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TECHNOLOGICAL INTERPRETATION OF TRADITIONAL CERAMIC MATERIALS ON THIN-SECTION PETROGRAPHY

Dilruba SHARMIN[*,]

[1] Department of Japanese Studies, Faculty of Social Sciences, University of Dhaka, Bangladesh

Abstract:

This paper is an initiative to analysis archaeological pottery by petrographic method and a comparative study of Asian potteries on the view of technological aspect. Research Method includes sample collection by field survey and laboratory analysis which was based on 'polished thin-section' method invented in the late 60s in Japan. Basic samples were collected from Bangladesh, Japan and Laos. Technological analysis reveals that, uniform fine- clay – made slip was applied on the both surface of Northern Black Polished Ware. A very thin top layer was also identified by the present research which shows organic characteristics. On the other hand, slip was not found from the pottery samples of Japan and Laos. Research found the prehistoric pottery of Japan was fired at pit-firing method and pottery was achieved the blackish surface due to carbon-impregnation. Many East and Southeast Asian archaeological wares were decorated with lacquer that was not used as a coating technique in ancient Bangladeshi pottery. This paper presents some very clear microscopy image which is reliable for future research in this field and presents a detailed description of the thin-section method which could be a pioneer method for future analysis in archaeological ceramics of Bangladesh.

Keywords: Ceramic; Thin-section; Bangladesh; Japan; Laos; Petrography; Geo-archaeology; clay-pot; Archaeology.

Introduction

Background of the study

The human culture is developed with many materials, pottery or earthenware is one of them which is a fundamental sources for historical reconstruction. Analysis of archaeological pottery has assisted archaeologists in three focused areas: (a) chronological construction (b) technological interpretation and (c) interpretation of ancient societies. By the analyses of pottery, archaeologists have evaluated the technological knowledge of ancient people and gathered important data about the nature of cultural patterns and complex cultural processes. In this view point, East Asian countries like Japan, China and Korea did many researches. But in the case of Bangladesh, we can see a gap between excavation work and technological interpretation of archaeological antiquity. Our historical research and heritage preservation is now in a vulnerable condition because of proper scientific research, inadequate excavation work and lacking of published report.

According to archeological evidence, pottery was first appeared during the era of Paleolithic art in East Asia (China, Japan, and the Amur River basin in Eastern Russia). The radiocarbon age of the earliest pottery from Russian Far East—Gromatukha and Osipovka cultures—is between around 13,300 BCE and around 10,400 BCE. This shows that the Amur

* Corresponding author: dsharmin.jsc@du.ac.bd

River basin was one of the centers of origin of pottery in East Asia. Today, there are three areas within East Asia with pottery-associated C ^{14} dates between around 14,000 BP and 13,000 BP—southern China, the Japanese Isles, and Russian Far East [1]. The discoveries at *Xianrendong* (c.18, 000 BCE) and Yuchanyan (c.16, 000 BCE) site in China, with the *Jomon pottery discovered at Odaiyamamoto* I site (14,540 BCE) at Aomori Prefecture, Japan, prove beyond doubt that pottery was created in these region before Neolithic era and probably these discovered pottery shreds were the oldest pottery evidence created by early humans [2]. Almost all the early-historic and historic archaeological sites possess numerous types of potsherds (fragment of a pottery). The presence of pottery within a culture shows the beginnings of complexity where trade and production are beginning to establish themselves. It is also important to note that pottery lends itself not only to the study of early technology and complexity but also to simpler aspects of early people's lives. Beliefs and religious practices can often be seen on ancient pottery. So, interpretation on traditional pottery technology helps the scientists to reconstruct the ancient manufacturing process which is the primary objective of this paper.

History of Petrographic research

Since the 1930s, petrographic microscopy has been used in the ceramic research [3]. In the second half of the 18th century, petrography was first used by Scottish geologist William Nicol. He studied fossilized wood in thin section to find the species of wood. English microscopist and geologist Henry Clifton Sorby was the pioneer of mineral and ceramic petrography, undertaking the study of rocks and minerals in thin section during the middle of the 19th century. His contribution to the techniques and method employed within petrography give many of the basic foundations used by ceramic petrographers today. In the early 1940s, Anna Shepard and Wayne Felts were used petrographic analysis in the study of archaeological ceramics. Their separate use of this technique on ceramics from New Mexico and Turkey respectively demonstrated the value of this scientific technique for archaeological analysis. Early prehistoric ceramic petrology was first used in the UK by David Peacock in the late 1960s [4]. The petrographic thin-section used in this research is known as 'Polished Thin-section method'. This method was first invented by Japanese researcher Masahiro Nagashima and developed by Prof. Dr. Okada Fumio in late 1980s.

Research Goal

This research aimed to decide the following queries:

a. to introduce the 'Polished Thin-section' in the Ceramic research arena of Bangladesh.
b. to identify the coating material of Bangladeshi historic pottery known as 'Northern Black Polished Ware or NBPW;
c. to characterize the surface coating of Asian traditional pottery.

Significance of the Research

The types of Asian traditional archaeological pottery and the nature of their surface coating have many varieties. To elucidate that, a modern method of thin-section petrography has been followed here. This Japanese 'Polished-thin-section method' is efficient in many aspect; such as, to identify the technology and quality of the applied slip, to find the characteristics of the clay used in pottery, to find the starch varieties in the surface coating as well as the characteristics of the pigments used in ancient wall paintings. Thus, both inorganic and organic archaeological materials can be subjected to technical analysis by using this method. As scientific research of pottery has not developed in Bangladesh yet, so this new method could be an authentic practice for those Bangladeshi researchers who want to do their analysis by using technical approach.

Scope and Delimitation

This study focused on the surface coating technique of Asian pottery which is based on the collected samples from East Asia, South-east Asia and South Asia. This study also aimed to introduce a modern scientific technique of thin-section petrography to the Ceramic researcher of

Bangladesh. Collection of archaeological material from different country is time-consuming and has to keep up many rules-regulations. Present research faced a major problem of inadequate pottery samples because collections of archaeological materials are usually prohibited for foreign researcher.

Research Methodology

Sample Collection

For this research, archaeological potsherd samples were collected from Bangladesh, Japan, and Laos.

Samples of Bangladesh

Pottery samples were collected from two famous well excavated site; Wari-Boteshwar and Mahasthangarh, in Narshingdi and Bogura district (Fig. 1). So far 50 archaeological sites have been discovered in and around the Wair-Boteshwar fort-city in the bank of the old Brahmaputra river. Different types of antiquity are unearthed from the Wari-Boteshwar excavation; semi-precious stone beads, hoard for silver punch-marked coins, amulet, fossil wood, chisel, weights and iron implements, silver punched-marked coin etc. Potsherd like Rouletted Ware, glass bead, Knobbed ware, Northern black polished ware (NBPW), different beads, amulets and pendants confirmed that Wari-Boteshwar had close connection with the contemporary several places of Indian subcontinent. By analyzing all the artifacts found in Wari-Boteshwar, there is clear evidence of the settlement stone age, the Neolithic era, the early historic era and historical settlement in the region.

