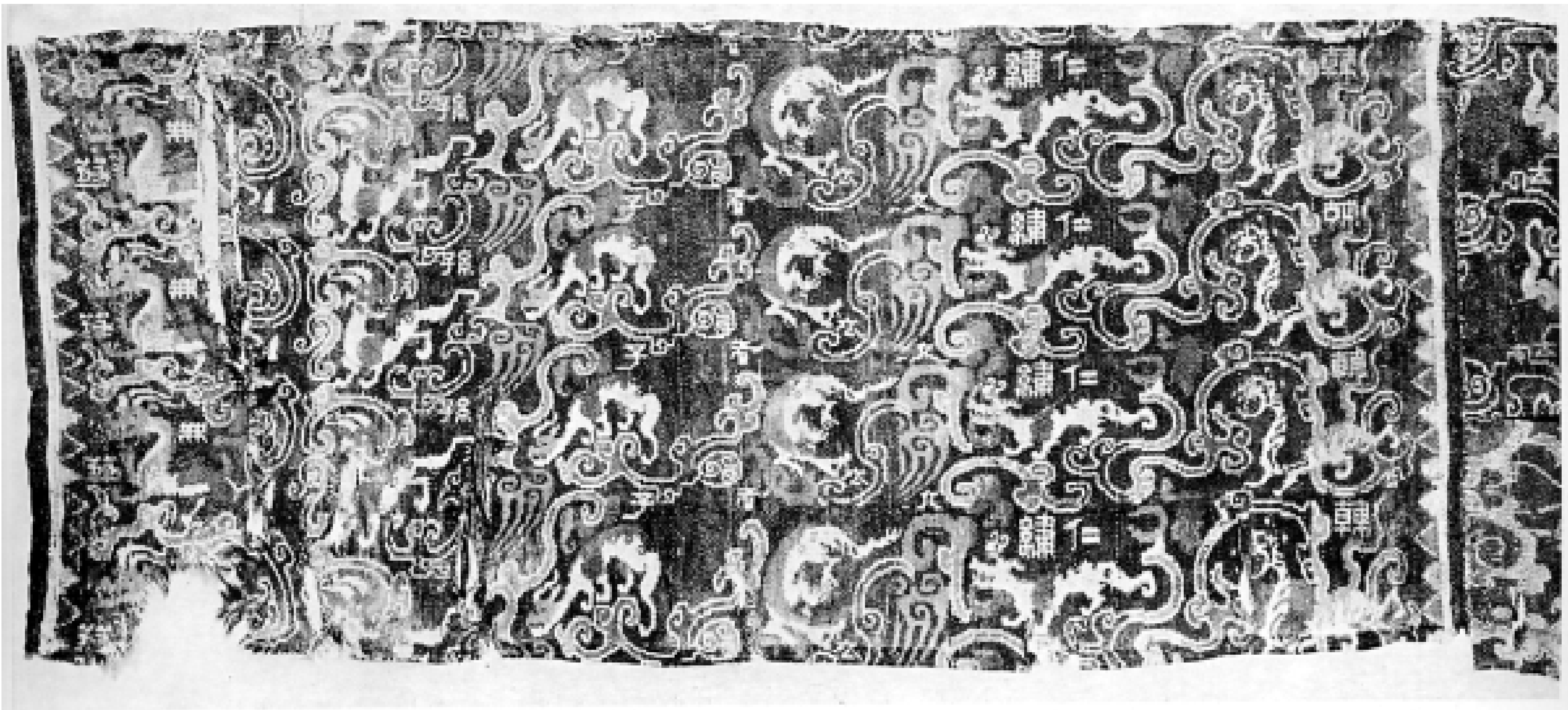

SILK TEXTILE DISCOVERED BY SIR AUREL STEIN IN LOU-LAN (L. C. 07.A-B), TURKESTAN, CF. P. 75

DESIGN SHOWS GROTESQUE BEASTS PURSUING EACH OTHER THROUGH VERNICULAR CLOUD SCROLLS. BANDS AT LEFT AND RIGHT SIDES ARE SELVAGES. PLAIN COMPOUND CLOTH. CHINESE, HAN DYNASTY (206 B.C.-220 A.D.). CENTRAL ASIAN ANTIQUITIES MUSEUM, NEW DELHI, INDIA

TECHNICAL STUDY

OF

Textiles from the Burial Mounds of Noin-Ula

Edited by

A. A. Voskresensky and N. P. Tikhonov

Translated by Eugenia Tolmachoff from *Izvestia* (*Bulletin*) *of the State Academy for the History of Material Culture*, Vol. XI, Parts 7-9, 1932. Copy of the original *Izvestia* and translation of the complete section of tables are available in the Library of the Metropolitan Museum of Art.

•

PART I—TEXTILES

A. TECHNICAL METHODS USED IN THE STUDY OF THIS ARCHÆOLOGICAL MATERIAL

THE rather complicated nature of archæological material, the variety of questions that arise in studying it, the ever widening circle of archæological interests, the desire to make the study of archæological objects more profound and exact—all this necessitates the discovery of new methods that will reveal those qualities of the material which hitherto aroused no interest, or else were inaccessible.

It is particularly valuable to apply these new methods to the enormous wealth of archæological material discovered by the Mongolo-Tibetan expedition of P. K. Kozlov in 1924-25, because the variety and unequalled number of rare objects—the examples of an ancient textile industry—make the material found in these excavations of tremendous scientific importance. The ordinary routine analysis used hitherto in archæological researches was not satisfactory when applied to this material, for it considered these objects from one standpoint only, that of the artistic style. Such analysis cannot go beyond certain limits, and yet, beyond those limits there is a large field for research. Moreover, the analysis in this case demands facts of an entirely different order. For example, no matter how carefully we analyze a group of embroidered woolen fabrics, we cannot tell positively whether these are Greek products that have, in some unknown way, penetrated into the heart of Mongolia, or if they are the work of local craftsmen. There are grounds for both conclusions. The only way to reach a decision, in such a case, is by an exact analysis of the material.

The ordinary study of tribal customs is not sufficient for this type of material: the only possible way to have a clear idea of a people's life and customs is to learn its technical ways and customs. This can be explained by an example: we have before us a collection of miscellaneous black pottery. What does this black colouring mean? Does it mean that a continuous use of this pottery for cooking food over a fire made it black? Or are we dealing with some special local technique? How was this pottery made, what kind of tools did the workman use, and did the local potter have his own wheel? What was this pottery used for? Can it stand the process of cooking food on a fire, or can it hold water?

Important questions about the origin of objects sometimes cannot be answered at all without a technical analysis, and these questions are often vital. The study of the primary materials, and of the technique and methods of using those materials for the manufacture of certain objects, will provide a basis for determining conclusively the provenance of these objects. It will also give a more vivid idea of the culture of the people who built the mounds of Noin-Ula, as well as a better understanding of the nature and durability of the materials they used. Such results are possible only when the most varied methods of technical analysis are employed. It is fortunate that these methods are now being improved very rapidly, because otherwise the significance of archæological finds would never be fully understood.

In November, 1925, the former Institute of Archæological Technology at the State Academy for the History of Material Culture[1] undertook the technical research of materials discovered at the excavations of the mounds in Mongolia in 1924-25. Complete technical research for the large list of objects found in the burial mounds presented a very complicated problem, owing to the unusual amount and character of its most precious materials (textiles, lacquers, furs, etc.). Therefore, the Institute organized several working groups, each having a consulting specialist, for

[1] Now the Institute for Historical Technology of the State Academy for History of Material Culture.

the study of separate classes of materials—stone, ceramics, metal, organic remains, textiles, etc. Owing to the extreme importance of the textiles, the group working in this field included not only the specialists from Leningrad but also those from Moscow. In studying the textiles the Moscow group applied the usual analysis of a purely technical nature. They analyzed consecutively the primary fibre, the thread, the weaving, the design, and finally the dye.

But as this is not the only analytical method possible, the Leningrad group also applied another one, beginning with the analysis of the whole fabric and coming gradually to the analysis of the thread. Both methods are the same; the only difference being the starting point of the analysis. For the analysis of the colouring, however, the Leningrad group adopted quite a different method, and emphasized not chemical analysis but photo-analysis. For this purpose the Institute equipped a special laboratory under the direction of N. P. Tikhonov.

In this way, the study of the material from the Mongolian mounds became a great enterprise, in which many prominent specialists of various branches of science took part. As the nature of this work required the use of different laboratories, the Institute had to apply for the collaboration of the laboratories of the Technical Institute, the Polytechnical Institute, the Textile Institute (Moscow), the Laboratory for the Study of Textiles in the Upper Cooperative Courses of the Central Union (Leningrad), the Histological Laboratory of the Institute of Experimental Agronomy, and others. In all instances this cooperation was offered willingly.

This book presents the results of scientific research in the silk and woolen fabrics, amazing in their weaves, dyes, and ornament, that were found in the excavations of P. K. Kozlov in Mongolia. These fabrics show us a highly developed technique of spinning and weaving, and the purpose of this book is the explanation of this technique. All the specialists, no matter how different their methods, had but a single purpose: to find out all the characteristics of the material they studied in order to have a clear idea of the technique of the textile industry of that period.

For this purpose, a detailed analysis was made of the primary materials which were used in making the textiles, silk as well as wool. The silk has been studied by micro-chemical analysis, and chemical, histological, and microscopical analysis was applied to the woolen fabrics.

The thread, being the foundation of the fabric, has been studied from the point of view of its technical nature: thickness, twist, strength, elasticity, and finish.

The silk fabrics present the most variety in structure; they have various weaves and pattern repeats, producing different woven designs. The woolen fabrics are much simpler in structure; in most cases they have a simple weave in which the threads of the weft are brought close together forming a fabric that is a prototype of contemporary woolen cloth. In analyzing the warp of these fabrics special attention was given to the thickness of the thread and the compactness of the texture, also its strength and, whenever it was possible, its durability.

Time, as well as the chemical processes going on in the ground where the fabrics were buried, have greatly affected their dyes without ruining the textiles themselves. The fabrics have lost colour and have become so dull that identifying their original colour became quite difficult. Nevertheless, owing to the new methods evolved by the scientists, it became possible, by chemistry and photo-spectography, to define the nature of some of the dyes and to reconstruct the colouring of the fabrics.

These Mongolian textiles can be easily separated into four groups: woolen fabrics embroidered with Greek designs, silk fabrics with woven Chinese designs, fabrics made of vegetable fibre, usually without any design; and finally, fabrics in which various materials and weaves are combined.

Before subjecting the textile material to correct analysis it is absolutely necessary to complete its proper restoration. Unfortunately, the greater part of the fabrics sent to the laboratory had been previously cleaned, so that it was not possible, in restoring the material, to use to the fullest extent the new methods recommended by such specialists as Walland, Max Bottler, Roggenhöfer, and others, or the methods worked out in our own laboratory of the State Academy for the History of Material Culture. The importance of adequate restoration is demonstrated by a splendid embroidery, representing the head of a warrior with a mustache, in different stages of restoration.[2] This embroidery, made on a small piece of woolen fabric, was impregnated with tar and grease and looked like a lump of rotten rags; it was found in some petrified stratum and discarded as useless material. When treated with carbon tetrachloride, ether, and chloroform, under a current of dry vapour with an atmospheric pressure of 0.5, all the dirt was taken off, and as a result of this process

[2] (Note. Figs. 1-3 in the original Russian publication. E. B. S.)

we got an example of a rare value. The systematic treatment of other small lumps, which first looked so hopeless, gave the same amazing results.

The electrolytical method of cleaning archæological objects (not only metallic ones) opens quite new and unexpected possibilities. The question of whether it would be possible to apply this method to textiles is a problem of the future; and the method has not yet been applied to the archæological material in question.

The silk fabrics form an outstanding and very characteristic group. A detailed technical analysis was applied first to a small group of silk fabrics of uniform type. By micro-analysis, first of all, it was possible to define the nature of the fibre. The fibre came from a semi-cultivated silkworm; its filament has a characteristic oval rhomboidal section, while the cultivated silkworm gives a filament with a round cross-section. The thread was obtained by winding several filaments, which were drawn simultaneously from the cocoons without any twisting. The fabrics analyzed are of different design, and show a well made and wonderfully executed type of weave, with three or four colours and a weft of a single colour.[3] It is an example of an unusual transition to the standard type of ornamental weaving. After having been buried for 2,000 years in the ground the material is wonderfully preserved as to its solidity and even elasticity.

The fine qualities of this "merchandise" proved to be especially striking in analyzing a large carpet, belonging to the fourth group of the textiles from Noin-Ula, in which are included fabrics made of different materials (Pl. 10). The great number of small pieces of stuff which were not numbered, and which could not be replaced during the restoration of the rug, made possible a series of very interesting experiments. Analysis of the material gave amazing results that can be explained only by a very original weaving technique, in these days entirely lost.

The problem of the dye is much more difficult. For many reasons, which need not be discussed now, the dye of the fabrics for the most part is in very bad condition, and most of them had a uniform reddish-brown shade in which other colours could hardly be distinguished. Because of very limited material, the chemical analysis could give only a few general indications; one can speak more or less positively about the presence of iron, perhaps of iron mordant that has been used before dipping the material in vegetable dyes. And that is all. Even the presence of aluminum

[3] (Note. The fabrics in question are of compound cloth weave [Pls. 1-7]. Analyses of the weave of one example in the Pennsylvania Museum is appended to this translation, p. 77. E. B. S.)

was difficult to establish because it would be necessary, for this purpose, to test by burning, which is not at all practical for such precious archæological material.

It is imperative to use great care in arriving at conclusions resulting from ordinary chemical analysis. Here is an example: in one instance chemical analysis established the presence of iron in the fabric, which made us suppose the existence of a dye containing iron or perhaps of an iron mordant. But in studying the filament under the microscope, we discovered on it small blue grains which, by micro-chemical analysis, proved to be vivianite, *i.e.*, hydrous phosphate of iron. Thus, the presence of iron here could be quite accidental. There were quite a few cases of this kind.

It is necessary, therefore, to apply some more thorough method which would not even slightly affect the material, *i.e.*, to use photography. In this kind of research the importance of photography is enormous. First of all, in order to show the condition of individual examples, it is necessary to use photography because the descriptive records are always incomplete and personal. The samples of fabric have been photographed not only in the usual way on orthochromatic and panchromatic films but also microphotographs were made of individual examples, sometimes enlarged 700 times, when it was necessary to ascertain the nature of the thread. After this, the fabric was photographed on a sensitive film by transmitted light (that is, by projection in the manner of a magic lantern); in this way, the present state of preservation of the fabric was shown, and it was possible to compare different pieces of the same fabric in order to discover the best preserved fragment. For further analysis, the best examples only were used, because the analysis of badly preserved pieces might make errors in determining the count of the thread, its elasticity, the thickness of yarn, the solidity of the fabric, etc.

Photography should also be used to reconstruct the true scale of values of the original colour scheme, because some of the colours can be detected by photography only. This method was invented by E. F. Burinsky, and worked out by A. A. Popovitsky, for the analysis of documents used as legal evidence, and later on it was applied with great success to the study of palimpsests and damaged manuscripts. Special care must be used in separating different wave lengths of light, and this method gives equally valuable results in bringing out faded colours in a photograph. In this way, it is possible to discover blue colour in a textile when the naked eye can no longer perceive it, and at the same time there is reproduced, in a monochromatic scale, an entire reconstruction of the values as originally planned by the textile maker (for example, the embroidered design of the warrior with the mustache, figs. 1-3 original Russian publication). The discovery of various shades brings up the question of a choice of filters for the separation of the different colours, and the selection of separate rays of light.

The problem of treating the true colours of the fabric, and also the exact correlation of the different shades, is the most vital, the most difficult, and at the same time the most interesting part of the study. At present we see only reddish and brownish colours, with hardly noticeable traces of some other dye (Pl. 3 and pp. 77, 78). But, of course, this was not the colour of the ancient Chinese fabrics: in part the colours were damaged in the ground by acids and salts brought by underground water; in part they were affected by ozone and oxygen after the excavation, and also by unsuccessful methods used in the preliminary cleaning and drying. In studying this problem numerous examples of modern Chinese silk fabrics (pongee) made from the filament of semi-cultivated silkworms were treated. They were subjected to iron and aluminum mordants and dyed with the most ancient dyes known to us: indigo, lakao, cochineal, madder, extract of gardenia grains, curcuma, litmus, and others. The fabrics dyed in this way were subjected to the influence of those chemical reagents which are most common in the earth, and first of all of nitric acid. During this experiment the blue indigo became white, but when reduced by hydrosulphite it became blue again, which means that the dye did not disappear but changed in character.

Examples treated had to be carefully spectrophotographed. Careful comparison of the spectrographs shows signs typical of some definite colouring agent, such as indigo. Now, in selecting the corresponding filter for the photographing of indigo, we have in the analyzed spectrograph definite indications of the colour required for the filter. Further, by employing the filter for the intensification of the colour blue, we obtain a complete picture, not only of values but also of the exact colour of this blue dye. In this manner, it is possible to determine the green colour of the background of the textiles, which at present appears to be dull reddish-brown, and the textile, therefore, from a dull reddish-brown with faded colours, becomes intense green, with a white and red pattern. The problem is to find a filter that corresponds as exactly as possible. This minute but necessary work, in some cases, may be made complete and more exact by analyzing the textile in the ultra-violet rays of Hereus' quartz lamp. In these rays examination of one sample of dull reddish-brown fabric revealed a background of bright green.

The last stage of this work is the attempt to restore the original colours of some of the examples,[4] which may be successful after careful preparation, first of all on the same examples of dyed pongee, and then on single threads and small pieces of the fabrics. That this is not altogether impossible is shown by the experiment of restoring indigo by hydrosulphite. Even a very delicate tint of lakao without mordant gave results that were not altogether hopeless, so that if the experiments of removing deposits of metallic salts from textiles by electrolysis are successful, we may perhaps obtain completely renovated textiles.

The methods employed by the Technological Laboratory of the State Academy for the History of Material Culture are new and unusual, but they are methods by means of which archæology may achieve results unobtainable in other ways. The systematic treatment of archæological material by these methods produced concrete results for Soviet science. From the realm of theoretical discussion the work has passed to concrete problems, and has become closely united to routine historical analysis, as well as to the study of life and customs.

