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METHODS OF NATURAL SCIENCES IN THE STUDY OF CULTURAL HERITAGE OBJECTS

Exotic Cotton Textile of the Bronze Age from the Southern Trans-Urals

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Abstract—An analysis of a fragment of Bronze Age textile found at the settlement of Kamenny Ambar in the South Urals is performed. Technological analysis makes it possible to establish that the textile was made from raw cotton, and the results of radiocarbon dating attributed it to the beginning of the II millennium BC. A comparative analysis of the textile fragment and the broad archaeological context of the early finds of ancient cotton fabrics suggests that the fabric could have been made in Pakistan or India and came to the South Urals along with migrants.

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INTRODUCTION

The spread of technological innovations had a huge impact on the interaction of populations that often lived far from each other. Among these innovations is the appearance of a new raw material, wool, in Northern Eurasia in the Bronze Age. Based on the direct radiocarbon dating of wool samples, it was found that the technology for the production of wool fiber in the second half of the III millennium BC penetrated from Western Asia to the North through the Caucasus into the Eurasian steppes and in the II millennium BC further East through the forest-steppe and forests of Eastern Europe to the Urals, Kazakhstan, southern Siberia, and China [1]. This demonstrated the rather rapid processes of adopting new raw materials, which stimulated the development of wool sheep breeding and the local production of wool products [2] and their possible exchange. Woolen textiles became a kind of "visiting card" of the masters of the Sintashta, Srubnaya, Alakul, Petrovka cultures of the southern Urals in the II millennium BC.

The discovery of an exotic cotton fabric in the Sintashta layer of the Kamennyi Ambar settlement in the Southern Urals does not fit into this context. Does this mean that, along with new woolen fiber, another textile raw material appeared in the steppe, or that the cotton product is the subject of direct or multi-stage exchange? It is all the more interesting to determine whether the cotton fabric could be the result of the production of local weavers or whether it comes from some other region and how it could arrive at the Eurasian steppes. This paper discusses the archaeological context of the find of cotton textiles, the results of technological and radiocarbon dating, as well as a comparative analysis of the fabric from Kamenny Ambar with other cotton fabrics of the Bronze Age. These new data allow a return to the discussion of the topical problem of the interaction of the Sintashta population with other cultural groups, in particular with the agricultural population living in the southern and southeastern regions of Asia.

ARCHAEOLOGICAL CONTEXT, SAMPLES, AND RESEARCH METHODS

The fortified settlement of Kamenny Ambar is located in the Kartalinsky District of Chelyabinsk Oblast in the Southern Trans-Urals. It occupies the first floodplain terrace of the left bank of the Karagaily-Ayat River (left tributary of the Tobol River) (Fig. 1). Its rectangular area of 18000 m^2 is bounded by a bypass ditch and a collapsed earth wall lined with stone slabs on the outside (Fig. 2b). The space inside the fortifications is divided by a low wall and a shallow moat across the long axis into two almost equal parts (Fig. 2a). Large-scale field studies of the site were carried out by an international interdisciplinary team in 2005–2013. During excavations of the Kamenny Ambar settlement over an area of 2800 m^2, 16 buildings of various ages, as well as several

