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Reviewed Article:

Documenting Traces Left on Ceramic Surfaces by Tools Used for Treatment and/or Decoration: an Experimental Approach

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This study explores the role of experimental archaeology in investigating ancient ceramic production techniques. Utilising materials analysed by Rammo (2017) from the fortified settlements of Asva, Ridala, and Iru in Estonia, we focus on two types of impressions on sherds dated to the beginning of the 1st millennium BC. Our aim was to test the hypotheses concerning the execution methods of these impressions and evaluate the effectiveness of

experimental methodologies in recreating them. Through an experimental protocol, we produced clay tablets to simulate the decorative techniques identified by Riina Rammo. Key findings indicate that decorating at the leather-hard stage, as opposed to the soft clay stage, yields notable differences in the visibility and depth of impressions. While our experiments confirmed some aspects of Rammo's hypotheses regarding Type 2 and Type 4 impressions, discrepancies emerged that suggest variations in pressure application and timing may significantly affect the resulting patterns. This study emphasises the value of experimental archaeology in hypothesis testing, while also highlighting topics for further research, particularly regarding post-firing treatments and their implications for understanding the functional and aesthetic roles of decorations on ceramic vessels.

> The study highlighted issues regarding the identification of the decorative phase within the chaîne opératoire. Our experimentation demonstrated that decorations executed at the leather-hard stage (...) produced traces comparable in general appearance to those described by Rammo (2017) for Type 2, suggesting that a more systematic comparison would be feasible in future studies.

Introduction

To date, experimental archaeology has validated analogies by applying repeatable methods, making it one of the most widely used approaches for understanding the social and environmental contexts in which artefacts were created and used. "Learning an ancient technique from a book or video covers only a few aspects; when one experiences it in reality, this involves all senses, it requires agility and one gets an understanding of space, form and material" (Paardekooper, 2019, p.2).

Stemming from these considerations, our objective was to highlight the advantages and disadvantages associated with the use of experimental archaeology in testing hypotheses regarding the ceramic production.

As a case study, we selected the materials analysed and published by Rammo (2017), which date to the beginning of the 1st millennium BC. The 170 sherds analysed by the author come from the fortified settlements of Asva, Ridala and Iru (Estonia) and show regular textile impressions. The in-depth morphological study allowed the author to acquire information on the types of textiles used and propose hypotheses on how these decorative patterns were executed.

The author recognised six types of textile impressions, based on the patterns identified through stereomicroscopic observation. Two types (Type 2 and 4) out of the six identified were selected, as they are the ones for which more than one execution method was proposed. The other types either show traces that are difficult to interpret (Type 3, 5, 6), or have a single hypothesis considered plausible by the author, allowing for a clear

interpretation (Type 1). The interpretive ambiguity characterising Types 2 and 4 provided the basis from which the experimentation presented in this article began.

In both groups (Types 2 and 4), "textile impressions were used together with other finishing methods, such as smoothing or striating" (Rammo, 2017, p.112), suggesting that these impressions could not have been made on fresh clay. The overlapping of treatments-such as striations applied after the impressions-indicates either that the surface had already begun to dry, or that the impressions were not the final step in the surface treatment process.

The author described Type 2 as impressions found on the outer surface of vessels, characterised by narrow furrows which often exhibit steep walls and sharp ends. It was also suggested that Type 2 (See Figure 1A) sherds "show rows which may at least partly belong to loosely twisted two-ply ropes [...] wound around a stick and rolled over the surface of a pot" (Rammo, 2017, p.115). On the other hand, Type 4 (See Figure 1B) sherds feature wavy diagonal rows with an arched shape, sometimes arranged in a net of notches and grooves. These impressions could have been left by plain weave textiles made primarily with plant fibres, even though the nålebinding technique has been suggested as well (Kriiska, Lavento and Peets, 2005). Another hypothesis consists in the use of two different unidentified textile items, as the grooves and notches resemble two distinct textile systems. The possibility that these impressions were not derived from textiles was also taken into account, as shown in Lopatina (2015).

The aim of this study is to verify the hypotheses advanced for Type 2 and Type 4, the latter only concerning the nålebinding technique, and assessing their applicability by creating a reference collection. This collection is based on traces detected and linked to decorative patterns and/or surface treatments used.