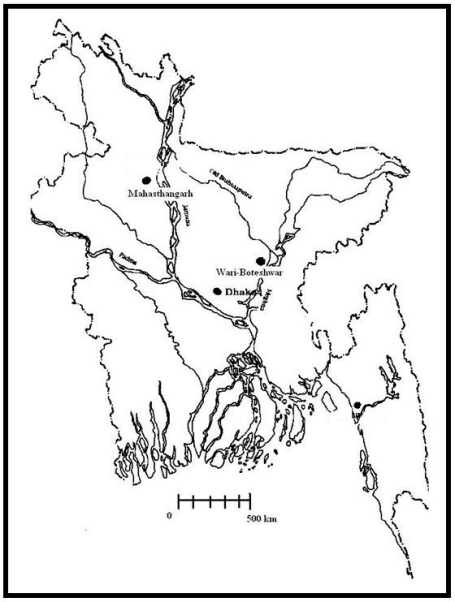

Fig. 1. Location map of Wari-Boteshwar & Mahasthangargh site in Bangladesh

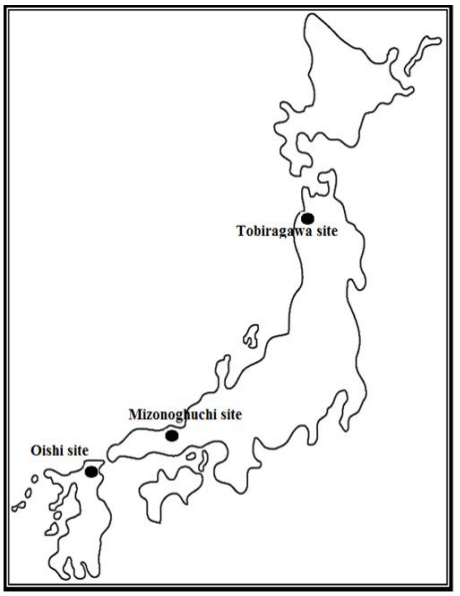

Fig. 2. Location map of Oishi, Mizonoguchi and Tobiragawa archaeological site in Japan.

'Mahasthangarh' site is situated in Mahasthan village in Bogura district of northern Bangladesh. During the 'Early history' (*c.* 500 BCE to 550 A.D) and 'Early Medieval periods' (c. 550 A.D to 1200 or 1300 A.D), Bogura district was a part of the kingdom of '*Pundravardharna*' and a part of the '*Gauda*' empire. According to a legend, *Pundravardhana* was a country of the *Pundras.* The Early Historic and Early Medieval sites of this district are situated on the red bed Barind tracts that are slightly elevated terraces on the alluvium.

The size of the sites of the Mahasthan area has been calculated on the basis of the area over which artifacts are 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 the explorations 135 sites were located in an area of 2920 sq.km in the Bogura district. 'Mahasthan' is one of these sites, from which potsherd samples were collected. Mahasthan citadel is situated in village Mahasthan, surrounded by the river of *Karatoya* on the east side and a moat on the other three sides. This moat is locally known as '*garh*'. No archaeological remains prior to the late 4th 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 center given its favorable location on the bank of the river of *Karatoya* [5] .

***Samples of Japan*:** Samples were collected from *Kyushu* - Oishi site, Oita prefecture, *Akita* - Tobiragawa site and Hyogo prefecture - Mizonoghuchi site (Fig. 2).

Three pieces of black colored potsherd were collected from Oishi site. Oishi ruins are situated in the Ogata town, Oita prefecture in eastern Kyushu. The survey of these ruins was carried out in the year of 1962-1966. Many archaeological sites were excavated in Kyushu which revealed black polished ware that named '*Kokushokumaken doki*'. Kyushu is the third largest island of Japan and most southwesterly of its four main islands, today it consisted of seven prefectures, which include Fukuoka, Oita, Saga, Nagasaki, Kumamoto, Miyazaki, and Kagoshima prefecture. Almost all the prefecture has many archaeological sites.

Two types of potsherds were collected from Tobiragawa site. One piece of red lacquer coated potsherd and three pieces of black lacquer coated potsherds. Tobiragawa site is located in the eastern part of Akita City, located about 20 meters above sea level on the left bank terrace of river Asahi and excavated in the year 1995-1996. Excavation revealed many lacquer-coated artifacts related to the late Jomon period (c. 14,000 BCE – 400 AD). Including these, lacquer ware, bows, combs, bracelets, earrings etc. From the excavated artifacts the advanced arts and crafts of the people of that time can easily perceive.

One piece of black lacquer coated potsherd sample was collected from Mizonoghuchi site in Hyogo prefecture. This ruin was discovered in 1967 during construction of the bypass Kakogawa. Numerous pottery of Yayoi period (c.400 BCE-300 AD) was excavated from this site and some of these artifacts are displaying in the Kakogawa Cultural Center (Hiraoka town).

Lacquer is a type of resin, made from the highly toxic sap of varnish tree **(**Rhus verniciflua*)* which is tapped like latex is tapped from rubber trees. In essence, it is a natural plastic and have remarkably resistant to water, acid, and, to a certain extent, heat. Purified lacquer can be applied to the surface of nearly any object as a glaze or coating. To apply lacquer to wooden or other material is to give that object a smooth, glossy finish. Once coated with a thin layer of lacquer, the object is placed in a warm, humid, draft-free cabinet to dry. As high-quality lacquer may require thirty or more coats, its production is time-consuming and costly.

Samples of Laos:

Laos, officially the Lao People's Democratic Republic, is a landlocked country (population 5.6 million in 2005) in South East Asia, bordered by Myanmar and People's Republic of China to the northwest, Vietnam to the east, Cambodia to the south and Thailand to the west. For this research, archaeological potsherd samples were collected from the cultural information Centre of Laos National Museum. Collected lacquer coated samples were broken parts of a vassal. Archaeological ceramic was first uncovered in Laos from the Vientiane area of the Mekong Valley in1970. The tradition of Lao ceramics dates back to the third millennium BCE. Pottery and ceramics were an essential part of the trade between Laos and its neighbors.

Instrumentation: Analytical study was carried out by using different types of microscope; for example, Camera attached Biological microscope, Stereoscopic microscopic and Scanning electron microscope. Preparation of thin-section is a fully scientific process which

was done in the laboratory of Historical Heritage Department, Kyoto University of Art and Design, located in Kyoto, Japan.

Design: This research is based on the scientific laboratory analysis related with quantitative method. Quantitative designs include experimental studies, quasi-experimental studies, pretest-postest designs, and others [8], where control of variables, randomization, and valid and reliable measures are required and where generalizability from the sample to the population is the aim [9].

This method served as a guide in gathering the data required to analyze, describe, record and interpret conditions and situations evaluated by the researchers. Likewise, this method assisted the researchers to determine the evolutionary changes of pottery, history of pottery and the lived experiences of the potters in Asian Continent.

