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Съдържание
Contents

Borislava Galabova 5
A BIOARCHAEOLOGICAL APPROACH FOR PERSONAL IDENTIFICATION BASED ON HUMAN HANDPRINT FROM THE VILLAGE OF PLOSKI, SOUTHWEST BULGARIA

Борислава Гълъбова
БИОАРХЕОЛОГИЧЕСКИ ПОДХОД ЗА ИДЕНТИФИКАЦИЯ НА ЛИЧНОСТТА ВЪЗ ОСНОВА НА ОТПЕЧАТЪК НА ЧОВЕШКА РЪКА ОТ С. ПЛОСКИ, ЮГОЗАПАДНА БЪЛГАРИЯ

Markus Spring, Thomas van den Brink, Sven Straumann, Tsoni Tsonev 13
INTERPRETING THE ARCHAEOLOGICAL RECORD: ARCHAEOLOGICAL SPACE

Маркус Спринг, Томас Ван Ден Бринк, Свен Страуман, Цони Цонев
ТЪЛКУВАНЕ НА АРХЕОЛОГИЧЕСКИЯ ЗАПИС: АРХЕОЛОГИЧЕСКО ПРОСТРАНСТВО

Krassimir Leshtakov, Philip Machev, Tsvetana Popova, Dian Vangelov, Viktoria Vangelova, Tanya Stoilkova, Vanya Petrova, Denitsa Ilieva, Nikolina Nikolova, Silvia Chavdarova, Mila Andonova, Hristina Vasileva, Hanna Hristova, Zhelyazko Zhelyazkov, Daniel Dimitrov and Nikol Blagoeva 33
SOCIAL DIMENSIONS OF TECHNOLOGY OF CERAMIC PRODUCTION IN SOUTHEAST BULGARIA IN 6TH – 2ND MILL

Красимир Лещаков, Филип Мачев, Диан Вангелов, Виктория Вангелова, Таня Стоилкова, Ваня Петрова, Деница Илиева, Николина Николова, Силвия Чавдарова, Мила Андонова, Христина Василева, Ханна Христова, Желязко Желязков, Даниел Димитров и Никол Благоева
СОЦИАЛНИ ИЗМЕРЕНИЯ НА ТЕХНОЛОГИЯТА НА КЕРАМИЧНОТО ПРОИЗВОДСТВО В ЮГОИЗТОЧНА БЪЛГАРИЯ ПРЕЗ VI-II ХИЛ. ПР.ХР.

Maria Kostadinova-Avramova 107
ADVANTAGES AND DISADVANTAGES OF BRICKS AS A MATERIAL FOR ARCHAEOMAGNETIC STUDY

Мария Костадинова-Аврамова
ПРЕДИМСТВА И НЕДОСТАТЪЦИ НА ТУХЛИТЕ КАТО МАТЕРИАЛ ЗА АРХЕОМАГНИТНО ИЗСЛЕДВАНЕ

This issue consists of four articles covering various topics of interest. The first article, presents the results of an anthropological analysis of human hand imprint on a brick. It is extremely rare to find human hands and feet imprints in various archeological sites and materials. Even rarer are the studies of these traces. The results of the investigation give reason to Galabova to assume that the hand on the brick from the village of Ploski belongs to a child.

In this summarizing article: *Interpreting the Archaeological Record: Archaeological Space* is presented 4 study is based on Session AR16 held at the EAA conference in Glasgow, 2015. In this joint paper it has been shown that space has its own social dimension that can help archaeologists understand how past societies used it to create social meaning and value. The first example reveals how past built environment within the frame of a single settlement sharpens the sensitivity of both its inhabitants and outside visitors to the established public norms of behavior. The next example shows how a visual culture contains mental stereotypes of monumental structures that influence the spatial behavior of modern observers that want to make their own image of these structures. The third example reveals the potential of GIS and 3D representations for analyses and interpretation of the spatial organization of the large urban center from Roman times. The final example provides a critique to the typical understanding of the organization of spatial data in archaeology and offers a way of analyzing both present and absent data in order to extract the maximum information and constitute a coherent interpretation from the otherwise disparate and loosely related data.

The results of the project:*SOCIAL DIMENSIONS OF TECHNOLOGY OF CERAMIC PRODUCTION IN SOUTHEAST BULGARIA IN 6th – 2nd mill. BC* show the application of different methods for the study of ceramics in prehistoric times. In this article are presents the activities and data received during the first year of the project. The research area covers Southeastern Bulgaria with nine major sites included. The subject of this instrumental study and archaeological feature are specimens that are divided into the following groups: denuded rocks, which serve as the basis of tectonic clay; clay; ceramics; organic residues and impressions of mats and baskets on the pottery bases. Different methods and analyzes have been applied to solve the problems posed: cartographic analysis and description of the landscape, morphological and typological analysis, dating; instrumental methods; Chemical analysis, Scanning Electron Microscopy (SEM), petrographic analysis etc.

Avramova applies a geomagnetic method in the study of three collections – Roman bricks (taken from the Diocletianopolis city wall, present Hissarya), Turkish bricks (coming from a mosque excavated on the territory of „40 Saint Martyrs" church, Veliko Tarnovo) and bricks with inscription (found also on the territory of „40 Saint Martyrs" church.. The dating intervals obtained on 95 percent probability level (2σ) are: 1817 – 1894 AD (Turkish bricks) and 1833 – 1894 AD (bricks with inscription) as they ended with the last year of the Bulgarian archaeomagnetic dataset. The archaeomagnetic dating interval obtained for the Turkish bricks indicate that they were produced rather in the end of the Ottoman ruling than in the end of XVII – beginning of XVIII century.The Turkish bricks and the bricks with inscription are included as new referent points with their archaeological dates in the Bulgarian archaeomagnetic database. With the new study of the Roman bricks an important correction for the referent site Hissarya was done. This demonstrates the importance and requirement of regular revision of the available archaeomagnetic dataset especially with regard to the old results.

A bioarchaeological approach for personal identification based on human handprint from the village of Ploski, Southwest Bulgaria

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ABSTRACT

The discovery of imprints of human hands and feet in various archaeological sites and on materials is extremely rare. Even rarer are the studies of these traces for personal identification. The current article concerns the analysis of a human handprint on a brick, unearthed in a tile kiln, excavated during 2017. The main goal is not only to establish the age and sex of the person left his mark but to pay particular attention to the possibilities of these type of anthropological investigations in the research of the ancient man. The handprint belongs to the right hand. It is preserved partly from second to fifth fingers. The values of the imprint gives us reason to assume that the hand on the brick from the village of Ploski belongs to a child aged between 6 and 7 (*Infans* I/*Infans* II), most probably a boy (?).

Key words: Handprint, physical anthropology, bioarchaeology, age determination, sex assessment, bricks, Revival period

Биоархеологически подход за идентификация на личността въз основа на отпечатък на човешка ръка от с. Плоски, Югозападна България

Борислава Гълъбова

РЕЗЮМЕ

Откриването на отпечатъци от човешки ръце и ходила върху археологически обекти и предмети е изключително голяма рядкост. Още по-голямо изключение е анализа на тези следи с цел биологична идентификация на човека. В настоящата статия е анализиран отпечатък от човешка ръка открит върху тухла от пещ за керемиди, проучена през 2017 г. Целта е освен да бъде направено възрастово-полово определяне на индивида, но и да се обърне специално внимание върху възможностите на този вид антропологични изследвания в изучаването на древния човек. Откритият отпечатък е от дясна ръка. Той е фрагментиран, като са запазени отпечатъците от втори до пети пръсти. Получените стойности ни дават основание да заключим, че отпечатъкът принадлежи на дете на възраст между 6 – 7 години (*Infans* I/*Infans* II), най-вероятно момче (?).

