AN UNKNOWN PREDECESSOR TECHNOLOGY OF CLOISONNE ENAMEL
ტიხრული მინანქარის წინამორბედი უცნობი ტექნოლოგია

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Abstract

Georgian cloisonné enamels represent a distinctive artistic and technological tradition within medieval art, characterized by vivid polychromy, unique glass composition, and specific approaches to color rendering. Despite extensive study, the origins and early technological development of cloisonné enamel remain unclear. The present study proposes a precursor technology based on the investigation of two Late Bronze Age daggers (inv. nos. 7232, 11220) from the Tserovani cemetery (14th–13th centuries BC), preserved in the Simon Janashia Museum of Georgia.

The daggers were examined through macroscopic observation, technological reconstruction, and non-destructive X-ray fluorescence (XRF) analysis. Results indicate that the objects were produced from tin bronze using lost-wax casting techniques. Particular attention was given to unusual inlays on dagger no. 7232, consisting of glass-like material combined with tubular tin-alloy elements (pewter). Spectral analysis confirmed the composition of both the bronze and inlay materials.

Based on structural and material evidence, two hypothetical methods for inlay production are proposed, both involving the integration of glass and low-melting tin alloy elements within pre-formed cavities. This composite technique differs significantly from later cloisonné enamel technology yet demonstrates conceptual similarities in combining compartments and vitreous materials. The study further highlights issues of glass preservation, noting severe leaching and degradation of archaeological glass.

The findings suggest that the Tserovani daggers represent an early technological stage that may have contributed to the later development of cloisonné enamel. This research offers new insights into the evolution of complex decorative metalworking traditions in the Caucasus.

Keywords: *cloisonné* enamel, bronze age, Georgia, dagger.

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აბსტრაქტი

ქართული ტიხრული მინანქარი, შუა საუკუნეების ხელოვნების ერთ-ერთ მნიშვნელოვან მიმართულებას წარმოადგენს, რომელიც გამოირჩევა მრავალფეროვანი პოლიქრომიით, მინის მასის სპეციფიკური შემადგენლობითა და ფერთა გადმოცემის თავისებურებებით. მიუხედავად ამისა, ტიხრული მინანქრის ტექნოლოგიის წარმოშობა და ადრეული განვითარების ეტაპები დღემდე სრულად გარკვეული არ არის. წინამდებარე ნაშრომი მცხეთის არქეოლოგიურ მუზეუმში დაცული წეროვანის გვიანი ბრინჯაოს ხანის (ძვ.წ. XIV–XIII სს.) ორი სატევრის (ინვ.N7232, ინვ.N11220) კვლევის საფუძველზე ამ საკითხში გარკვევის მცდელობას წარმოადგენს

კვლევა მოიცავდა მაკროსკოპულ დაკვირვებას, ტექნოლოგიურ რეკონსტრუქციას და არადესტრუქციულ რენტგენოფლუორესცენტურ (XRF) ანალიზს. დადგინდა, რომ სატევრები კალიანი ბრინჯაოსგან ცვილის დაკარგვის მეთოდითაა დამზადებული. განსაკუთრებული ყურადღება დაეთმო N7232 სატევრის ტარზე აღმოჩენილ ინკრუსტაციას, რომელიც შედგება მინისებრი მასისა და კალის შენადნობის (პიუტერის) მილაკოვანი ელემენტებისგან. სპექტრალური ანალიზით დადგინდა, როგორც ლითონის, ისე ინკრუსტაციის მასალის ქიმიური შემადგენლობა.

სტრუქტურული და მატერიალური მონაცემების საფუძველზე წარმოდგენილია ინკრუსტაციის დამზადების ორი ჰიპოთეზური მეთოდი, რომლებიც გულისხმობს მინისა და დაბალდნობადი კალის შენადნობის კომბინირებას წინასწარ შექმნილ ღრმულებში. აღნიშნული ტექნოლოგია მნიშვნელოვნად განსხვავდება კლასიკური მინანქრისგან, თუმცა მასთან გარკვეულ კონცეპტუალურ მსგავსებას ავლენს.

შედარებითმა ანალიზმა აჩვენა, რომ ანალოგიური მასალა იშვიათია, თუმცა პარალელები იკვეთება თლიას სამაროვნის ერთეულ ნიმუშთან. ასევე განხილულია არქეოლოგიური მინის დეგრადაციის პრობლემები.

კვლევის შედეგები მიუთითებს, რომ წეროვნის სატევრები შესაძლოა წარმოადგენდეს იმ ადრეულ ტექნოლოგიურ ეტაპს, რომელმაც საფუძველი შეუქმნა ჭედური მინანქრის შემდგომ განვითარებას კავკასიაში, კერძოდ - საქართველოში.

საკვანძო სიტყვები: ტიხრული მინანქარი, ბრინჯაოს ხანა, საქართველო, სატევარი.

Introduction

In Georgia, alongside works of relief plastic art, decorative objects and jewelry produced using the *cloisonné* enamel technique and distinguished by remarkable polychromy enjoyed widespread popularity from an early period.

As noted by Sh. Amiranashvili, *despite the common assumption that Georgian cloisonné enamels resemble those of Russian art, significant differences can be observed between them. In particular, the selection of colors and the transparency of the glass paste in Georgian enamels possess distinctive characteristics: Russian enamels display a more limited color range and a less refined surface treatment. In contrast to Byzantine enamels, Georgian cloisonné enamels are characterized by a lighter and more vivid palette, as well as by a specific rendering of the so-called "flesh tones" of faces and hands. At the same time, a certain group of Georgian enamels exhibits a lower level of technical refinement compared to Byzantine examples, manifested in the uneven execution of general contours and facial details, the juxtaposition of sharply contrasting tones, and a relatively lower technological quality of smalt production, often resulting in surfaces marked by fine cavities* (amiranashvili, 1961: 329).

