

In this study, microscopic analysis of NBPW is carried out by surface observation as well as preparing thin sections of 200 glass slides from the collected potsherds of NBPW. Scattered black spot over the reddish color surface coating has been found by the binocular microscopic observation and two distinct layer of coating is identified by surface observation in SEM; ground layer is smooth and plain, on the other hand top layer is solid and possessed many cracks. The thin section observation suggests that, the NBPW was coated by two different kinds of material. One is an iron rich clayey material that was applied as a ground coat and would be more accurately referred as a 'slip'. On the other hand, the glossiness of the NBPW was acquired by the top coat, which result either impregnation or application of non-clayey substances over the slip.

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