It is important that these new methods should also be generally adopted for the study of material culture, and for this purpose it was necessary to explain their nature and their application to certain types of material. As in other fields, we hope that these methods of archæological technology, which have been applied to the study of objects from remote antiquity, will give to modern science new and fruitful data, which will be of increased value as showing the effects of time—the greatest of experimenters.

---

[4] See N. P. Tikhonov, "Treatment of Ancient Textiles by means of Photo-analysis," *Reports of the State Academy for the History of Material Culture,* 1931, no. 1, pp. 17-19. V. N. Kononov, "Deposits of Dirt in the Coloring of Objects from Archæological Excavations," idem, no. 2, pp. 10-12.

B. MONGOLIAN SILK FABRICS FROM THE EXCAVATIONS OF P. K. KOZLOV [5]

WHEN the Institute of Archæological Technology sent twelve examples of textiles from the excavations of P. K. Kozlov in Mongolia to the laboratory of the Moscow section of the Academy for the History of Material Culture, the scientists of this institution, in a series of conferences, worked out a program for a combined chemical and technical research. This program not only included all the questions mentioned in "The specimen scheme of analysis" of the Institute of Archælogical Technology but it considerably developed and enlarged them. The laboratory found it necessary to adopt such an enlarged scheme after a preliminary study of the examples revealed the tremendous technical importance of these textiles. Therefore, the program included not only a definition of the materials and their classification according to their fundamental construction but also their appearance under the microscope, as well as illustrations of the different weaves and designs. Thus, when studying the first examples, the general scheme of the chemico-technical analysis will work out, in more or less detail, the following questions:

1. Description of appearance of example, its measurements and photograph.
2. Description of design, that is, the nature of its outlines and its distribution over the surface of the fabric.
3. Size of the repeat of the design.
4. Study of the materials composing the fabric:
   (a) Description of the yarn [6] and its treatment.

[5] (Note. Except for the gauzes [Pls. 8-9] the silk fabrics are of the same weave [see p. 75]. Since a piece of the fabric no. 14501 [Fig. 31 in the original book] exists in the Pennsylvania Museum of Art [Pl. 3], a description and analysis of its weave has been appended to this translation [see pp. 77, 78]. This silk is of the same weave as some of the Chinese silk fabrics of the Han Dynasty discovered by Sir Aurel Stein; see Stein, *Innermost Asia,* Pl. 34, L. C. 04.A. A description and analysis of a piece of gauze [Pl. 9], similar to no. 13930 [Figs. 4, 5, 26, 27 in the original book] also has appended [p. 78]. E. B. S.)

[6] (Note. Yarn here denotes spun thread of whatever material—silk, wool, etc. E. B. S.)

(b) Nature of the filament and method used to analyze it.
(c) Mechanical treatment of the fibre.
(d) Count of yarn according to metric system, by weighing pieces of thread on analytical scales.
(e) Mechanical treatment of the thread, the twist, etc.
(f) Chemical treatment of the yarn.
(g) Thickness and evenness of threads.
(h) Tensile strength [7] and elasticity (elongation) of the threads, and state of preservation of their original qualities.
(i) Amount of finishing, as well as other mechanical alloys in the fabric (dirt, mineral deposits, etc.), and, if possible, their composition.
(j) Analysis, by photography and micro-photography, of separate items of special interest.

5. Count of threads of each material making up the fabric.
6. Estimate of general density of the fabric (if possible) in the entire width of the textile or in one square metre.
7. Conclusions concerning the weave of the fabric and its construction, that is, the arrangement of the weft and warp, making a design on paper and canvas of the construction of the fabric (on the principle of a working pattern for a textile).
8. Notes on the condition of the fabric at the time of this research.

At the beginning, the research was conducted with all the examples simultaneously. Later on, owing to the reasons stated below, this method was abandoned, and example No. 14021 (Pl: 1) was chosen for the research.

First of all, the minute study of each fabric required the use of all necessary instruments, and as the laboratory of the Moscow Section did not have them, it was forced to seek the cooperation, kindly offered to us, of the laboratory of the Moscow Textile Institute.

Then another problem arose. As is well known, any analysis, and especially an exact analysis, requires the use of a certain amount of material. In the case of the Mongolian textiles it transpired that some threads on the edges of the fabrics were so pulled out and worn that they could not give any idea of their original nature and construction. At times it was not even possible to separate them from the fabric in order to analyze

[7] (Note. Resistance of the threads measured by the strain necessary to break them. E. B. S.)

them. Therefore, it was necessary either to give up the research or to draw the minimum number of necessary threads out of a good part of the fabric.

Moreover, the amount of warp threads taken from example No. 14021 was insufficient for the practical carrying out of at least ten different experiments. In order to draw conclusions according to section 4, i, (see p. 12), it would have been necessary to have a piece of fabric weighing about 5 grams, which was not always possible because of the small amount of fabric in the sample. For instance, it was not possible to determine the count of thread on example No. 13958,[8] because the few threads taken out of this piece weighed so little that their weight could not be detected on Paul Bunge's analytical scales in the laboratory of the Textile Institute.

As to conclusions based on data obtained from this study, it is necessary to point out that no standards of measurement exist for such tests as elongation of the thread at the breaking point, etc., when the fibre is examined in such inconsiderable lengths as 10 or 15 cm. No more could be obtained, however, because of the small size of the examples. Considering the great "age" of the fabrics, it would be necessary to undertake a comparative study of many identical fibres. Without obtaining standard data relating to the fibre, it is not possible to determine to what extent the fibre has preserved its original qualities. This is undoubtedly the most important point in the problem of future preservation of these and other similar fabrics.

As to the chemical analysis of the dye of these textiles it is possible to give the following remarks about all the examples:

All the examples look as if they were dyed with brown dye of different shades. In those remote times the dyeing of fibre could be performed only with: (1) vegetable dyes on mineral mordants (alum of iron) or without mordants; (2) mineral dyes; and (3) animal dyes (cochineal).

The analysis showed the presence of iron in all brown dyes, from the lightest to the darkest. This was proved by: (1) heating and burning a sample in a crucible which produced ashes of the colour of iron oxides; (2) analysis of these ashes by means of potassium ferrocyanide. In all these cases the presence of iron was established without any doubt.

These data are sufficient grounds for the supposition that iron compounds

[8] (Note. Figs. 10-13 in original book. These illustrations, which are of a plain fabric without any pattern, could not be photostated for reproduction in this translation. E. B. S.)

are important in the dyeing of these fabrics. It is quite possible that in dyeing the silk, especially into deep brown shades, not only iron compounds were employed but also extracts from local plants used for dyes, as well as bark, roots, etc. A few silk threads of warp found in some of the fabrics were apparently dyed with madder on alum mordant. It is very difficult to come to definite conclusions, because, owing to the extremely small amount of material, it was not possible to determine the presence of aluminum in the ashes by the process of burning. It was possible only to obtain a characteristic reaction for madder with alum mordant, for instance, strong HNO_3 (nitric acid), weak solution of NaOH (sodium hydroxide), etc. (See Heerman's Table for definition of dyes.)

Among the examples there is one dyed a brick-red colour, but as the dye is not fast it smears white fabric and even paper when slightly rubbed. A more minute analysis showed that this dye had been applied mechanically to the surface of the fabric only, and probably no mordant was used at all, which explains its smearing the white fabric when rubbed. Chemical analysis of this dye revealed that it is nothing but iron oxide, and so after burning a sample we obtain ashes of brick-red colour. A reaction with potassium cyanide proved without doubt that this dye is an iron compound.

PLATE I

SILK FABRIC NO. 14021. THE DIAGRAM SHOWS A CROSS-SECTION OF THE FABRIC. IT WAS MADE FROM THE PLAIN BACKGROUND OF THE FABRIC, AND RUNS VERTICALLY IN THE DIRECTION OF THE WARP THREADS. (REPRODUCED FROM *Izvestia,* FIGS. 22, 23, P. 43.)

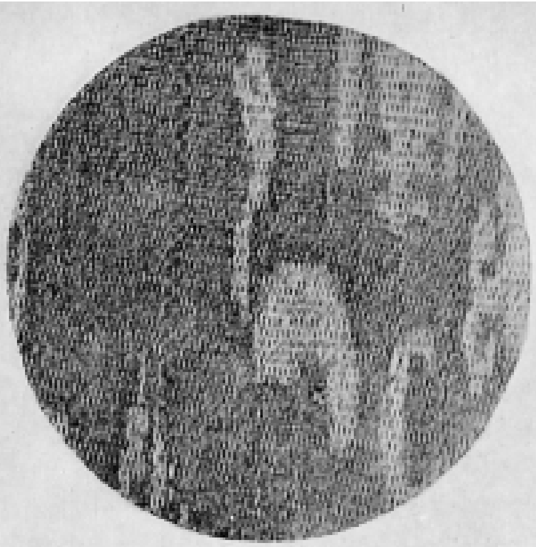

Рис. 24. Переплетение нитей в ткани № 14021 при увеличении в 3 раза

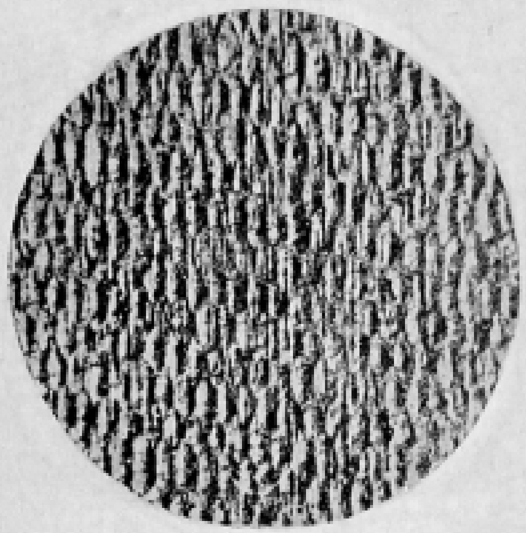

Рис. 25. Переплетение нитей в ткани № 14021 при увеличении в 10 раз.

PLATE 1A

WEAVE OF FABRIC NO. 14021, ENLARGED 3 TIMES. WEAVE OF FABRIC NO. 14021, ENLARGED 10 TIMES. (REPRODUCED FROM *Izvestia*, FIGS. 24, 25, P. 44.)

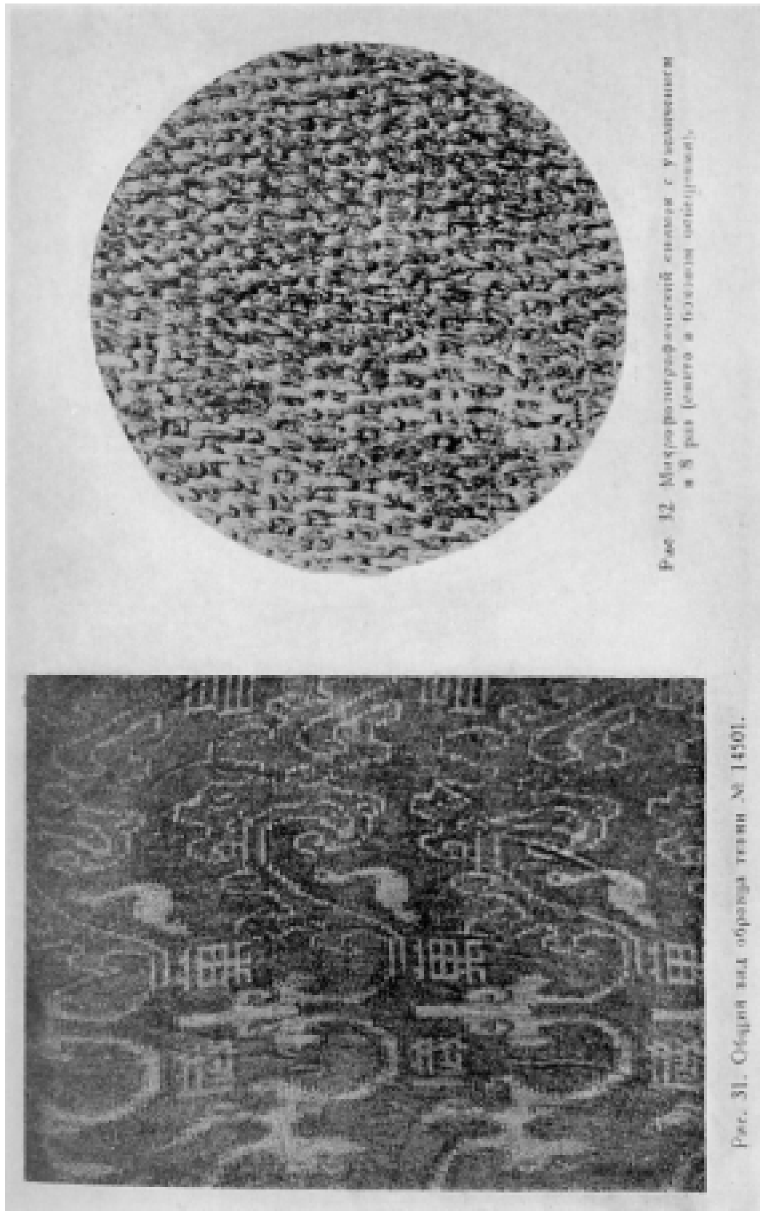

PLATE 2

SILK FABRIC NO. 14501. MICROPHOTOGRAPH, ENLARGED 8 TIMES, OF PART OF SAME FABRIC. (REPRODUCED FROM *Izvestia,* FIGS. 31, 32, P. 60.)

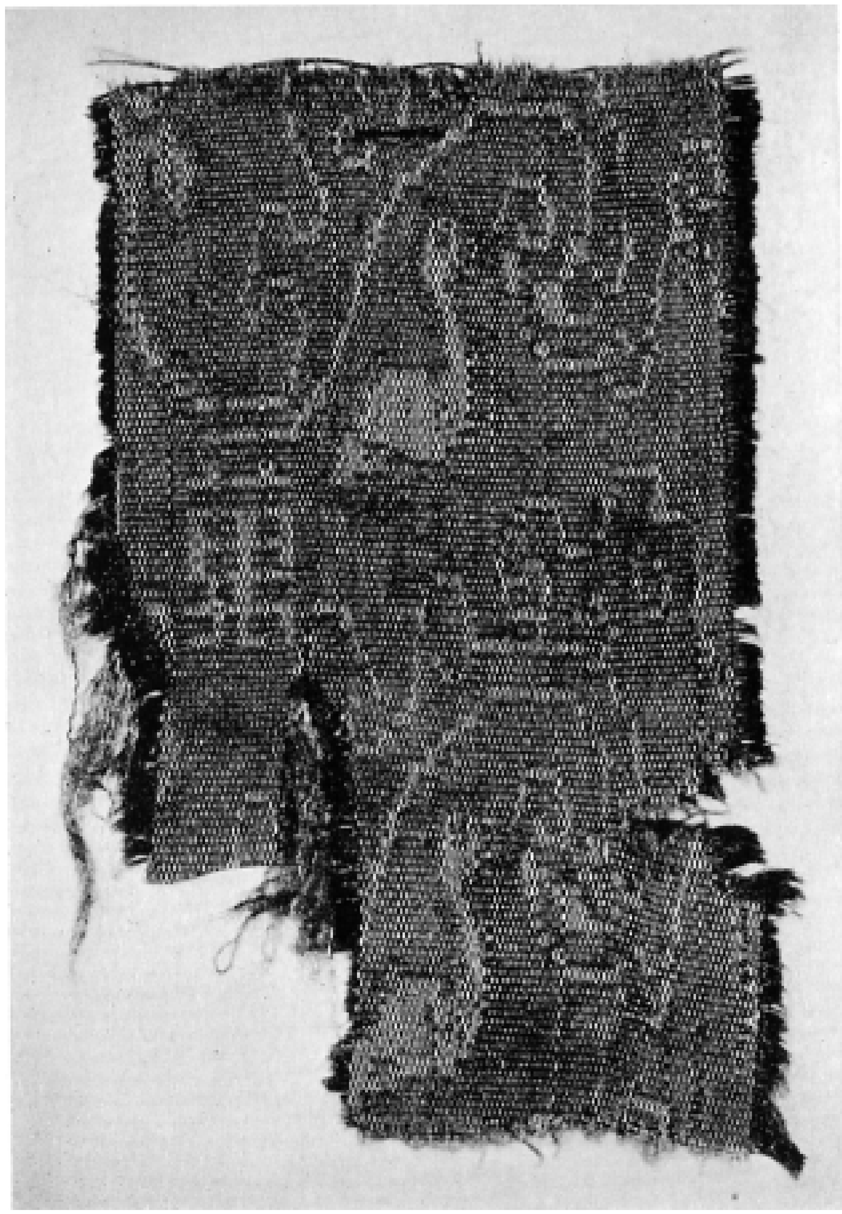

PLATE 3

FRAGMENT WITH DESIGN OF A HERON CHARACTER. PLAIN COMPOUND CLOTH WEAVE: SILK. SIZE IN METRES: LENGTH 0.091, WIDTH 0.058. PENNSYLVANIA MUSEUM OF ART ('34-2-2). SAME FABRIC, *Izvestia,* FIG. 31 (SEE PLATE 2).