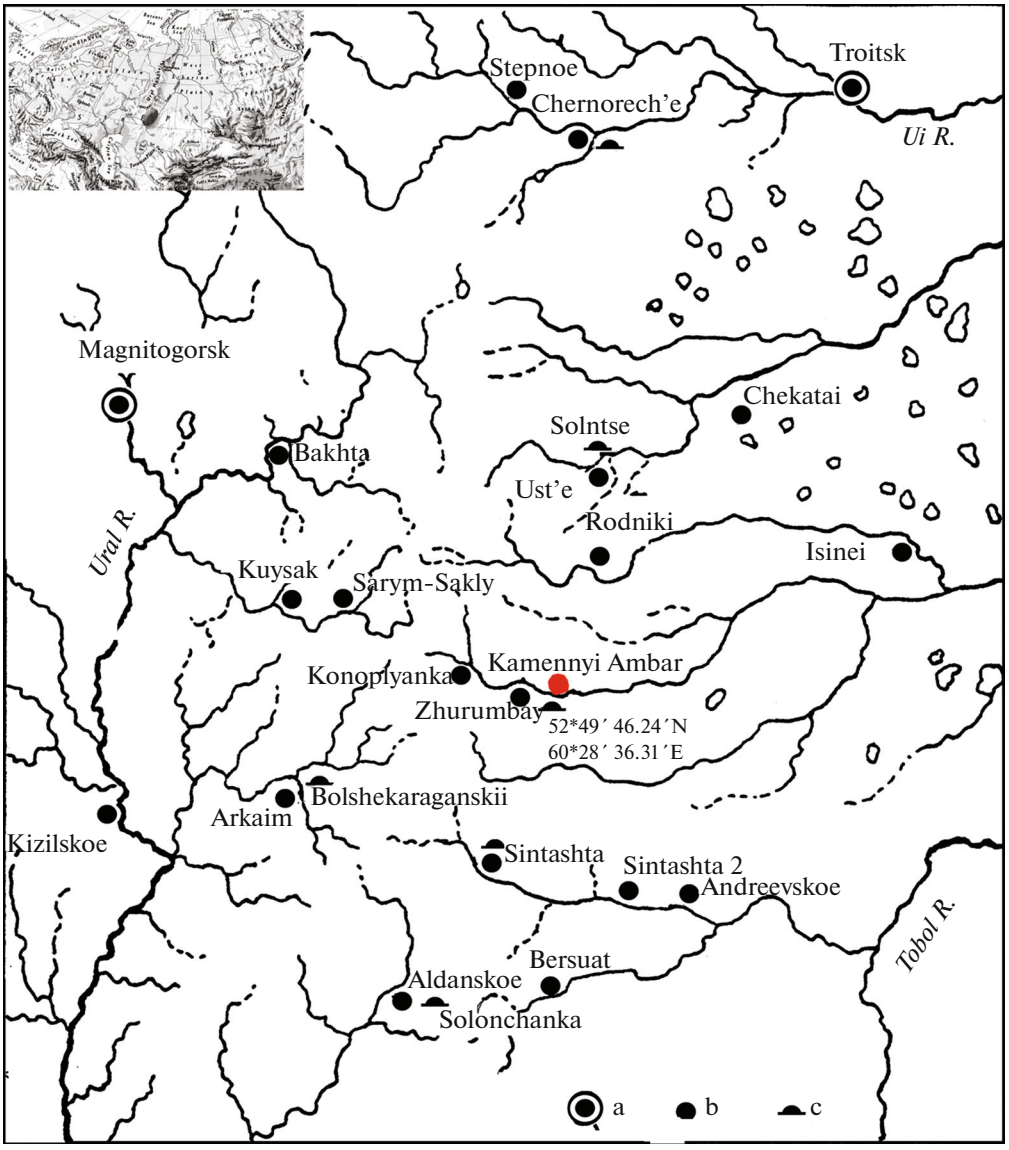

Fig. 1. Location of the fortified settlement of Kamenny Ambar on a map of the main sites of the Sintashta culture.

sections of the defensive line, were studied. Within the buildings, 34 wells were investigated [3, 4]. The correlation of stratigraphic data, the vertical and horizontal distribution of various types of pottery, and radiocarbon dates, including those obtained from plant seeds from well filling [5], made it possible to model the time of settlement existence. The Sintashta-Petrovka period with three building phases is dated in the interval of 2030–1870 (1σ) or 2050–1760 (2σ) BC, spanning a maximum of 85 years (95.4% probability). The Srubnaya-Alakul period refers to 1980–1780 (1σ) or 2040–1770 (2σ) BC lasting a maximum of 61 years. The break between them amounted to a maximum of 37 years [6–9].

In the first phase, the settlement was planned and laid down, its main elements were built: modular residential buildings, a fence system, and the first wells. In the second phase, there were changes in the layout of dwellings and the settlement itself, which was reduced by half [7, 9]. Serious changes took place in the second, Srubnaya-Alakul period.

Under the floor of dwelling 2 of the Sintashta-Petrovka period, south of wells 2/1 and 2/1a (Fig. 3), a children's burial was found with an accompanying sacrificial complex. A grave pit was not discernible. However, during the study of wells under a layer of continental clay, an inclined structure of pine boards was found, oriented along the north-northeast-south-southwest direction, consisting of two longitudinal boards 40 to 65 cm long, on which lay shorter transverse metal plates from 32 to 45 cm long. The width of the plates was 6–7 cm; the thickness of the structure was 4–5 cm. Under the overlap, poorly preserved infant cranial bones were cleared, and below, frag-