INTRODUCTION

The discovery of imprints of human hands and feet in various archaeological sites and on materials is extremely rare. Even rarer are the studies of these traces for personal identification. The methods of physical anthropology used for studying living populations permit similar analysis to be carried out. They enable as well age and sex assessment of the individuals as the reconstruction of their stature and weight (Paulis 2015). In recent years, the attention of scientists has focused on different kind of imprints left by

the ancient people, which led to a significant increase in the number of these type of studies (Gunn 1998, Greer, Greer 1999; Gunn 2006; Wang, Ge, Snow, Mitra, Giles 2010; Tung 2012; Linge 2012; Pettitt, Castillejo, Arias, Peredo, Harrison 2014; Carden, Blanco 2016; Nelson, Hall, Randolph-Quinney, Sinclair 2017; Rabazo-Rodrígueza, Modesto-Mataa, Bermejoa, García-Díezc 2017; Marado, Ribeiro 2018; Atamtürk, Özbal, Gerritsen, Duyar 2018; Chopra 2018; Panarello, Mazzardo, Mietto 2018).

At this stage anthropological research of human hand and foot imprints on ancient bricks and tiles have not been carried out in Bulgaria. We find scarce information for some handprints in three publications.

In 2009, Maria Inkova refers for a footprint on an ancient tile discovered in the Kalyata fortress, near the town of Yakoruda, Blagoevgrad district. According to her, the footprint belongs to a two-year-old child. However, Inkova does not specify how these results have been obtained (Инкова, Ковачев, Гошев 2008; Инкова 2009; Инкова, Робовянов, Иванов 2010).

Another famous handprint is the one on the pithoi mouth, discovered in a grave from the mound 1, near the village of Dolna Rositsa, Targovishte region (4th-3rd c. BC) (Овчаров 1961). Given its small size (6. 5 cm x 3. 5 cm), the author has the right to assume that it is a seal (Овчаров 1961, 62), not a child handprint (Radev 2000, 156).

The third note belongs to Georgi Kitov. He mentioned about a hand stencil on the murals in the tomb from Sarafova Mound (4th-3rd c. BC), Kazanlak region. According to him the stencil have been painted in red but did not give more details (Китов 2008, 102).

The current article concerns the analysis of a human handprint on a brick, unearthed in a tile kiln. The main goal is not only to establish the age and sex of the person left his mark but to pay particular attention to the possibilities of this type of anthropological investigations in the research of the ancient man.

The site is located in the northwestern part of the village of Ploski, Sandanski region, Southwest Bulgaria and was explored during the rescue archaeological excavations in 2017 by A. Harizanov (Харизанов, Косева 2018, 564, 1). Two tile kilns placed one over the other were excavated. They have functioned seasonally at the end of the 19th century. (Харизанов, Косева 2018, 568). A brick fragment with human handprint was discovered in the lower chamber of the second kiln. (Харизанов, Косева 2018, 568).

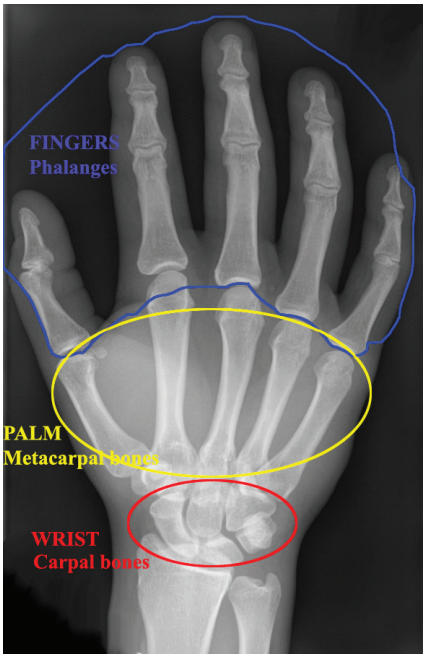


Fig. 1. Composition of the hand (X-ray of human right hand)

The bones, muscles nerves, blood suppply, and veins formed the human upper limb. It consists of the upper arm – from the shoulder to the elbow, the forearm – from the elbow to the hand and the hand. The hand (*manus*) extends beyond the wrist to the fingertips. Most often, the term hand is used for the whole upper limb, which is incorrect.

There are twenty-seven bones in the composition of the hand, forming its three main parts – wrist, palm and fingers. The wrist is composed of eight carpal bones, the distal ends of the radius and ulna and the proximal portions of the fifth metacarpal bones. The palm includes five metacarpal bones located between the bones of the wrist and the base of each of the five fingers of the hand. Fingers, except for the thumb, consist of three bones called phalanges. There are two phalanges in the thumb composition. (Fig. 1)

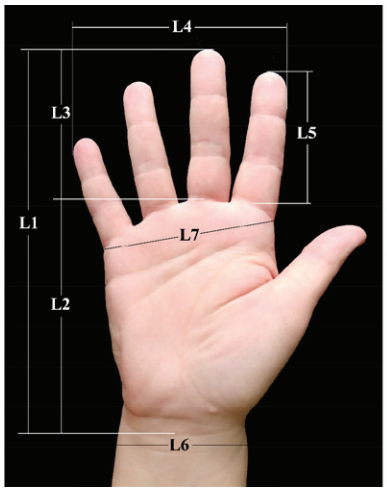
MATERIAL AND METHODS

The brick fragment is with a rectangular shape, well-formed sides and very well smoothed upper surface. The brick is made of clay, with small amount inclusions of quartzite and limestone of small size (under 2 mm) and a large



Daktylion (da III)	At tip of the middle finger
Metacarpale radiale (mr)	At metocarpophalangeal junction of index finger
Metacarpale ulnare (mu)	At metocarpophalangeal junction of little finger
Phalangion (ph III)	At metocarpophalangeal junction of middle finger
Stylion radiale (sty.r.)	At the radial styloid process (*processus styloideus radii)*
Stylion ulnare (sty.u.)	At tip of ulnar styloid process (*processus styloideus ulnae*)
Interstylion	Mid-point of line connecting *stylion radiale* and *stylion ulnare*

Fig. 2. Somatometric points of the hand according methods of Martin- Saller (1957)



L1 **Hand length** (the straight distance from *intersty* to *da* III)

L2 **Palm length** (the straight distance from *intersty* to *ph* III)

L3 **Length of middle finger** (the straight distance from *ph* III to *da* III)

L4 **Fingers outspread** (the distance between the tips of index and little fingers at maximum span)

L5 **Index finger length**

L6 **Wrist breadth** (the straight distance from *sty. r.* to *sty. u.*)

L7 **Hand breadth** (the straight distance between *mr* and *mu*)

Fig. 3. Directly measured features.

amount of mica. The surfaces are yellowish red (5YR5/8, 5YR6/8) with grey spots (5YR7/1) caused by secondary firing. The brick fractures are grey to the red, result of irregularly baked. Preserved brick sizes: length of 14 cm in its shortest part, 24 cm in the longest part, 22. 6 cm depth and height varies from 4. 2 cm to 5. 4 cm in various sections (Fig. 4).

Method selection to study the handprint was quite difficult. On the one hand, the methods for assessing the biological profile based on the hand size and hand imprints developed from Bulgarian samples are insufficient. On the other hand, all methods known in the literature are related to the identification of adults and are missing for children.