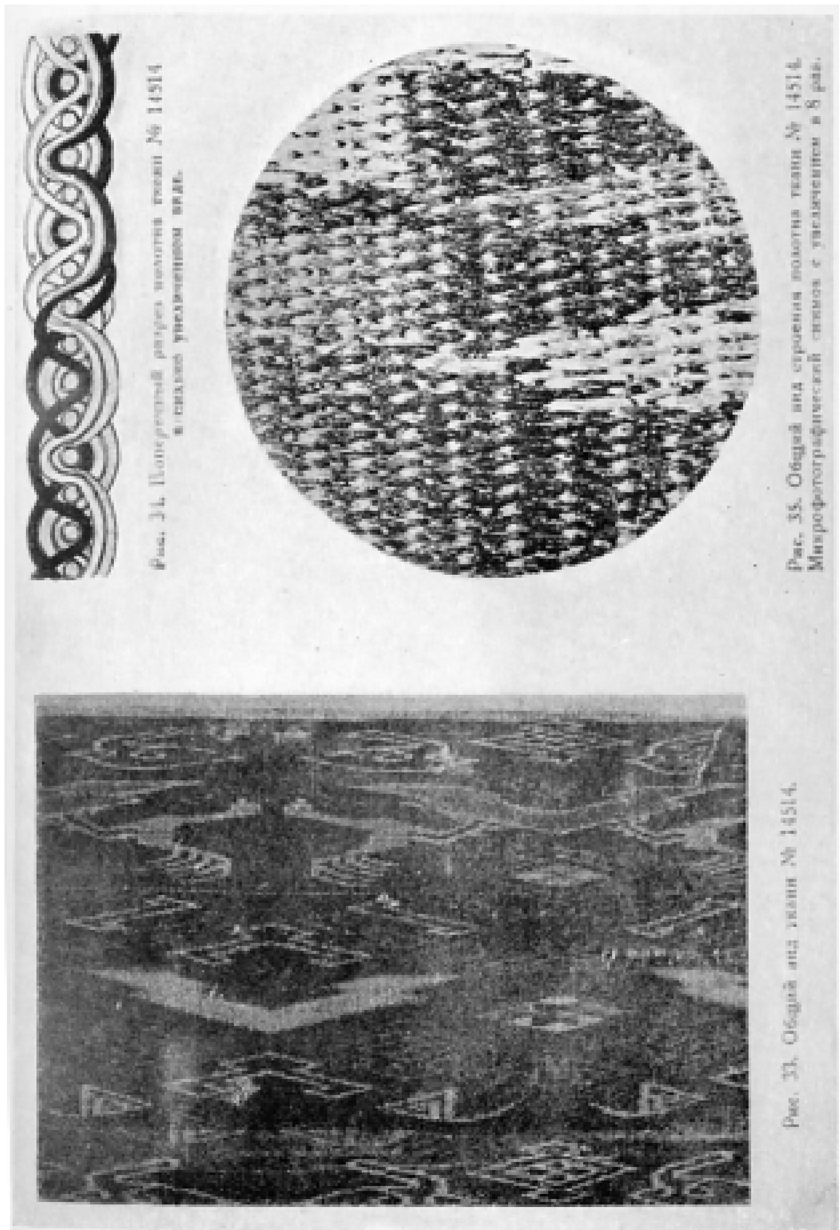

PLATE 4

SILK FABRIC NO. 14514. THE DIAGRAM SHOWS A CROSS-SECTION OF SAME FABRIC, VERY MUCH ENLARGED. MICROPHOTOGRAPH OF WEAVE OF SAME FABRIC, ENLARGED 8 TIMES. (REPRODUCED FROM *Izvestia,* FIGS. 33, 34, 35, P. 72.)

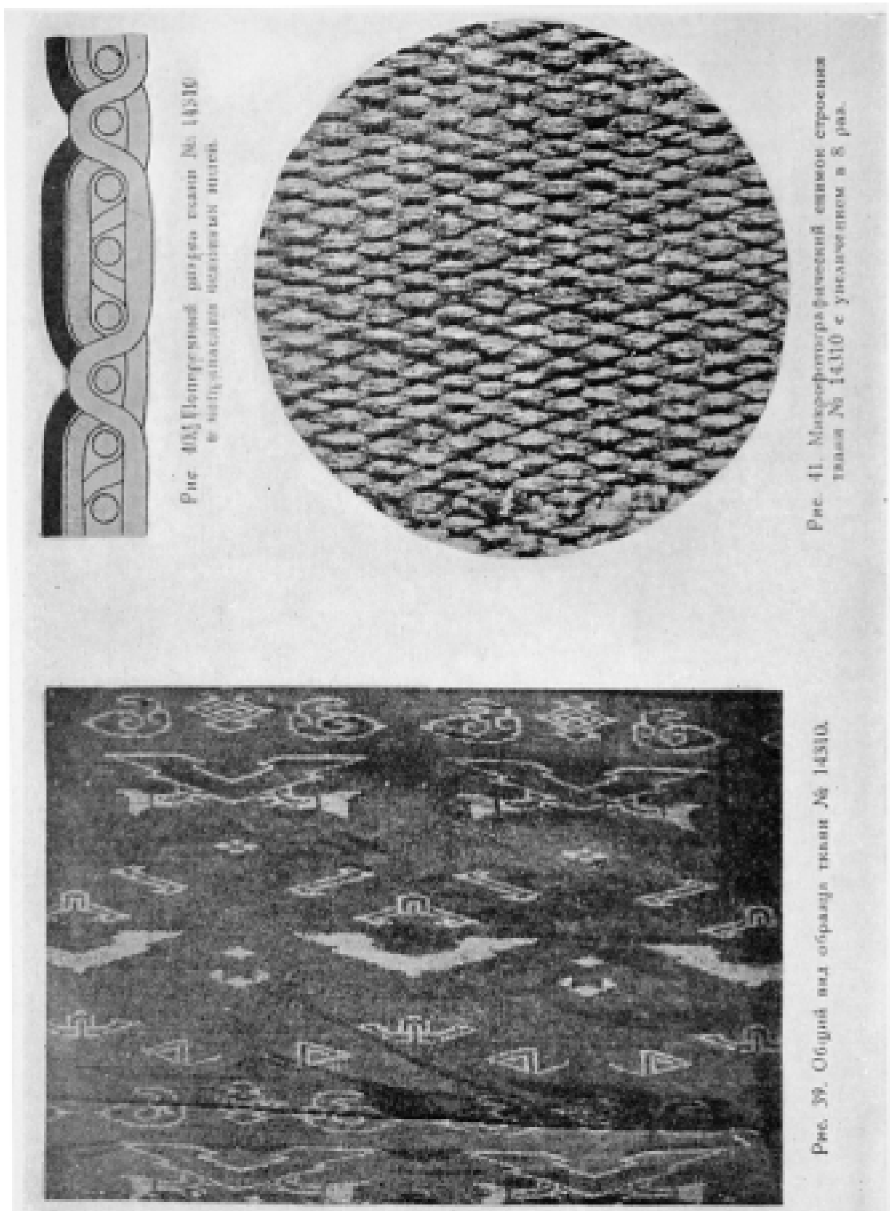

PLATE 5

SILK FABRIC NO. 14310. DIAGRAM OF CROSS-SECTION OF SAME FABRIC, RUNNING VERTICALLY IN THE DIRECTION OF THE WARP THREADS. MICROPHOTOGRAPH OF WEAVE OF SAME FABRIC, ENLARGED 8 TIMES. (REPRODUCED FROM *Izvestia*, FIGS. 39, 40, 41, P. 75.)

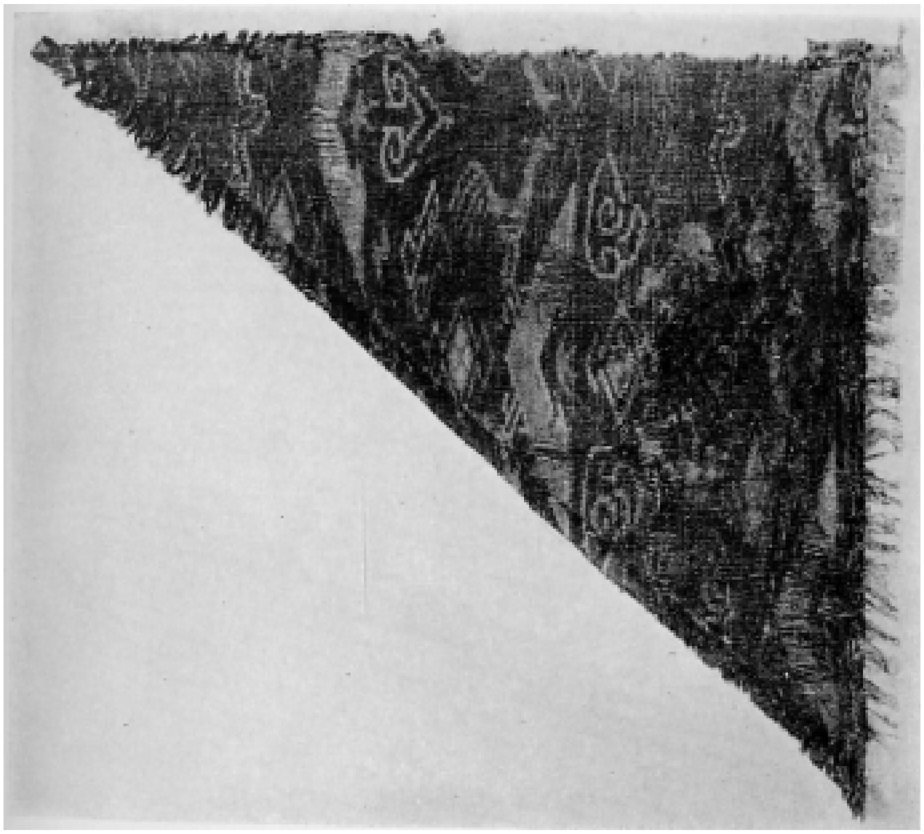

PLATE 6

FRAGMENT SHOWING DESIGN OF WIDE CHEVRONS (OR HALF LOZENGES) SUPPORTING A COCK SURROUNDED BY ANGULAR SCROLLS AND TRIPLE LOZENGES. PLAIN COMPOUND CLOTH WEAVE: SILK. SIZE IN METRES: LENGTH 0.195, WIDTH 0.218. PENNSYLVANIA MUSEUM OF ART ('34-2-1). SIMILAR FABRICS, *Izvestia,* FIGS. 33, 39 (SEE PLS. 4, 5).

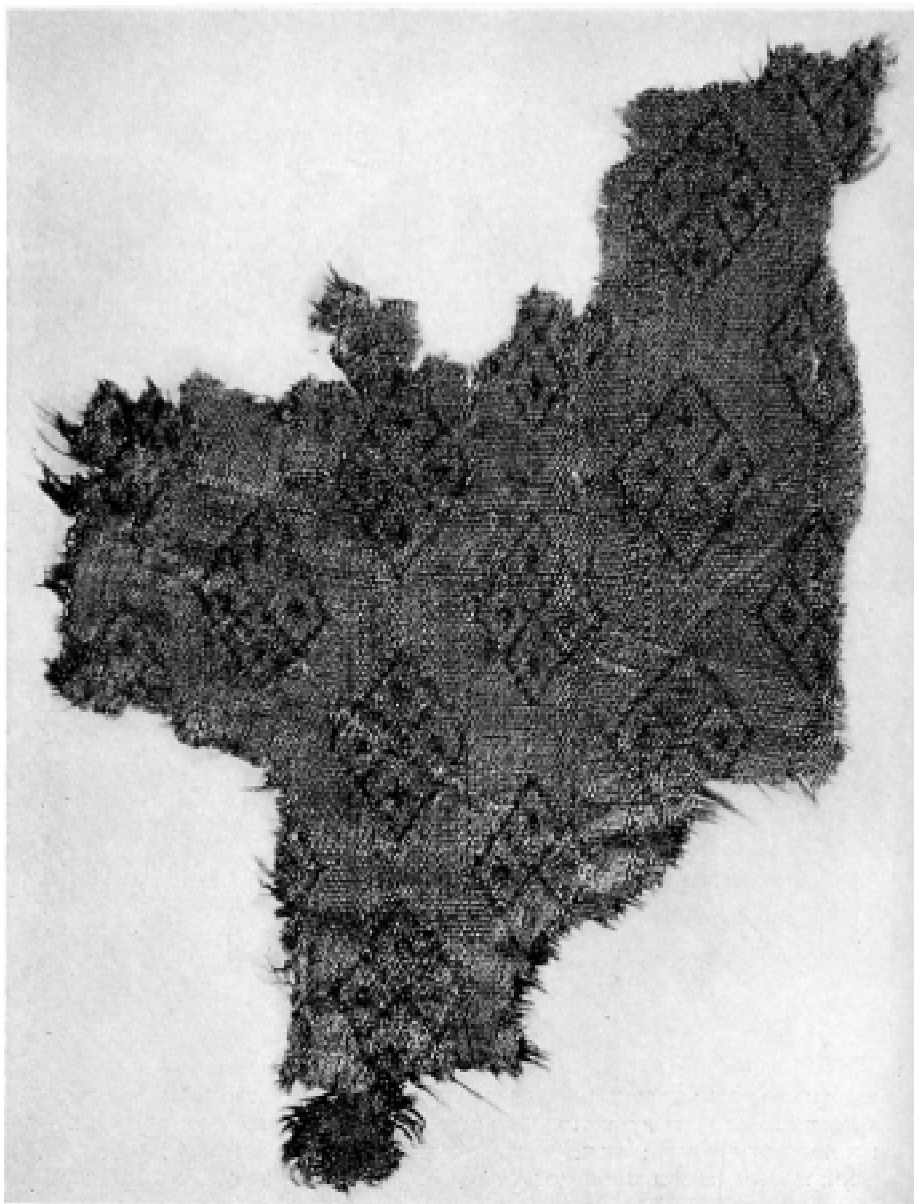

PLATE 7

FRAGMENT WITH DESIGN OF REPEATS OF A LOZENGE WITH FOUR DIAMOND-SHAPED COMPARTMENTS EACH CONTAINING A DOT. PLAIN COMPOUND CLOTH WEAVE: SILK. SIZE IN METRES: LENGTH 0.141, WIDTH (APPROXIMATE) 0.10. PENNSYLVANIA MUSEUM OF ART ('34-2-4). FABRIC OF SAME DESIGN AND WEAVE, *Izvestia,* FIGS. 14, 15.

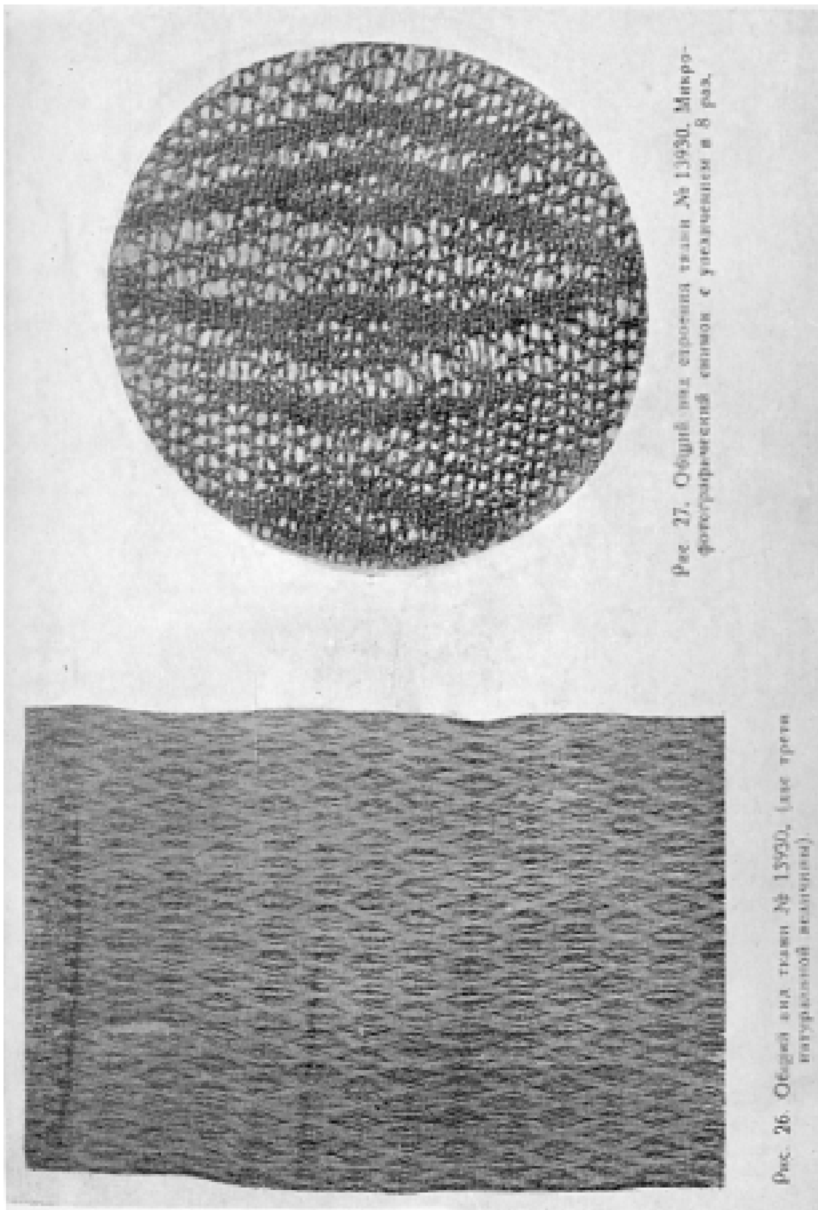

PLATE 8

SILK FABRIC NO. 13930 ($2/3$ NATURAL SIZE). MICROPHOTOGRAPH OF WEAVE OF SAME FABRIC, ENLARGED 8 TIMES. (REPRODUCED FROM *Izvestia*, FIGS. 26, 27).