Materials and methods

The main parameters considered for this experimentation (See Table 1), as well as the tools used for surface treatments, were partly chosen based on two articles; *Approaching surface treatment in prehistoric pottery: Exploring variability in tool traces on pottery surfaces through experimentation* (Bonilla, et al., 2020) and *Reading ceramic surfaces: Characterizing surface treatments for functional identification of pottery* (Rueff, et al., 2021).

ID	Pre-Firing treatment tool	Gestuality	Applied Decoration	Stage of the tablet at the time of decoration	Decoration Type (Rammo 2017)
1	pebble	clockwise movement (with index and middle finger)	crocheted wool	leather-hard clay	Type 4

2	pebble	clockwise movement (with index and middle finger)	wooden instrument with rope (repeated movements)	leather-hard clay	Type 2
3	pebble	straight movement	crocheted wool	leather-hard clay	Type 4
4	pebble	straight movement	wooden instrument with rope (repeated movements)	leather-hard clay	Type 2
5	pebble	clockwise movement (with index and middle finger)	none	leather-hard clay	/
6	pebble	straight movement	none	leather-hard clay	/
7	wet hand	clockwise movement (with index and middle finger)	crocheted wool	leather-hard clay	Type 4
8	wet hand	clockwise movement (with index and middle finger)	wooden instrument with rope (repeated movements)	leather-hard clay	Type 2
9	wet hand	clockwise movement (with index and middle finger)	none	leather-hard clay	/
10	none	none	crocheted wool	fresh clay	Type 4
11	none	none	wooden instrument with rope (single movements)	fresh clay	Type 2
12	none	none	wooden instrument with rope (repeated movements)	fresh clay	Type 2

TABLE 1. SUMMARY TABLE OF PRE-FIRING TREATMENTS, GESTUALITY, DECORATIONS, CONDITIONS AND DECORATIVE TYPE (RAMMO 2017) OF THE TWELVE TABLETS AT THE TIME OF DECORATION.

Firstly, to reduce the number of parameters influencing the result, we decided to reproduce surface treatments and textile impressions on purified clay tablets (10x10x1cm). Our experiments were aimed at understanding the steps of the pre-firing procedure, such as the application of imprints. Post-firing experiments, useful for understanding any practical utility of the decorative motifs (found only on coarse paste fragments, attributable to forms related to food cooking), were omitted because of time constraints.

It is important to stress that the work was influenced by this factor, as the experimentation took place during four-hour lectures over three days, as part of the MA university course of experimental archaeology held by Professor Cristina Lemorini (Sapienza University of Rome). Another limitation to take into account is the selection of materials. In fact, no nålebinding fabric was employed for the reproduction of Type 4 impressions; instead, a crocheted woollen cloth was used.

The main problem we encountered was firing the tablets. The tablets were left to dry under a plastic cover in a dark, dry room for two weeks to reach the appropriate degree of dryness. In similar experiments (similar tablet dimensions, type of clay used, and controlled environment during the experimental protocol) this stage has typically been reached after approximately 14 hours (Bonilla, et al., 2020). In such cases, the final product is recognised here as being at the leather hard stage, though actual drying time may vary depending on the characteristics of the clay and the environment. The tablets were then fired at 750°C for four hours (Rueff, et al., 2021).

Unfortunately, the experimental samples were still too moist when fired and consequently began to explode at a temperature of 250/300°C. For this reason, the results and conclusions of this study are derived from the analysis of unfired samples (an important parameter considering the effect that firing has on pottery, as many experiments have shown). The experimentation was carried out by two inexperienced experimenters in three days. Of these, only one was involved in the making of impressions and surface treatments, in order to reduce the variables considered during interpretation of the results.