The ancient treasures of Georgian art were repeatedly damaged as a result of enemy invasions and the activities of collectors. Nevertheless, Georgian *cloisonné* enamels occupy a prominent place in the global history of medieval art due to their artistic value and historical significance.

Significant research into the technology of Georgian *cloisonné* enamel production was conducted in 1950 by I.Taruashvili, a researcher at the Art Museum. He observed that one of the most challenging aspects of *cloisonné* enamel production lies in attaching thin metal wires (cloisons) to a base in such a manner that the enamel paste filling each compartment does not flow out during firing. At the same time, the use of open flame during the attachment of cloisons is excluded. Taking into account the fact that gold forms an amalgam with mercury, Taruashvili hypothesized that ancient craftsmen employed mercury to attach gold cloisons to a gold base.

Experimental tests demonstrated that when the edges of the cloisons were dipped in mercury and then placed onto the base surface according to the contours of the design, the cloisons adhered firmly to the base (amiranashvili, 1972: 12).

Based on these experiments, Taruashvili also elucidated the recipes for producing Georgian and Greek enamel paste and identified the differences between them, determined by variations in the chemical composition of the raw materials. The research showed that Georgian craftsmen used local raw materials. Chemical analyses revealed that the wine-red hue characteristic of Georgian enamel paste, which distinguishes it from Byzantine examples, results from the use of manganese (Mn). Through experimental work, the recipes for producing all the principal colors of Georgian enamel paste were also established (amiranashvili, 1972: 12).

As a result of these studies, Taruashvili produced replicas of the *cloisonné* enamel medallions depicting *Saints Peter* and *John the Evangelist* from the 10th-century icon of the *Virgin of Vardzia* in Imereti (inv. no. I-61), as well as medallions from the 11th-century icon of the *Savior* from Tsalenjikha. These replicas are currently exhibited in the Treasury of the Sh. Amiranashvili Museum of Art.

The earliest examples of *cloisonné* enamel identified in Georgia include, from eastern Georgia, a *cloisonné* enamel medallion placed at the tip of the upper side of a four-lobed gold dagger sheath dated to the second half of 2nd century AD (inv. no. 18-55:2), discovered during archaeological excavations in Armaziskhevi and preserved in the Treasury of the S. Janashia Museum of Georgia (Fig. 1_a), and from western Georgia, a gold object fragment bearing a Greek inscription and dated to the 6th centuries AD (inv. no.12-974:4219), discovered at the site of Nokalakevi-Archaeopolis and housed in the same museum (Fig. 1_b).

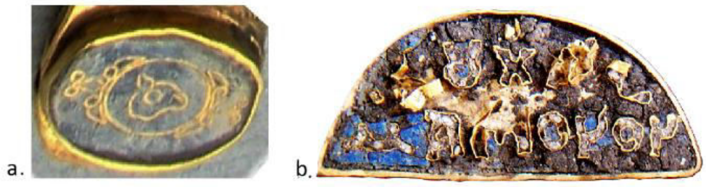


Figure 1.

To this day, the predecessor technology of *cloisonné* technique - and consequently of *cloisonné* enamel - remains unknown: it is unclear when it first emerged, how it evolved, and at what stage it acquired the form that remained essentially unchanged in Georgia for approximately eighteen centuries.

The present study represents an attempt to demonstrate, based on an artifact preserved in the Mtskheta Archaeological Museum, what the precursor form of *cloisonné* enamel inlay and its production technology might have been.

Materials and Methods

In 2019, a pair of daggers discovered at the Bronze Age cemetery N2 of Tserovani were submitted for conservation to the Restoration and Research Laboratory of Archaeological and Ethnographic Materials at the Simon Janashia Museum of Georgia. The cemetery is located on the lower terrace of the northern slope of the Skhaltba Ridge (sadradze, 2002: 115). The daggers are registered under inventory numbers: no. 7232 (Fig. 1_a) and no. 11220 (Fig. 1_b).