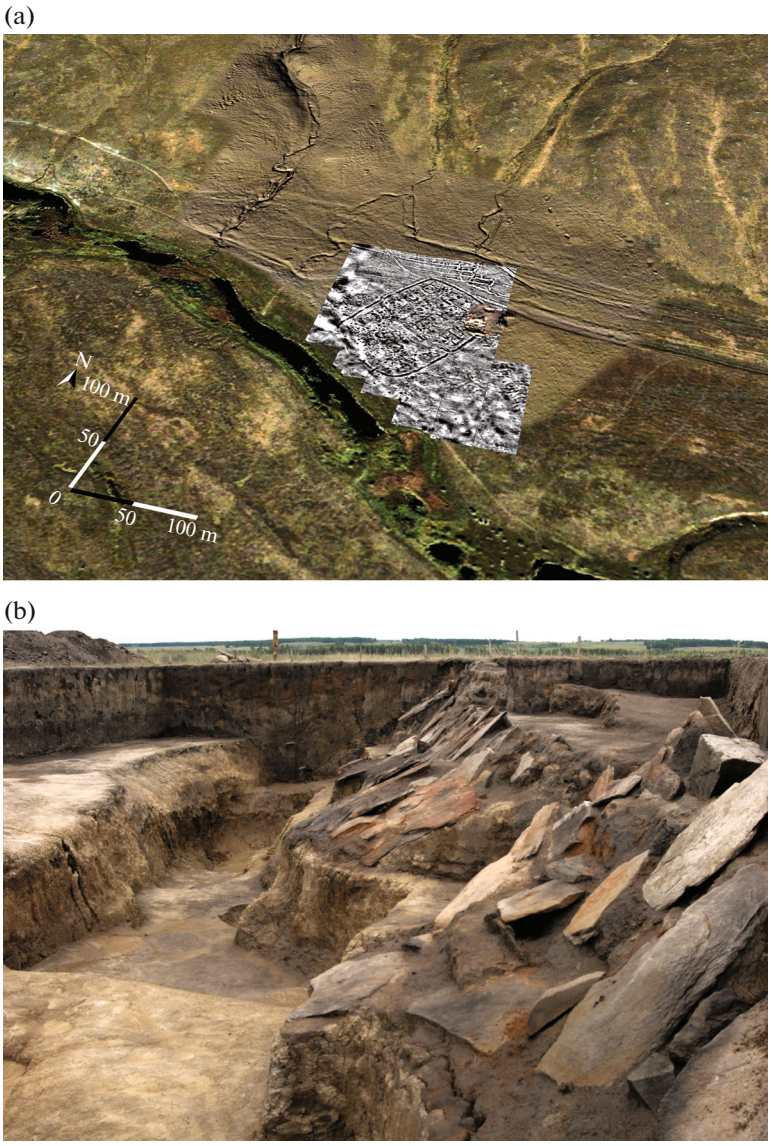

Fig. 2. Settlement Kamenny Ambar: (a) magnetogram, (b) fragment of the bypass ditch and wall [2].

ments of ribs, possibly femurs or tibias were found. Judging by the position of the skull, the deceased infant was oriented with his head to the south-southwest. At the head on the right was a vessel of the Sintashta type. At the legs (below) a sacrifice was found: fragments of a paired lower jaw and metacarpus without epiphyses of a newborn sheep, fragments of an adult sheep's skull and a paired lower jaw. A fragment of tissue 3.2 × 1.2 cm in size was preserved on the jawbone of the adult sheep. It is possible that the heads of the sheep were wrapped in cloth, or the bones of the animals were in a woven bag. The inclined position of the burial structure was caused by displacement of the soil towards the wells when they were abandoned and destroyed.

As it is known infant mortality in ancient societies was quite high. In the Bronze Age in the Southern Urals, children were mostly buried extramurally: either in separate burial mounds or in areas near the burial mounds together with adults. However, at the same time, some of the children, mostly newborns, were buried intramurally, in the settlements. They are regularly found at Sintashta settlements excavated over wide areas [10].

This tradition began early and was relatively widespread. Intramural burials of children are known in the Middle East, Anatolia, and the Balkan-Carpathian region since the Neolithic [11, 12]. In the II millennium BC, this tradition spread in Europe, the Urals and Central Asia.

For the study, a fragment of the jawbone of a sheep, with preserved textile was selected. Visual analysis of the tissue was originally carried out by A.G. Besenev