For the purpose of the current investigation, the somatometric points of the hand were applied according to the methods of Martin-Saller (1957) for studying living population (Fig. 2).

Seven are directly measured features (Fig. 3).

The obtained results are assessed in comparison with characteristics for adult living population in Bulgaria aged between 30 and 40 years (Йорданов, Начева, Торньова-Ранделова, Кондова, Димитрова, Паскова-Топалова 2006) and with biostatistical data for physical development in children and youths in Bulgaria (Начева, Жечева, Янкова, Филчева, Митова, Йорданов 2012).

The Munsell soil-color charts (Munsell color Company 2009) are used for colour changes on the brick during secondary firing.

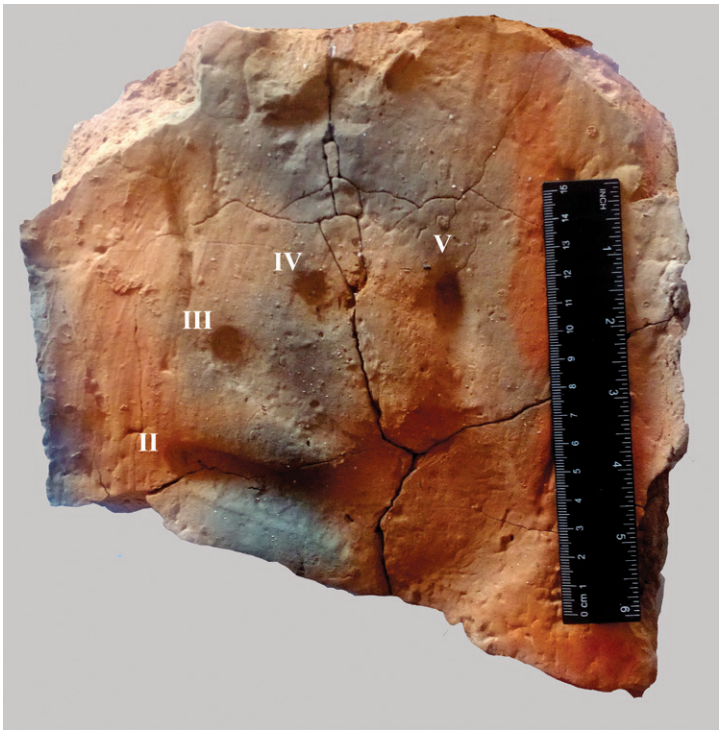


Fig. 4. Handprint on the brick from village of Ploski, Sandanski region.

RESULTS

The handprint is detected almost in the middle of the brick surface. It belongs to the right hand. The imprints of second to fifth fingers are preserved. The brick section with the first finger (the thumb) place is missing (Fig. 4).

The hand was placed unintentionally on the brick, while the clay was still wet. The depth of the fingerprints in their distal (front) part gives us a reason to assume that in contact with the wet clay, the pressure has fallen on the fingertips. No papillary patterns are count in the print, which not allows made a dactyloscopy examination.

The obtained results from the directly measured features in the handprint based on the somatometric points are detailed described in Table 1.

The comparisons between the obtained results with the biostatistical data from the studies of the living adult population aged between 30-40 years (male/female) from Bulgaria indicate significant differences in the size of the hand (Table 2) (Йорданов, Начева, Торньова-Ранделова, Кондова, Димитрова, Паскова-Топалова 2006, 313, табл. 78; 314, табл. 79; 315, табл. 80; 316, табл. 81; 317, табл. 82). These results prove that the handprint on the brick belongs to a child.

Table 1. Results of directly measured features of the handprint from village of Ploski, Sandanski region

Feature		Measurements (mm)
L1	Hand length	141.0
L2	Palm length	76.0
L3	Length of the middle finger	65.0
L4	Fingers outspread	125.0
L5	Index finger length	62.0
L6	Wrist breadth	48.0
L7	Hand breadth	70.0

Table 2. Comparisons between the handprint dimensions and the average hand size of the living adult population of both sexes in Bulgaria

Feature	Village of Ploski	♂		♀	
L1	**138.0**	min	175.0	min	151.0
		max	238.0	max	225.0
		mean	206.4	mean	188.1
L2	**76.0**	min	73.0	min	62.0
		max	119.0	max	113.0
		mean	99.5	mean	90.5
L3	**65.0**	min	89.0	min	80.0
		max	125.0	max	116.0
		mean	106.9	mean	97.6
L6	**48.0**	min	51.0	min	44.0
		max	70.0	max	66.0
		mean	60.0	mean	53.0
L7	**70.0**	min	75.0	min	65.0
		max	105.0	max	100.0
		mean	88.9	mean	78.9

Table 3. Comparisons between handprint mesurments and mean hand size in children and adolescents of both sexes in Bulgaria by L1 feature

L1	Boys			Girls			Village of Ploski
Age	min	max	mean	min	max	mean	
0	5.1	7.0	6.29	5.3	7.4	6.21	**141.00**
3	9.5	13.1	11.31	9.6	12.4	10.98	
4	10.5	13.1	11.97	9.8	13.3	11.58	
5	10.8	14.7	12.65	10.7	13.8	12.41	
6	11.7	15.0	13.29	11.0	15.7	13.18	
7	12.5	20.4	15.84	12.6	23.0	15.78	
8	12.6	19.2	16.17	12.9	18.7	15.78	
9	13.7	19.9	16.63	11.8	20.1	16.60	
10	14.6	20.1	17.39	14.4	21.2	16.89	
11	14.8	20.1	17.81	15.2	21.2	17.79	
12	15.1	21.5	18.26	14.4	21.7	18.21	
13	15.3	24.2	18.69	15.0	29.1	18.46	
14	15.4	23.0	19.92	14.8	21.9	18.75	
15	17.2	24.0	20.43	15.3	22.5	18.47	
16	15.2	24.9	20.72	16.1	21.7	18.58	
17	18.1	27.2	21.03	15.6	22.7	18.70	

To determine the child age left his mark on the brick, we compared some features with the results of the studies of children and adolescents from Bulgaria (Table 3 and Table 4), (Начева, Жечева, Янкова, Филчева, Митова, Йорданов 2012, 284, табл. 5. 5. 1. ; 286, табл. 5. 6. 1.).

Unfortunately, the investigated hand features in children and adolescents from Bulgaria are insufficient, which does not allow us to make a comprehensive comparative analysis for the age determination of the individual left his mark on the brick. For this reason, we conducted an experimental measurement of the right hands of two children – a girl and a boy at the age of six and a half.