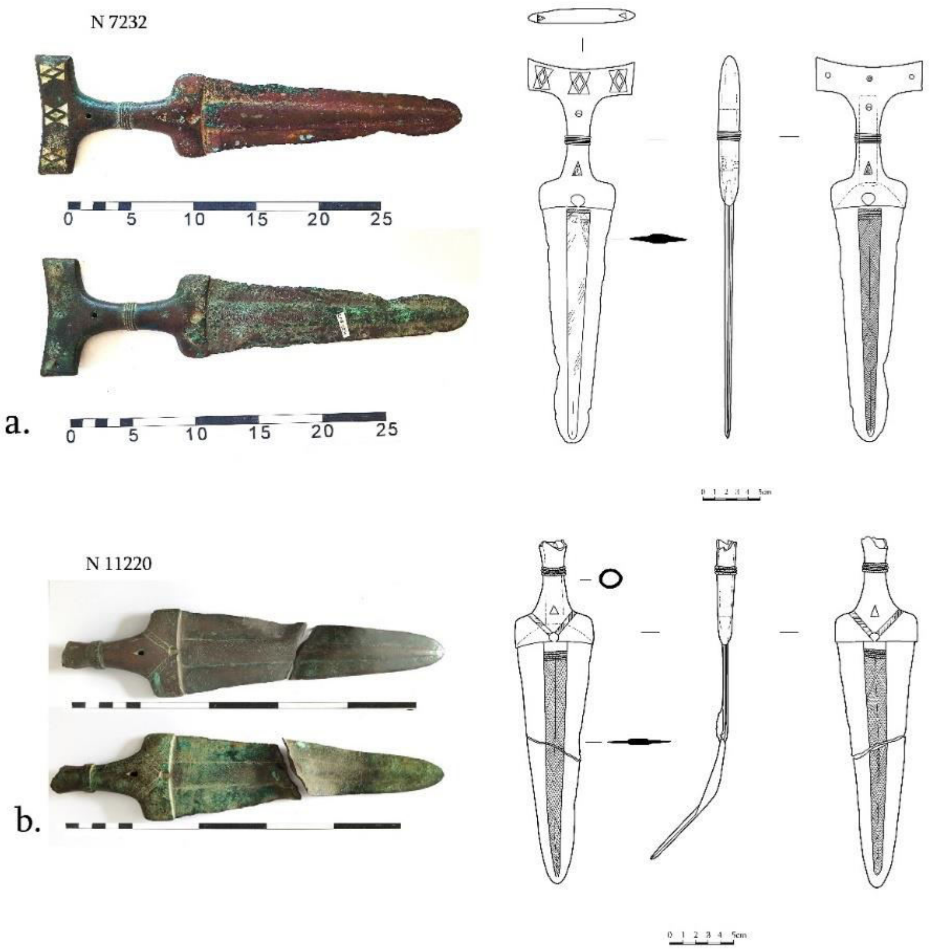


Figure 2.

The results obtained during the study of the two daggers proved to be complementary and enabled the reconstruction of their manufacturing technology.

Dagger no. 7232 was discovered in 1977 in grave no. 55 of the Tserovani cemetery (14th–13th centuries BC). The burial was individual: the skeleton was placed on its right side in a contracted crouching position. The dagger was positioned on the chest of the deceased, with its tip oriented toward the south. Only two additional objects were recorded in the grave: a horn standard head (length 12.4 cm) and a bone ring-pendant (sadradze, 1991: Pl. L; Pl. LXXXI; Figs.: 810-813; sadradze, 1989: 118).

Prior to the commencement of conservation treatment, all artifacts undergo detailed examination and documentation, including microscopic observation. It was at this stage that an unusual inlaid element on dagger no. 7232 attracted our attention; this feature will be discussed in greater detail below.

Macroscopic Examination

Dagger no. 7232 is richly inlaid. Its total length is 33 cm, the length of the hilt is 12 cm, and its width at the guard reaches 6.5 cm (Fig. 2_1). The dagger had undergone an earlier restoration, during which both its surface coating and form were altered. A comparison between the photograph taken at the time of its discovery, published in Sadradze's article *'Bronze–Iron Age Cemetery'* (Sadradze, 1991 Fig. 811), and the object in its current condition confirms this assumption. No information could be traced regarding the location or date of this earlier restoration.

Dagger no. 11220 (length 28 cm) represents an accidental find. The blade of the dagger (length 20 cm, width 5.8 cm) and handle are broken (Fig. 2_2), and the pommel was not recovered during excavation. These damages, however, provided valuable insight and allowed for a clearer understanding of the manufacturing technology of both daggers.

The daggers from Tserovani are composite objects. While bronze daggers in many regions were produced as fully cast items, daggers of this type associated with the Colchian cultural sphere are composite and manufactured using forming techniques, as clearly demonstrated by the two examples discussed here. In other regions, this technological approach became widespread only later, following the introduction of iron. Typically, the blade was produced from iron or steel, after which a bronze hilt or decorative elements were cast onto it.

The pronounced guard of the daggers extends onto the blade. The broad, oval midribs of the blades are decorated on both sides with engraved, net-like, rhomboid patterns arranged in repeating sequences that gradually diminish toward the tip of the dagger (Fig. 2).

Engraving involves cutting or incising the metal surface using chisels made from alloys harder than the cast metal itself. For this purpose, tools with sharply profiled tips were commonly employed. Their operating principle consists of applying angled pressure to the metal surface in order to remove material from the original surface.

Technological and spectral analysis

Within the fractured cast hilt wall of dagger No. 11220, approximately 3 mm in thickness, as well as inside a triangular perforation, moulding sand was identified. Numerous gas porosities observed on the hilt surface, formed as a result of gases released during chemical reactions in the molten metal during solidification (tavadze, et al. 1950:14), together with moulding sand preserved inside the socket cavity, indicate that the hilt was cast in a two-part mould using refractory core sand (tavadze, et al. (b) 1956:138). Similar core sand was also detected in the circular through-hole on the hilt of dagger No. 7232; the thickness of the cast socket wall is approximately 3 mm.

It may be assumed that the blade was first cast in a stone or clay mould and possibly lightly forged, after which the axis of the hilt was formed using core sand. After the sand dried, a wax model of the hilt was created, incorporating all necessary details. The resulting wax model was then covered with moulding clay, shaped, and dried (Fig. 3).