While the first two "experimental days" were dedicated to the creation and decoration of the twelve tablets, the last working day was used for microscopic observation and trace identification. The materials used for experimentation during the first two days included industrial clay free of inclusions, which was used to create tablets that were then treated with a rounded wooden tool to flatten their surface. A smooth pebble and moistened fingertips were used to polish the surface. Two types of decoration were applied on 9 tablets out of 12 (IDs 1, 2, 3, 4, 7, 8, 10, 11, 12), of which six underwent both pre-firing treatment and decoration (IDs 1, 2, 3, 4, 7, 8), while the remaining three were only decorated (IDs 10, 11, 12). Three additional tablets (IDs 5, 6, 9) underwent only pre-firing treatment and serve as control samples. The first type of decoration corresponds to what Rammo (2017) defines as Type 2, and was created using a stick and two thin ropes made of plant fibre which were rolled on the surface repeatedly. The second type, corresponding to Type 4 in Rammo (2017), was initially applied with a rolling pin, which was later replaced by a quadrangular stone (measuring approximately 10 cm per side and 4 cm in height) and a segment of crocheted wool, as the impression was not sufficiently visible when using the wooden tool. Samples referred to Type 2 are IDs 2, 4, 8, 11, 12, while the ones related to Type 4 are IDs 1, 3, 7, 10. For the surface trace study, conducted on the third day, two selected tablets (IDs 4 and 7) were examined

under a stereomicroscope. One tablet underwent a pre-firing surface treatment with a pebble using straight movements and was decorated with a thin rope wrapped around a stick (ID-4), while the other was treated with a wet hand with clockwise movements, and decorated with a woollen crocheted cloth (ID-7) (See Table 1 for details regarding individual tablet parameters). The two tablets were observed with the Nikon SMZ-U, 10X oculars, 1X objective, zoom range 0.65X-6.5X, reflected light optical fibers system, Topview digital camera at the Laboratory of Technological and Functional Analyses of Prehistoric Artefacts (LTFAPA) at Sapienza University of Rome.

Results

The experimentation was carried out in four main phases over the course of three days. During the first day, of the 12 tablets cut and flattened, nine were left untreated and stored in a dry, dark and ventilated area to reach the desired consistency. The remaining three tablets were decorated without undergoing any surface treatment (IDs 10, 11, 12) and only stored with the others afterwards. During the second day, pre-firing treatments, i.e. pebble and wet hand, were performed on the nine undecorated tablets of which only six were decorated (IDs 1, 2, 3, 4, 7, 8), allowing for the observation of potential differences in surface traces and the distinction between those related to treatment and decoration. Before applying the surface treatments, the nine tablets (IDs 1, 2, 3, 4, 5, 6, 7, 8, 9) were placed on a heat source for approximately 15 minutes at a temperature of circa 35-40 °C, in an enclosed environment with a temperature of approximately 20-25 °C. The third day was dedicated to the creation of a photogrammetric model and observation of the tablets under an optical microscope.

Phase 1 - Making clay tablets

12 clay tablets (10x10x1 cm) were made and treated using a rounded piece of wood to flatten their surface (See Figure 2).

Phase 2 - Surface treatments on leather-hard clay

Surface pre-firing treatments were applied using pebbles or wet handprints. In addition, some of the tablets were not treated to encompass all possible combinations with available materials. These treatments were conducted on nine tablets (IDs 1, 2, 3, 4, 5, 6, 7, 8, 9) during the second day.

Phase 3 - Decoration

Two types of decoration were applied (See Table 1 for details on individual tablet decoration). The first involved impressing a moist woollen cloth using a rounded piece of wood (See Figure 3A), which was subsequently replaced by a quadrangular stone (see Materials and Methods section; Figure 3B).

The second was carried out by intertwining two plant fibre ropes (each with a thickness of 2 mm) and wrapping them around a stick, with a diameter of approximately 1 cm (See Figure 4). Three tablets (IDs 10, 11, 12) were decorated during the first day (one with woollen cloth and two with wrapped ropes, without pre-firing treatment). After the pre-firing treatment conducted on nine tablets during the second day (with the use of pebbles for IDs 1 to 6 and wet hand for IDs 7, 8 and 9), six of them were decorated (IDs 1, 2, 3, 4, 7, 8; see Table 1 for further details); therefore, a total of nine tablets were decorated. The remaining three undecorated tablets underwent only surface treatment and served as control samples (IDs 5, 6 and 9). Figure 5 shows the twelve tablets.