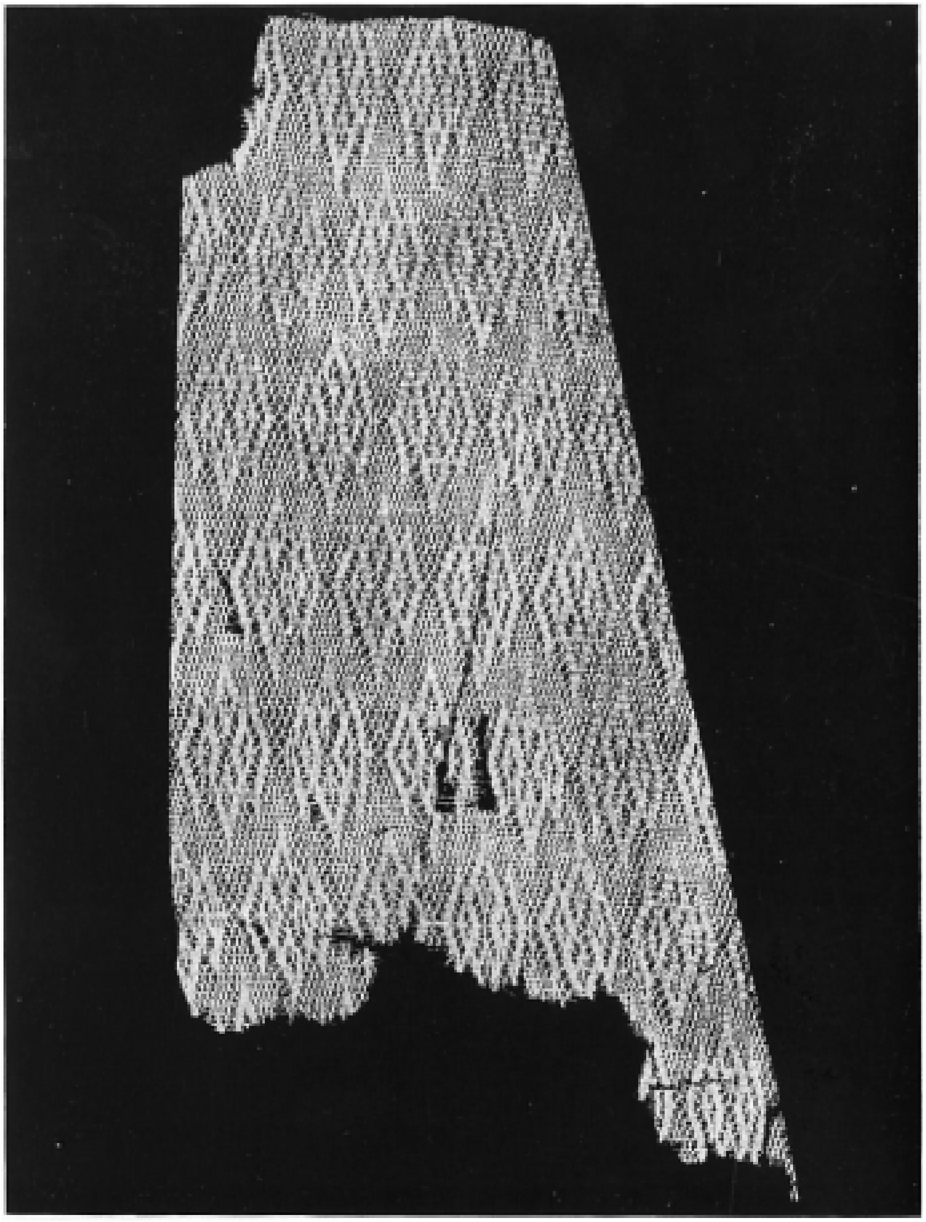

PLATE 9

FRAGMENT WITH DESIGN OF TRIPLE LOZENGES. FANCY GAUZE WEAVE: SILK. SIZE IN METRES: LENGTH 0.08, WIDTH 0.05. PENNSYLVANIA MUSEUM OF ART ('34-2-6). FABRIC OF SAME DESIGN AND WEAVE, *Izvestia,* FIGS. 4, 5, 26, 27 (SEE PL. 8).

C. CHEMICO-TECHNICAL ANALYSIS OF FABRICS

No. 13958a, No. 13958b, No. 14112

C. CHEMICO-TECHNICAL ANALYSIS OF FABRICS No. 13958a, No. 13958b, No. 14112[9]

	Mongolian Textile No. 13958a	*Mongolian Textile No. 13958b*	*Mongolian Textile No. 14112*
Sample of textile.	Not a very large piece, irregular shape (see Fig. 10).[10]	Two identical pieces, irregular shape, not very large (see Fig. 12).[11]	Not a very large piece, irregular shape (see Fig. 14).[12]
Size of sample.	Along the warp—about 10 cm. Along the weft—about 17 cm. Selvage on one side, 13 cm. long. In colour and weave the selvage is the same as the ground of fabric, but is more closely woven in a width of 80 threads from the edge.	Along the warp—about 10 cm. Along the weft—about 16.5 cm. Selvage on one side of both pieces, 12.5 cm. long. In colour and weave the selvage is the same as the ground of the fabric, but it is twice as closely woven in a width of 20 threads from the edge.	28 x 23 cm. No selvage.
Design.	----------	----------	Design of the textile is a combination of lozenges of different sizes, arranged as follows: lozenges upright on their points are scattered in rows on a background of beige color. Each lozenge is composed of four small lozenges, each with a dot, also lozenge-shaped, in its centre. Size of the repeat: Width: 3.4 cm. Length: 3.4 cm.

[9] (Note. It was unfortunately impossible to include here the translation of this complete section of tables, giving the chemico-technical analyses of the silk fabrics from the excavations of P. K. Kozlov. A few pages are appended to show the form and content of the tables, but copies of the translation of this complete section will be sent to subscribers upon application to the Editor. The excerpts appearing here were selected in order to illustrate the tabulated material for at least one of the silk fabrics of which an example may now be found in this country. Thus, a piece of the textile, No. 14112, the chemico-technical analysis of which will be found in the third column of the pages following, is in the Pennsylvania Museum of Art and is illustrated in Pl. 7. E. B. S.)

[10] (Note. In original Russian publication. E. B. S.)

[11] (Note. In original Russian publication. E. B. S.)

[12] (Note. In original Russian publication, and Pl. 7 in this translation. E. B. S.)

Analysis of the Materials in the Fabrics

I. Warp No. 1.	Boiled off silk, dyed beige colour.	Boiled off silk, dyed brick colour.	Boiled off silk, dyed beige colour.

Technical Analysis of Materials in Warp No. 1

1. Nature of the fibre.	A preliminary microscopic study of the fibre, enlarged 500 times, showed many characteristics of silk. Other fibres than silk were also found in the threads. Thus, if it is assumed that the thread is silk, it is necessary to make the most complete and thorough analysis of the nature of the fibre in this yarn.	Same as No. 13958a.	Same.
2. Thickness and evenness of yarn.	A microscopic study of about 10 mm. of 5 single threads, enlarged 60 times, with calculations made on each mm., gave the following results: 1st thread, average, 126 microns. 2d thread, average, 102 microns. 3d thread, average, 164 microns. 4th thread, average, 71 microns. 5th thread, average, 52.5 microns. Therefore: (a) range of average variation: 52.5 to 164 microns. (b) average thickness for 5 tests of the thread: 105.1 microns.	Same test gave the following results: 1st thread, average, 90 microns. 2d thread, average, 96 microns. 3d thread, average, 111 microns. 4th thread, average, 90 microns. 5th thread, average, 95 microns. Therefore: (a) range of average variation: 90 to 111 microns. (b) average thickness for 5 tests of thread: 96 microns.	Same study of 4 single threads gave following results: 1st thread, average, 183 microns. 2d thread, average, 186 microns. 3d thread, average, 195 microns. 4th thread, average, 195 microns. Therefore: (a) range of average variation: 183 to 195 microns. (b) average thickness for 4 tests of thread: 189 microns.

	Mongolian Textile No. 13958a	*Mongolian Textile No. 13958b*	*Mongolian Textile No. 14112*
3. Count of yarn.	It was not possible to ascertain this owing to the small size of the sample.	Same as No. 13958a.	To ascertain the count of yarn, 11 threads were used. Their total weight on the analytical scales was 0.0041 grams. Length of the threads in mm.: 57.5; 63; 64.5; 56.5; 50; 57; 71; 57; 62.5; 60; 61. Total length of measured threads: 660 mm. Metrical number (approximate), 16.0.
4. Preparation of the thread.	A microscopic study shows that the thread of the yarn consists of a ball of cocoon filaments. This ball was made by unwinding many cocoons simultaneously without twisting them when unwinding or during subsequent operations. Examination of the thread on Louis Schopper's untwisting machine showed a complete lack of twist. It is clearly seen on the microphotograph of the warp and weft threads, enlarged 16 times.	The same study also showed a complete lack of twist. It is necessary to note here the exceptional evenness and cohesion of the thread produced by the closeness of the fibres to each other. Thus very few separate fibres can be seen at the end of the thread.	The same study showed a complete lack of twist.
5. Fineness.	88.2 threads in 1 cm.	43.2 threads in 1 cm.	42.5 threads in 1 cm.
6. Tensile strength and elasticity (elongation) of the yarn.	Was ascertained on Louis Schopper's hydraulic dynamometer (yarn strength tester), the grip length of the fibre being 10 mm. Five tests were made. Results: (a) average strength of the thread in grams: 3.7 grams. (b) the elongation at breaking was too small to be photographed.	Was ascertained on the same machine. Five tests of the same kind were made. Results: (a) average strength of the thread in grams: 15.15 grams. (b) the elongation at breaking was too small to be photographed.	Was ascertained on the same machine. Five strength tests were made. Results: (a) average strength of the thread in grams: 28.35 grams. (b) average percentage of elongation at breaking was 4.6%

7. Chemical analyses of the dye.	An analysis of the ashes showed that the textile was dyed with vegetable dye after treatment with an iron mordant.	The red colouring of this fabric was produced by a mineral dye obtained from iron. The dye is not fast and was applied only to the surface of the fabric.	A chemical analysis of the ashes and a study of the dye in this sample show that it was dyed with vegetable dye after treatment with iron mordant.
II. Warp No. 2 (of different colour).	------	------	Boiled off silk, dyed light brown.

Technical Analyses of Material in Warp No. 2 (of different colour)

1. Nature of the fibre.	------	------	A preliminary microscopic study of the fibre, enlarged 500 times showed many characteristics of silk. Other fibres than silk were also found in the threads. Thus, assuming that the thread is silk, it is imperative to make a most complete and thorough analysis of the nature of the fibre in this yarn.
2. Thickness and evenness of yarn.	------	------	A microscopic study of about 10 mm. of 4 single threads, enlarged 60 times (calculations made on each mm.), gave following results: 1st thread, average, 290 microns. 2d thread, average, 210 microns. 3d thread, average, 245 microns. 4th thread, average, 242 microns. Therefore: (a) range of average variation: 210 to 290 microns. (b) average thickness of the thread, as result of 4 tests: 247 microns.

	Mongolian Textile No. 13958a	*Mongolian Textile No. 13958b*	*Mongolian Textile No. 14112*
3. Count of yarn.	------------	------------	To ascertain the count of yarn, 11 threads were used. Their total weight on analytical scales: 0.0046 grams. Length of the threads in mm.: 51.5; 75; 83; 77; 77.5; 74; 55; 74; 75; 76; 77. Total length of 11 measured threads: 792 mm. Approximate metrical number, 172.
4. Preparation of the thread.	------------	------------	A microscopic study shows that the thread of the yarn consists of a ball of cocoon filaments. This ball was made by unwinding simultaneously many cocoons without twisting them when unwinding or during the later operations. Examination of the thread on Louis Schopper's unwinding machine showed a complete lack of twist, although in 4 tests there were two cases where the angular path of the thread made a half turn. This does not at all prove that a twist was given to the thread as it could be accidental as a result of purely mechanical factors.
5. Tensilestrength and elasticity (elongation) of the yarn.	------------	------------	Ascertained on Louis Schopper's yarn strength tester (dynamometer). The grip length of the fibre being 10 mm. Five tests were made; results: (a) average strength of the thread in grams: 24.25 grams. (b) average percentage of elongation at breaking—4%.

6. Chemical analyses of the dye.	A study of the dye used in this sample and a chemical analysis of its ashes show that the fabric was dyed with a vegetable dye after treatment with an iron mordant.
7. Fineness.	42.5 threads in 1 cm.
III. Warp No. 3 (on the wrong side).	Boiled off silk dyed beige colour.

Technical Analysis of the Material in Warp No. 3

1. Nature of the fibre.	The fibre looks very much like silk, as in warp No. 2, but the thread also contains fibres which cannot be classed as silk.
2. Technique (thickness) and evenness of yarn.	A microscopic study of about 4 mm. of 4 single threads, enlarged 60 times (with calculations made on each mm.) gave following results: 1st thread, average, 213 microns. 2d thread, average, 192 microns. 3d thread, average, 179 microns. 4th thread, average, 197 microns. Therefore: (a) range of average variation: 179 to 213 microns. (b) average thickness for 4 tests of the thread: 195 microns.

	Mongolian Textile No. 13958a	*Mongolian Textile No. 13958b*	*Mongolian Textile No. 14112*
3. Count of yarn.	----------	----------	To ascertain the count of yarn, 9 threads were taken. Their total weight on the analytical scales: 0.0027 grams. Length of the threads in mm.: 39; 28.5; 39; 42; 71; 59.5; 66.5; 75; 46.5. Total length of the measured threads: 467 mm. Metrical number (in round figures): 173.0.
4. Preparation of the thread.	----------	----------	The lack of twist, as in warp No. 2, was proved by testing the thread on Louis Schopper's untwisting machine.
5. Tensilestrength and elasticity (elongation) of the yarn.	----------	----------	Was ascertained on Louis Schopper's yarn strength tester (hydraulic dynamometer); the grip length was 10 mm. Five tests were made. Results: (a) average strength of the thread in grams: 18.85 grams. (b) average percentage of elongation at breaking: 3.2%.
6. Fineness.	----------	----------	42.5 threads in 1 cm.
IV. Weft.	Boiled off silk, dyed beige colour.	Boiled off silk, dyed brick colour.	Boiled off silk, dyed beige colour. Woven with double thread, *i.e.*, with two threads unwound together from one bobbin.

Technical Analyses of the Material in the Weft

1. Nature of the fibre.	A preliminary microscopic study of the nature of the fibre in the weft yarn shows that it is identical with the material in the warp (see above). Thus, it is necessary to make a thorough analysis of this fibre, which for the time being is called silk.	Same as No. 13958a.	Same.
2. Thickness and evenness of yarn.	A microscopic study of about 10 mm. of 5 single threads enlarged 60 times (calculations made on each mm.), gave following results: 1st thread, average, 175 microns. 2d thread, average, 216 microns. 3d thread, average, 209 microns. 4th thread, average, 219 microns. 5th thread, average, 240 microns. Therefore: (a) range of average variation: 173 to 240 microns. (b) average thickness of the thread in 5 tests: 211 microns.	Identical study, in same conditions, gave following results: 1st thread, average, 105 microns. 2d thread, average, 119 microns. 3d thread, average, 135 microns. 4th thread, average, 126 microns. 5th thread, average, 122 microns. Therefore: (a) range of average variation: 105 to 135 microns. (b) average thickness of the thread in 5 tests: 121 microns.	Identical study, in same conditions, gave following results: 1st thread, average, 308 microns. 2d thread, average, 188 microns. 3d thread, average, 299 microns. 4th thread, average, 207 microns. Therefore: (a) range of average variation: 188 to 308 microns. (b) average thickness of the thread in 4 tests: 251 microns.
3. Count of yarn.	It was not possible to ascertain this owing to the small size of the sample.	Same as No. 13958a.	To ascertain the count of yarn 10 threads were taken. Their total weight on the analytical scales was 0.0034 grams. Length of the threads in mm.: 44; 44; 42; 43; 46; 43; 51; 50; 43; 44. Total length of the measured threads: 450 mm. Approximate metrical number: 132.0.

	Mongolian Textile No. 13958a	*Mongolian Textile No. 13958b*	*Mongolian Textile No. 14112*
4. Preparation of the thread.	A microscopic study shows that the thread of the yarn consists of a tuft of cocoon filaments. This tuft was made by unwinding many cocoons simultaneously without twisting them when unwinding or during later operations. The cohesion of thread here is produced by the closeness of the fibres to each other. Thus, very few separate fibres can be seen at the end of the thread. The lack of twist was confirmed by testing the thread on Louis Schopper's untwisting machine.	----------	The lack of twist has been proved in this case. It should be noticed, however, that the two threads of the weft are twisted together. But this twisting has nothing to do with the preparation of the weft thread itself; it is merely a treatment of the weft before it becomes part of the fabric. This can be done either before weaving, by winding the bobbin from 2 spools of yarn, or else during the process of the weaving, by putting two bobbins together into the shuttle, so that two weft threads are thus unwound from the shuttle at the same time.
5. Tensilestrength and elasticity (elongation) of the yarn.	Ascertained on Louis Schopper's yarn strength tester (hydraulic dynamometer), the grip length of the fibre being 10 mm. Five tests were made. Results: (a) average strength of the thread in grams: 30.8 grams. (b) elongation of the yarn at breaking was too small to be noted.	Ascertained under the same conditions. Six tests were made. Results: (a) average strength of the thread in grams: 4.5 grams. (b) the elongation of the yarn at breaking was too small to be noted.	Ascertained under the same conditions. Five tests were made with a full length weft yarn, *i.e.*, having both ends of it. Results: (a) average strength of the weft yarn in grams: 41.2 grams. (b) average percentage of elongation at breaking: 2.6%.

6. Chemical analysis of the dye.	The dye of the weft is the same as the dye of the warp (see above).	The dye of the weft is the same as that of the warp, because the dye was evidently applied to the fabric after weaving (see above).	The dye of the weft is apparently the same as the dye of the warp and can be distinguished only by its shade.
			It was impossible to obtain exact data because the sample was too small.
7. Fineness.	41 threads in 1 cm.	Fineness varies: 36.2; 34.7; 33.0; 45.6 threads. Average, 57.4 threads in 1 cm.	28.3 threads in 1 cm.

Technical Characteristics of the Sample

1. Count of threads.	In 1 square meter:	In 1 square meter:	In 1 square meter:
	Warp: 8,820 threads of boiled off, dyed silk.	Warp: 4,320 threads of boiled off, dyed silk.	1st warp: beige colour. Boiled off, dyed silk, 4,250 threads.
	Weft. 4,100 threads of boiled off, dyed silk.	Weft: 3,740 threads of boiled off, dyed silk.	2d warp: light brown, 4,250 threads. Boiled off, dyed silk.
			3d warp: beige colour, 4,250 threads. Boiled off, dyed silk.
	In 1 square meter:		Average fineness of warp threads: 12,750 threads in 1 meter.
			Weft: 2,830 threads in 1 meter. Boiled off silk, dyed beige colour.