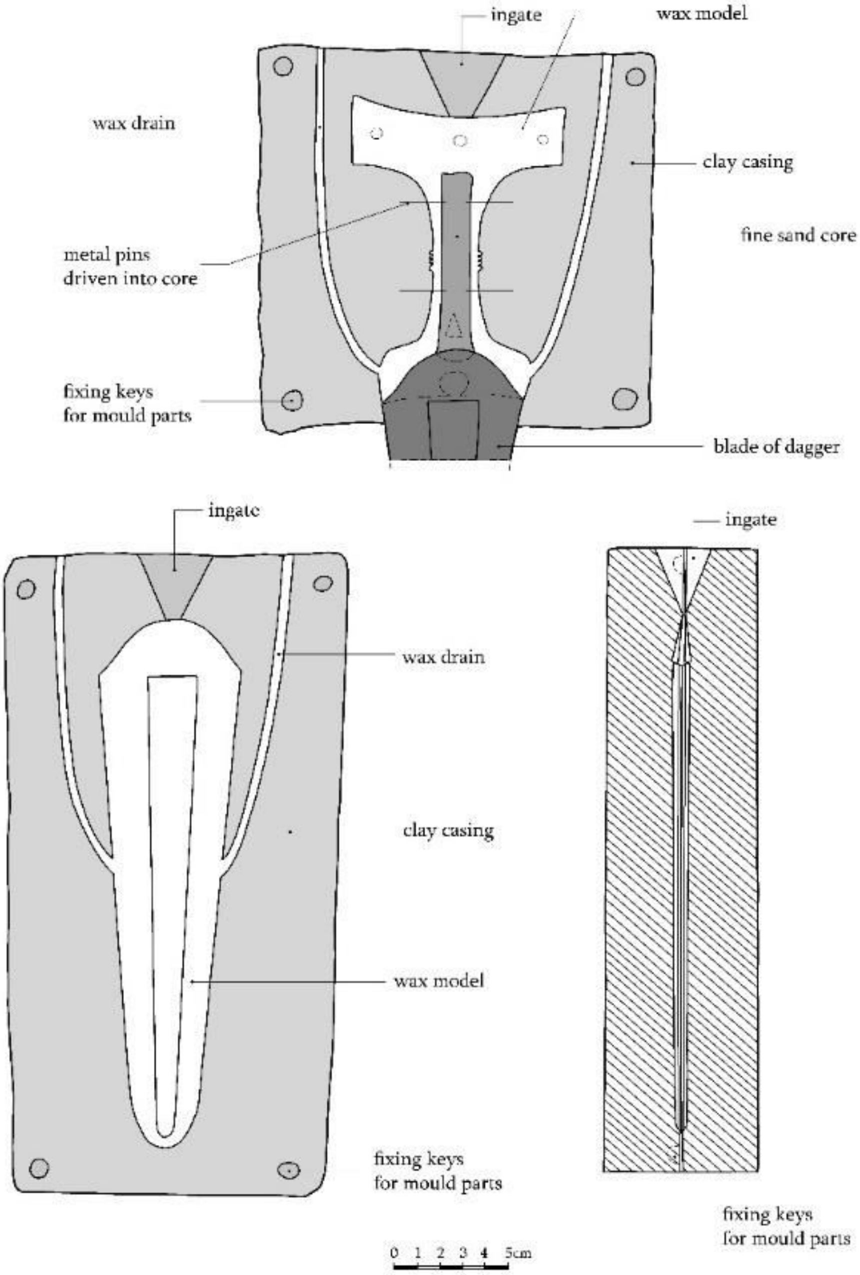


Figure 3.

At the next stage, the wax was melted out of the mould, and highly fluid, overheated molten metal was poured into the heated mould. This technological approach ensured the complete filling of thin-walled cast sections and inlay cavities. After solidification of the metal, the mould was broken, and the final stage involved mechanical finishing of casting defects.

The metal and surface deposits of the daggers from Tserovani were analyzed using non-destructive X-ray fluorescence spectroscopy with an ElvaX spectrometer. The analyses were conducted at an accelerating voltage of 45 kiloelectron volt (keV) with a live time of 100 seconds. Elemental concentrations (expressed in weight percentages) were determined using a quadratic regression model based on the analysis of appropriate reference standards corresponding to the material under study.

The results of the analysis demonstrated that the daggers were manufactured from tin bronze (Table) using the lost-wax casting technique.

Table. Chemical composition of the metal of the daggers from Tserovani (wt.%)

No.	Sample	Cu	Sn	Pb	Ag	As	Sb	Pd	Fe
1	Blade of dagger No. 7232	94.841	4.236	0.224	0.429	0.270	–	–	–
2	Hilt of dagger No. 7232	90.162	8.579	0.413	0.478	0.368	–	–	–
3	Hilt of dagger No. 11220	90.951	0.810	2.500	0.551	3.631	1.559	–	–
4	Blade of dagger No. 11220	86.331	8.985	0.308	0.475	3.911	–	–	–
5	Wedge-shaped tubular element	4.868	94.305	–	0.335	–	–	0.114	0.378

Incrustation of Dagger No. 7232

The hilt of dagger No. 7232, terminating in an oval-curved pommel (length 9.3 cm; width 1.5 cm), features three circular recesses (diameter approx. 4 mm) on one side, located near the upper edges and in the central area, in which remnants of wooden material from the incrustation are preserved (Fig. 6). Microscopic examination revealed that the base of the left recess is formed of metal. A circular through-hole (diameter approx. 5 mm) was also identified on the socket (Fig. 5). The central part of the hilt of dagger No. 7232 is accentuated by a band composed of four spiral elements (Fig. 2_1), while the corresponding band on dagger No. 11220 consists of three spirals (Fig. 2_2). The opposite side of the hilt of dagger No. 7232 is decorated with three incrustations located near the upper edges and the center. Each consists of four opposing triangular elements with a rhombus positioned at the center, forming three distinct ornamental accents.