Data Analysis Procedure: Research samples were collected with adequate information of excavation data as well as site context. Initially, visual analysis was done by binocular microscope and then prepare a list of all measurements. After completion of the initial data collection, petrographic analysis was initiated by using 'Polished Thin-section Method'.

The first step of polished thin-section preparation is called 'sampling'. The necessary equipment for sampling includes a nipper, forceps, labels, a magnifying glass, brass, and a colour pencil/pen. Potsherds should be divided into many suitable pieces carefully with the nipper.

The second Step is 'Preparation of the Polyethylene Tube'. The materials used are a polyethylene tube, slides, scissors, and a hot plate. Cut a polyethylene tube with an inside diameter of 16mm to a length of 1cm. Heat one end of the cut tubes on the hot plate at about 150°C to melt the ends flat (Fig. 3). Otherwise, resin will flow out from the openings.

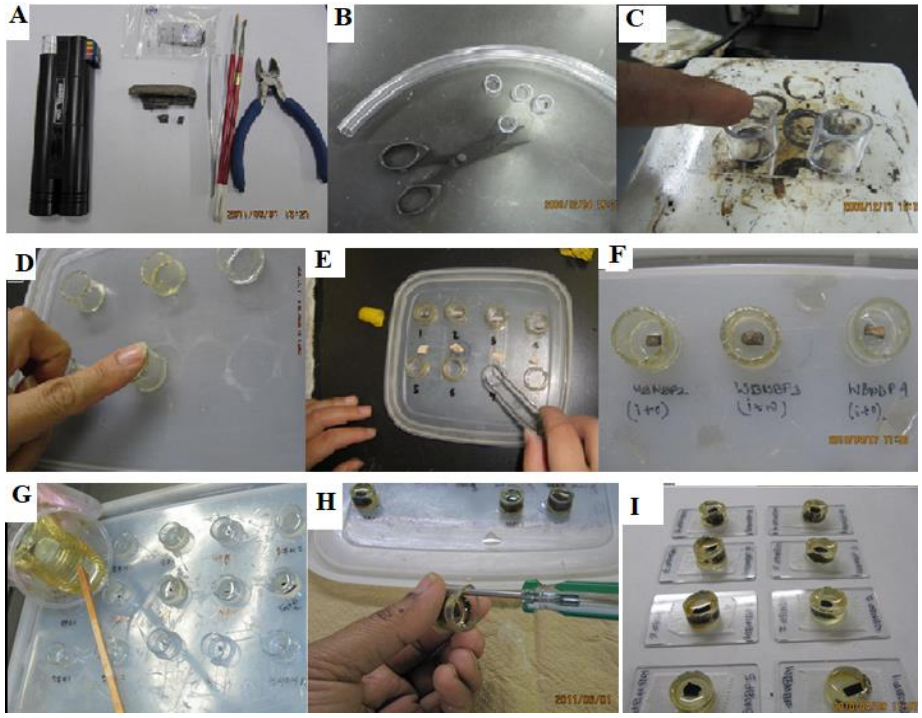

Fig. 3. Preparation of the Polyethylene Tube:
A. Preparation of samples; B. Preparation of tube; C. Melting one end of tube on a hot plate;
D. Affixing the tube on a plastic cover; E. Adhering samples to the inside of tubes;
F. Samples adhere inside the tube with water soluble adhesive; G. Resin sealing the tube;
H. Removing sealed sample in the resin; I. Adhere sample in on the glass slide

The third Step is 'Affixing Polyethylene Tubes'. A thick polyethylene plate, such as the flat lid of a plastic Tupperware container, to embed the potsherd samples is necessary. Attach the cut tubes securely to the thick plate by using water-insoluble adhesive (cellulose)**.**

The fourth Step is 'Adhering Samples'. The necessary materials are tweezers, plastic Tupperware, water-insoluble adhesive and an oil-based marker. Fix the samples to the insides of the tubes with adhesive, using tweezers to fix them in the proper position. Use an oil-based marker to record the sample numbers on the Tupperware cove.

The Fifth Step is 'Resin Sealing'. The necessary materials are transparent epoxy resin, a mask, gloves, disposal cups, a glass stick, polyethylene film, a balance, vacuum desiccators, and a vacuum pump. An epoxy resin that has low viscosity, transparent, and easily allows for the removal of bubbles was used for this research. The epoxy base agent and the hardener were mixed in a 2:1 weight ratio, using a stirrer in a disposal cup. When mixing is complete, place the disposable cup into the vacuum desiccator to remove the bubbles. After decompression, remove the disposable cup from the vacuum desiccators and embed the potsherd samples in the resin (Fig. 5A) and wait until the resin hardens.

Next Step six is 'Removing Sealed Resin'. The necessary materials are a pair of gloves, a knife, nippers, and a screwdriver. The sealed samples were removed from the thick plate together with the polyethylene tubes with a screwdriver (Fig. 4A and B).

Then Step seven is 'Adhering Samples'. The bottom surface of the samples was sanded with a sheet of waterproof abrasive paper (#400). After sanding, affix the double-sided tape to the flat bottom of the sample and adhere it to the slide.

Step eight is called 'Sanding Samples'. The necessary materials are slides, double-sided tape, a felt pen, a belt sander, a stereoscopic microscope, and a lighting system (fibre type). The resin was sanded flat with a belt sander (#100) until the embedded sample is reached. Step nine is known as 'Sanding and Polishing Samples'. After the rough sanding, the upper surfaces of the samples were finely sanded with #400, #800, #1200, and #2000 waterproof abrasive papers in that order; then polish them with a cloth-based polisher. Examine the upper surface with a binocular or stereoscopic microscope (with reflected light) (Fig. 4A and B).

Step ten is 'Adhering the Samples to the Permanent Slides with Epoxy Resin'. The necessary materials are epoxy resin, disposable cups, tweezers, polyethylene film, weights, and a knife. Tape the samples to the slides temporarily, and place these slides on a desk in numerical order. Place the same number of empty slides next to the sample slides. The new slides should be unused and free of scratches. Remove any oil spots with alcohol, and wipe off any dust from their surfaces with a cloth. Transcribe the same numbers from the sample slides to both ends of the new slides before taking the tape off to avoid later confusion. Cut the samples from the slides with a knife, and place them in order beside the new corresponding numbered slides. Prepare transparent epoxy resin to adhere the sample to the new slide. Use the same type of resin that was used previously. Mix the epoxy resin with a stick to remove any bubbles before use. Remove a small amount of resin from the cup with a bamboo stick, and drop it into the centre of a new slide. Place the polished side of the sample onto the drop of epoxy resin. Place a 3×3cm piece of polyethylene film onto the sample, and then place the old slide on top of the film, and hold it down with pressure from above. Leave the samples until the epoxy resin is hardened (Fig. 4C1-C4).