Table 4. Comparisons between handprint mesurments and mean hand size in children and adolescents of both sexes in Bulgaria by L7 feature

L7 Age	Boys			Girls			Village of Ploski
	min	max	mean	min	max	mean	
0	3.0	4.0	3.44	2.9	3.7	3.35	
3	4.8	6.1	5.44	4.7	5.8	5.27	
4	5.0	6.5	5.74	4.7	6.3	5.55	
5	5.3	7.2	5.99	5.3	6.9	5.83	
6	5.4	7.1	6.23	5.0	6.8	6.05	
7	5.4	7.5	6.25	5.1	7.2	6.06	
8	5.8	7.5	6.52	5.4	7.1	6.26	
9	5.9	8.2	6.79	5.8	7.5	6.65	**70.00**
10	6.0	8.3	6.99	5.6	7.7	6.81	
11	6.4	8.0	7.26	6.1	8.0	7.14	
12	6.6	9.0	7.59	6.0	8.5	7.40	
13	6.7	9.3	7.87	6.5	82	7.46	
14	6.8	9.3	8.25	6.8	8.5	7.56	
15	7.2	9.4	8.40	6.7	8.4	7.52	
16	7.5	9.8	8.51	6.6	8.7	7.59	
17	7.7	9.6	8.58	6.8	8.6	7.58	

Table 5. Comparisons between the dimensions of the handprint with the print of the right hands of two children – girl and boy aged 6.5 years

Feature	Village of Ploski	Boy 6 years 5 months	Girl 6 years 5 months
L1	141.0	145.0	135.0
L2	76.0	78.0	75.0
L3	65.0	67.0	60.0
L4	123.0	113.0	107.0
L5	60.0	57.0	50.0
L6	50.0	52.0	41.2
L7	70.0	72.0	61.7

Table 6. Value of directly measured features of handprint with standard shrinkage of the clay and comparisons with the values of the hand of both children

Feature	Village of Ploski				Boy 6 y. 5 m.	Girl 6 y. 5 m.
	Directly measured feature (mm)	Min. shrinkage 7%	Max. shrinkage 10%	Avr. shrinkage 8.5%		
L1	**141.0**	147.66	151.80	149.73	145.00	135.00
L2	**76.0**	81.32	83.60	82.46	78.00	75.00
L3	**65.0**	69.55	71.50	70.53	67.00	60.00
L4	**123.0**	133.75	137.50	135.63	113.00	107.00
L5	**60.0**	66.34	68.20	67.27	57.00	50.00
L6	**50.0**	51.36	52.80	52.08	52.00	41.20
L7	**70.0**	74.90	77.00	75.95	72.00	61.70

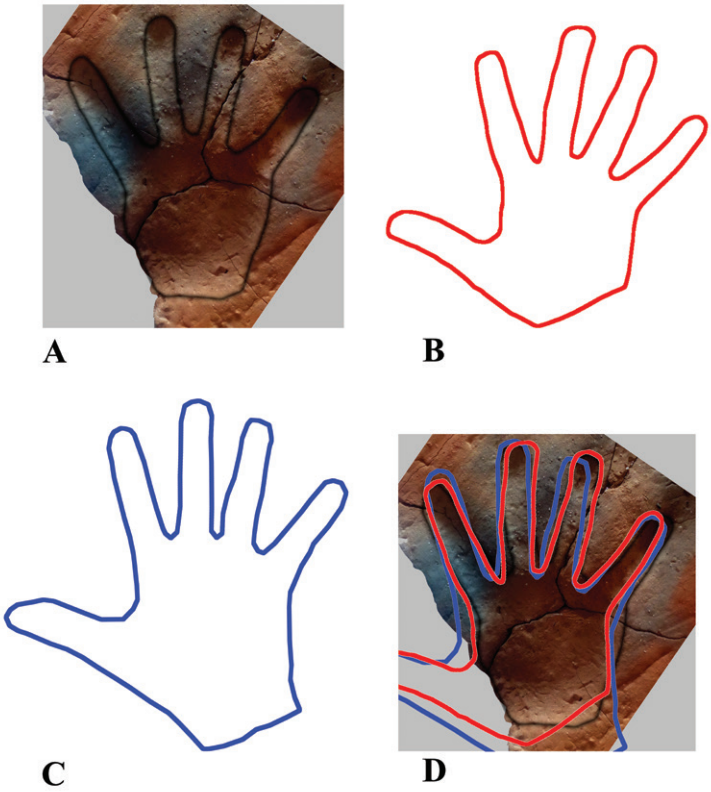


Fig. 5. Comparision of handprint from village of Ploski with the hands of two children: A – imprint of right hand in the brick from Ploski; B – right hand, 6.5 year old girl; C – right hand, 6.5 year old boy; D – The hands of two children – red (girl), blue (boy) over the imprint of the hand from village of Ploski

The results indicate that the dimensions of the handprint from the village of Ploshki fall between the hand size of both children, but is more close to the dimensions of the boy. (Table 5).

In the analysis of the results, we have to take into account also the standard shrinkage of the clay dough during firing (7-10%) (Table 6).

Thus, from the obtained results, we can conclude that the imprint of the right hand on the brick from the village of Ploshki is to a child aged between 6 and 7 (*Infans* I/*Infans* II). Because the sex differences in this age are too poorly identifiable, it is difficult to determine the exact sex of the child. The values of the separate features of the hand are closer to the boy's arm, which permits to assume that the child was a boy (?) (Fig. 5).

DISCUSSION

It is hard to say what has been the purpose of leaving all handprints in ancient time. One is sure, they provide a real view for the physic of the ancient man, his faith and beliefs, and remain a record for the future.

With this study, we would like to pay more attention to this kind of archaeological finds that will allow us to expand the demographic picture of the ancient inhabitants in the future.

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Interpreting the Archaeological Record: Archaeological Space

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ABSTRACT

The present study is based on Session AR16 entitled: 'Interpreting the Archaeological Record: GIS' held at the EAA conference in Glasgow, 2015. The particularity of the session was that each presentation asked particular questions, such as: (i) how a built space of a single settlement talks to its visitors; (ii) how the monumentality of megaliths is perceived in the field by observers both past and present in relation to their visual reproductions; (iii) how large archaeological spatial data can be managed with GIS so that they become visualized and made available for on-going and future studies; (iv) how partial and incomplete archaeological spatial data can be analyzed properly and provide coherent interpretations.

The answers to these and related questions are not straightforward. Insights are borrowed from various disciplines related to the theory of mind, psychological reactions to built environment, cognition, and art. These involve technically informed studies such as GIS and multi-dimensional statistics. This wider problematic requires from participants in the session capabilities of proper way of representation of archaeological spatial data, analytical inquiry, and theoretically informed interpretation. From this point of view the disparity of the examples in this joint paper provide a vantage point that shows the necessity of developing these different topics together for any archaeological research scheme and interpretation of already acquired data.

Key words: built environment; GIS; incomplete archaeological data

Тълкуване на археологическия запис: Археологическо пространство

Маркус Спринг, Томас Ван Ден Бринк, Свен Страуман, Цони Цонев

РЕЗЮМЕ

Настоящото изследване се основава на представените доклади на сесия AR16 „Интерпретиране на археологическия запис: ГИС", която се състоя в рамките на годишната конференция на Европейската асоциация на археолозите в Глазгоу през 2015 г. Особеността на тази сесия бе, че всяка презентация поставяше определени въпроси като: (1) как застроеното пространство на едно селище говори на неговите посетители; (2) как монументалността на мегалитните паметници се възприема от посетителите в миналото и настоящето, като се вземе предвид визуалната им репродукция; (3) колко големи могат да бъдат масивите данни, които да се управляват от ГИС, така че да могат да се визюализират и

направят достъпни за настоящи и бъдещи изследвания; (4) как частични и непълни археологически пространствени данни могат да се анализират правилно, което да води до кохерентни интерпретации.

Отговорите на тези и свързаните с тях въпроси не са непосредствени. Заемат се идеи от различни дисциплини, свързани с теорията на съзнанието, психологическите реакции към застроената среда, когнитивни науки и изкуство. Това включва компетенции от технически характер и многомерната статистика. Тази по-обхватна проблематика изисква от участниците в сесията умения за подходящо представяне на археологически пространствени данни, аналитични умения и теоретични интерпретации. От тази гледна точка, различните примери в тази съвместна публикация дават предимство, защото показват необходимостта от развитието на различни теми, които са необходими за всяко археологическо проучване и интерпретация на вече получени данни.