It is known that recesses for metal inlays were produced using different methods. In one case, recesses were cut into a smooth metal surface using sharp tools (Born, 1984:18–21). In another method, cavities and perforations of the desired shape were cut directly into the wax model, and the walls of the resulting recesses in the cast object were subsequently refined mechanically. Glass powder was then placed into the prepared cavities and melted in situ. Based on the available evidence, it may be assumed that all inlay recesses and circular through-holes on the dagger hilt were produced using the latter method. At present, the inlay material has largely lost its glass-like properties.

At the edges of the elongated oval pommel, one whitish (Fig. 4) and one blue (Fig. 4) triangular inlay are preserved. Faint circular traces are visible on the blue inlay, the possible origin of which will be discussed below.

Figure 4.

In both daggers, the junction between the blade and the socket is decorated on both sides with oval recesses in which no inlay material is preserved (Fig. 5). Between these recesses and the spiral band located at the midsection of the socket, a triangular through-type inlay cavity is present. In the case of dagger No. 11220, the inlays are not preserved; however, the damage clearly demonstrates that the triangular cavity is perforated (Figs. 5_c, 5_d).

Figure 5.

On one side of the hilt of dagger No. 7232, the triangular recess contains a partially preserved inlay. Within the cavity, remnants of a glassy material (Fig. 6_a) and grey, tubular metal pins (Figs. 6_c, 6_d) embedded in residual wooden material (Fig. 6_b) are observed

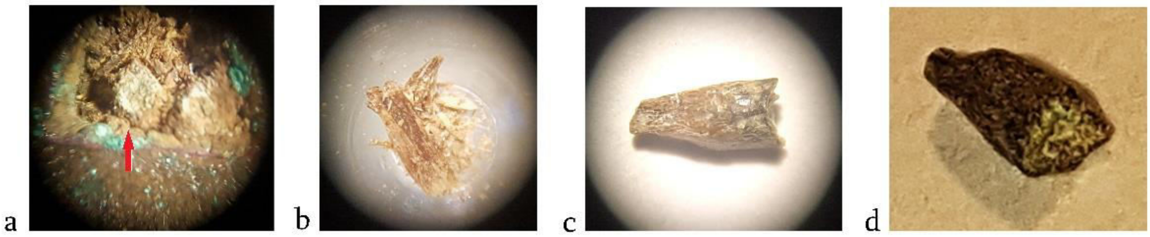


Figure 6.

It was precisely this damaged inlay that drew attention at the initial stage of the study and made it possible to identify the previously unknown technology discussed in the subsequent part of this article. The tubular metal elements proved to be mechanically unstable, which allowed one specimen to be temporarily removed for analysis and subsequently returned and stabilized after completion of the study. Spectral analysis revealed that the tubular pin was made of a tin-based alloy: Sn ≈ 94.305%, Cu ≈ 4.868%, Ag ≈ 0.335%, Pd ≈ 0.114%, Fe ≈ 0.378%. This type of alloy is known as tin alloy (Rus. *пьютер*, Eng. *pewter*, Ger. *Hartzinn*), which traditionally consists of 85–99% tin with additions of copper, antimony, bismuth, and occasionally silver or lead.

Faint circular traces were also observed on a bluish glass inlay located on the opposite side of the hilt and on the pommel (Fig. 10_2). It is likely that these inlays were produced using the same technique as the damaged example, and that the background color of the damaged inlay was originally blue.

As noted above, the tubular pins embedded in the glass inlays are made of a tin-based alloy with a melting temperature of approximately 170–230°C. In contrast, the melting temperature of silicon dioxide (SiO_2), the primary component of glass, is approximately 1700°C. This temperature can be significantly reduced by the addition of alkali and alkaline-earth metal oxides, as well as other metal oxides. Nevertheless, the melting temperature of silicate glass ($SiO_2 + Na_2O + CaO + MgO + Al_2O_3$), which ranges between approximately 425–600°C, remains substantially higher than that of the tin alloy from which the tubular elements were produced.

Tin was widely used in antiquity as an imitation of silver. Pliny the Elder mentions early mirrors in which tin was used prior to the adoption of silver. According to authors contemporary with Pliny, tin alloy (*stannum*) was produced from tin and so-called “white copper” in a ratio of 3:1. Tin was referred to as ‘white lead’, while lead itself was known as ‘black lead’ (Pliny, 1819: 259–260).

Proposed Methods for the Manufacture of the Inlay

The research enabled us to reconstruct the probable methods used for the manufacture of the inlays.

Method I

A piece of soft wood was tightly fitted into the triangular through-cut, leaving a few millimetres of empty space from the surface on both sides. Separately, a mould corresponding to the shape of the cut was prepared, into which glassy powder was poured and heated until the mass melted. Before the molten glassy material had fully solidified, wedge-shaped tubular elements (approximately 3–4 mm in length), previously filled with white glassy material, were inserted into it. The tapered ends of these tubes (with perforations) protruded above the surface of the glassy mass in the mould by approximately 2 mm. After removal from the mould, the resulting inlay element was gradually pressed into the pre-fitted wooden insert within the cut, using the protruding tapered ends of the tubes (Fig. 7).