Phase 4 - Microscopic observation

We examined two tablets (See Table 1, IDs 4 and 7) using a stereomicroscope at 10x magnification (see Materials and Methods for microscope specifications). In ID-4, individual filaments of the rope are visible, as well as the pre-firing treatment in areas where the rope impression is absent. Additionally, the repeated movements are distinguishable; as shown in Figure 6A (box 1), two overlapping impressions can be observed. In ID-7 (See Figure 6B), the impressed pattern is not clearly evident at a microscopic level. This is likely due to the magnification, which does not allow for its recognition; however, surface irregularities strongly suggest it is a fabric impression.

Discussion and Conclusions

The study highlighted issues regarding the identification of the decorative phase within the *chaîne opératoire*. Our experimentation demonstrated that decorations executed at the leather-hard stage (technically 14 hours after tablet creation, in our case after 1 week, see Materials and Methods section) produced traces comparable in general appearance to those described by Rammo (2017) for Type 2, suggesting that a more systematic comparison would be feasible in future studies. It has been noted that it is challenging to apply a uniform pressure across the entire tablet when rolling the stick with ropes over the surface. It is important to note that in this experimentation a flat support surface was used to apply the pressure necessary for the decoration. This flat surface enabled the use of tools and pressure angles that would be difficult to apply during the making of a vessel, as opposed to a tablet. Furthermore, points where greater pressure was applied are visible for Type 2 only. On the contrary, Type 4 impressions appear to be more uniform as using a stone allowed the creation of an equally distributed pressure on the clay tablets. This is because using the rolling pin created impressions that were barely visible at a macroscopic level and required multiple passes, further reducing their clarity. In contrast, a single application with the stone was sufficient to create a more distinct impression. Individual filaments of the ropes are visible, making it possible to trace back to the fibres used, both from a dimensional perspective (the thickness of the rope) and in relation to the plant taxa employed. Regarding Type 4 decoration (stone and wool), applying the author's hypothesis, we observe that the

traces are less visible and distinguishable compared to the archaeological sample. This may be due to both the pressure applied by the experimenter during the impression and the timing chosen for the decoration, along with other factors such as the type of fabric, the stitch size and yarn size. Although the decorations were applied at the leather-hard stage, as reported in Rammo (2017), it is possible that they were originally executed on softer clay, prior to reaching this consistency. While Type 4 decoration provides for a complete coverage of surface treatments, the tablets on which Type 2 decoration was applied (in accordance with the typology proposed in Rammo, 2017) allowed us to observe differences in surface treatments. In particular, undecorated tablets with surface treatments have demonstrated that, even on a macroscopic level, the use of pebble leaves characteristic grooves on the surface, resulting in a finish that is less smooth and homogeneous when compared to the hand-treated tablets.

To compare the same type of decoration at two different stages, tablet ID-10 was created, where the impressed pattern is more evident because the decoration was made when the clay was fresh. Unfortunately, due to time constraints, it was not possible to photograph this tablet using the stereomicroscope. Nevertheless, even at a macroscopic level, the differences between the two samples (ID-7 and ID-10) are clearly recognisable. It was observed that using a stone to impress the crocheted wool decoration was more effective than using a wooden rolling pin. Regarding the timing of the application of the two decorative motifs, it was noted that the three tablets (IDs 10, 11, and 12), which exhibited decorations made on fresh clay without pre-firing treatments, showed macroscopic impressions at a greater depth compared to their counterparts, which were decorated at the leather-hard stage. Variables such as different pressure applied to the same material were not tested in this experimentation, although they could provide further useful information regarding the methods of producing decorative patterns.

A deeper exploration of this study would be valuable, specifically by testing the proposed hypotheses through the application of the decorations not on tablets but on ceramic vessels. This approach could yield a more precise understanding of the optimal stage in manufacture for creating the selected decorations as a case study. Additionally, investigating post-firing treatments and their impact on decoration is essential. In this way, hypotheses could be made regarding the potential function of the containers and whether the decorations serve functional purposes or are purely aesthetic.

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decoration

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FIG 1A. MACRO AND MICROPHOTOGRAPH (8X) OF A TYPE 2 FRAGMENT. MODIFIED FROM RAMMO (2017).

FIG 1B. MACRO AND MICROPHOTOGRAPH (8X) OF A TYPE 4 FRAGMENT. MODIFIED FROM RAMMO (2017).