Step eleven is 'Finished Slide'. The necessary materials are waterproof abrasive papers, double sided tape, cover glass, a slide box for storing samples, and an optical microscope. When the epoxy resin has hardened and the samples are fixed to the slides, the upper surfaces of the samples were sanded until they turn transparent enough to allow examination by transmitted light. Sand them with #400 waterproof abrasive paper first, and then switch to #800, #1200 and #2000abrasive papers in that order. Sanding was continued until the sample is about 20 μm in thickness (Fig. 5).

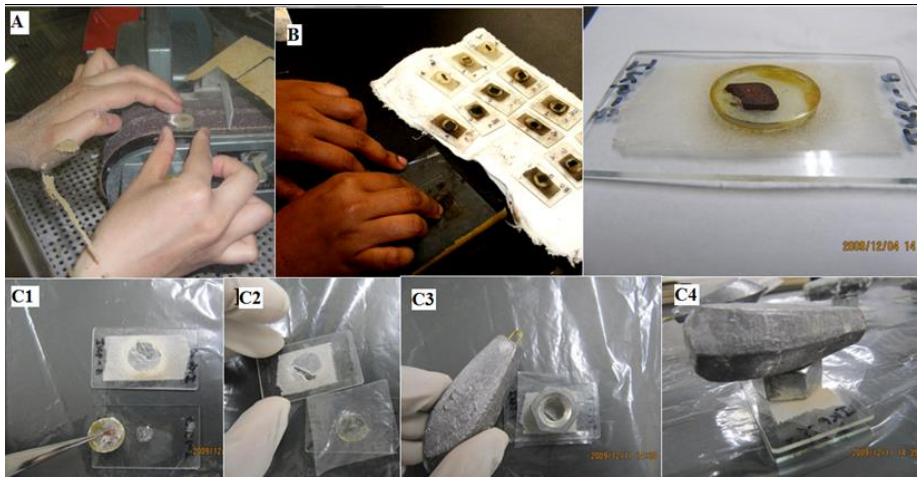

Fig. 4. Sanding the samples (A), Polishing the samples (B) and Adhering samples to the permanent glass slide (C1-C4)

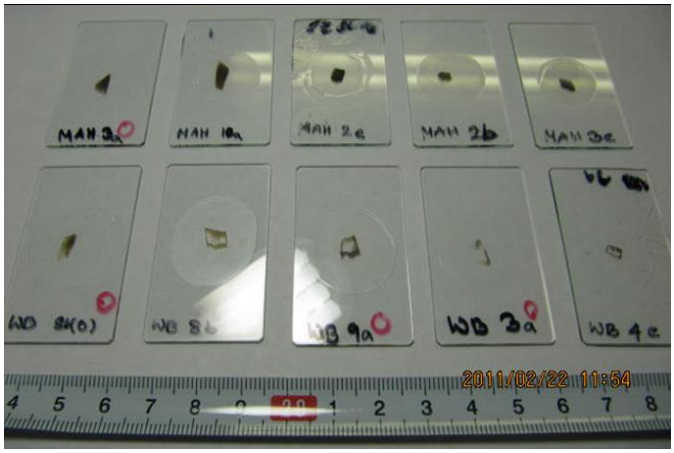

Fig. 5. Final slides for observation by microscope

Finally the last Step is 'Photographing Transparent Samples'. A camera attached to the optical microscope was used to capture images of the prepared thin-sections. Take note of the samples numbers and their corresponding magnifications.

Analysis

Data Analysis by Initial Visual Observation: Documenting and interpreting the archaeological record is the core concept in archaeology. The physical attributes were recorded by traditional pen-and paper method and surfaces of all samples were observed in a binocular microscope (Olympus SZH10) with Fiber light FL-50 before preparing microscopy thin-sections.

Surface observation: Samples from Bangladesh

The measurement, quality and site information of the collected 5 pieces of potshards from Wari-Boteshwar site are as follows:

WB Potsherd A: A broken rim part of a bowl which was about 3×5cm in measurement and 4.6 mm in thickness was collected from Trench-2, Dig-30, Q-north, Depth-152cm in 2005.

Both the surface was coated, smooth and black in color (Fig. 6A). Gray color body surface was visible where the coating was damaged.

WB Potsherd B: This potsherd was a broken neck part of a Bowl, excavated from Trench-RT_1, Dig-18, northeast (pit), Depth-176cm in 2009. Potsherd was about 3×3 cm in measurement 3.8mm in thickness and core was deep ash color. Both the surface was smooth, glossy and black color (Fig.6B).

WB Potsherd C: Collected potsherd was a broken rim part of a bowl, excavated in 2005, from the Trench-7, Dig-27, Q-north, Depth-163cm. Potsherd was about 4×6cm in measurement and 5.1mm in thickness (Fig. 6C). Overall quality shows the same quality like previous samples.

WB Potsherd D: This thick potsherd was a broken rim part of a dish, excavated in 2009, Trench-RT_1, Dig-22, Depth-156cm. Potsherd was about 3.5×5cm in measurement and 7mm in thickness. This potsherd was reddish in visual observation which may be the cause of excess cleaning; in which top surface was damaged and lower surface was visible (Fig.6D).

WB Potsherd E: This interesting potsherd was the lower part of a NBPW dish on stand, excavated in 2009, from Trench-2, Dig-33, Q-north-west, Depth-152cm. Potsherd was about 5×5.5cm in measurement and 5.58mm in thickness (Fig. 6E). Surface characteristics shows the same quality as samples in figure 6A-C.

Fig. 6. Collected potsherds of Wari-Boteshwar site

Three pieces of black colored potsherds were collected from Mahasthangarh site (Fig. 7).

MAH Potsherd A -This potsherd was a broken body part of a dish, about 4×2cm in measurement and 3.0mm in thickness. Core was deep ash color. Both the surface was coated, smooth, glossy and black in color (Fig. 7A).

MAH Potsherd B - This potsherd was a broken body part of a bowl, about 2.4×3.1cm in measurement and 3.6mm in thickness. Core was brown in color. Outerside surface was smooth and black in color. Inner side was without coating and gray color. Seems that, this surface was also originally coated but coating was missing at present (Fig. 7B).

MAH Potsherd C - This potsherd was a broken body part of a dish, about 3.8×3.6cm in measurement and 3.9mm in thickness. Core was gray color and black coating is exists only some portion of the inner side. The other portion of inner side and whole outer surface was lack of coating (Fig. 7C). There is a possibility that originally the whole potsherd was coated, but coating missing at present.