	Mongolian Textile No. 13958a	Mongolian Textile No. 13958b	Mongolian Textile No. 14112
2. Weave.	The fabric is made with a single warp and single weft, making a plain (linen) weave. Thus, the right and the wrong sides are exactly alike (see Fig. 11).[13]	Same as No. 13958a. (See Fig. 13.)[14]	The fabric is made with three warps and one weft; the right side of the material has its own warp, and the wrong side of the material has its own warp; warp No. 1 is used for the right side, and warp No. 3 for the wrong side (see Fig. 14).[15] In the patterned areas, the different colour of Warp No. 2 can be seen on the right side, in place of warp No. 1. Warp No. 1 is then carried through to the wrong side where it appears woven with warp No. 3. Thus, the whole design is obtained by using light or dark coloured warps on the right side of the material, and this change of colours does not alter in the least the structure of the weave. Usually two warps appear on the wrong side of the material. One of these is warp No. 3, which is always on the wrong side. The other is sometimes warp No. 1 and sometimes warp No. 2, which is carried through to the wrong side when not in use on the right side. As to the weave, it cannot be classified with any of the standard weaves. It is a weave derived from plain or linen weave.

[13] (Note. In original Russian publication. E. B. S.)

[14] (Note. In original Russian publication. E. B. S.)

[15] (Note. In original Russian publication, and Pl. 7 in this translation. E. B. S.)

3. Condition of the sample.	The condition of the sample is rather good, especially considering the light weight of the material (a kind of silk "foulard"). The colour and the lustre of the fabric are especially well preserved: the lustre is typical for this kind of silk fabric. As to the strength of the thread, it is below normal, especially the warp. This also is usual in fabrics of the foulard type. The surface of the fabric has a moire effect, possibly the result of pressing with a hot and heavy object.	The sample is in a fairly good condition, especially considering the light weight of the material (a kind of *mousseline de soie*). The brick coloured dye is not fast, and is peeling off like light dust.	The condition of the sample is good, its lustre is well preserved. The texture of the fabric is excellent to the touch (the "touch" being a combination of fineness, closeness, softness, elasticity, etc.) Its lustre, however, is somewhat more pronounced than it should be in a silk fabric of this kind. This may be the result of too much pressing with a hot object which gave a moire effect to the material. The loss of strength in the thread has been considerable, and it is different in each material,[16] as shown by the figures above. This can be explained by the construction of the fabric and by the arrangement of the threads in each kind of material.[16] In the upper part of the piece there are several small holes which are not due to weakness of the thread in these worn places but which are the result of some outside damage. This was inevitable considering the conditions under which the fabric was buried, and the length of time it was in the mount.

[16] (Note. "Material" probably means the three warps and the weft. N. A. R.)

PLATE 10

PHOTOGRAPH FROM A DRAWING OF THE LARGE CARPET NO. 14568.
(REPRODUCED FROM *Izvestia*, FIG. 42, P. 77.)

I. *Field:* Spiral pattern made by applied cord on a wool background of tapestry weave, which is foundation material of whole rug.

II. *Main Border:* Animal motives arranged in pairs, applied, made of felt, and decorated with stitching. Background decorated with rhomboidal figures in running stitch.

III. *Inner Border:* Alternating motives of a cross, a square, and a shield, made of felt, applied, and decorated with stitching.

IV. *Outer Border:* Made of silk fabric of same construction as other silk fabrics, already described.

D. CHEMICAL AND TECHNICAL ANALYSIS OF THE LARGE CARPET (No. 14568)

IN THIS part are given the results of the work of the Institute of Archæological Technology in its study of a most remarkable example of the textile industry. This study is not final, because at present some questions cannot be answered definitely. The only way to answer them is to continue the same kind of study with similar material from the same mounds. Besides, we should not forget that it is necessary to perfect the methods of the work while studying the object.

Fortunately, a comparatively large quantity of experimental material made it possible, in this case, to perform some very important tests; there were found, together with the rug, several small pieces of the fabric which could not be replaced anywhere when restoring the rug, and which had no number, but were undoubtedly of an identical nature. These pieces could be used, without any harm, as material for the study of the fabric.

Of course, all these pieces put together were no more than a few square centimeters, but even this small quantity of experimental material was a very lucky find.

The large carpet, no. 14568 (Pl. 10), belongs to the group of textiles described in the section entitled "Technical Methods Used in the Study of this Archæological Material" (p. 3),[17] as the type of object made from different kinds of textile material. The silk outer border of the rug was not subjected to any special analysis, because it is of the same construction as the group of silk fabrics, but we give a micro-photograph of a cross-section of this additional silk fabric from the rug,[18] and this micro-photograph confirms the complete identity of structure.

All other parts of the rug have been subjected to a minute analysis. Besides, the technique of the embroidery stitches has also been studied, and this proved to be important for further conclusions as to the origin of the object.

[17] (Note. Pp. 1-10 in the original book. E. B. S.)
[18] (Note. Fig. 43 in the original book. This illustration could not be photostated for reproduction in this translation. E. B. S.)

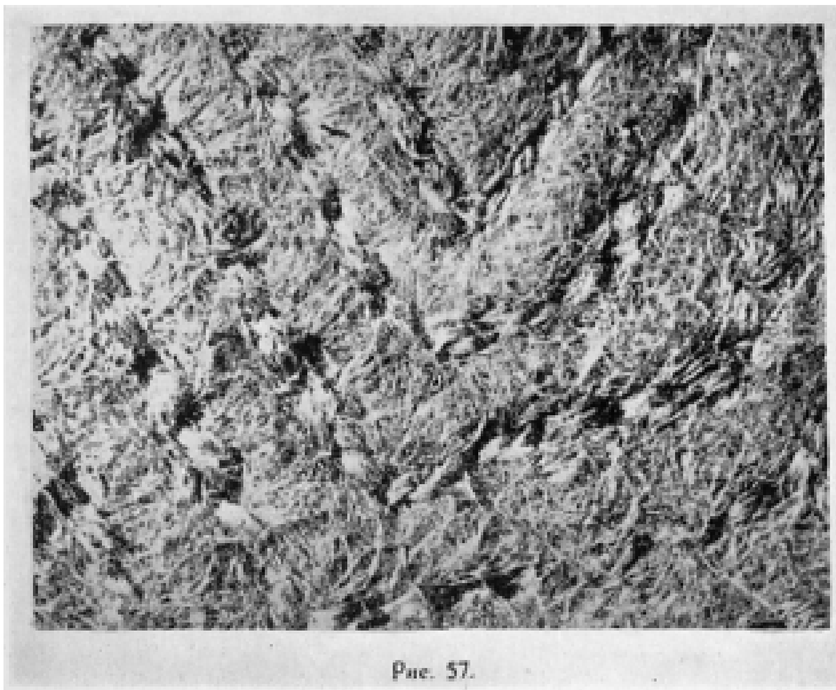

PLATE II
PART OF RUG SHOWING STITCHING. (REPRODUCED FROM *Izvestia,* FIG. 57, P. 95.)

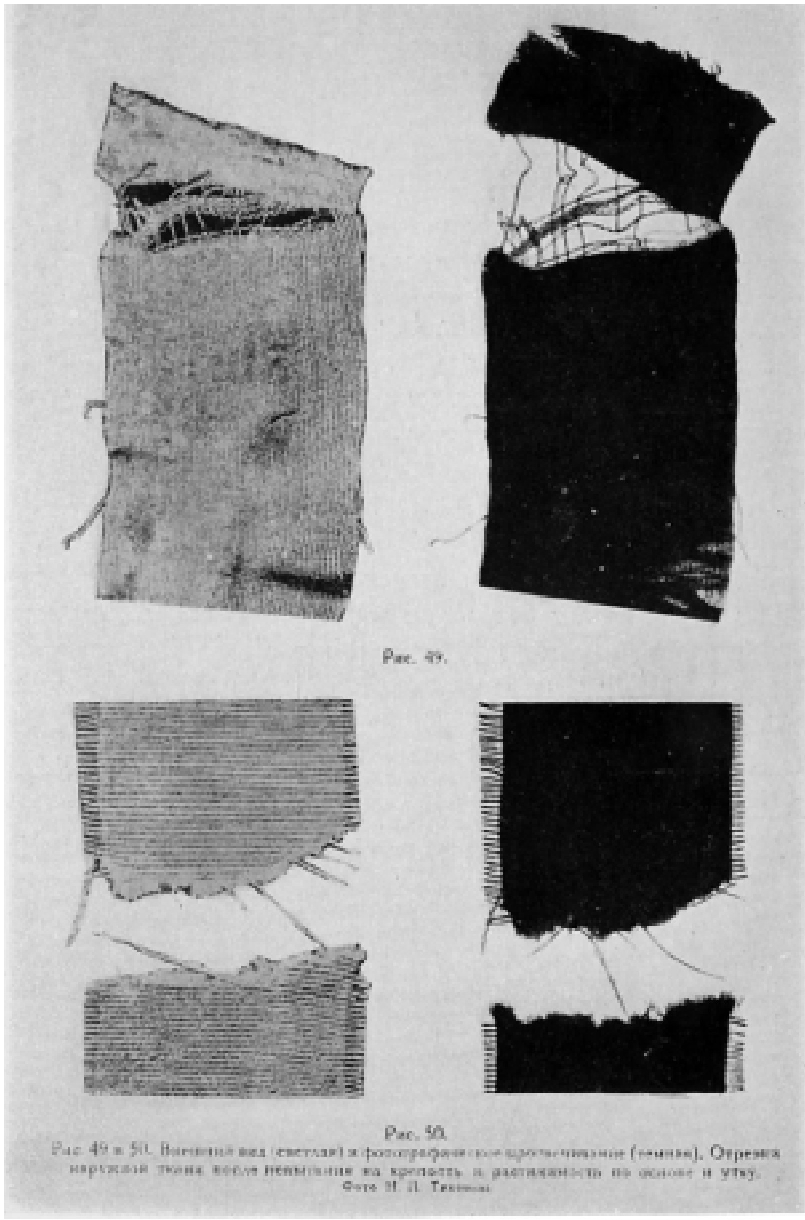

PLATE 12

TWO FRAGMENTS FROM THE MAIN BORDER OF THE CARPET (LIGHT), WITH PHOTOGRAPH (DARK) TAKEN BY TRANSMITTED LIGHT. THESE PHOTOGRAPHS WERE TAKEN AFTER STRENGTH AND ELASTICITY TESTS OF WARP AND WEFT HAD BEEN MADE. (REPRODUCED FROM *Izvestia*, FIGS. 49, 50, P. 84.)

All the work of technical analysis was done by the Institute in the Textile Merchandise Laboratory of the Cooperative High School in Leningrad, which is equipped with excellent instruments of the type necessary for this kind of work. The analysis was made by scientists of the State Academy for the History of Material Culture. The special histological study of the materials of this rug was conducted in the histological laboratory of the State Institute of Experimental Agronomy, using for comparison material that was provided by the Zoological Museum of the Academy of Science and the State Zoological Garden in Leningrad. The analysis of the embroidery stitches was made in the Leningrad Technical School of Peasant Industry. The spectral analysis of the red dye was made in the Technological Laboratory of the State Academy for the History of Material Culture.

Chemical and Micro-chemical Study of the Materials

The following were studied: woolen felt lining, materials composing the field and the border (warp and weft threads analyzed separately), red cord in embroidery of field of rug, thin cord of animal motives, thick cord of inner border, threads used for sewing the motives, and thin felt composing the motives.

The results of the study were the same for all the parts mentioned above, that is:

1. When burned, they produce smoke with a smell characteristic of wool.

2. When dissolved in alkali, they form a precipitate of a mineral character. Most of this precipitate can be dissolved in nitric and muriatic acids; it contains iron compounds and some traces of aluminum. The indissoluble part is probably silica.

The alkaline solution of the fibre obtained by nitro-prussic natrium has a purple shade.

3. A solution of zinc chloride does not dissolve the fibres.

4. After the fibres have been heated and washed, treated with rose aniline solution and bleached with ammonia, they turn pink.

5. The reaction with Schweizer's solution is typical of wool.

All these facts enable us to reach the conclusion that the fabric was made of pure wool.

Microscopical Study of Materials

The following were examined: woolen felt lining, materials composing the field and the border (warp and weft threads studied separately), red cord in embroidery of field of the rug, thick cord of the animal motives, thick cord of inner border, and threads used for sewing the motives.

A microscopic study of the nature of the fibre of all the samples mentioned above reveals the presence of woolen fibres only, with a characteristic scaly surface which distinguishes them from wood fibre or silk fibre. With the exception of woolen felt, all the samples are composed mainly of a great number of woolly hairs; bristly hairs with a cerebral cylinder are found occasionally. The hair was not plucked from the animal's hide, but it was sheared, because it has no root.

The thickness of the woolly hair is 10 to 50 microns.

The average thickness of bristly hair is 90 microns.

The thickness of the hair in the woolen felt is sometimes as much as 420 microns.

The attempts to determine the kind of animal whose wool was used as material for the rug are described in the chapter containing the histological study of the material.

Histological Study

The following pieces were studied histologically: fragments of blackish lining preserved in places under the applied motives, compact black threads used for stitching together the separate parts of the rug (such as applied motives, the cord, etc.), and the wool which is the foundation material of the whole rug.

Study of the Lining Under the Motives

The lining consists of thin dark sections, very damaged, with an uneven surface that is much dried up and out of shape. Part of this lining had disappeared, and could not be found under the many pieces of appliqué. A cross-section of the lining shows clearly and without any doubt the construction of hide (a fibrous structure, with a spongy surface on which traces of roots of hair still can be seen, etc.). The material was evidently subjected to some treatment which shows under the microscope. It was not possible to ascertain the exact character and purpose of this treatment.

Study of the Black Threads

The thread consists of several fibres, black on the outside and lighter in the cross-section; these fibres swell in water in a light solution of acetic acid, which is very typical for sinews. This material, treated with acetic acid, shows under the microscope a series of swollen fibres of animal tissue.[19] A cross-section of the threads shows the density, the similarity, and the uniformity so characteristic for sinews.

The exterior black colouring can be partly attributed to the charing process to which the fibre, or the substance with which it was permeated, was subjected while buried in the earth.

Therefore: these threads are sinews, a very strong material for sewing.

Study of the Felt and of the Woolen Threads

For this study the samples were used that had been least damaged by chemical processes in the earth. Still, it would not be safe to rely entirely on this material, because the degree of the damage could not be established, and it was not possible to reconstruct the process of deterioration with new material, because no method has been worked out for such an experiment. Thus, at the very beginning, there was a serious handicap in the process of the study. To identify the nature of the hair, we used archæological and contemporary samples, and the most similar ones were studied under the microscope, and in the case of identity they were checked by careful comparison. This examination gave an idea of the degree of damage due to drying up, chemical reactions, and physical influences (the pressure of the earth, etc.).

To determine the kind of animal whose hair was used as material for making the woolen felt, textiles, cords, and woolen threads, we took samples of camel's hair, of the wool of different kinds of domestic and wild sheep, goats, and buffaloes. Although a great amount of material was analyzed, it was not possible to come to any definite conclusion. This can be explained partly by the damaged condition of the samples, and partly by the fact that the hair was sheared, and that there were therefore no roots, which would have been of great help in ascertaining the kind of animal.

As a result of the examination, the only possible conclusion seems at first sight quite contradictory: the material used in the rug is very similar to the wool of the sheep of the Sudan, acclimatized in Ascania Nova.

[19] (Note. Fig. 45 in the original book. This illustration could not be photostated for reproduction in this translation. E. B. S.)

This, of course, could be explained in several ways: the animal whose excellent wool was used to make the rug could have come from Africa and been acclimated in China:[20] or wool from African sheep might have been brought to China from Alexandria; but there might also be a quite different explanation: there could have been in China, 2,000 years ago, a variety of sheep, now extinct, which had exactly this kind of wool; there could even have existed somewhere in Mongolia wild sheep whose wool made them the object of intense hunting, and this led to their complete extermination during the period of 2,000 years.

Analysis of the Fabric

The Weave

A superficial examination of the fabrics used as background for the border and the field shows a rep-weave in which the ribbing is vertical. When studying the weave under a magnifying glass we see that the warp and the weft go over one thread exactly as in modern linen and woolen cloth, forming so-called linen or *gros de Naples* weave (Pl. 13).

Nevertheless, the fabric has this characteristic: probably two wefts were used for its manufacture, and the fabric was made in such a way that one weft was laid upon another and, when interwoven with the warp, it forms a figure eight. In this way were manufactured some hand-made velvet fabrics, using one weft for making the fabric, and the other, to be cut, for making the pile.[21]

Density of the Fabric

Border Fabric—The density of the fabric, *i.e.*, the count of yarn of the warp is different from that of the weft.

Count of warp yarn: in 1 cm.—11 threads; in 1 meter—1,100 threads.

Count of weft yarn: in 1 cm.—91 threads; in 1 meter—9,100 threads.

Field Fabric—This fabric is less dense.

Count of warp yarn: in 1 cm.— 8 threads; in 1 meter— 800 threads.

[20] It is known that China, in the Han period, from 206 B.C. to 201 A.D., had very active relations with Syria and Alexandria, and therefore acquired a variety of technical knowledge, *i.e.*, glass-manufacture, which was later forgotten and revived under the T'ang dynasty (618-906). (E. Zimmermann, *Chinesisches Porzellan*, I, 20-22.) Thus, it would not be impossible to admit the export of a high quality of wool from Egypt at that time.

[21] (Note. The fabric is of ordinary tapestry weave, although without any pattern. It has not two wefts but only one, which is so woven that it hides the warp threads. The weave is in no way related to velvet. N. A. R.)