Ключови думи: застроена среда, ГИС, непълни археологически данни.

GENERAL INTRODUCTION

Studies of social space in archaeology play a special role in bettering the understanding of past human and social behavior. This particularity is due to the special angle of observation of spatially organized archaeological data. It stems from human ability to accumulate spatially distinct items of knowledge (Heersmink 2016). This is a process of discretization of spatially distinct items of knowledge by assigning different weights of importance to individual/social strategic aims (these are defined as "ontological categories that are potentially innate 'recipes' for construing new concepts" (Halloy and Wathelet 2014)) and may be considered as an epistemological device for initial management of incoming information from human perception (widely dependent on situations and contexts. Also this is a way of accumulation of knowledge that can be measured not that much in terms of distance and time as in terms of relations with different intensity established between the elements of past social behavior.

The real problem arises when it comes to managing large and diverse bodies of data and assembling their disparate elements into coherent and theoretically informed explanations. At rescue comes the technology – GIS and its potential to enable archaeologists to change their points of observation which may switch from past to present and vice versa. Such an approach leads inevitably to fragmentation of archaeological knowledge into different study domains with different theoretically and technically informed levels. This paper illustrates this fragmentation by shifting the observation points both of the researchers and of the past and present-day observers. The first part represents the ways a past observer conceptualizes the social space of a Bronze Age settlement. The second one uses both past and present observation points to present the past and present comprehension (rational and aesthetic) of megalithic monuments in the Netherlands. In both cases theoretical approaches are built-in and illustrated by particular case studies. On the side of novel technical applications in this kind of studies the next part presents how to use GIS for organization of spatial data to accurately assess the social efficiency of settlement organization of the past. The last part accounts for the particularities of archaeological spatial data and the ways to improve their interpretative features.

Although this paper may seem patchy in terms of "cultural-historical" uniformity it may be useful in illustrating how different approaches can be integrated into theoretically and technically informed studies of the past.

HOW SPACE TALKS

Markus Spring

Introduction

When people come back from trips, they often talk about their spatial impressions in foreign places. Towering cathedrals, Medieval cities with narrow lanes or wide boulevards leading to a palace may be lasting memories. These impressions illustrate that we are constantly influenced by the space

around us, whether it is the natural one or the built environment of our cities. Built space and how spatial layouts are arranged influence our feelings and reactions.

There are different ways built environments influence human behaviour (Table 1). These mechanisms function physically and according to social norms or obligations. Added to this, there are also intangible aspects such as colours, smells and sounds that can trigger human reactions (Montello 2007).

However, there are certain cultural differences in how spatial aspects influence human behaviour, which are also in today's societies not yet fully understood. Furthermore, additional filters reduce what is left from built environments in archaeological records. It is therefore impossible to reconstruct psychological reactions of individuals in the past. Still, it might be possible to look at prehistoric settlements from this perspective.

Methodology

This short sketch is not a journey into human's mind but likes exploring different ways to describe a prehistoric traveler's spatial experience in a foreign settlement. It employs methods of Space Syntax (Hillier, Hanson 1984; Hillier 2007) to illustrate where travellers could have gone or what they could

Table 1. Psychological mechanisms (Montello 2007, iv-02).

Sensory access	What can be seen, heard, etc.
Attention	What is looked at, listened to, etc.
Memorability	What is remembered, what is forgotten, etc.
Behavioral affordance	Where one can walk, eat, etc.
Affect	Mood, comfort, stress, fear, aesthetics, etc.
Sociality	Pedestrian flows, noise, eye contact, social distance, etc.

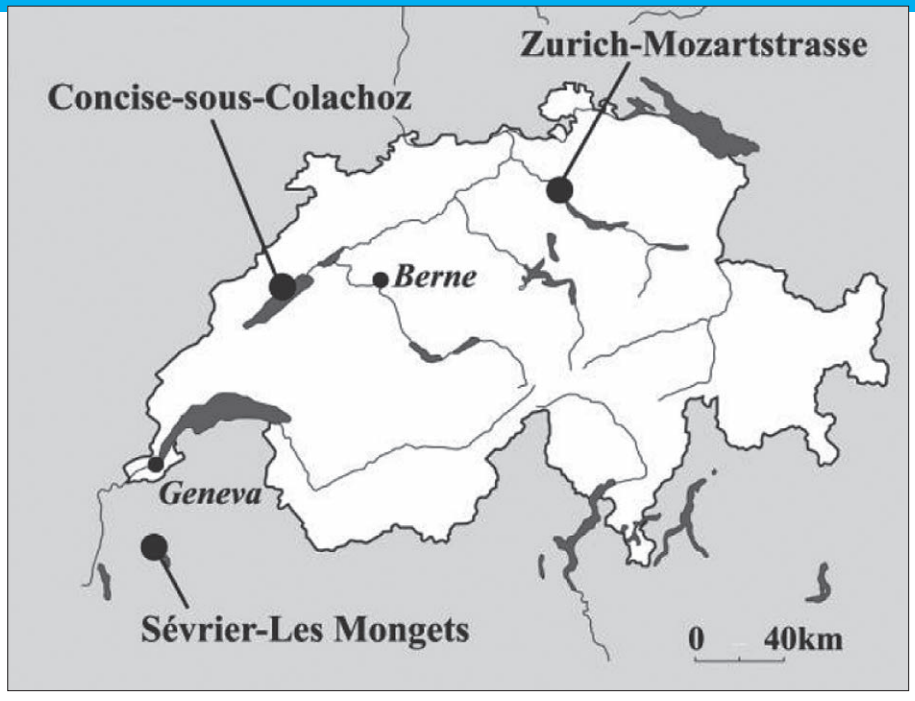


Figure 1. Location of sites mentioned and modern cities of Berne and Geneva, (author Markus Spring).

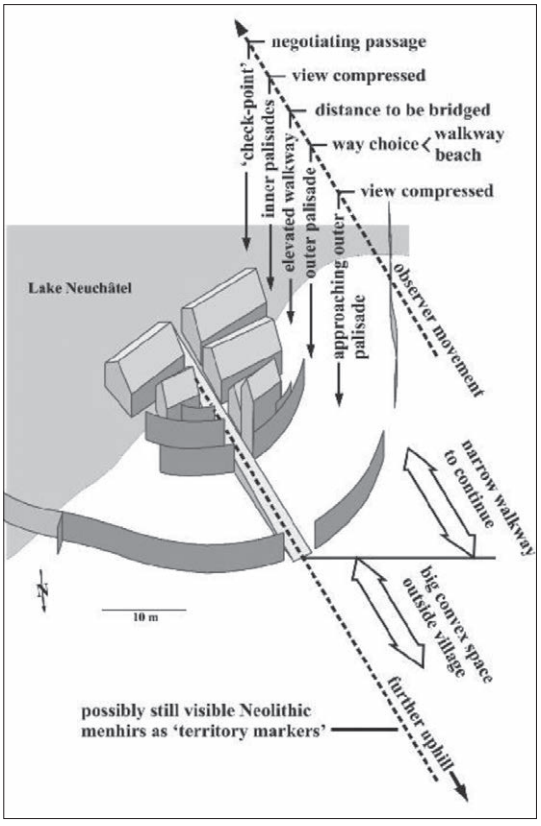


Figure 2. Approaching Concise-sous-Colachoz, phase E11 (1801-1773 BC); reconstruction based on Winiger&Burri-Wyser, 2012: 76, Fig. 8.