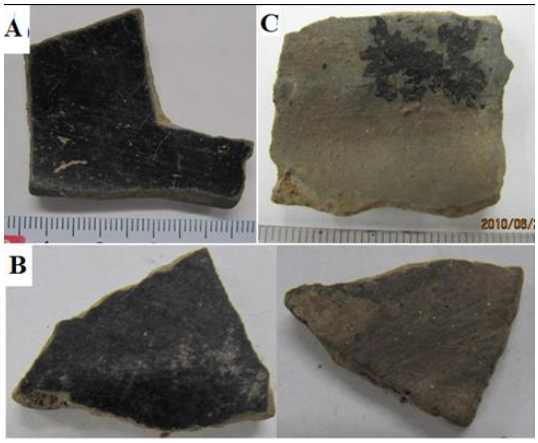

Fig. 7. Collected potsherds of Mahastangarh site, Bogura district, Bangladesh

Surface observation: Samples from Japan

Collected samples were very tiny parts of a black colored vassal (Fig. 8), which was flourished in mainly Kyushu region of southern Japan and believed to migrate from Korean peninsula. It was popularly known as '*Kokushokumaken doki*'. Research samples were collected from the excavated site of Oishi, Kyushu. Both side was black coated and smooth, core was ash color and fabric was medium, about 10-25mm in length and 5.0mm in thickness.

Fig. 8. Collected potsherds from the Oishi site, Oita prefecture, Japan

Two types [red and black] of archaeological potsherds were collected from Tobiragawa site of Akita prefecture (Fig. 9A and B).

(i) Lacquer coated Red potsherd: The measurement of the potsherd was about 7×5mm and thickness was 4.2mm. The core was black color and sandy in texture. Smooth surface was red color on the both side.

(ii) Lacquer coated Black potsherds: The measurement of the potsherds were about 6×5 - 4×5mm. Thickness was 3.0mm. The core was black color and sandy texture. Surface was black coated and smooth in the both side.

Fig. 9. Collected postherds of Tobiragawa site, Akita prefecture, Japan:
(A) red colored potsherd; (B) black colored potsherds.

One piece of lacquer coated black potsherd was collected from Mizonoguchi site located in Kakogawa city of Hyogo prefecture, Japan. Collected potsherd was a broken part of a vase-

shaped pottery; which is known in Japanese as '*Tsubogata doki*' (Fig. 10) and belong to Yayoi period of Japanese history (300 BCE-300 A.D). The measurement of the potsherd was about 1.4×1.0m. Thickness was 8.2mm.

Fig. 10. Collected potsherds of Mizonoguchi site, Hyogo prefecture Japan

Surface observation: Samples from Laos

The collected samples from Laos were broken outer part of a vassal; large sized potsherd's length was 15~30mm and width was 5~15mm. Small sized potsherd's length was 1~10mm and width was 0.5~2mm. Surface of the potsherds were reddish-black and glossy. Body surface of the potsherds were rough where the coating was damaged (Fig. 11).

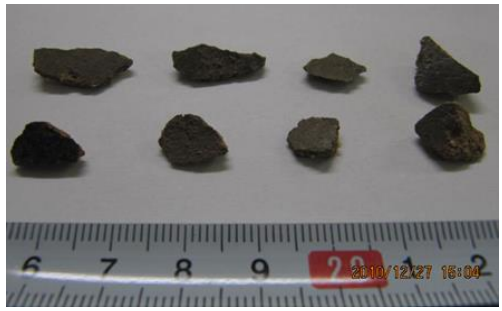

Fig. 11. Collected potsherds of Laos

Data Analysis by Thin-section Observation

After recorded the preliminary information, thin-sections were prepared by using the 'Polished thin-section' method. About fifty slides were prepared from collected research samples of Bangladesh, Japan and Laos.

Samples of Bangladesh

WB potsherds: observed under the polarized light microscope and scanning electron microscope (SEM, HITACHI, Miniscope TM-1000) to interpret the aspects of surface coating. Observation identifies that body clay was well refined. Small mineral particle was about 10~20µm in length and large one is about 50~60µm. The void of organic dirt is not found in the observation, such as, husk, grass or shell was not identified in the body clay. The raw clay straight from the ground does need to be processed. The clay usually needs to be sieved to remove unwanted material such as rocks, twigs, and roots. Sieving can be done either of two ways. The clay can be pulverized when dry and then sieved, or dried, slaked down in water, then sieved. Thin-section observation also found that, Clay made ground/base coating was present on the surface which should be referred to as slip; which is about 25~30µm in thickness. The clay of this slip is finer than the clay used to make the body, and it is brownish in color (Fig.

12A). This clay made coating or slip was uniformly applied in both the interior and exterior surfaces of the pottery. Over this ground coat or slip, another thin coat was observed, which was 2~4µm in thickness (Fig. 12C). SEM observation suggested that, ground coat or slip has many horizontal cracks and thin top coating has vertical cracks (Fig. 12D).

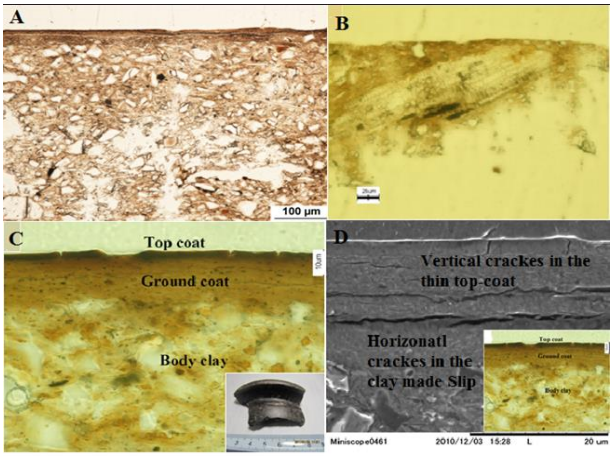

Fig. 12. Examination of Wari-Boteshwar samples: (A) refined body clay, mineral particle and slip is visible; (B0 impression of husk is visible in the body clay; (C) body clay, ground coat or slip and top coat is visible; (D) SEM image: horizontal cracks in the clay-made slip, top coat with many vertical cracks.

MAH potsherds: Microscopy observations are as follows:

Sample 1: Analysis found that body clay of this potsherd was made by fine refined clay, included large mineral particle was about 50~100µm and small mineral particle were 5~10µm (Fig.13A and B). The layer of the surface coating was thick, about 25~50µm in thickness. Polarization image of an optical microscope suggests that surface coating was dark color and different from body clay. Some observation lump of reddish clay on the surface. In some observation, a thin top coating has located over this surface coating, which was 2~4µm in thickness. SEM observation identified the surface coating, 25~50µm in thickness. Ground coating was made from clay and has many horizontal cracks (Fig. 13E and F).