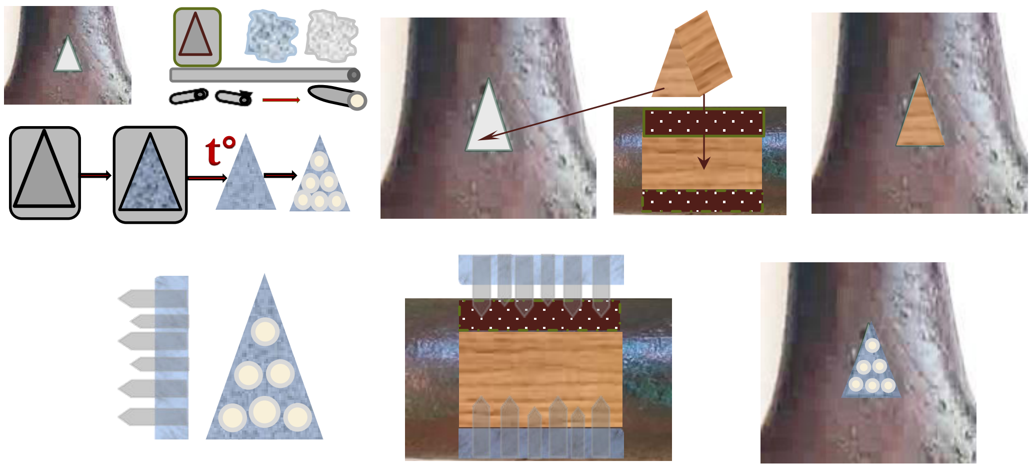


Figure 7.

Method II

Glassy material was poured into a mould, melted, and allowed to cool. The resulting glass plate was perforated at several points with holes of the desired diameter, then attached with natural adhesive to a wooden insert previously placed into the triangular through-cut of the dagger. Subsequently, pre-prepared tubular tin pins filled with white glassy material were inserted into the holes in the glass (Fig. 8).

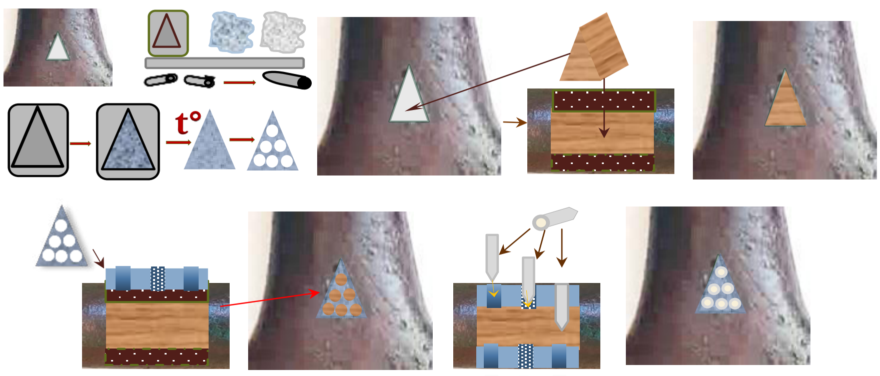


Figure 8.

In both cases, the surface was finished at the final stage.

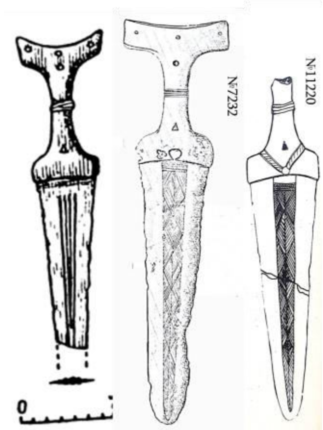
Results and Discussion

Parallels and Comparative Analysis

During the course of the research, no direct parallels for the recorded inlay were identified, nor was a description of a similar technology found in the literature. However, a fragmentary dagger dated to the 12th–10th centuries BC from the Tlia cemetery was identified (Fig. 9_1; Tekhov, 1977: 106, Fig. 894), the description of which closely resembles that of the Tserovani specimens.

As noted by the author of the publication, B.Tekhov: *The dagger hilt is very elegant and terminates in an oval-curved pommel. The hilt features three square-shaped recesses filled with some substance, possibly paste. Below the central square, a circular through-hole is present on the hilt. The midsection of the hilt is encircled by a band composed of three spirals. Further down, a triangular recess is observed, also possibly filled with paste* (Tekhov, 1977: 104).

Presumably, this satevari is kept in the Tskhinvali Museum. Unfortunately, due to objective reasons, it was not possible to see the satevari or find photographs, and we have to judge only by the sketches in Tekhov's book.



1. 2. 3.

Figure 9

Only one side of the dagger is described in the publication. Fortunately, the same work includes a photograph depicting the opposite side (Fig. 9_1), where a second triangular recess and its similarity to the Tserovani daggers can be clearly observed (Figs. 9_2, 9_3).

This dagger is not associated with a specific archaeological complex and was discovered in the northeastern part of the cemetery, where burials of the early phase of the Late Bronze Age were concentrated. Tekhov was unable to identify exact analogues from securely dated complexes and therefore could not precisely date the Tlia daggers.

According to Tekhov, the tribes who left the Tlia cemetery were in contact with other tribes of Transcaucasia, who carried the archaeological cultures of Western Georgia and Samtavro. In his opinion, no less close ties existed with the tribes who left the Kobani semetery and its synchronous monuments from the slopes of the North Caucasus. According to the author, in some details a connection with the countries of the Far East, in particular with Iran, is noticeable. These connections were carried out through the territories of Transcaucasia, including Eastern Georgia (Tekhov, 1977: 110).

As can be seen, the Tlia specimen is very similar to the Tserovani dagger in terms of description. Although circular inserts are not mentioned in the description of the triangular inlay, their presence cannot be excluded, especially considering that the circular elements identified by us were also not mentioned in the original description of dagger No. 7232 discovered nearly 50 years ago at Tserovani.