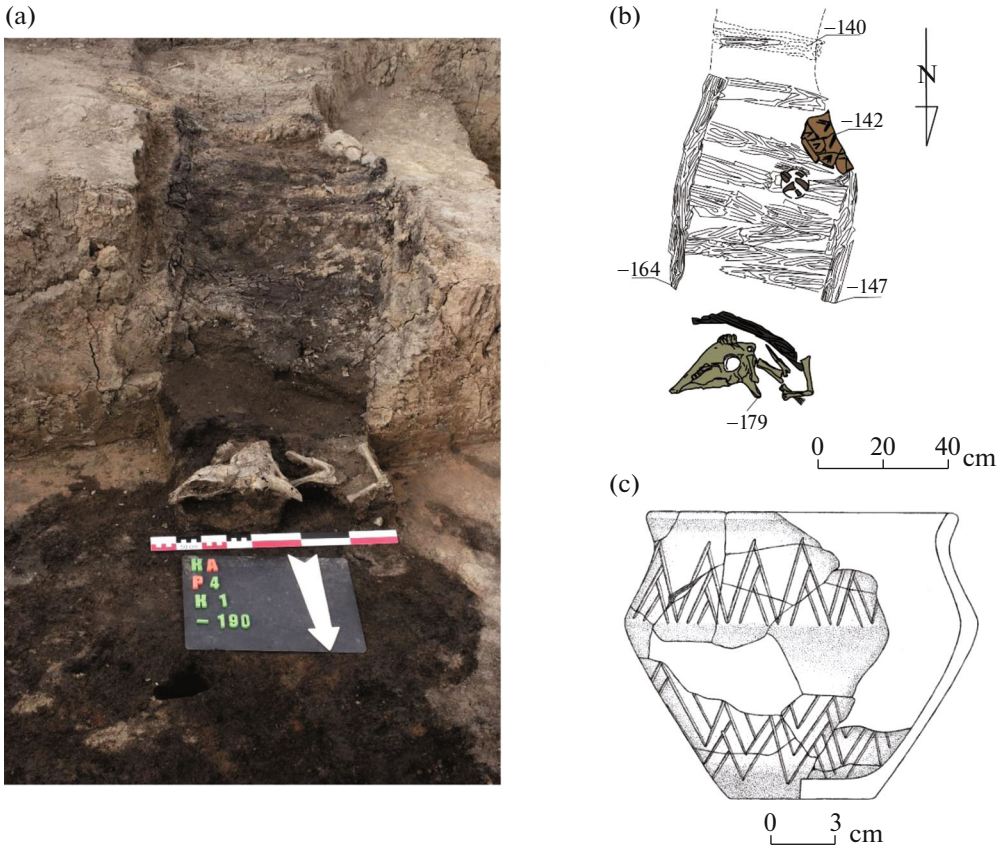

Fig. 3. Burial, sacrifice, well 2/1 (a), burial, sacrifice (b), and clay vessel (c).

(Chelyabinsk), who determined that it was made of vegetable fiber.

Then, the technological analysis of textiles was carried out in the restoration workshops of the Historical Museum and in the laboratory of the Center for Egyptological Investigation of the Russian Academy of Sciences using the visual method and the microscopy in transmitted nonpolarized and polarized light. Microsamples for study were collected with minimal damage to the textile sample. Sampling and preparation of the samples and measurement of the metric parameters were carried out using a Hund Wiloskop stereomicroscope in reflected light at a magnification from ×6.7 to ×45, an Olympus BX51 polarizing microscope at a magnification from ×40 to ×600. The nature of the fibers was determined by morphological features. For the work, a permanent immersion preparation in fir balsam was prepared. The comparison was made with a reference collection of fibers. Fiber analysis was repeated at the Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, using the method of scanning electron microscopy (SEM).

Since the textiles were treated with chemicals for preservation in the field and thus contaminated, a bone fragment from the inside of the jaw of an adult sheep was selected for radiocarbon dating using accelerator mass spectrometry at the Poznań Radiocarbon Laboratory (Poland). To analyze the radiocarbon age of the bone sample, we used the data obtained as a result of dating wood from wells [13].

Additionally, we analyzed the variations in strontium isotopes in a sample of cotton fiber by the method of multicollector mass-spectrometric analysis at the Common Use Center "Geoanalyst" of the Institute of Geology and Geochemistry, Ural Branch, Russian Academy of Sciences. This study was aimed at possibly identifying the cultural and geographic area from which the cotton fabric may have originated. Similar studies carried out on variations of strontium isotopes in cotton textile samples from the sites of southeastern Arabia in the early Middle Ages showed the promise of this direction [14].

For comparative analysis, we collected data on early finds of cotton fabrics in Northern Eurasia and Southeast Asia.

RESULTS

Technological analysis of textiles. Textiles were made from raw cotton (Fig. 4). SEM images clearly showed the ribbon-like twisted structure of the fiber (Fig. 5). The plain weave fabric was 3.0 × 1.5 cm in size, the

edges were uneven. Threads with almost no twist had a thickness of 0.3–0.6 mm. The fabric density was 26 × 26 N/cm^2. Under the fabric layer, another layer, visually identical to the upper fabric, was visible.

Radiocarbon dating. The results are presented in Table 1 along with published radiocarbon data obtained from wood samples from well 2/1 and the simulated date.

The fragment of sheep bone was dated the turn of the III–II millennium BC, most likely to the beginning of the II millennium BC, i.e., to the early phase of the Sintashta stage in the history of the settlement. The fragment of cotton fabric also belonged to this time.

Isotopic analysis of textiles. Variations in the strontium-isotope ratios in the fragment of cotton fabric from the burial at the Kamenny Ambar settlement $^{87}Sr/^{86}Sr$ were 0.70910366.