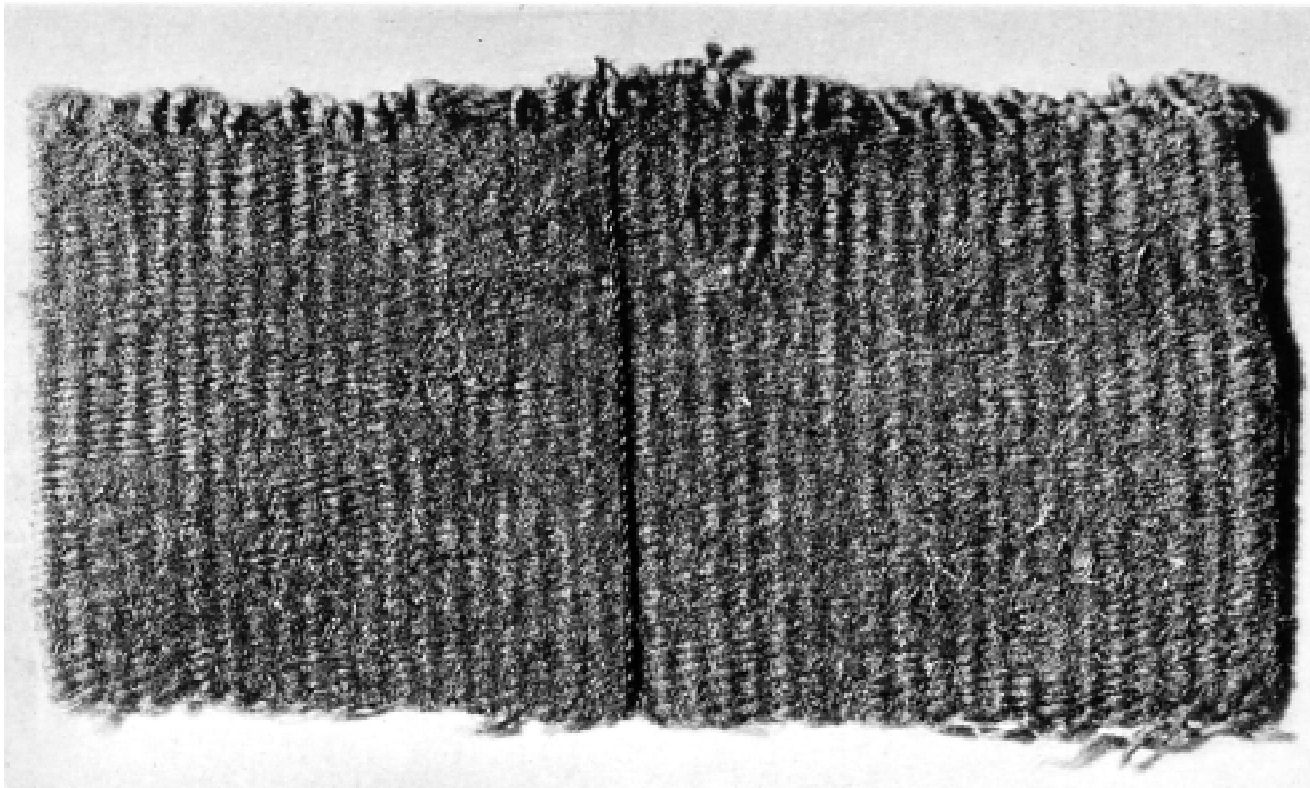

PLATE 13

FRAGMENT FROM BORDERS OF THE CARPET NO. 14568. TAPESTRY WEAVE: WOOL. SIZE IN METRES: LENGTH 0.26, WIDTH 0.05. PENNSYLVANIA MUSEUM OF ART ('34-2-11B). SAME FABRIC, *Izvestia*, FIGS. 49, 50 (SEE PLATE 12).

Count of weft yarn: in 1 cm.—28 threads; in 1 meter—2,800 threads.

These figures were obtained after five counts in different sections of the fabric.

Tensile Strength and Elasticity (Elongation) of the Fabric

Border Fabric—To ascertain the breaking strength and the elongation of the fabric on Louis Schopper's yarn strength tester (dynamometer) two strips of fabric were used—one running in the direction of the warp, and the other of the weft; the breaking of these strips gave the following results:

The warp strip, 10 cm. long and 5 cm. wide—48 threads

Breaking weight, kg.	*Elongation, mm.*
5	0.2% 1
10	1% 2
15	5.2% 17
17.4	12% 36

The breaking occurred with a weight of 17.4 kg. and the elongation 12%—36 mm. The breaking resistance of a single thread in the fabric—362.5 grams.

The weft strip, 10 cm. long and 5 cm. wide—755 threads

Breaking weight, kg.	*Elongation, mm.*
10	1.4% 4
20	2.2% 6
30	2.6% 7
40	3% 9
50	3.2% 10
60	3.8% 11
70	4.8% 12
80	5.2% 15.5
86	6.8% 20

In appearance, this weft strip is a sample of a wonderfully preserved fabric which shows an amazing breaking resistance at 86 kg. of weight, with a comparatively small elongation—6.8%—20 mm. (Pl. 12).

Breaking resistance of a single thread in the fabric—189 grams.

The curve [22] shows a considerable elongation in the warp and a very gradual one in the weft. This gradual elongation of the weft can be explained by the peculiarity of the construction of the fabric mentioned above. (Cf. note 21, p. 45.)

[22] (Note. This may refer to the diagram, Pl. 14. E. B. S.)

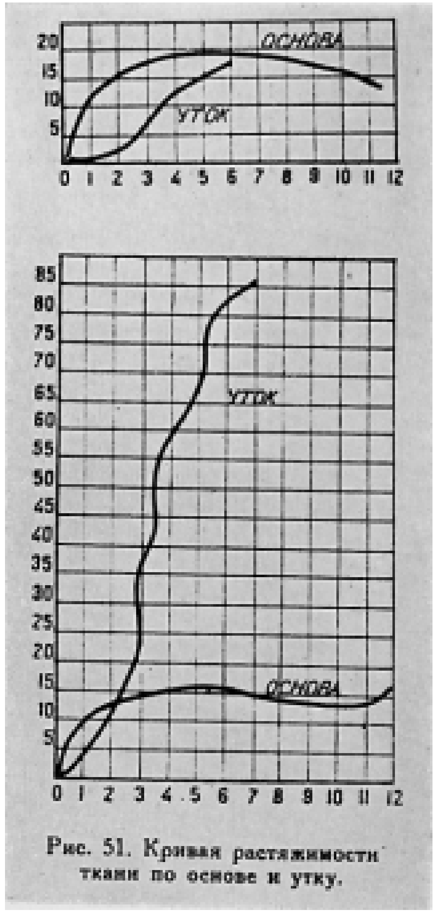

PLATE 14

DIAGRAM SHOWING CURVE OF THE ELASTICITY OF THE FABRIC IN THE DIRECTION OF THE WARP (*Ochoba*) AND WEFT (*Ytok*). (REPRODUCED FROM *Izvestia,* FIG. 51, P. 85.)

Field Fabric—To ascertain the breaking strength of the fabric used for the field two samples also were taken, one running in the direction of the warp, and the other of the weft.

The warp strip, 10 cm. long and 3 cm. wide—24 threads		The weft strip, 10 cm. long and 3 cm. wide—86 threads	
Breaking weight, kg.	*Elongation, mm.*	*Breaking weight, kg.*	*Elongation, mm.*
5	0.2%	5	2.6%
	0.5		8
10	0.6%	10	3.6%
	1.5		11
15.4	10.6%	16.75	6%
	31.5		18

The breaking occurred with a weight of 15.4 kg. and the elongation 10.6%—31.5 mm.
The breaking resistance of a single thread in the fabric—642 grams.

The breaking occurred with a weight of 16.75 kg. and the elongation 6%—18 mm.
The breaking resistance of a single thread in the fabric—194 grams.

Comparing the breaking strength of one single thread in the warp and the weft of the border fabric with the strength of the same threads in the field fabric we find that the border one is stronger.

Calculation of the Wearing Capacity of the Field Fabric

The calculation of the wear of the fabric was made with the wear tester of Prof. Herzog and Geiger, of the firm Louis Schopper, in Leipzig.

A weight of 1.5 kg. was put on the grooved frictioning surface of the apparatus; under the frictioning surface there was a table covered with the fabric, which was put in motion, making 10,000 turns; before starting the process of friction, and after 10,000 turns, the sample was weighed, and the loss of weight due to friction was calculated in per cents.

Four friction tests were made with the following results: at the first friction the fabric did not show any visible change, except that the surface nap was slightly rubbed off. The loss of weight from friction was 2.22%.

After the second test the fabric was slightly damaged in some places and at the edges, but the connection of the warp and weft threads was not disturbed, only these threads were not now so close to each other. The center of the fabric was not disturbed. Loss of weight from friction—2.08%.

After the third test the fabric was rubbed through at three places in the weft, but the warp stayed intact; a little hole was visible in the center of the sample subjected to the test. Loss of weight from friction —2.73%.

The fourth test was completed after 6,500 turns. Loss of weight from friction—4.2%. The result of the friction was a hole nearly the whole length and width of ⅙ of the frictioning surface.

Thus, the wearing capacity of the fabric was completely established after 36,500 turns of the table under the friction surface, and the fabric lost from friction a total of 11.23% in weight.

Analysis of the Yarn [23] of the Fabric

Warp of the Border Fabric—The warp and weft threads were taken for this test. The following were studied: the twist of every sample of the yarn, thickness in metrical numbers, tensible strength, and elongation.

Twist of the Yarn—The twist was ascertained, on Louis Schopper's twist testing machine, by unwinding a sample one inch long.

The yarn of the warp is formed by two twisted threads [24]; the average twist of the thread, 17.5 turns, was ascertained after 6 tests (18; 22; 11.5; 20); the direction of the twist is to the right.[25] The twist of one single thread of the yarn, being a part of the twisted thread, is on the average 5.1, and was ascertained after 6 tests (1.9; 2; 2.5; 6; 10); the turn of twist is to the left.

This difference of twist is generally used in twisted yarn. In this way the yarn, twisted in opposite directions, usually is very strong and solid, and does not untwist.

The average twist of the weft yarn, although not conspicuous, is 6.4 (7; 7; 5; 9; 7; 6; 6; 4; 4; 7; 5; 6; 5).

Count of the Yarn—The count of the yarn—its thickness—was ascertained on Staube universal scales, especially used for determining the count of yarn.

The metrical number of the warp yarn, two threads twisted together, is 10, and of the single thread, composing the twisted thread, 20. Metrical number of the weft yarn—17.

Tensile Strength and Elasticity (Elongation) of the Yarn—The strength and the elasticity of the yarn were ascertained on Louis Schopper's yarn strength tester (dynamometer), made especially for determin-

[23] (Note. See note 6, p. 11. E. B. S.)

[24] (Note. Fig. 56 in the original book. This illustration could not be photostated for reproduction in this translation. E. B. S.)

[25] (Note. That is, from upper left to lower right. N. A. R.)

ing the breaking resistance of a single thread; the tensility was regulated by a pneumatic compressor.

The threads used for the test were 20 cm. long; their average strength was ascertained as follows:

Warp Threads: strength, 443.75 grams; elasticity, 8.65%—17.25 mm.; four tests were made, with the following results:

Strength:	390	grams	Elasticity:	7%	14 mm.
"	425	"	"	7.5%	15 "
"	480	"	"	10%	20 "
"	480	"	"	10%	20 "

Weft Threads: strength, 77 grams, elasticity, 8.2%—16.6 mm.; five tests were made, with the following results:

Strength:	25	grams	Elasticity:	10%	20 mm.
"	42	"	"	5%	10 "
"	42	"	"	7.5%	15 "
"	119	"	"	11.5%	23.5 "
"	158	"	"	7.5%	15 "

The strength of the warp yarn in reality proved to be greater than the strength of the fabric, worked out theoretically (see Calculation of the strength of the border fabric, p. 47). To ascertain the strength of the warp yarn, the threads were taken from another sample, better preserved than the fabric that had already been subjected to treatment.

The strength of the weft yarn proved to be less than the strength of the fabric. In breaking, the weft thread was easily torn owing to its slight twist.

Twist of the Yarn. Warp of the Field Fabric—The warp thread, as in the border fabric, is of two threads twisted together. The twist of this thread is equivalent to 10.3 turns, and was ascertained after 6 tests (11; 10; 9; 9; 11; 12); the turn of the twist is to the right. The twist of one single thread of the yarn that composes the twisted thread is 4, and was ascertained after 5 tests (2; 3; 5; 5; 4; 5; 5); the turn of the twist is to the left.

The twist of the weft yarn in the field fabric proved to be considerably less than the twist of the weft in the border fabric. It was ascertained after five tests (1; 1; 1; 3; 3; 5); an average of 2 turns was the result.

Count of Yarn—The metrical number of the twisted warp yarn is 13, and the number of a single thread, composing the twisted thread, is 25. The metrical number of the weft yarn is 10.

Tensile Strength and Elasticity (Elongation) of the Yarn—The average strength of the warp threads is 566.4 grams, with the elasticity reaching 6.5%—13 mm.; 7 tests were made giving following results:

Strength:	675	grams	Elasticity:	6.5%	13	mm.
"	735	"	"	10%	20	"
"	270	"	"	4%	8	"
"	370	"	"	5%	10	"
"	700	"	"	7.5%	15	"
"	465	"	"	5%	10	"
"	750	"	"	7%	14	"

The average strength, as can be seen from the data shown above, should be somewhat higher; evidently, the threads with a strength of 270 and 370 were considerably damaged, and thus reduced the average strength.

It was not possible to determine the tensile strength and the elasticity of the weft threads. When tested for its breaking strength, the yarn, because of its extremely slight twist, stretched and became looser, but it did not break, and did not show any breaking resistance.

NOTE: All tests with the yarn were made with humidity at 66%.

Analysis of the Cords in the Pattern of the Carpet

Red Cord from Field of Carpet—Cord dyed a typical red, very well preserved. The cord consists of 13 threads twisted together. The twist of the cord equals 3.5 turns; the twist turns to the right. The twist of each thread composing this cord averages 9.9 (result of 6 tests—5; 8; 11.5; 12; 12; 11); the twist of each thread turns to the left. The metrical number of the thread—8.8.

A calculation of the strength of the cord gave the following results: strength—3.88 kilograms; elongation—14%—28 mm.

Strength of the thread composing the cord:

Strength:	180	grams	Elasticity:	5.5%	11	mm.
"	106	"	"	4%	8	"
"	220	"	"	5%	10	"
Average Strength:	168.7	"	Average Elasticity:	4.8%	9.7	"

Thin Cord from the Animal Motives—The cord consists of 4 threads twisted together. The twist of the cord equals 5.5; the twist turns to the left.

The twist of the thread composing this cord—4.6 (10; 4; 3; 3.5; 6.5; 5; 4; 1.5); the twist turns to the left. Metrical number of the thread, 4.

Strength of the cord: 1.57 kilograms; elasticity: 14.8%—29 mm.

Strength of the thread composing the cord:

Strength:	34	grams	Elasticity:	8%	16 mm.
"	100	"	"	11.5%	23 "
"	87	"	"	11%	22 "
Average Strength:	60	"	Average Elasticity:	10%	20 "

Thick Cord from Inner Border—The cord, consisting of 4 threads, has a twist to the left. The twist of the threads composing this cord averages 3.6 (3; 5.5; 3; 2; 3; 4). The twist turns to the left.

The metrical number of a single thread of yarn is 2.4.

The strength of the cord is 2.37 kilograms; the elasticity—10%—22 mm.

Strength of the thread composing the cord:

Strength:	710	grams	Elasticity:	5%	10 mm.
"	540	"	"	9.5%	19 "
Average Strength:	625	"	Average Elasticity:	7.25%	14.5 "

Thus, it is evident that the study of the fabric gave us very interesting results.

The ordinary, plain, or so called *gros de Naples* weave is common now in woolen cloth fabrics. At the present time, however, to make the cloth stronger it is fulled, while the fabric we are studying was never subjected to this treatment. On the other hand, it was woven exceedingly thick, and the extreme density and especially the very compact method of weaving—with double weft [26]—show that the fabric was meant for strong wear and for continuous use.

The test of wear confirms this: the fabric, after a long stay in the ground, where it was subjected to earth pressure, to the action of water, and of time, which destroys all, underwent greater friction than modern fabrics, and yet it was not entirely destroyed.

The peculiarity of the weft—the absence of twist, or else a very slight one—makes one wonder about the methods of weaving the fabric.

To make a fabric with such a weft it would be necessary to be very careful when interweaving the warp and weft, in order to avoid unnecessary tension on the weft (to prevent breaking), and to insert it in such a way as to obtain a nearly uniform thickness everywhere.

[26] (See Note 21, page 45. N. A. R.)

Having but one sample it is difficult, of course, to get a definite idea of the general strength and elasticity of the fabric. Moreover, the fabric is worn, and was damaged in many places during the process of sewing on the applied motives. Therefore, the fabric has not much strength and breaks at 15-17 kg.

A better, and evidently less damaged sample, gives us amazing results: the strength of the weft, 86 kg., is rather good and proves the fabric to be extraordinarily thick.

The elasticity of these fabrics is somewhat unusual; ordinarily it should be greater in the weft, rather even, and not so irregular as it is in this fabric.

A study of the curves[27] shows that: the elasticity resistance in the warp is not great, because the section occupied by the curve, and which gives the straight line, is small (the elongation is in direct proportion to the weight)[28]; on the contrary, in the weft the elasticity resistance of the material is nearly 100%, because the curve of resistance is very near to the straight line, and shows, therefore, the proportion of the stretching to the weight.[29]

Since in most textiles the weft wears out first, we must admit that the construction of this fabric, in regard to elasticity resistance, is very good (better than that of modern fabrics), and the wearing capacity of the fabric must be great, which is proved by the test of the wear.

Examinations of the yarn of which the fabric is made show how skillful was the technologist of ancient times in preparing the twisted warp thread, in making the yarn even throughout its length, in turning the twist in different directions, and in obtaining a comparatively small thickness of yarn.

An almost complete lack of twist in the weft yarn, and at the same time the cohesion of such yarn, show an amazing skill in disposing the fibres in such a way that they produce a compact thread.

Of course, it is not possible to give a complete description of the technical construction of the fabric and of all its peculiarities. The study of this fabric could only be complete if the data obtained were compared with something else, and then corrected where required. In order to do this, it would be necessary to make an exact replica of this fabric and then to reach conclusions after having examined it.