FIG 2. FIRST DAY OF EXPERIMENTATION. THE CLAY WAS PROCESSED AND ROLLED OUT WITH A ROLLING PIN TO A THICKNESS OF ABOUT 1 CM, AND FROM THIS HOMOGENEOUS PASTE THE TWELVE TABLETS WERE THEN CUT OUT. PHOTO BY AUTHORS.

FIG 3A. REPRESENTATION OF THE TEXTILE AND DIFFERENT MATERIALS USED FOR RECREATING TYPE 4 IMPRESSIONS ON THE TABLETS. IMPRINT MADE WITH A ROUNDED PIECE OF WOOD ON A MOIST WOOLLEN CROCHETED CLOTH. PHOTO BY AUTHORS.

FIG 3B. REPRESENTATION OF THE TEXTILE AND DIFFERENT MATERIALS USED FOR RECREATING TYPE 4 IMPRESSIONS ON THE TABLETS. IMPRINT MADE WITH A STONE ON A MOIST WOOLLEN CROCHETED CLOTH. PHOTO BY AUTHORS.

FIG 4. RECREATION OF TYPE 2 IMPRESSIONS ACCORDING TO THE HYPOTHESES PROPOSED BY RAMMO (2017). PHOTO BY AUTHORS.

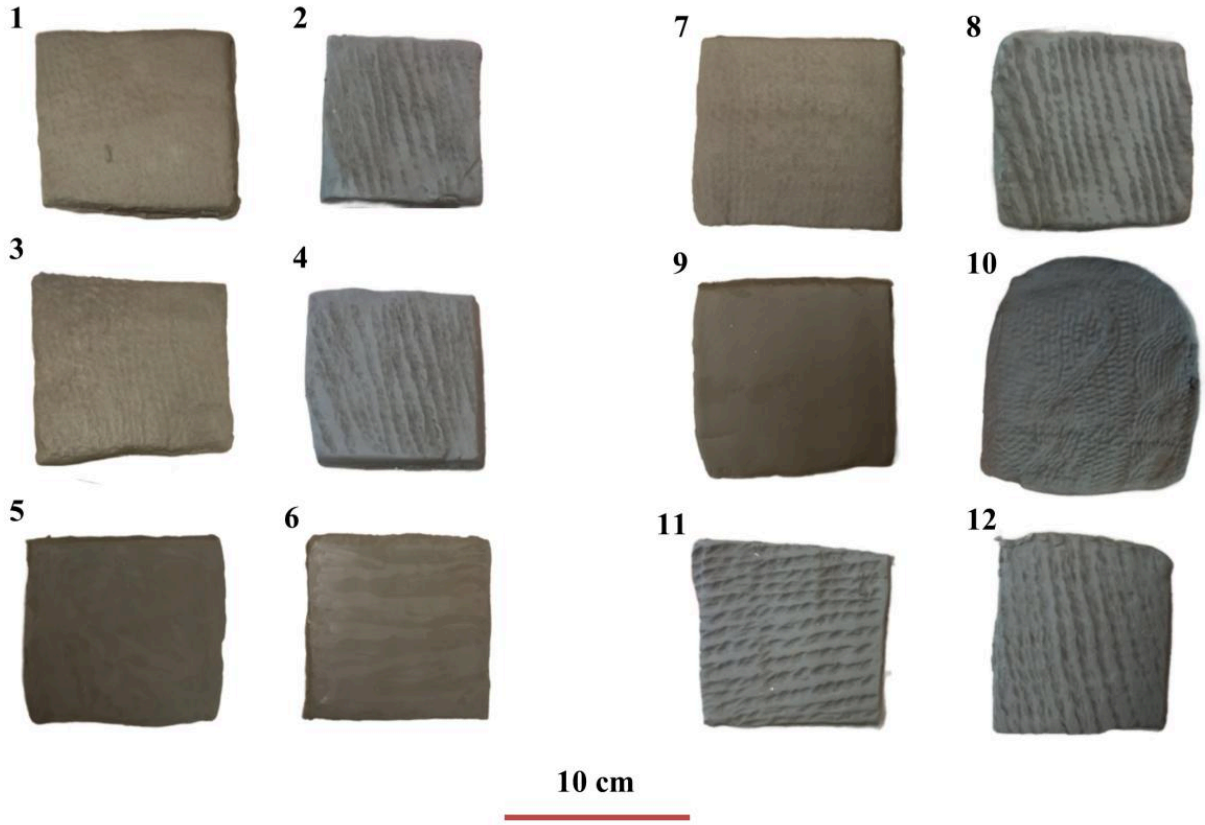

FIG 5. PHOTOGRAPHS OF THE TWELVE TABLETS AT THE END OF THE SECOND DAY OF EXPERIMENTATION. SEE TABLE 1 FOR IDS. PHOTO BY AUTHORS.