According to Tekhov, daggers of this type are rare in the Late Bronze Age material of both the North and South Caucasus. As approximate parallels, he cites daggers from the Upper Rutkhi cemetery (central North Caucasus, Digora Gorge) and from Koban (Tekhov, 1977: 104). However, the graphic illustration cited by Tekhov from Uvarova's publication and reproduced in Krupnov's work (Krupnov, 1960:177, Fig. 21.6) could not be located in the original source (Uvarova, 1900, Pl. X, 2). Instead, a different image appears on the plate indicated by Krupnov (Uvarova, 1900, Pl. XCIII, 19).

The dagger from Koban was excluded from consideration due to the absence of inlay. Among the remaining examples, only the description of the Upper Rutkhi dagger suggests the possible presence of paste inlay.

During further investigation, attention was drawn to a dagger discovered during excavations at the Kumbulta burial ground (Uvarova, 1900. Pl. XCVII, 5). A later photograph of the cleaned dagger was published by I. Domansky (Domanskii, 1984, Fig. 26). In this image, three inserts are visible within the triangular recess on the hilt. The artefact is preserved in the Hermitage Museum.

Secondary Use and Intentional Damage

As noted above, dagger No. 11220 exhibits damage that suggests intentional breakage. In this context, a particularly interesting object is a fragment discovered near the village of Chmi, approximately 21 km from Vladikavkaz. In her work, Uvarova describes this object as a cast bronze pectoral ornament or possibly a weight (perhaps a standard finial?) (Uvarova, 1900: 115). The author notes that the object has a straight pommel (length 8 cm, width 2 cm) and a cast spiral band.

The brief description provided by Uvarova, together with the resemblance visible in the photograph, allows us to hypothesize that the object discovered near Chmi may represent the pommel of a dagger hilt. This assumption is further supported by the fact that Uvarova's documentation and photographs were made prior to restoration. The dimensions provided by the author closely correspond to those of the Tserovani dagger pommel (length 9.2 cm; width 1.6 cm).

Given the sophisticated manufacturing technique and complex decorative elements, the hilt of dagger No. 7232 may be regarded as a work of jewellery art. It is therefore possible that, due to its visual qualities, the dagger hilt was reused as an ornament or as a decorative element for another special object. If this hypothesis is accepted, it provides a plausible explanation for both the intentional breakage of dagger No. 11220 and the absence of its hilt.

Glass Analysis and Preservation

As several of the inlays on the dagger hilt are severely damaged, it was possible to examine the inlay cavities in detail. Small fragments (approximately 1 mm^2) of greenish-yellow and blue glassy material were extracted and subjected to spectral analysis. Qualitative analysis identified the following microelements in the glass composition: Si, Ca, Fe, Cu, Sr, Sn, and Pb.

It is well known that glass has been produced since ancient times. Archaeological excavations indicate that glass was used in jewellery as early as six thousand years ago (Golba, 1938: 92). The basis of glass is silicon dioxide, which is an excellent glass-forming substance, as in its molten state it transitions into a glassy, amorphous condition and imparts this property to various crystalline substances—silicates (bakht'adze, 1977: 51).

Early glass consisted of crushed quartz, the grains of which were fused together by sodium and potassium, added in the form of carbonates as fluxes and transformed into corresponding oxides during the melting process. It is now known that soda or plant-derived sodium was primarily used as a flux in ancient glass production (bakht'adze, 1977: 54). The use of plant ash in glass production is mentioned as early as a Babylonian chemical text dated to around 1700 BC. According to Lucas, the sodium and potassium content in ancient glass did not exceed 1–3% (Lucas, 1958: 288–305).

Pliny the Elder reports that in antiquity glass melting occurred in two stages. Glass was first melted in furnaces with a constant fire, producing black-coloured masses, some of which were so sharp that they could cut the human body without being felt, penetrating almost to the bone. These masses were then remelted in workshops and coloured (Pliny, 1819: 340–350).

Depending on the period, various metals, metal oxides, and salts were used as colorants to produce different glass colours. For example, in the territory of Georgia during the 30th-6th centuries BC, copper and iron oxides were used to obtain blue, greenish-blue, and green colours: CuO, CuO > Fe_2O_3 (blue); FeO > Fe_2O_3 (greenish-blue); FeO < Fe_2O_3, CuO + Fe_2O_3 (green) (bakht'adze and sarajishvili, 1988: 87, Tab. 1).

From the 15th century BC onwards, true soda-lime glass (Na_2O – CaO - SiO_2), with sodium content reaching 15–20%, begins to appear. At this stage, metal oxides were systematically used as glass colorants.

During the search for inlays produced used on dagger no. 7232 our attention was drawn to a buckle from the Ude hoard, discovered accidentally in 1956. The object has survived in three fragments and is currently exhibited in the Akhaltsikhe Museum. The fragment of interest has been thoroughly described by Aleksandre Javakhishvili and Tariel Chubinashvili: "On its surface, a dog figure was depicted in inlay. The body of the dog, carved in a nest-like manner, is covered with small nail-like metal pins, which appeared as colored dots. These colored elements, in this case red, were set against a background of glassy paste filling the recesses" (javakhishvili, et al. 1959: 62).

It was important to examine the chemical composition of the inlay and comparable materials. It was found that the buckle had been studied shortly after its discovery in the chemical-restoration laboratory of the Simon Janashia State Museum of Georgia by Rusudan Bakhtadze and Tsisana Abesadze. A metallurgical analysis was also conducted. The buckle is made of a Late Bronze Age alloy: Cu – 85.0%, Sn – 12.28%, As – 0.016%, Fe – 0.1%, Pb (abesadze, et al.1958: 74, Tab. 25, tab.$XXXV_9$).