---

[27] (Note. Probably referring to diagram, Pl. 14. N. A. R.)
[28] (Note. The warp is heavy—see page 82 in the original Russian publication. N. A. R.)
[29] (Note. The weft is light—see page 82 in the original Russian publication. N. A. R.)

We have only studied the dye of the applied red cord, of the border fabric, and of the reddish parts of the ornamental motives of the rug. These parts were chosen because their colouring was better preserved and appeared to be closer to the original colouring. Definite conclusions were reached in regard to the original colour of the material, the dye used, and the raw material from which it was obtained, as well as the method of dyeing.

The primary colour of the materials analyzed (that is: the cord, the border fabric, and parts of the ornamental motives) was a luscious, bright red (colour of the red Turkish fez). To give a better idea of the shade of this colour, a sample is given together with the coloured picture of the rug.[30] The colour of the sample is the same as that of two freshly dyed pieces of white woolen fabric, which were dyed with dye extracted from the cord and from the border fabric. The size of these woolen pieces is one square centimeter. To extract the dye from the cord, 9 cm. of the cord were used and also threads from the border fabric that were left from the technical study of the fabric. Dye was extracted by the use of glycerin with strong sulphuric acid, after which the dye was transferred into ether. Then the ether solution of the dye was evaporated. The dry dye, thus obtained, was dissolved in water, and in this solution were dyed the white woolen pieces, previously treated with aluminum mordant. These pieces then became bright, luscious red, which is so characteristic for woolen fabric when dyed with madder (morena). These pieces of white woolen material, treated with aluminum mordant, were subjected to the dyeing process at the same time as another set of white woolen pieces, previously treated with iron mordant. The latter took a colour which showed no likeness to the original shades of the material, but was very similar to the colour of the fabric in the ornamental motives, which can be seen in the coloured picture of the rug. The shade of this dye is blackish-cherry.

This experiment, performed in order to discover the original colour of the fabric, was the final result of long work with quite a number of natural dyeing substances which would be used to dye wool red. Our purpose was to establish a safe method for the analysis of the dye in the of this dye is blackish-cherry.

[30] (Note. No coloured picture or sample appears in the original Russian publication. N. A. R.)

The principal material used for red dye in the rug was the root of madder, a perennial plant (Rubia tinctoria) whose characteristics are well known to botanists. Madder grows in hot and moderate climates (Asia, Caucasus; in Europe it was artificially cultivated).

After a growth of two years the dye is extracted from the root. The roots of madder contain a considerable amount of substances (glucosides), which acquire the properties of dye after the process of fermentation or of chemical treatment. The most important substances are alizarin and purpurin.[31] The root itself cannot be used for dyeing; it must be subjected to a special treatment in order to obtain the alizarin and the purpurin, and also to remove the substances which would give dark and brown colours. We have dyed woolen samples with the root of madder from which the alizarin and the purpurin were not removed, and the other substances were not removed either. The samples of woolen fabric containing the aluminum mordant, when dyed with this kind of substance, acquired a colouring which was not at all like the colour of the cord and of the border fabric. Neither was it like the colour of the woolen samples dyed with dye obtained from the cord and from the border fabric. It is evident that the original dye did not contain any harmful outside substances. All this proves that the dyers who treated the materials for the rug were entirely familiar with the art of dyeing with madder, no matter how complicated this process was. It should be especially noted that alizarin and purpurin by themselves cannot dye any fabric. These colours do not show on the fabric unless it has been treated with a mordant. Different mordants give different shades, and what we observe in the rug, in the cord, and the border fabric, indicates aluminum mordant, even when due consideration is given to the fact that dirt has accumulated for a long time, etc. After establishing definitely the kind of dye used in the red parts, the author studied the paintings found during the Khara-Khoto excavations, now in the Russian Museum, which belong to a culture and epoch very close to those of the rug. In the costume of the figures represented there, we find fabrics of a colour corresponding to the alizarin and purpurin dye, treated with aluminum and iron mordants. We do not judge it necessary to describe in detail the technique of dyeing fabrics with madder, because in the special literature, old and new, this item has been much discussed, from the technical as well as from the economical point of view.

[31] Which has no relation to the ancient purple.

In this work we are not going to describe the technique, established by the author, of methods for discovering alizarin and purpurin (*i.e.*, madder) in fabrics mostly from archæological sources, because this method is to be published by the State Academy for the History of Material Culture, but I want to point out the following: when choosing a method for the detection of alizarin and purpurin we could not be satisfied with what had already been published. Even microscopical and spectrographical methods proved to be inadequate. Finally, we managed to work out extremely simple and safe methods for the detection of alizarin and purpurin; these methods could even be used for archæological work in the field, and do not require any special knowledge or skill. The essential part of this method is the treatment of small pieces of fabric and threads (no more than 0.5 cm. square of the fabric, and 0.5 cm. of the thread) in a glass test tube (5-7 cm. long, 0.5 cm. in diameter) with a drop of strong sulphuric acid combined with glycerin, and adding later some water (about 3-4 cub. cm.) and ether (0.5-1 cub. cm.). The ether layer is tested by a repeated dipping of a strip of filter paper (0.5 cm. wide), on which two coloured streaks appear after evaporation; these streaks are very characteristic for alizarin (the streak farthest from the end) and for purpurin (the streak nearest to the end). Their colouring becomes considerably brighter in the vapors of ammiak.

The discovery of alizarin and purpurin (madder) was very important for archæologists. The analysis of the dye makes it possible to get a definite idea of the colour of the fabric, not only when the dye has preserved to a certain extent a shade which suggests its original colour but also in cases where the fabric is so dirty that no trace of the colour can be seen. During his experiments the author succeeded in discovering madder in a deep black-brown silk fabric, without any trace of red, which belonged to an epoch very close to that of the fabric in the rug (Khara-Khoto excavations). After chemical cleaning of this fabric, its dye disappeared, and as a result we obtained a white fabric on which a pattern in black paint was visible, which could not have been suspected before. The discovery of madder in the fabric makes it possible to identify the original material of the dye, which is a productive plant, and thus we can decide whether the textile material was dyed on the spot, or was brought in already dyed, or whether the raw material for the dye was imported. Furthermore, the use of madder indicates that the people in question were familiar with methods of dyeing, and were of very high culture, as proved by the technique of the rug. To ascertain the presence of alizarin, the author analyzed separately, by his own methods, the weft and the warp of the border fabric of the rug. He found that the warp contained a considerably smaller amount of purpurin than was found in the weft. The fibre absorbs alizarin much better than purpurin, which means that it was the whole fabric which was subjected to the dyeing process, and not the yarn.

In our future analysis of the dyes of the rug fabrics, we plan to find other colours too. Most of all, the author wants to prove the existence of yellow, blue, and green, because the experiments that we have already made with the materials of the rug indicate the presence of those colours.

Technical Analysis of the Embroidery of the Carpet

Three parts of the carpet have been studied: the field of the carpet, the main border, and the inner border.

I. The entire field of the carpet is covered with a uniform spiral pattern (Pl. 10). The spirals are made with applied cord consisting of 12 woolen threads. The plain cord motives—"cord design"—are very early primitive ornaments which can be seen in the art of many races.

The cord is attached to the woolen surface of the rug with a peculiar black thread, formed by 2-3-4 twisted fibres; it is thick and solid, and looks like waxed thread.[32]

Further examination showed that the cord was attached by this thread to the woolen felt lining found under the woolen fabric. In the spots where woolen felt was well preserved, we could see distinctly that the thread pierced the cord, and also the surface fabric of the rug, and that it made regular stitches on the back of the woolen felt. We should think that an awl made holes in the three materials at once: the cord, the surface fabric, and the woolen felt; a needle with a strong thread was inserted in the hole, or perhaps, a thread without a needle, because the thread was pliable enough, and was nearly as hard as a waxed thread. It is possible that the thread was impregnated with a mixture which made it strong and hard. After scraping off the exterior hard surface, the waxed thread was analyzed and proved to be made of two tightly twisted threads, with centres of lighter colour than the outside.

It is not surprising that, in order to sew together the three parts of the rug, which were rather thick, it was necessary to use an especially strong

[32] The histological analysis proved it to be sinew.

thread, that had, perhaps, been previously subjected to special treatment. It is known that the strength of woolen hair is 3-4 times less than flax and cotton, therefore, a woolen thread would not be strong enough for stitching the rug.

II. The main border of the rug is formed by four strips joined at right angles. The background of the border is stitched with a double thread of twisted wool; the stitches form regular rhomboidal figures.[33] The sewing is done in "running stitch."

Doubtless, in this case the holes were made first with some sharp instrument, for the layer of material was very thick—the felt under the woolen surface of the rug is one centimeter thick. The stitches are regular, and at regular intervals are slanted to one side (they form diagonal lines, not straight ones).

On the back of the felt, the fastenings of the thread can be seen—roughly made knots, with loose ends (the lining of the centre of the rug looks exactly the same).

After this preliminary stitching, the ground of the border was covered with a pattern of animal motives arranged in pairs, and a tree ornament in the space between the groups. The embroidery of the pattern is appliqué work, which is so often used for decoration by ancient Eastern races. The animals and the trees are in several colours, and are made of thin felt. The figures are cut out very skillfully, with great care taken to follow exactly the details of the pattern, which has very elaborately curved outlines.

The method of the appliqué is as follows:

1. The groups of figures were cut from stencils (that a stencil was used is proved by the identical form of the repeated figures). The parts dyed in different colours were cut out separately; they are: (a) areas in the centre of the animals' sides; (b) ears and details of the horns; (c) tips of feet; (d) details of tails; (e) wings; (f) details of trees.

2. The second step was the application of these small patches to the main body of the figure. Appliqué ornament is very popular in Persia, and also with the Mongolian races who use it mostly for leather.

The technique of the sewing is as follows: the motive is put in its proper place, and then fastened at the corners to the material. Then the two adjoining pieces are fastened from the wrong side in such a way that the sewing runs in a straight line away from the sewer.

[33] (The effect is the same as quilting. N. A. R.)

The needle makes a slanting stitch on the back of the material. Then the needle appears to the left, makes a straight stitch on the surface (the wrong side of the figure), makes a straight stitch, which unites both pieces, then goes down again, making another slanting stitch on the back. As a result of this overcasting (*verbindungsnaht*) the applied patches are sewed to the main body of the figure and lie freely one beside the other. Since the material is very soft, it was probably not necessary here to pierce a hole for the needle with an awl. This supposition must be correct because the sewing follows the very edge, and catches only few fibres of the felt.

3. Then the leather lining is cut out to correspond to the whole figure, including all the applied pieces. This lining is nothing but the thinnest layer of leather, at many places entirely gone, leaving nothing but dust. It is quite probable that it was glued to the cloth; otherwise it is not possible to explain the accurate cut of the edges, which would be difficult to obtain if the different layers of material used for the appliqué were detached. The use of a leather lining makes the very soft material of the appliqué absolutely smooth. The fact that appliqué was generally used for objects made of leather probably was the reason why a leather lining was adopted in this case.

4. Then comes the decoration of the figure by stitching. Each separate detail is sewn along the edges in "back-stitch" (Rückstich). At a distance of two mm. from the outer line of sewing, in most cases there is a second line, then at the same interval another line, and so on, as far as the space of the detail permits. Therefore, the decoration of each separate detail of this type of figure is concentric, and thus forms in the centre either a triangle, or an oval, or an elongated figure, or simply a straight line, according to the general shape and character of that particular detail. The bodies of the winged animals are decorated with the same kind of stitching, but in this case the arrangement of the lines of sewing is not concentric, because it is intended to represent scales or feathers. This "back-stitch" is one of the most ancient and primitive methods of sewing. There is no doubt that an awl was used in this case to pierce both the cloth and the leather, and a needle with a very thin woolen thread was introduced into the hole thus made. It is evident that a puncture was made first, because we can see small regular round holes, still preserved in the leather; the extreme neatness and regularity of the stitches on the right side, which is the main beauty of the sewing, is further proof of this fact.

The technique of the sewing is as follows:[34] the needle goes backward (hence the name of the stitch) to form the surface stitch, then goes down, and takes in the distance already covered, plus an equal distance ahead. It then comes to the surface and makes another stitch backward to the point of the first puncture. Thus, on the right side a straight line of regular stitches is obtained, resembling modern backstitching made by a sewing machine; on the wrong side we see twisted threads which look very complicated at first sight, but which are characteristic of this kind of stitch. Judging by the wrong side of some fragments on which the colour of the thread was better preserved, we can suppose that the decorative stitching was done in two shades: darker lines on the edges and lighter ones nearer the centre. We notice a perfect appreciation of line in the decoration of the animals with this regular stitch. It is especially striking in the pattern of the head, where the sewing outlines the ears, the mouth, and the neck, and also makes shading. In some places it departs from the usual arrangement of concentric lines, in order to make a pattern appropriate to the shape of the motive.

5. The next step is the application of the cord along the edges of the whole animal motives, along the lines of the patches, and also in places where the pattern required especial emphasis and relief, as, for instance, in the outlines of the feet. The cord that forms the edge of the figures and of the patches is made of four thick woolen threads twisted together; on smaller parts—on the horns and on the tails—it is of three threads. It is dyed a colour that gives strong emphasis to the outlines of the figure. The cord is stitched to the felt of the figure with a thread like that used for the sewing of the cord on the field of the carpet. It is evident that here again it was necessary to attach the cord tightly, so that the line of the cord would follow the outline of the figure. A plain woolen thread, which is not very strong, could not be of any use in this case.

6. The figures in the border of the carpet, prepared as above, were arranged on the background and then sewed to it. As far as it was possible to ascertain, the stitches were made along the edges of the layer of leather by means of an awl; sometimes the stitching goes along the cord and also attaches it. In some places it can be seen that the central part of the felt figure is stitched securely to the ground of the border with a soft double woolen thread.

III. The inner border of the carpet, joining the field to the main

[34] (Note. Probably referring to Pl. 11. This illustration is Fig. 57 in the original book where it had no caption. E. B. S.)

border, has a pattern composed of alternating motives—a cross, a square, a shield, and a background for the cross. The general character of the decoration in these motives is the same as that described above. Each figure is sewn on the surface in "back-stitch" with regular stitches and equal intervals between the lines. On the wrong side the thread is also fastened with a knot. In these motives we can see particularly well traces of the original puncture of the felt before it was stitched with woolen thread. The different colours of the threads do not appear to be exactly the same as the threads of the main border of the carpet, but they are very similar; the thread itself is coarser, thicker, and often better preserved. The wrong side of the motives shows the technique of the sewing much better; the thread lies in a distinct compact chain on the wrong side of the felt. The cord which frames the motives of the inner border differs from the cord of the animal motive by its character and thickness; it is made of nine thick threads. All these details which we do not observe in the decoration of the main border of the rug make us suppose that the separate parts of the carpet were made by different workers, *i.e.*, that the carpet was manufactured by several people.

E. ANALYSIS OF THE WOOLEN FABRICS FROM BURIAL MOUND NO. 6, EXCAVATIONS OF P. K. KOZLOV

Four large pieces of fabric were analyzed; they were considerably damaged, and were numbered as follows: 14360, 14365, 14422, and 14544.[35]

Example no. 14360

This example is a piece of fabric 2.07 meters long; its average width is 0.33 m. The arrangement of the pattern shows that this piece was cut across the fabric, *i.e.*, the width of 0.33 m. is along the line of the warp, and the length of 2.07 m. is along the line of the weft.

This example is not a single fabric, but is made of eight fragments sewed together; these fragments differ from each other in color and type of weave. Of these, five have different patterns and weaves; they are numbered: 1, 2, 3, 4, and 5. The three others are duplicates. The description and analysis of the example will follow the order of the numbers of the five fragments.

Fragment no. 1

According to the data of the microscopical analysis, both warp and weft are of wool. On the surface of the fibres are scales, well preserved and with a diameter of 20 to 40 microns. This gives reason to believe that for this fragment a very thin soft wool, a kind of down (or loom fly), was mixed with the other wool.

Analysis of the yarns used in this fragment:

(a) *Warp*—yarn of two threads, twisted together, the average metrical number (thickness) 16/2 [36]; the twist of the yarn is 20 revolutions to 1

[35] (Note. No illustrations of these woolen fabrics appear in the original book. E. B. S.)

[36] (Note. The meaning of the sign / between the numbers 16 and 2 is not clear, but it is probably simply a reference to the fact that the yarn is composed of two threads twisted together. It is used throughout this section whenever the yarn is of this type. E. B. S.)

inch; the twist of the single thread which composes the twisted warp is 12-18 revolutions to 1 inch.

According to the data obtained by six tests with an accurate dynamometer (yarn strength tester) the tensile strength of the whole warp, with average metrical number 16/2, has an average of 449 grams, with a variation from 334 to 720 grams; the average elongation, as a result of the same number of tests, is 9.5 mm., varying from 7 to 12 mm., which, in a piece of fabric 77 mm. long, gives an average of 13.6%, with a variation from 10% to 17.1%.

(b) *Weft*—made of single yarn, with the average metrical number 16, and an average twist of 7.6 revolutions to 1 inch; the variation in number of revolutions is from 5 to 10 revolutions in 1 inch.

Seven tests, made with a precise dynamometer (yarn strength tester), show that the average tensile strength is 46.2 grams, varying from 28-70 grams; the average elongation is 11.2 mm (16%), varying from 7 to 15 mm. (10%-21.1%)

Analysis of the weaving technique in fragment no. 1:

(a) The fabric is made in *gros de Naples* weave, weft backed, and is woven according to the method used for fabrics with a weft pile.[37]

(b) Count of warp threads is 8.4 in 1 cm., varying from 7 to 10; count of weft threads—34, varying from 26 to 44.

Fragment no. 5 of Example no. 14360 has a pattern in embroidery, that is, the embroidery is done on the finished fabric, catching the threads of the warp and of one of the wefts (the surface weft). For this embroidery a thin crocheted cord is used, probably made with a hook and knitting needles. This type of embroidery made it impossible to detach the cord from the fabric without damaging the embroidery as well as the fabric.