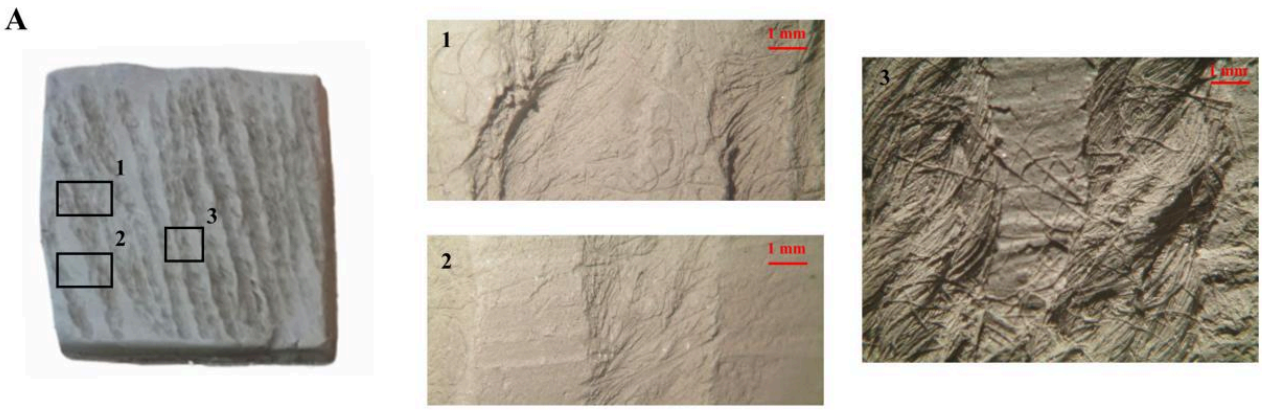

FIG 6A. MACRO AND MICROPHOTOGRAPH (10X) OF A TYPE 2 (ID-4). PHOTO BY AUTHORS.

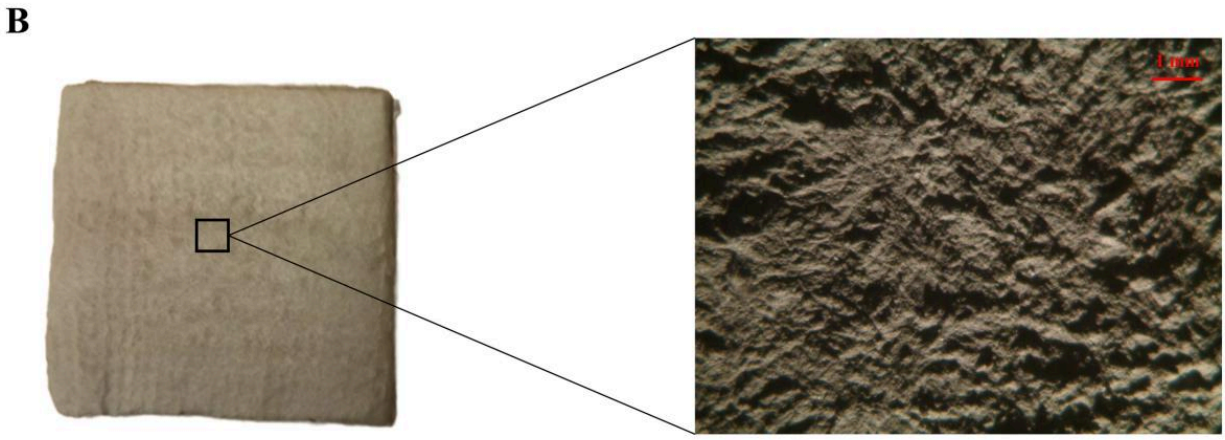

FIG 6B. MACRO AND MICROPHOTOGRAPH (10X) OF A TYPE 4 (ID-7). PHOTO BY AUTHORS.