Among the numerous parallels identified for the Ude buckle, we will refer to only one later example (9th–7th centuries BC), discovered in North Ossetia and currently preserved in the Geneva Museum. This bronze buckle (L = 16.2 cm) is inlaid with powdered glass. The object is fully cast and produced using the lost-wax technique. The inlay is believed to have been made by placing loose glass powder into prepared cavities and firing it in situ (Born, 1984: 19).

Two colors—red and blue—were used for the inlay. A sample of the blue inlay was analyzed in 1995 in Geneva by X-ray fluorescence (XRF) analysis by F. Schweizer, which identified cobalt as the coloring agent. However, our analysis did not detect cobalt in the composition of the blue glassy material. Instead, copper, iron, and tin were identified, suggesting that copper and iron oxides were used as colorants, while tin oxide served as an opacifier. This finding supports the hypothesis proposed by Rusudan Bakhtadze that cobalt was not used as a glass colorant before the 6th century BC.

Therefore, it may be suggested that the dating of the Geneva specimen should be shifted toward the earlier end of the proposed chronological range.

Although the buckle represents a different period and technique, it similarly demonstrates - like the dagger - the search for new stylistic and technological solutions. These tendencies appear to be characteristic of Caucasian artistic metalworking and span a considerable chronological range.

According to Kepler, water is the principal enemy of glass (bakht'adze and sarajishvili, 1988: 93). However, archaeological glass is also affected by other damaging agents, both inorganic and organic. The degree of deterioration depends on chemical composition, melting and forming technology, and the duration of burial in soil.

As noted by Jenny Cronyn, severely deteriorated glass may survive only as a chalky siliceous mass, making it difficult to recognise as glass (Cronyn, 2004: 133). This phenomenon is observed in the case of the white inlay on the pommel of the dagger hilt. As a result of glass leaching, alkalis are removed from the glass matrix, leaving a silica-rich "iridescent" layer (bakht'adze, 1988: 98). The samples analysed in this study represent strongly leached glass that has completely lost its original appearance and disintegrates with minimal mechanical stress.

Under unfavourable environmental conditions, deterioration may continue even in museum settings. For example, when relative humidity exceeds 42% (RH > 42%), unstable compounds migrate toward the glass surface, forming alkaline droplets that can cause severe damage (Cronyn, 2004: 137).

A different situation is observed in the triangular recesses decorated with blue glassy material (Fig. 10). Based on the manufacturing technology of these elements-the composition of the glass batch and the temperatures employed-the glassy material appears to have been more resistant.

Figure 10.

Some scholars consider the earliest artefacts with glassy inlay in the Caucasus to be axes (*abzindebi*) (Tenisheva, 1930: 55). A. Iessen established that cut or engraved ornamentation on already cast objects, combined with inlay using coloured materials (iron, bone, wood, glass), is characteristic of Caucasian metallurgy of the late 2nd millennium and early 1st millennium BC.

Conclusions

It has been established that carved or engraved ornamentation on an already cast object and inlay with colored mass (iron, bone, wood, glass) is characteristic of the metallurgy existing in the Caucasus at the end of the 2nd millennium BC and the beginning of the 1st millennium BC.

The composite daggers No. 7232 and No. 11220 from Tserovani, manufactured using the lost-wax casting technique, exhibit all the defining features of the Bronze Age Colchian tradition in terms of technology, decorative methods, and ornamental motifs. Their chronological framework also corresponds to this cultural horizon. This indicates that, alongside axes, Caucasian weaponry also featured sophisticated inlays made of glassy material.

In addition to the polychromy created by glass inlays on dagger No. 7232, dagger No. 11220 demonstrates the deliberate use of alloys of different colours for the blade and hilt, evidently intended for aesthetic rather than functional purposes. The blade of dagger No. 11220 would have appeared ‘warm’ golden in colour, while the hilt would have had a more silvery appearance.

As noted above, no parallels could be identified for the inlay technique observed on dagger No. 7232, which combines glassy material embedded in wood with tin-alloy tubular element partitions. Given its dating, the dagger studied here constitutes the earliest and a unique example of inlay produced using a proto-cloisonné technique. Color separation is achieved not by flat metal partitions typical of cloisonné, but by vertically inserted micro-tubes filled with white vitreous material and embedded into a colored glass matrix. This technological solution represents a unique intermediate stage between non-compartmentalized vitreous inlays and classical cloisonné, demonstrating an independent local trajectory in the development of compartmentalized inlay techniques. This allows us to suggest that the cloisonné technique, which was later widely employed in Georgia, has local roots.

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Captions:

Figure 1. a) 2nd century AD *cloisonné* enamel (no.18-55:2) from eastern Georgia b) 6th century AD *cloisonné* enamel (no.12-974:4219) from western Georgia (Nokalakevi-Archaeopolis).
Figure 2. a) Dagger no.7232; b) Dagger no.11220.
Figure 3. Graphics of the technological process of making dagger.
Figure 4. Triangular blue inlay at the edge of the elongated oval pommel of dagger no.7232.
Figure 5. Locations of the inlays on daggers a) no.7232 and b) no.11220.
Figure 6. Material from partially preserved inlay of dagger no.7232: a) remnants of a glassy material. b) residual of wood; c-d) tubular metal pins.
Figure 7. Proposed Method I for the manufacture of the inlay.
Figure 8. Proposed Method II for the manufacture of the inlay.
Figure 9. Daggers from Tlia and Tserovani.
Figure 10. Three different triangular glassy inlays from dagger no.7232.