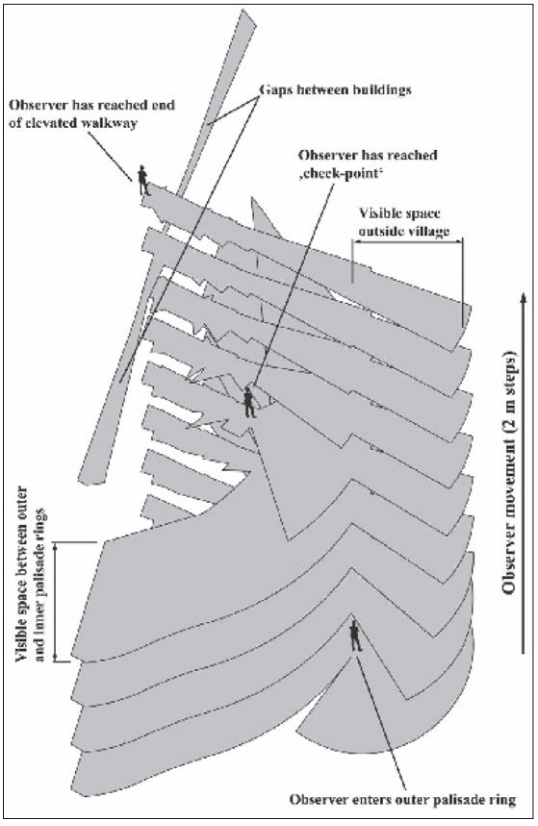


Figure 3. Concise-sous-Colachoz, phase E11. Minkowski model with observer moving along elevated walkway. (author Markus Spring).

have seen when visiting a 'foreign' village. As examples, the paper looks at Concise-sous-Colachoz and Zurich-Mozartstrasse, two Early Bronze Age lakeside settlements in today's Switzerland (Figure 1).

Concise-sous-Colachoz

Concise-sous-Colachoz is located at Lake Neuchâtel in western Switzerland. The site extended over more than 5'000 m^2 and its excellent data base has allowed individualizing more than 25 villages spanning from 4300 to 1570 BC (Winiger, Burri-Wyser 2012: 21). This paper will focus on the first two of three well preserved Early Bronze Age phases tree ring dated between 1801 and 1570 BC.

Concise-sous-Colachoz, phase E11 belonged to the Aare-Rhône-Group of the Rhône Civilisation. It started out as a small village with a handful of houses oriented parallel to the shore line and perpendicularly to a central axis (Figure2). An elevated walkway connected the buildings to higher ground. The village was encircled by a 3m high outer palisade and an additional set of concentric inner palisades. There were one or two small structure(s) next to the inner palisade, not seen as normal house(s) but probably more as a 'check-point' controlling access to the living quarters (Winiger, Burri-Wyser 2012: 76-77).

When approaching Concise-sous-Colachoz from land, visitors faced a number of aspects that may have influenced upcoming interactions with inhabitants. Palisades repeatedly compressed and released their view; spatial qualities were different outside or inside the village and distinct physical distances had to be bridged to meet locals (Figure 2).

To analyse the 'intelligibility', the way a visitor may have made a map of a settlement in his mind (Hillier, 2007: 92-98), a Minkowski model can be generated (Figure 3). This space-time model shows in its horizontal plan the space seen at different stages of an arbitrary given path, in this case when moving from the outer palisade to the end of the elevated walkway. The model reveals that a visitor

to Concise-sous-Colachoz, phase E11 never lost sight of his starting point at the entrance of the outer palisade. This may have helped to understand the spatial layout of the village.

Interesting to the first phase of Concise-sous-Colachoz is that a village with very similar spatial layout can be found about 150 km further south-west in contemporaneous Sévrier-Les Mongets at Lake Annecy in the Savoy Alps. Also Sévrier-Les Mongets had a central access way, was encircled by concentric palisade rings and houses were built perpendicularly to the central axis. It too belonged culturally to the Rhône Civilisation.

Zurich-Mozartstrasse

Intriguing spatial changes occurred in the lakeside dwelling of Zurich-Mozartstrasse under Zurich's opera house. The site was discovered in 1981 during construction works and excavated under immense time pressure. The chronological basis is a complex combination of radio carbon and tree ring data.

The village started out as a handful of houses loosely clustered within a palisade ring (Figure 4a). The justified permeability graph ('j-graph') of early phase AA (Figure 4b) illustrates how different parts of the open space within the village were interconnected. Its rhizomorphus form indicates that despite houses being built and others thorn down, the interconnect ability of subspaces offered a multitude of interaction points. This is also reflected in the 'ring' form of people movement simulated by an agent based analysis (Figure4c). However, after a short hiatus radical spatial changes happened.

In phase B, nine houses were built in three parallel rows separated by narrow lanes. Even though village entrance and passages through different palisades cannot be identified, a split into living quarters and surrounding court yards is noticeable (Figure 5a).

The j-graph is 'deeper' with house no. 6 and the only building entrance found at the least accessible level (Figure 5b). Also visible are different cul-de-sac. When simulating pedestrian movements, a further partition within the innermost part becomes obvious. Most potential interactions occurred

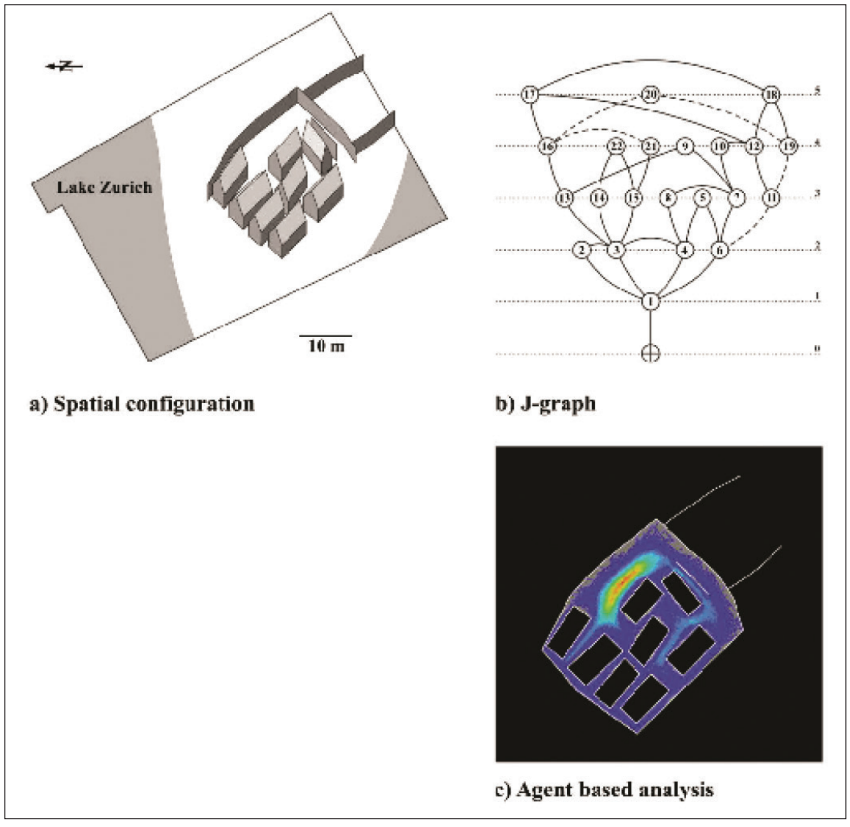


Figure 4. Spatial layout (a), justified permeability graph (b) and simulated people movement (c)in Zurich-Mozartstrasse, early phase AA (approx. mid 20th century BC). (author Markus Spring).