Early cotton fabrics of Northern Eurasia and Southeast Asia. Cotton textiles (*Gossypium arboretum* or *G. herbaceum*) have been found at sites of the VI millennium BC in the plains of Kachchi in central Pakistan, the province of Balochistan, appearing in northern Arabia and eastern Jordan in 4000 BC [15, 16]. Cotton seeds and fibers have been found in Nubia and dated to 2600–2400 BC [17]. A fragment of fabric made of mixed cotton and woolen fibers was found in one of the dolmens of the village of Novosvobodnaya at the end of the IV millennium BC in the Northern Caucasus [18]. Starting from III millennium BC, in II millennium BC, and later, cotton seeds, fibers woven from cotton threads of fabric are known in India in the Harappan culture of the Indus Valley, in Mohenjo-Daro [19, 20], in Southern India [21], as well as in the southern part of Central Asia [22, 23]. Another piece of cotton textile came from the Safar-Kharaba burial ground in the South Caucasus and was dated to 1500–1400 BC [24].

Thus, the area of distribution of early finds of cotton textiles can be outlined by the regions of Southern and Southeastern Asia and Northern Africa. Cotton textiles at Mehrgarh in Balochistan suggest that in the foothill areas of the Kachchi Plain, where the conditions for the successful cultivation of water-dependent *Gossypium* sp., cotton could have been domesticated as early as 6000 BC [23]. Another center of cotton domestication could be the Indus Valley [15] and Northern Africa [20].

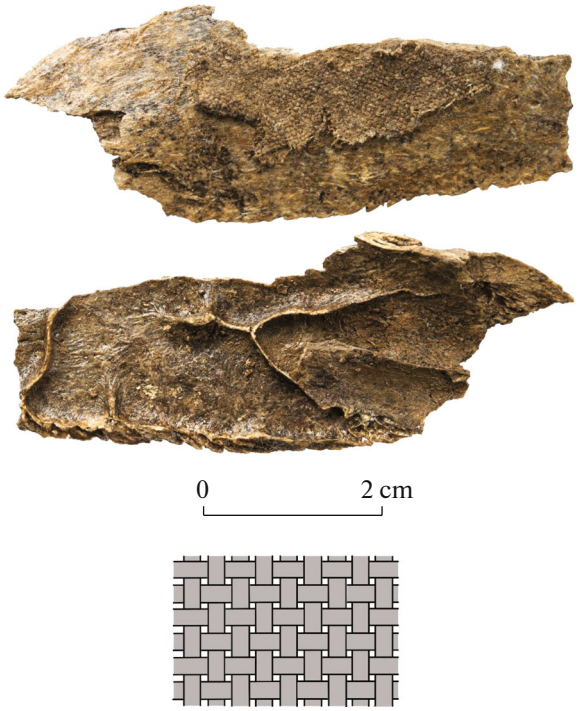

Fig. 4. Fragment of a bone with remnants of tissue (front and back) and a scheme of textile weaving of the fabric.

Cotton fabrics of the late IV millennium BC and the middle of the II millennium BC in the Northern and Southern Caucasus are considered as imported, possibly originating from the southeastern cultural regions of the Near East or regions located to the south [18, 24]. There were no wild forms of cotton in Europe [25].

DISCUSSION

^{14}C data. According to new radiocarbon data, which correlate with the Sintashta time periods (2030–1870 (1σ), 2050–1760 (2σ) BC) of the Kamenny Ambar settlement, the burial was carried

Table 1. Settlement Kamenny Ambar. Radiocarbon data

Laboratory number	Sample	Context	Radiocarbon age (from p.t.)	Calibrated date BC (probability)	Modelled calibrated date BC (probability)
Poz-112117	Sheep bone	Burial	3600 ± 30	1979–1920 (1σ) 2036–1882 (2σ)	
Hd-28430	Wood	Well 2/1a	3617 ± 31	2026–1936 (1σ) 2039–1890 (2σ)	2026–1956 (1σ) 2041BC–1924(2σ) X2-Test: *df* = 1 *T* = 0.4 (5% 3.8)
Hd-28403	Wood	Well 2/1a	3644 ± 31	2036–1954 (1σ) 2069–1924 (2σ)	