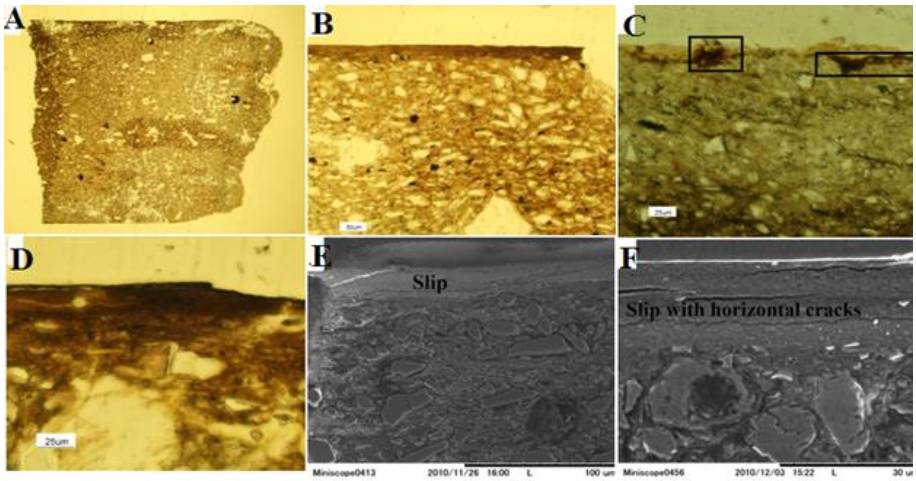

Fig. 13. Examination of the Mahasthangarh samples: (A) refined body clay; (B) thick layer; (C) lump of reddish clay; (D) thin top coating; (E) SEM image shows thick clay-made slip; (F) horizontal cracks.

Sample 2: Observation found that, body clay of this potsherd was made from non-refined clay, included large mineral particle was about 100~300µm and small mineral particles were 50~100µm in length (Fig. 14A and B. Upon the body surface, a thick coating, least 25~40µm in width, was observed. Coating was deep red color and divided into 4 stages (Fig. 14C). In some observation, very thin black color slender marks has noticed in the coating. SEM observation find a 4-staged coating on the surface of this potsherd which possessed many cracks with no direction (Fig. 14D). Coating seems solid and pure.

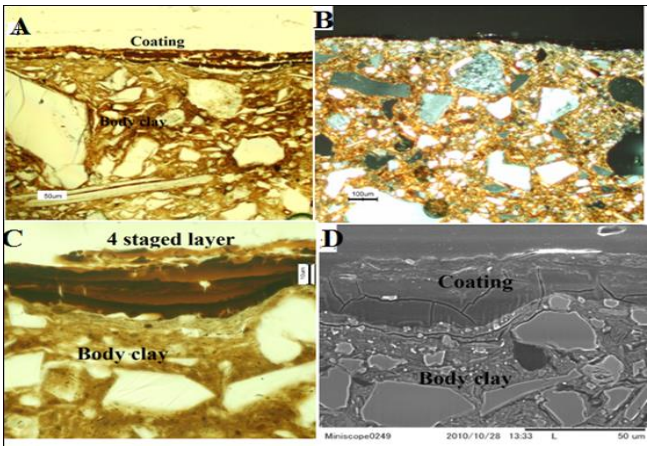

Fig. 14. Optical Microscope observation: (A) non refined clay body with multi-layered coating; (B) Polarized microscopy – with mineral particles; (C) 4 staged thick layer of coating; (D) SEM image – cracks with no direction.

Sample 3: Microscopic observation found that, this pottery was made from refined clay as large-sized particles were not identified in the body clay. Usually important mineral in the pottery is kaolinite which has 1:1 silicon to aluminium oxides. In this observation, large mineral particles are about 40~80µm and small mineral particles are 10~50µm (Fig. 15A-D).

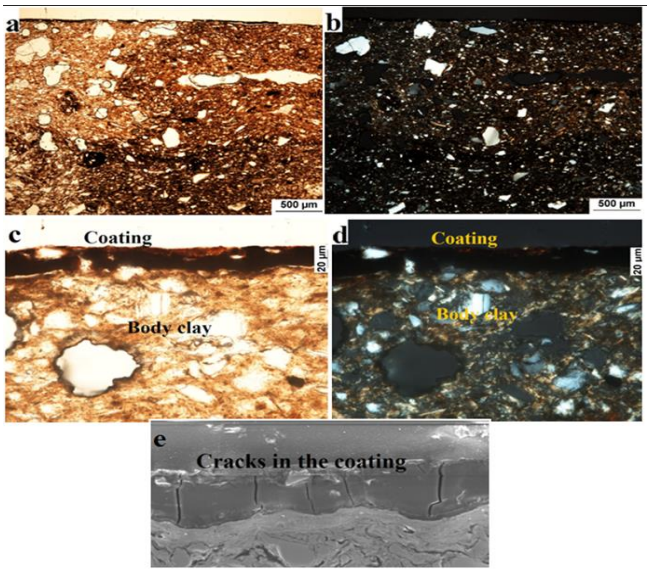

Fig. 15. Refined body-clay and one staged layer of coating (A); Polarized view (B);
Thick layer (C); Polarized image with solid non-clay layer (D); SEM image with many horizontal cracks (E).

Upon the body surface, a thick coating, about 25~30µm in width has identified. This coating is one- staged and black in color (Fig. 15c-d). SEM observation also identified a one-staged coating on the surface of this potsherd which possessed many horizontal cracks in it and seems solid and pure (Fig. 15e).

Samples of Japan

Oishi potsherds: Observation found that, non refined clay was used for preparation of this pottery, because as many large mineral particles are present in the body clay. Large mineral particles are 200~300µm and small one are 4~6µm (Fig. 16a). In some few observations, surface was coated with a thick layer of coating are about 40~50µm in width (Fig. 16b). SEM observation identifies that, thick coating possessed many cracks with no direction (Fig. 16d).

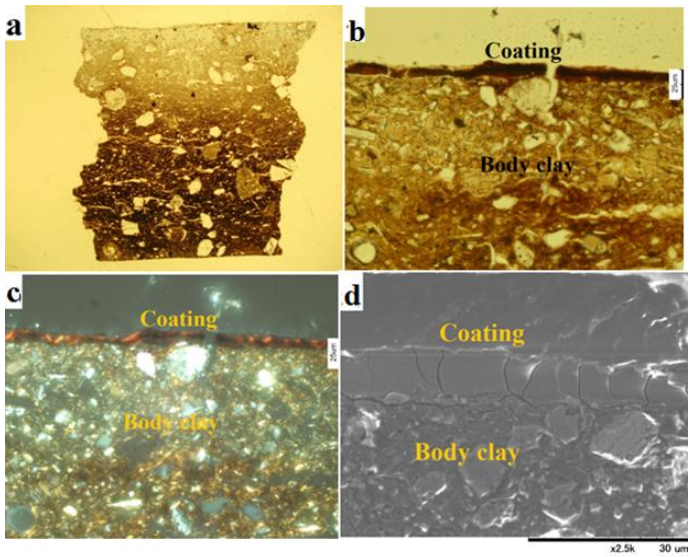

Fig. 16. Non-refined body-clay (A); one staged layer (B);
Polarized view (C); SEM image with vertical cracks (D)

Lacquer coated samples: Thin-sections, prepared from red lacquer coated potsherd, found that body clay contains big mineral particles. Two layer of lacquer coat is present on the surface; ground layer is yellow and top layer is dark red color (Fig. 17A and B). Both layers are thick, in total 30~50µm in width. Yellow color ground layer is very clean; little impurity is present on the ground coating and dark red top layer is mix with pigments. SEM observation showed ground layer is transparent, solid and originated from raw lacquer. Upper layer is mix with pigment called '*Bengara'*.