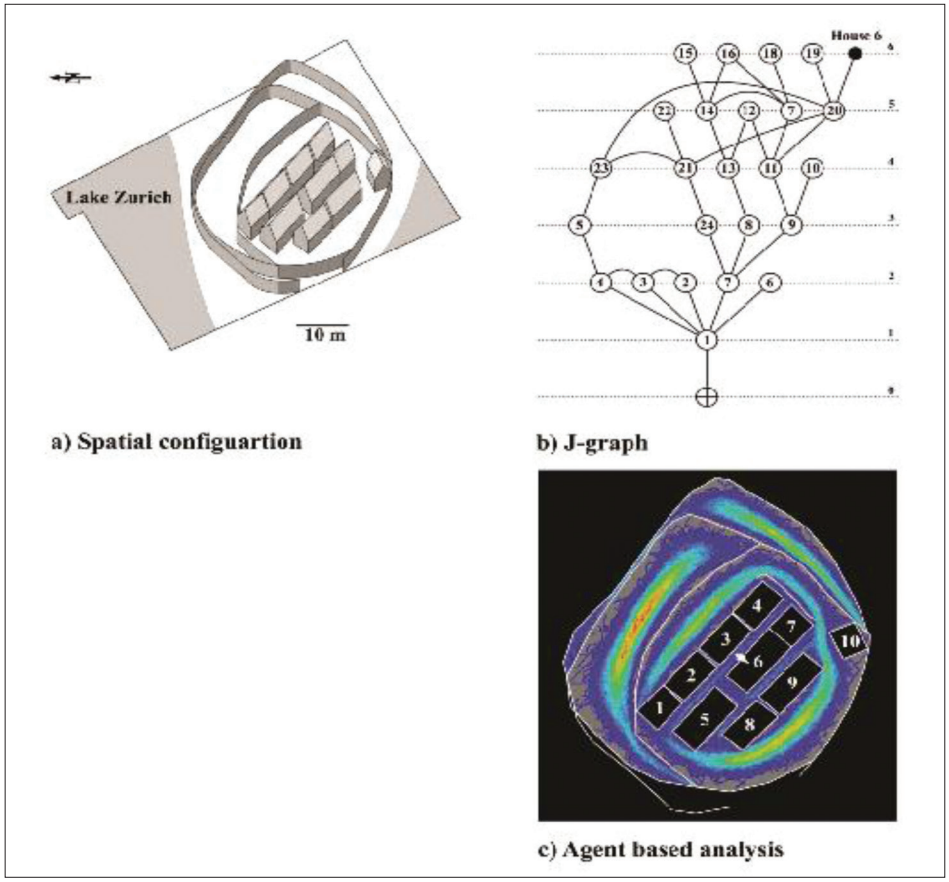


Figure 5. Spatial configuration (a), justified permeability graph (b) and simulated people movements (c) in Zurich-Mozartstrasse, phase B (end of 20th century BC). (author Markus Spring).

along the inner palisade circle (Figure 5c; yellow and red dots). And unless houses no. 1 to 4 had their entrances towards north-east, none of the buildings was accessible without passing house no. 10. Even though the function of this house is unknown, overall 'more channelled' people movements now governed life which may also have influenced a visitor's experience in Zurich. This spatial segregation accelerated even further in phase C1A.

Striking feature in phase C1A was a 200 m^2 wooden platform built most likely as substructure of houses (Figure 6a). It was encircled by a double wattle wall and additional palisade rings (Schmidheiny 2011: 85-86).

Pedestrian movement simulation reveals likely interactions in the court yard around the living quarters in the centre (Figure 6b). Interactions within the living quarters cannot be precisely reconstructed due to missing palisade sections but may have been fewer.

Following a path from the suspected village entrance along the locations with most interactions, the Minkowski model (Figure 6c) lacks any for a visitor's memorable structures. This rendered Zurich-Mozartstrasse, phase C1A less 'intelligible' (Hillier, 2007: 92-98). Visitors would therefore have experienced this phase as socially more segregated from its surrounding than previous ones.

The end of the wooden platform was marked by a fire. Circumstances of this incident are unclear. Imaginable is that parts of the surrounding fence were set on fire after houses on the platform had been dismantled (Schmidheiny 2011: 90).

However, even though the interpretation of structural remains and palisade alignments of later phases causes problems for further analysis, the spatial configuration of Zurich-Mozartstrasse had become rectilinear and less segregated with new buildings constructed around the re-used platform (Schmidheiny 2011: 66-67).

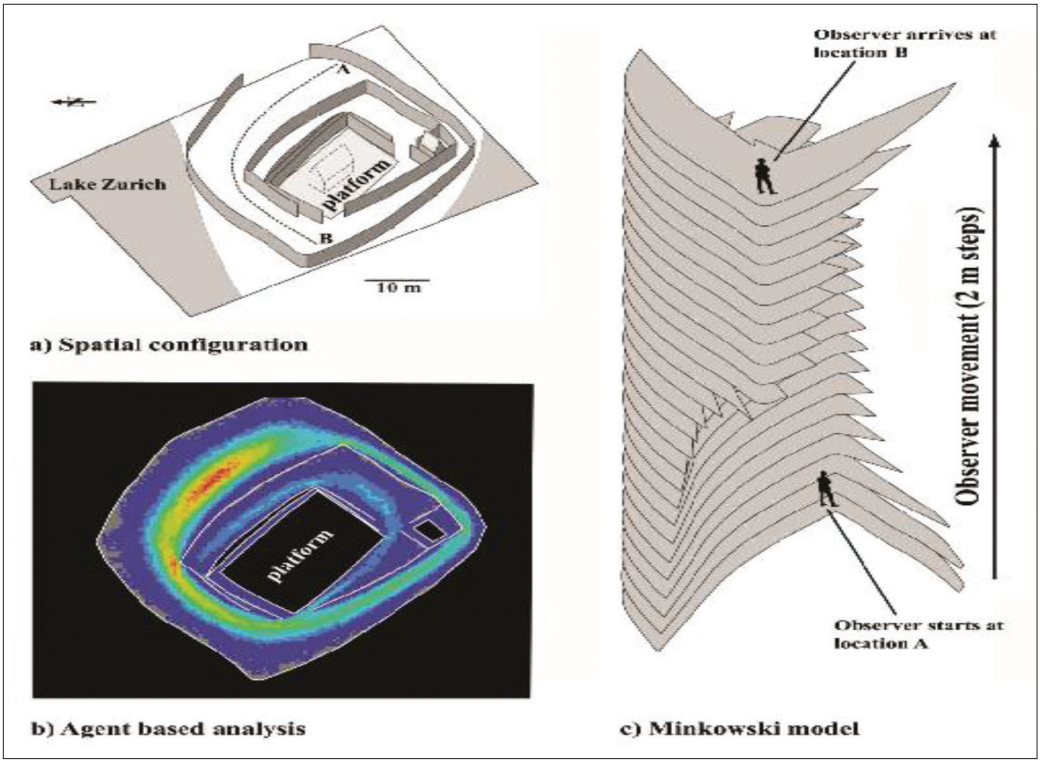


Figure 6. Spatial configuration (a), simulated pedestrian movement(b)and Minkowski model(c) of Zurich-Mozartstrasse, phase C1A (approx. 2nd half of 19th century BC). (author Markus Spring).