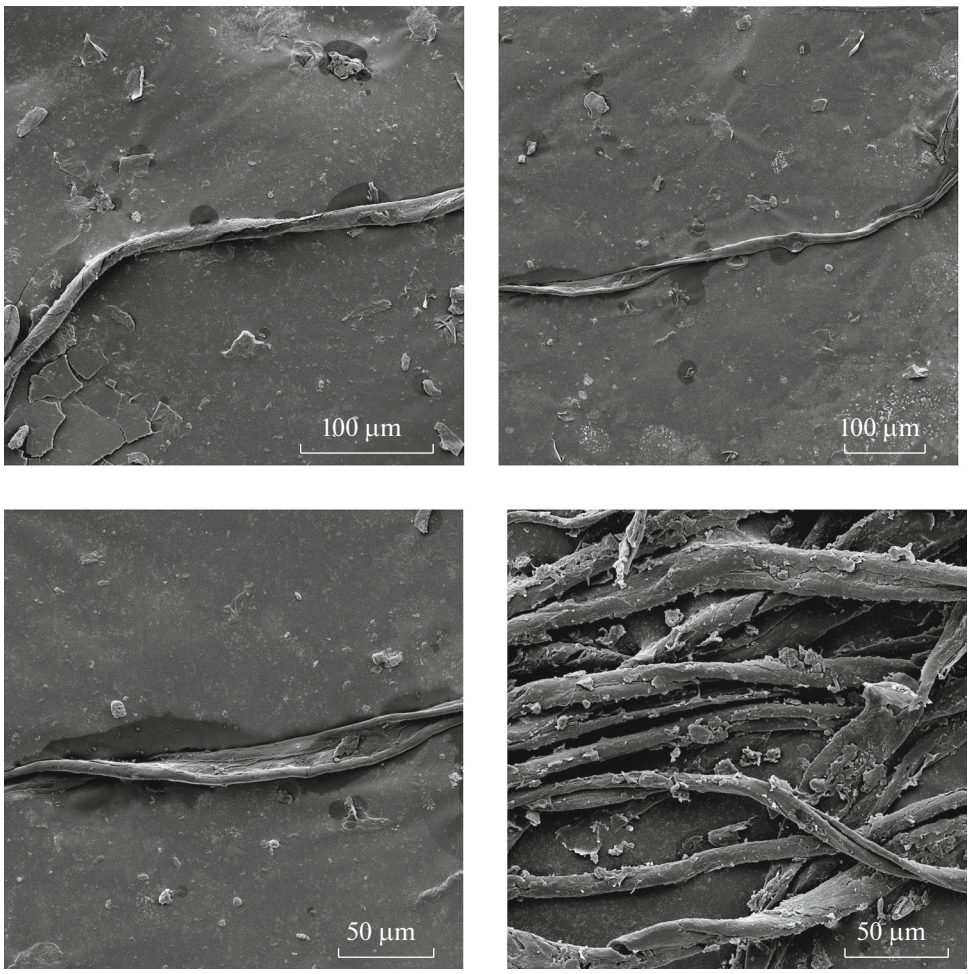

Fig. 5. SEM image of cotton fibers.

out at that time under the floor of building 2. The floor of later building 3, which destroyed the Sintashta layer in this place, was 10–15 cm higher than the burial. Radiocarbon data make it possible to correlate well 2/1 and the burial in the floor of the building: the burial could have been carried out at the same time as the well, or somewhat later. During destruction of the well, movement of the nearby soil also affected the burial, which partially shifted down, and the sacrifice ended up in a humid environment without oxygen, which determined its relative safety.

Textile traditions of the Sintashta culture. Reconstruction of the technological characteristics of textiles of the Sintashta culture is based on the results of analysis of textile imprints on the inner surface of vessels, on the floor of settlements, textile products themselves [26–29], and spinning and weaving tools [30]. A study of the nature of textile fiber showed that Sintashta weavers used both wild bast plants and woolen fiber. The remains of woven mats made of cattail (*Typha* sp.), fragments of hemp (*Cannabis* sp.) and nettle (*Utrica* sp.) stalks among the remnants of the ceilings of the dwellings of the Sintashta settlements of Alandskoe, Kusak, and Arkaim suggest that such bast plants were used as textile raw materials [31]. This is confirmed by a fragment of a cord made of hemp, preserved on a bronze hook in burial 6, burial mound 1, at the Sintashta burial ground. A thread with a thickness of 1–2 mm had a twist of S(2z).

Prints of plain weave fabric with Z-twist warp and weft threads on vessels from the burials of the Sintashta mound, the burial grounds of Krivoe Ozero and Kamenny Ambar-5 made it possible to reconstruct the technology of local weavers [26–29]. Fragments of woolen textiles were also found in the Sintashta burials 25 and 111 of the Bestamak burial ground in Kazakhstan [28]. These were plain weave fabrics, with a thread thickness of 0.5–0.8 mm, with S and Z twist. Thus, the textile masters of the Sintashta culture possessed many craft skills and used both plant (wild bast plants) and woolen fiber to make ropes and plain weave fabrics.