Fragment no. 2

Made of wool, of the same type as Fragment no. 1. The analysis of the yarns used for making this fragment is as follows:

(a) The warp is made of two threads of yarn twisted together; the count of the twisted yarn could not be made because it was impossible to pull the warp threads out of the fabric without damaging the fragment. Judging, however, by the general construction of these threads, we can assume that the character of the warp threads in Fragment no. 2 of

[37] (Note. See Note 21, on page 45. N. A. R.)

Example no. 14360, is identical with that of the warp in no. 1, *i.e.*, that its thickness (number), twist, and therefore its strength, are the same.

(b) The weft is made of single yarn, and its average metrical number is 10. Its average twist (as is shown in 5 tests) is 9.2 revolutions to 1 inch, varying from 6 to 13 revolutions.

The average tensile strength, according to the results of three tests with the accurate dynamometer, is 74.3 varying from 54 to 96 grams, the average elongation being 12 mm. (17.1%), varying from 9 mm. (12.8%) to 14 mm. (20%).

Analysis of the weaving technique of Fragment no. 2:

(a) The fabric is made in *gros de Naples* weave, weft backed, and is woven according to the method used for fabrics with a weft pile.[38]

(b) The count of warp threads, as ascertained in 10 tests, is 7.5, and of the weft, 33.6

Fragment no. 2 of Example no. 14360 has a pattern in embroidery, that is, the embroidery is done on the finished fabric, catching the threads of the warp and of one of the wefts (the surface weft). For this embroidery a crocheted cord is used, of the same type as the cord in Fragment no. 1.

In addition, Fragment no. 2 has a woven pattern, in which the count of the warp is 7.4 threads in 1 cm., and of the weft, 26.8 in 1 cm. The variations are: in the warp, 7-8 threads, and in the weft, 24-80.

The outlines of the woven pattern and of the background fabric have selvages along the edges of the weft.[39]

The woven pattern is joined to the background fabric by the overlapping of 3 or 4 warp threads.[40]

The same pattern and the embroidery are repeated in all three parts, no. 2, no. 2a, and no. 2b of Example no. 14360.

Fragment no. 3

Both warp and weft of Fragment no. 3 are made of coarser wools than those of Fragment no. 1, because a microphotograph shows woolen fibres with very pronounced ring-shaped scales and also fibres which have oval and oval ring-shaped scales, which are characteristic of the

[38] (Note. See Note 21, page 45. N. A. R.)
[39] (Note. This probably means simply that the fabric has a selvage. E. B. S.)
[40] (Note. Since this fabric is not illustrated in the original book, it is difficult to determine exactly what this statement means, but it probably refers to the way in which the pattern threads are bound down.)

transition to beard-hair,[41] although the amount of beard-hair is not considerable.

The thickness of the down (or loom fly) fibres pulled out of the red and yellow yarns varies respectively from 24-32 microns, and in the beard-hair it is 56 microns.

Fragment no. 3 and the similar fragments no. 3a and 3b are narrow strips separately woven; the warp threads in these strips do not run in the same direction as those in the other fragments but are at right angles to them.

Thus, in these strips the warp runs parallel with the length of Example no. 14360, and the weft runs across it.

The analysis of the yarn used in Fragments no. 3, no. 3a, and no. 3b is as follows:

(a) the warp running the length of Example no. 14360 is made of single yarn, the average metrical number of which is 6.

The twist of the warp equals 11 revolutions in one inch, varying from 7 to 15 revolutions in one inch.

The average strength of the warp, according to the results of 5 tests made with the precise yarn strength tester, is 334, varying from 220 to 445 grams; the average elongation is 10.6 mm. (15%), varying from 8 mm. (11.4%) to 13 mm. (18.6%).

(b) The weft is made of threads of two colours, yellow and red, which produce the woven pattern of the fabric.

The metrical number of the red yarn is 4; the average strength, according to 8 tests made with the precise yarn strength tester, is 229.9 grams, varying from 66 to 530 grams.

The average elongation of the weft threads, according to the same number of tests, equals 15.25 mm. (21.8%); the average twist equals 9.4 revolutions in one cm., varying from 9-11 revolutions.

The average metrical number of the yellow weft is 5; the average strength, according to 8 tests made, is 96.6 grams, varying from 40 to

[41] (Note. "Sheep in a natural condition produce two kinds of hair; one giving a long stiff fibre which we may call 'beard-hair,' and the other a shorter, softer, and more curly fibre, which we may designate as 'wool-hair.' Sheep can be made to produce nearly all wool hair." J. M. Matthews, *The Textile Fibres,* London, 1913, p. 17. The same author [pp. 33-35, Fig. 13] describes as follows the differences to be observed under the microscope of the epidermal scales of the fibres. "In fine merino wools the scales are in the form of cylindrical cusps—a single scale completely surrounding the entire fibre. In some varieties of wool two or more scales occur in the circumference of a fibre." These types of scales have a slightly projecting edge. "In other wools there is hardly any projection, but the scales are arranged as a series of plates. Wools of this class are more hair-like in structure, stiffer and straighter and not capable of being readily felted. Beard-hairs are of this type." E. B. S.)

195 grams; the average elongation is 13 mm. (18.6%), varying from 7 mm. (10%) to 17 mm. (24.3%).

The weave is identical with that of the fragments of the example previously described.

Fragment no. 4

It differs distinctly from the fragments described above, in technical structure, as well as in colour, and in its complicated varied patterns, which are simply ordinary embroidery and not woven.

Fragment no. 4 is of wool of even thickness (24-36 microns in diameter), with strongly pronounced oval and oval ring-shaped scales, that is, it is made of soft wools.

The analysis of the yarns used in this fragment of the example is as follows:

(a) The warp is made of yarn that is not twisted,[42] the average metrical number of which is 17; the twist equals 26.4 revolutions in one inch, varying from 20 to 30 revolutions.

The strength of the warp yarn, according to 7 tests made with the precise yarn strength tester, is 78.6 grams, varying from 54 to 118 grams; the average elongation, as shown in the same tests, equals 12.1 mm. (17.3%), varying from 8 mm. (11.4%) to 16 mm. (22.8%).

(b) The analysis of the weft yarn could not be made, because the embroidery is so solid that it was impossible to pull the weft yarn out of the fabric.

The construction of the fabric in Fragment no. 4 is entirely different from those described above; in this case an ordinary single weft, in *gros de Naples* weave, is used (not the type used for making velvet pile fabrics). (cf. Note 21, p. 45.)

The average thickness of the cloth, as to the count of threads in one cm., is 10.5 for the warp (4 tests made), and 25.9 for the weft (10 tests made), varying respectively from 10 to 11 and from 22 to 23.

The embroideries, of a varied design, are made of twisted yarn, in black, red, green, and brown.

(a) Analysis of the yarn used for the red embroidery:

The yarn is made of semi-coarse wools showing transition to beard-hair with strongly pronounced oval and oval ring-shaped scales;

---

[42] (Note. Probably an error; it should no doubt read "single," instead of "not twisted." N. A. R.)

microscopical examination shows that it contains a small amount of beard-hair.

The average thickness of the fibre varies from 44 to 80 microns.

The metrical number of the yarn, made of two threads twisted together, is 10.4/2; the average twist of the yarn equals 9 revolutions in one inch, and of the single thread which composes the twisted yarn, 10 revolutions in one inch.

The tensile strength and the elasticity of the yarn were not ascertained because it was impossible to pull out a thread of the required length.

(b) Analysis of the green yarn:

The yarn is made of the same woolen fibre as the red yarn; the average metrical number is 10/2; the average twist in the yarn is 6.6 revolutions in one inch, and in the single yarn thread which composes the twisted yarn, 15.7 revolutions in one inch.

The average strength of the twisted yarn, as ascertained in 3 tests made with the precise yarn strength tester, equals 495 grams, varying from 470 to 520 grams; the average elongation, as shown by the same number of tests, is 11.6 mm. (16.6%), varying from 11 mm. (15.7%) to 13 mm. (18.6%); the average strength of the single thread which composes the twisted yarn, as ascertained in 4 tests, equals 199 grams, varying from 138 to 249 grams; the average elongation is 9.7 mm. (14%), varying from 7 mm. (10%) to 11 mm. (15.7%).

(c) Analysis of the brown yarn:

The yarn is made of the same woolen fibre as the preceding ones; the average metrical number is 12.2; five tests show that the average twist in the yarn equals 8.7 revolutions in one inch, varying from 6 to 12 revolutions, and the average twist of the single thread which composes the twisted yarn equals 17.5 revolutions in one inch, varying from 13 to 22 revolutions.

According to two tests with the precise yarn strength tester, the average strength of the twisted yarn is 92.5 grams (67-118 grams) with an average elongation of 9 mm. (12.9%), varying from 8 mm. (11.4%) to 10 mm. (14.3%).

The average strength of the single thread, which composes the twisted yarn with the metrical number 12/2, is 125.5 grams; the elongation, 8 mm. (11.4%).

Besides the above-mentioned yarn with the metrical number 12/2, there is in the same embroidery a brown yarn, metrical number 9.8/2, *i.e.*, which is thicker than the yarn number 12/2. The average twist in this yarn equals 7.6 revolutions in one inch, varying from 5 to 9 revolutions; the single thread equals 7.8 revolutions, varying from 3 to 15 revolutions.

The average strength of the yarn, metrical number 9.8/2, as shown in 4 tests, is 153.2 grams, varying from 90 to 245 grams; the elongation is 12 mm. (17.1%), varying from 10 mm. (14.3%) to 15 mm. (21.1%); the strength of the single thread is 52 grams and 12.5 mm. (17.9%).

(d) Analysis of the black yarn:

The character of the yarn is the same as that of the other yarns in the embroidery. The average metrical number is 10/2; the average twist of the yarn as shown in seven tests equals 9.1 revolutions in one inch, varying from 5 to 12 revolutions. The twist of the single thread which composes the twisted yarn equals 14 revolutions in one inch (8-18 revolutions).

The average strength of the twisted yarn, according to the precise yarn strength tester, is 106.5 grams (97-106 grams); the elongation—16.5 mm. (23.6%).

Cord Connecting Fragments no. 3 and no. 4 of Example no. 14360

This cord is on the wrong side, and joins together Fragments no. 3 and no. 4 of the example; it does not appear on the right side.

The connecting cord is made of coarse woolen fibre, because a microscopical analysis reveals oval scales on the fibre and shows that the wool contains a considerable amount of beard-hair which has a diameter of nearly 100 microns and a very pronounced core.

The connecting cord is really not a cord; it is an ordinary thick yarn of two threads, twisted together, with an average metrical number of 3/2; the metrical number of its single thread is nearly 3.9, which makes a metrical number of 3.9/2 for the twisted yarn. Thus, the thickness of the connecting cord varies within the range of one number.

The average twist of the yarn equals 3.25 revolutions in one inch, varying from 3 to 4 revolutions in one inch. The average twist of the single thread which composes the yarn equals 4.5 revolutions in one inch, as shown in four tests.

The average strength of the connecting cord, as shown in four tests made with the precise yarn strength tester, equals 1,990 grams, varying from 1,630 to 2,290 grams; the average elongation is 12.3 mm. (17.6%), varying from 6 mm. (8.6%) to 19 mm. (27.1%).

The average strength of the single thread which composes the connecting cord, metrical number 3/2, equals 184 grams (6 tests made), varying from 54 to 300 grams; the average elongation is 15 mm. (21.4%), varying from 10 mm. (14.3%) to 24 mm. (34.3%).

Besides this connecting cord, there is a real cord sewn on the seam in approximately the same place; it is a tightly twisted cord (4-5 revolutions in one inch), made of two twisted yarns. Each twisted yarn is made of 8 threads, the twist being 9 revolutions in one inch. The average twist of the single thread which composes the twisted yarn equals 11.4 revolutions in one inch.

The metrical number of this cord is 0.4; the number of the twisted yarn which composes this cord is 6.4/8.

Fragment no. 5

Narrow strips (tape) red on the edges and yellow in the centre, which are sewn to Fragment no. 4 of Example no. 14360.

Fragment no. 5 is made of semi-coarse wools; the fibre has oval and oval ring-shaped scales, and contains a small amount of beard-hair. The average diameter of the fibre is from 20 to 64 microns.

The strips (tape) have an ordinary *gros de Naples* weave; the count of the threads in 1 cm. is 25 for the warp and 7.5 for the weft. A twisted yarn is used in these strips (tape). The metrical number of the warp is 33/2 and of the weft, 27/2. The average twist of the red warp yarn equals 13.4 revolutions in one inch, and the twist of the single red threads is 18.6; the average twist of yellow yarn is 15.2 in one inch, and of the single threads—17.2 revolutions in one inch.

The weft, metrical number 27/2, is all one colour, and equals 26.8 revolutions in one inch; the average twist of the single thread equals 18.7 revolutions.

Ten tests made with the precise yarn strength tester show that the average strength of the twisted warp yarns, metrical number 33/2, is 100.9 grams, varying from 65 to 165 grams; the average strength of the single threads which compose twisted yarn is 42.6 grams, varying from 28 to 54 grams. The elongation of the twisted warp yarn, metrical number 33/2, is 12 mm. (17%), varying from 8 mm. (11.4%) to 17 mm. (24.3%), and of the single threads, 10.8 mm. (15.4%), varying from 5 mm. (7.1%) to 20 mm. (28.4%).

The average strength of the weft yarn, metrical number 27/2, as shown in three tests, is 227 grams, varying from 231 to 350 grams; the elongation is 14.3 mm. (20.4%), varying from 13 mm. (18.6%) to 16 mm. (22.9%).

The strength of the single weft threads could not be ascertained because the thread was too worn.

The strips (tape) are sewn on Example no. 14360 with red woolen threads. These threads are made of twisted yarn (metrical number 17/2); the twist of the yarn is 8 revolutions, and of the single threads—15 revolutions in one inch, varying respectively from 7 to 9, and from 11 to 18 revolutions in one inch.

The average strength of the twisted yarn, used for the sewing, metrical number 17/2, is 340 grams, and of the single threads—101 grams; the elongation is respectively 12 mm. (17.1%) and 10.5 mm. (15%).

Example no. 14544

This example is very much damaged; it is made of five fragments sewn together. Fragments no. 6 and no. 7 only were examined. These fabrics are the main parts of Example no. 14544 and also of Examples no. 14422, 14360, and 14365.

Fragment no. 6

Both warp and weft are of soft wool, the fibres of which have ring-shaped scales, with a diameter of from 23 to 44 microns.

Analysis of the yarns used in this part of the example:

(a) The warp yarn is made of two threads twisted together; the average metrical number is 17/2; the average twist of the yarn equals 18 revolutions in one inch, varying from 16 to 20 revolutions. The single thread was so decayed that it was not possible to determine its twist.

(b) The yarn of the weft is single and is slightly twisted; as to the thickness, the metrical number is 20.

Other tests could not be made because the weft was too worn.

Fragment no. 6 is in *gros de Naples* weave, of the type of velvet pile fabrics.[43] The count of the threads in one cm. is 9.6 for warp and 52 for the weft.

[43] (Note. See Note 21, page 45. N. A. R.)

Fragment no. 7

Made of wools similar to those of Fragment no. 6.

Analysis of yarns used in this part of the example:

(a) The warp yarn is made of two threads twisted together, with a metrical number of 23/2; the average twist of the yarn equals 11.5 revolutions in one inch, varying from 11 to 12 revolutions; the average twist of the single thread equals 8.5 revolutions in one inch, varying from 6 to 11 revolutions.

The average strength of the twisted warp, as shown in four tests made with the precise yarn strength tester, equals 500 grams, varying from 300 to 600 grams; the elongation is 12 mm. (17.1%), varying from 10 mm. (14.37%) to 14 mm. (20%).

(b) The yarn of the weft is single, and has the average metrical number 14; the average twist, as shown in 10 tests, equals 8.5 revolutions in one inch, varying from 11 to 6 revolutions.

The average strength of the yarn, as shown in 5 tests with the precise yarn strength tester, equals 32 grams, varying from 24 to 54 grams; the elongation, respectively, is 10.2 mm. (14.5%), varying from 7 mm. (10%) to 14 mm. (20%).

(c) Fragment no. 7 is made in *gros de Naples* weave of the velvet type.[44] The count of the threads in 1 cm. is 9 threads in the warp, and 42 threads in the weft, varying from 36.5 in the green yarn, and to 46.3 in the yellow yarn.

Example no. 14365

This example is a large piece of fabric, very much damaged along the seams, but otherwise fairly well preserved. It is made of 15 pieces sewn together without regard to the correct arrangement of the patterns and the colours.

The main material of Example no. 14365 is the same as that of the other three, nos. 14544, 14360, and 14422, and therefore this piece was tested only for its strength and elasticity.

To determine the strength of the fabric, two samples were taken, 5 cm. wide and 10 cm. long, one running in the direction of the warp, and the other of the weft, and they were subjected to a breaking test on the L. Schopper yarn strength tester.

[44] (Note. See Note 21, page 45. N. A. R.)

The strength of the fabric in the direction of the warp is 16.8 grams; the elongation, at the moment of breaking, is 23.5 mm. (23.5%); in the direction of the weft the strength is 13.65 grams, and the elongation, 14.5 mm. (14.5%).

Example no. 14422

This example is a large piece, made of three fragments; it has at one end the same kind of embroidery as in Example no. 14360.

Since the material is the same as that of the preceding Examples, one test only was made—to determine the wear of the fabric. The definition of the wear was made on Prof. Herzog and Geiger's apparatus for testing the wear by friction (made by the firm of Louis Schopper in Leipzig).

To perform a friction test, we used a sample 7.5 cm. in diameter, the same as the diameter of the friction disc, and we subjected it to friction on a fluted friction disc of the apparatus, using a weight of 1.5 kilograms; the result of the friction was ascertained by the appearance of the sample and by its loss in weight.

After the fluted friction disc made 2,500 revolutions, breaks appeared at the edge of the fabric, which lost 4.5% in weight. After 4,500 revolutions the breaks became more pronounced, and the fabric was worn thin in the centre. Finally, after 5,500 revolutions, the fabric was worn very thin in the middle and near the edges, but the warp threads were very little damaged.

The loss in weight, as compared to the weight of the sample before the process of friction, equals 10.7%.