Thin-section prepared from black lacquer coated potsherds, found that, body clay has contains many big mineral particle and organic substance like grass and shell particle (Fig. 18). Surface possessed a coating of lacquer, which is thick, around 25~30µm in width. Applied lacquer seems very clean and dirt free. Polarized view of thin section identifies a coating which is transparent in color.

Lacquer coated samples from Mizonoghuchi site: Microscopic observation found a thick; about 30~50µm width solid lacquered layer is present on the surface. Polarization image showed the solid characteristics of the coating; solid coating is dark red color and not clayey. Used lacquer is very clean and little impurity is present on the lacquer. Thin section observation in SEM identified a thick and solid layer of coating on the potsherd surface (Fig. 19).

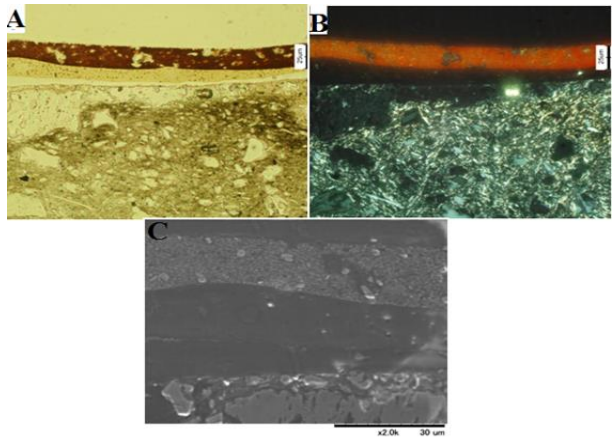

Fig. 17. Non-refined body-clay (A); two staged layer (B); SEM image shows two layer coat – upper coat is pigment mixed lacquer and lower coat is made from raw lacquer (C)

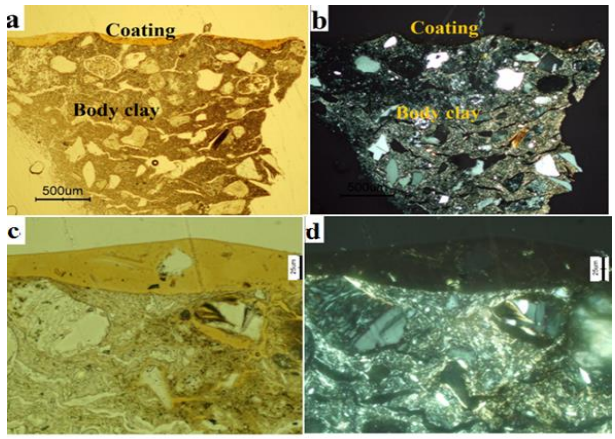

Fig. 18. Non-refined body-clay: shell and husk impressions (A); polarized image of the same thin-section (B); One stage layer thick and made from refined lacquer (C); SEM image show staged thick lacquer coat (D)

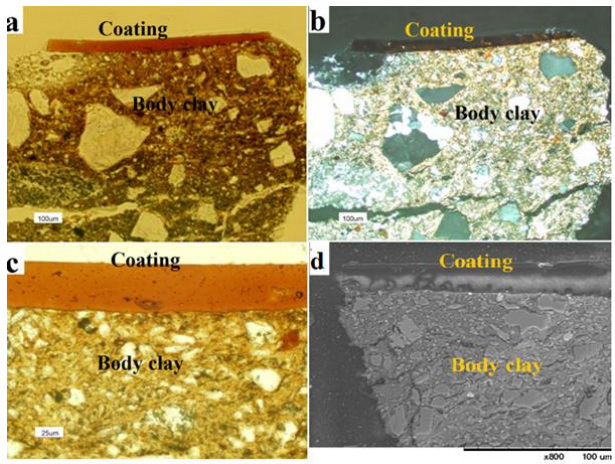

Fig. 19. Large minerals (A); Polarized image of same thin-sample (B); thick one stage layer made of rafined lacquer (C), SEM image show staged thick lacquer coat (D)

Samples of Laos

For microscopic observation, 25 pieces of glass slides (thin sections) were prepared and observed in an optical and SEM. Body clay of the pottery possessed many mineral particles, including these, large one was about 500~1200µm in length and small one was about 10~30µm in length (Fig. 20a). Thick coating of lacquer was present on the surface of the sample, about 25~40µm in thickness (Fig. 20c and d). Applied layer of lacquer was very fine and dirt's were not present in large amount. In the SEM observation, solid coating was visible on the surface. This coating was transparent in color and no cracks were identified.

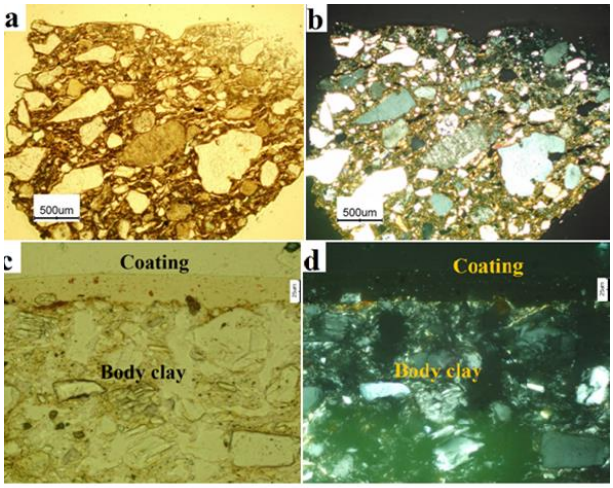

Fig. 20. Optical image with large mineral particles (A); Polarized image of same thin-section (B); one staged layer made from refined lacquer (C); Polarized image with transparent surface coating (D)