Woolen fabrics appear due to the rapid spread of the technology of their production among the steppe

and forest-steppe population of the Volga region, the Southern Urals, and Kazakhstan in 1925–1775 BC [1]. However, textiles made of cotton threads, according to novel ^{14}C data, could have appeared in the Southern Trans-Urals, when woolen fabrics were already known. It is very likely that the experience of making them was brought to the Southern Urals due to large-scale migration as a result of climatic cataclysms that affected most of Eurasia in 3000 BC (4200–3800 calBP) [32]. As for cotton, its presence in the Southern Trans-Urals looks quite exotic. How could this fabric get here? Clearly, there was no way it could be local.

Origin of cotton fabric from the Kamenny Ambar settlement: hypotheses. Variations in the isotopic composition of strontium in a cotton-fiber sample from Kamenny Ambar and a comparative analysis with the proposed isoscapes of strontium-isotope variations for a rather significant area of four large megazones of the Southern Urals (Central Urals, Magnitogorsk, East Urals, and Trans-Urals), coinciding with the area of distribution of Sintashta-Petrovka sites [33], have not yet yielded any results. Strontium-isotope variations in cotton fiber from Kamenny Ambar are less radiogenic than strontium-isotope variations obtained from bioavailable water/plant samples collected around the settlement, but coincide with the values of modern samples from other analyzed regions [33]. In the future, with expansion of the source base, it will be possible to conduct a comparative analysis of strontium-isotope variations in the South Ural fragment of cotton fabric and in those potential regions where early cotton textiles have been recorded.

Therefore, other data were used to determine the probable region of the origin of cotton fabric.

It is important to note that the economic structure of the inhabitants of not only Kamenny Ambar, but also other Sintashta settlements in the southern Urals included breeding domestic animals, gathering, hunting, metallurgical production, mining, construction, processing of stone and bone, pottery [4, 7, 15]. A long-term study of seed and fruit samples from layers of the steppe settlements of that time showed the presence of only wild plants and, thus, the absence of agriculture in the economy of their inhabitants [5, 34].

We note that the cultivation of water-dependent cotton requires certain climatic conditions, a developed irrigation system, although it is possible to allow cotton cultivation in small fields, which does not require a significant irrigation system [23]. In the modern world economy, cotton growing is widespread in tropical, subtropical and southern temperate latitudes [25], since its cultivation requires warm temperatures, the absence of frosts, and annual precipitation in the range of 600 to 2000 mm. It is known that the climate of the Trans-Urals is continental, with cold winters, but rather warm, often hot summers with an average temperature of 22°C and an annual precipitation of about 300 mm. The steppe landscape, interspersed with pine forests and birch groves, dominates [35].

However, at the turn of III and II millennia BC the climatic conditions were relatively favorable, the territory was sparsely populated, natural resources were attractive for pastoral cattle breeding and gathering, which led to an influx of people from the west [32]. Nevertheless, the inhabitants of the Sintashta settlements did not even cultivate grain crops, and it was generally impossible to grow cotton in the study area.

Thus, there is probably no unequivocal answer to the question of how cotton fabric ended up in the Southern Trans-Urals, so far from the place of its manufacture. But several hypotheses can be put forward.

As is known, the decline of the first civilizations, including Harappan, was at the end of III millennium BC. It disappeared due to a sharp change in climate towards aridity, which led to rejection of the urban lifestyle and a high increase in interpersonal violence [36, 37]. Serious changes towards the deterioration of climatic conditions occurred in Anatolia [38] and other regions. As a result, with the spread of drought, the migration activity of the population increased; this led to greater contact, the formation of new alliances, and serious contradictions and military conflicts arose [39]. The need for more efficient means of transportation, which also had military functions, led to the invention at the turn of III and II millennia BC of war chariots. According to [40], they were invented in the steppe area, where horses were already widely used, but not without the influence of Middle Eastern wheel manufacturing technologies.

An analysis of early finds of cotton fabrics suggests that cotton fabric could have entered the Sintashta environment from the northwestern part of South Asia, from the cultural area of the Indus civilization, where cotton was already grown and used in eastern Pakistan and northwestern India at that time as a raw material for textile production. It is possible that cotton fabric came to the Trans-Urals during the Sintashta migration, which brought Anatolian architectural schemes and chariots there at the turn of the III and II millennium BC [32]. There may be other scenarios.

Due to the mobile pastoral economy, various groups of the East Eurasian steppes interacted with the population of Asia, Altai, Tien Shan, and China since the Bronze Age [41]. Starting from the III millennium BC, numerous trade routes connected Xinjiang, Central Asia and regions further south (the mountain valleys of Kashmir, Khyber, Swat in Pakistan). A feature of this area is a multicomponent exchange system, and from the middle of the I millennium BC cotton, linen and woolen fabrics became the subjects of trade. However, cotton began to penetrate Central Asia around the III–V centuries AD [23].

The latest results of DNA analysis of the population of South and Central Asia, and the steppe and forest-steppe zone of Northern Eurasia demonstrated the movement of the bearers of the steppe cultures in the southeast direction at the very beginning of the II millennium BC [42]. It was at this time that burials with chariots appeared in the sites of the late Harappan civilization in South Asia, which came to Hindustan around 1900–1800 BC with groups of the Sintashta population [43]. Perhaps this was not a direct single act of migration from the Southern Urals so far to the southeast, but a more complex gradual interaction, mutual influence and penetration of representatives of the steppe Sintashta groups or individuals, first into the near marginal regions, into Central Asia, into the territory of the Bactria–Margiana Archaeological Complex, at the sites of which typical objects of the Sintashta culture were found, for example, bone cheek pieces [43], and then further to the southeast [42]. It is possible that cotton fabric could be made from local Central Asian fiber grown in the oases of Bactria and Margiana, especially since in the XIX–XX centuries AD and today Turkmenistan is one of the main regions of cotton production. However, although prints of plain weave fabric have been found on the ceramics of this region, for example, vessels from Gonur Depe [26], until cotton fabrics of this time have been found in one of the oases of this civilization, it is not possible to connect the fabric from the Kamenny Ambar with the Bactria-Margiana Archaeological Complex.

It is necessary to emphasize once again the complex multi-component trans-civilizational trans-Eurasian ties between the steppe population of the Sintashta settlements of the Southern Urals, the cultural area of the deserts and oases of the Bactria-Margiana Archaeological Complex, and the Indian civilization at the beginning of the II millennium BC. Such deep relationships have transformed the transcontinental trade network. Copper, tin, turquoise, and gold are prestigious raw materials and the products become objects of exchange [43].

This was facilitated by the appearance of a chariot complex in the Southern Trans-Urals, Western, Northern and Central Kazakhstan in the Sintashta, Petrovka, and Alakul sites [44]. Thanks to the Sintashta masters and warriors from the steppe, the technology of making chariots spread to China, northern India and Mesopotamia [45], almost at the same time and a little later, from west to east, the innovative technology for the production of woolen fabrics reached China [1]. At the beginning of the II millennium BC, first Chinese silk fabrics came from the eastern regions through the Asian trade routes to Northern Bactria [43]. The culture of millet penetrated from China to the steppe regions. Wheat and barley came from East Asia and southern regions of Central Asia [23]. We believe that cotton from India could also enter the orbit of such trade or exchange operations.

Whether cotton fabric appeared in the South Ural steppes as an object of a multi-stage exchange or together with one of the settlers is unknown. However, we note that among the analyzed residents of the South Ural settlements, a small group of "outsiders" was revealed. An analysis of 50 individuals buried in the Kamenny Ambar 5 burial site showed the presence of five individuals genetically different from the local population. Thus, representatives of other populations also lived in this fortified settlement [42]. This suggests that the exotic fabric could have entered the territory of the fortified settlement as part of a foreign accessory, which was later used in a funeral ritual, according to which a child was buried under the floor of the dwelling along with a clay vessel of local production.

CONCLUSIONS

A burial complex of the turn of III–II thousand BC practically in the center of the Eurasian steppe world, discovered at the settlement of Kamenny Ambar in the Southern Trans-Urals, remains so far, the only one where exotic cotton fabric has been found. The regional context, the natural conditions of the steppe ecozone of this time, the absence of any evidence of agriculture among the Sintashta population indicated that such imported fabric was a prime example of exotic items in the steppe cultural environment of this time. Comparative analysis of the distribution trajectories of early cotton fabrics, cultural trans-regional relationships of the Sintashta population, and the hypothesis that the representatives of this culture themselves moved to the regions of Central and Southeast Asia, i.e., in those regions that are now identified as the oldest areas of cotton domestication, suggest that the origin of cotton textiles may be associated with the distant areas of Pakistan or India.

Thus, entry of this textile through multi-stage exchange was not confirmed, although it was at this time that a trading system was formed, the scale of which expanded due to the short seasonal movements of mobile groups [1]. However, it can be supposed that not only important goods of exchange were involved in the orbit of such movements, but also the people themselves, who set off on a long journey due to necessity for various reasons. It is these paths that connected from the end of III thousand BC distant steppe regions, areas of Central, Southern and Southeastern Asia, and subsequently became the main trade routes of the Great Silk Road [41, 43].

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COMPLIANCE WITH ETHICAL STANDARDS

We declare that we have no conflicts of interest.

This article does not contain any studies involving animals or human participants performed by any of the authors.

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