Discussion

Case Study: Bangladesh

Laboratory analysis suggested that, samples of NBPW have contained surface coating originated from two different sources. 25~30µm thick base-coating is made from clay and can called as 'slip'; and the very thin top coating is not a clayey material. This top coating is originated from organic source. In this regard, Dr. B.B. Lal (1959-60) and H.C. Bhardwaj (1979) said that slip of NBPW was prepared by refined clay and organic substances like oil and plant juice to produce the lustrous surface of the shard [6]. Again, Robert Harding's research (2004) concludes that 'all the examined samples have two slip, with the upper surface being about a micron in width…' [7]. Present research identifies a ground coating made from clay which is popularly known as 'slip' and about 25~30µm in thickness. On the other hand, clay was not identifies in the top coating which is 2~4µm in thickness. H.C. Bhardwaj said that 'the organic substance of the slip will carbonized without burning out, resulting in a uniform lustrous black surface'. Present research suggests that organic substance will be destroyed if it apply to the surface before firing. The thin top-coating is probably result of reduction firing method in where fired ceramics were smoked with husk, dry wood, dry leaves, or dry cow dung. Smoking is produced by a period of extreme reduction at the end of the firing, so that the nearly total deprivation of oxygen saturates the atmosphere with un-burnt carbon in very fine particles, which produces black smoke that invades the kiln and impregnates the surface of the unglazed pieces which will have after cooling a color ranging from gray to black. The color is thus due to the fuel and not to a transformation of the shard. There is a caution to conserve of this kind of surface coated pottery that not to over-wash after collection or excavation. Due to the excess

wash surface coating could be damaged and thus become unavailable for further research. Initially a decision can be made from present technical analysis that, (1) This historic black polished pottery or NBPW was consist from refined clay; (2) A fine clay-made slip was applied on the surface of NBPW to achieve the non-porous quality; (3) Thin top-coating was covered the slip which was probably the result of reduction firing. The clearly identified slip, organic top coating and fine clay-made core of NBPW has been identified by the microscopy analysis which tells us the secrete technique of ancient Bangladeshi potters who perceive the most beautiful skill to prepare a world-class pottery Industry.

Case Study: Japan

The prehistoric potsherds of Japan were collected from Oita prefecture, Akita prefecture and Hyogo prefecture. Selected samples of Oita prefecture were belong to 'black surfaced pottery' and the other collected potsherds from Akita and Hyogo prefectures were 'East Asian lacquered' pottery.

The prehistoric potsherds of Oita prefecture were collected from Oishi site, belong to famous pottery type, '*Kokushokumaken doki*'. Initially potsherds surface were analyzed in the binocular microscope and Scanning Electron Microscope (SEM), then thin sections were prepared for optical microscopic observation. Previous research by Japanese researcher suggested that '*Kokushokumaken doki*' was fired at reduction method and impregnated with dried leaves, husk or animal droppings and no coating was applied. In this firing method, pots are piled up on a flat piece of ground, on a raised platform, or in a dug-out hallowed ground. The fuel is placed below, among or above the pot. After firing pot was impregnated with dried leaves or animal dropping which resulted black surface pottery.

In the present research, microscopic thin-section observation found that surface is polished; but in some few sample, thick surface coating was clearly visible in the inner part of thin-sections. Outer part is polished without coating. Again, the applied coating does not seem as a residue part of the potsherd though it is not a mass finding. May be the examined potsherd was some experimental item or only inner portion was coated for liquid preservation or resistance for water porosity. Another possibility also thinks that, probably surface of the pottery was coated with organic substance for achieve the surface luster. In any case, more sample collection and microscopy analysis is necessary for accurate result.

The collected lacquer coated potsherds of Tobiragawa site, Akita prefecture was belong to two types, red and black. In the red lacquer coated potsherds, thin section observation identified two layer of coating. Base layer is light yellow color and thick; however, top layer is dark red. Observation also suggested that lacquer was applied on the polished surface of the pottery. In the black lacquer coated pottery, thin section observation identified one staged layer of coating which was yellow color, refined and thick. Observation also found that body clay of this potsherd was containing shell and organic dirt like grass and husk. The collected lacquer coated potsherd of Mizonoguchi site, Hyogo prefecture was black. Thin section observation identified a thick layer of coating on the surface which is made from refined raw lacquer and applied on a polished surface.

The analysis result of the Japanese potsherds suggested that, tree sap or lacquer was applied on the pottery surface to make not only the color but also to protect the pot against the water porosity. Many lacquered pottery has been excavated from Japan which were dated from Jomon period dated of 14000 BCE – 400 BCE. These types of pottery was first coated with the raw lacquer as a ground coating and then applied the top coating which was mixed with pigments named *'Bengara'* or cinnabar. Both these pigments are reddish in color, but cinnabar is more reddish than the 'Bengara'. Usually ''Bengara'' was common pigment for mixing with the lacquer of prehistoric Japanese pottery. This very special technique was originated from Jomon period and still it is one of the main technologies of surface coating of Japanese tableware.

Case Study: Laos

Analyses recommend that lacquer was used as a glaze or surface coating on traditional pottery of Laos. Thick coating, 25~30µm in width, was observed in the thin-section, which is made from raw lacquer. Observation also suggested that, body clay containing many large mineral particles. Lacquer was used on the surface of the clay-made pot to make it water resistance and these type of pottery was used as a liquid container from ancient time.

Conclusion

Present research aimed to identify the coating technology of Asian traditional potteries. For that purpose, samples were collected from Bangladesh, Japan and Laos. Microscopic analysis of the pottery samples has been done by petrographic method, in which, thin sections were prepared and observed in an optical and scanning electron microscope. Analysis found that collected Bangladeshi pottery samples were coated with two different kind of material; one is a clayey material and applied as a ground coating made of 'Slip'. Another thin top coating was applied on the base slip, which is 2~4µm in width and different from the base slip, originated from organic source. In the SEM observation, this top coating is solid and having many cracks in it. Slip was used as a surface coating for water resistance non-porous quality and top coating was for polished beautiful appearance. Analysis of the black colored pottery samples of Japan suggested that carbon-impregnation was used to coat traditional pottery, although drying oil was found in the surface of some collected samples as a form of layer. Analysis of another type of Japanese samples shows that tree sap or lacquer was used as a basic medium of coating to enhance the quality of water resistance and multi-color surface appearance of a pottery. Lacquer could give longevity to a ware whether made from wood or clay. A conclusion could be made by this research that, three main coating technique were used for Asian historic pottery; (a) application of clay-made slip or slip casting; (b) firing in reduction method and smoked with dry leaves or animal droppings; and (c) application of lacquer or tree sap. Thin-section petrography could be pioneer to reveal all these information and reconstruction our cultural history.

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Notes

Ceramic Petrography: Ceramic petrography is one of the indispensible analytical techniques for modern ceramic studies with the use of a polarizing microscope, electron microscope and electron microprobe.

Thin-section: thin section is a laboratory preparation of a rock, mineral, soil, pottery, bones, or even metal sample.

Lacquer: It is one kind of tree sap that gives a beautiful surface finishing to the wooden materials as well as clay-made ancient objects.

NBPW: 'Northern Black Polished Ware', a sophisticated table ware of Asian continent, dated back to c. 10th BCE. It was first excavated from Sarnarh, India in 1904 by Sir John

Marshall. NBPW has been excavated from the two early historic sites of Bangladesh, named 'Wari-Boteshwar' and 'Mahasthangarh'.

Pottery: Pottery is a form of ceramics. Ceramics is a broader aspect of molding certain materials into something artistic or something of use. The Greek meaning of Ceramics' is burnt stuff. Clay, Silica and feldspar are the main three ingredients of ceramics.

Potsherd: broken parts of pottery.

Impregnation: A method of strengthening a fired porous ceramic surface by smoking with dry animal manure or leaves.

Slip: Slip is a liquefied suspension of clay particles in water.

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