Discussion

Even though this quick comparison only allowed a glimpse at Concise-sous-Colachoz and Zurich-Mozartstrasse, there are intriguing differences between these two villages.

The existence of Concise-sous-Colachoz, phase E11 and Sévrier-Les Mongets as two contemporaneous settlements with very similar spatial layouts is striking. Should it not be pure coincidence, is it possible that decision makers able to mobilise resources to build these settlements had a 'shared label', a common understanding, of how these villages should be experienced by visitors?

The spatial layout of Concise-sous-Colachoz also finds similarities already in Neolithic villages around neighbouring Lake Bienne (Hafner 2012). Therefore, the spatial configuration of these two western sites was not unfamiliar there.

In contrast, the strong spatial segregation in Zurich-Mozartstrasse, increasing from phase B to C1A, was something 'strange' in an environment where houses were built in less regular alignments than in the two western sites. Most settlements here had loose rows of houses still enabling human interactions taking place on different paths within the villages.

Linking the short duration of the wooden platform in Zurich-Mozartstrasse, phase C1A to human perception discussed above may be too farfetched. It is further not possible to draw any conclusions from where the idea for spatial changes in Zurich may have come from. However, they occurred in Zurich quickly within two or three generations and most likely did not go unnoticed by its environment.

Comparing these two sites, it could be asked whether the success of a settlement also depended, apart from economic or military powers, on how it was perceived by its environment and whether it was seen by visitors as fitting into it or being considered a treat. The situation may be comparable to many modern luxurious housing developments planned as 'gated community' but causing opposition in their existing neighbourhoods.

VISUAL CULTURE AND ITS INFLUENCE ON SPATIAL BEHAVIOR

Thomas van den Brink

Human beings experience their environment through all their senses: through their eyes, ears, nose, skin and tongue. Hence, the impression of their surroundings is composed of various types of information, including light, sound, scent, touch and flavor. In a new or hostile situation, this combination can be vital for survival. However, with regard to everyday circumstances, the influence of some senses on our geographical behavior is larger than others. The things you hear and see are, for example, more dominant than information acquired from taste.

Although there is obviously more to say about the working of the (instinctive) mechanisms per sense, the focus here will be on the visual dimension. That is because over the last millennia, 'the visual' has become a separated and essential sphere within western culture. It is a process that is characterized by the transmission of the general mental process called imagination onto the physical reality of flat surfaces in the form of images (such as paintings, engravings, photo's etc.). Because the number of images produced in this way is enormous, and the period in which they were created extensive, a distinctive visual culture came about. As such, images are on the one hand singular examples while on the other hand part of a comprehensive visual culture.[1]

The argument to analyse landscape images to understand geographical behavior becomes clear when the nature of the visual history is contrasted with that of other sensory histories. Compared to the history of visual culture, the history of, for example, music is much more interrupted. The main reason for this is that sounds do not persist without the reproduction, which was true until very recently. Images can however survive without performance over very long periods of time, although reproductions have strengthened their presence. This has led to their exchange between people over time and space. It also led to the accumulation of images, regardless of loss of individual pieces.

To analyze the relation between spatial behavior and a visual culture, images are thus the first objects to investigate. To do so, an approach that was inspired by the work of the famous art historian Ernst Gombrich is central for this case study. His theory originates from three important insights, namely: 1) each image is produced by specific techniques, each with its own possibilities and restrictions; 2) every image is part of a visual culture; and 3) the visual culture, in terms of style, creates a mental set which functions as a conventional filter for the artist as well as the spectator. To comprehend this statement, 'technique' should be interpreted broadly, namely: the combination of materials, instruments, knowledge and skills that are used to create an image. Central to his way of thinking is the cultural determined and appropriated 'mental stereotypes' of things (Gombrich 1962, 61). These schemata are conceptualized as fluid forms with only basic characteristics. Nevertheless, they are crucial for us to recognize objects on images but they also influence the way images are (re) produced (Gombrich 1962).

His theory was tested by applying it onto a large amount of images of a Dutch landscape object called *dolmen* (see figure 7 for some examples). The images were analyzed based on the question: which formal similarities between multifarious images of the same object can be distinguished when looked at a large collection, and how can their obvious differences be explained? The goal of this approach was to assess what the mental stereotype of the dolmen is and how this influences the corpus of dolmen-images. In other words, are we dealing here with schemata or, if one prefers, with a convention of a visual culture?

Second, a visual culture can influence the spatial behavior of its members in the real landscape. In this respect, the characteristics of the stereotype are compared with the real behavior of people in space. Especially how it influences the way people approach landscape objects they knew previously only from images and that they themselves want to make a picture of.

The analysis of the corpus of images depicting dolmens reveals a pattern that hints at the core visual characteristic of a dolmen. This core can be described as follows: 'its image consists of at least

[1] This text is a summary of a paper by Thomas van den Brink, to be published in 2017. It concerns one of Ernst Gombrichs interpretations of images within the context of art history applied to the images produced of dolmens.



Figure 7.A Selection of the images that were produced of dolmens and that were included in the analysis: photo's, engravings, map symbols and paintings: (Tilburg, 2006), 170. And: Historische Atlas Drenthe Chromopografische kaart des Rijks 1:25.000, (1989), 1.;Toeristische Sleewijkkaart 1.120.000, (±1920).;Atlas van de geschiedenis van Nederland, ingedeeld vloggers de vensters van de Canon van Nederland, (Groningen, 2008), 6.; ANWB / VVV Toeristenkaart Drenthe 1:100.000, (2003).;Hottinger map (1773-1794), in: Versfelt, 45.;ANWB Topografische atlas Drenthe 1:250.000, (2006), 1., W. Roelofs, 'Het Hunebed van Tynaarlo', 1861, watercolour, 30,7 x 49,5 cm, Teylers Museum, Haarlem.

three objects where one of them is on top of the others'. This has two implications. First of all, that it can consist of more than three objects, but never less. Second, the positioning of these objects is crucial: at least one of them must be on top of the others.

The differences between individual images can be explained largely by the techniques used to create them. It influences the final appearance of the image extensively if it was engraved or a shot as a photo. Furthermore, the individual variation could, in theory, be explained by the freedom the maker has made use of, as a convention does not prevent someone to deviate from it. This however could not be tested empirically due to a lack of information about the maker's intentions.

The pattern does suggest that these stereotypes are shared as if the producers had an idea beforehand how such an image should look like. As such, it governs the production-process of individual images. This is something that seems to be in line with the locations people chose to make photos of dolmens from as archeologist Yftinus van Popta convincingly showed in his analysis (Figure 8).

However, the spatial behavior of people in the immediate vicinity of these objects is also strongly related to the physical context. Roads, obstacles and potential background vegetation, all play a role in the position the photographer chooses for his picture. Thus, it seems that the relation is quite complex (Y. van Popta 2011).

Nevertheless, it seems that the before mentioned stereotype governs us at least in two ways. On the one hand, it enables us to recognize an image as that of a dolmen despite its singularity. This is done by the comparison of the image with the mental stereotype. On the other hand, it directs us by influencing the reproduction of dolmen images. Together, these mechanisms lead to a complex reproduction cycle of images (see Figure 9).

Simplified, this cycle would have three phases. Firstly, a person is exposed to a large amount of different images about an object called 'dolmen' – often before seeing one in reality. These images are as diverse as dealt with in this paper. Secondly, all these images are reduced in the mind to a fluent, mental stereotype of a 'dolmen'. Thirdly, when this person makes an image of a dolmen, there is a big chance he will make it in line with his mental stereotype. This step is complicated by the fact that



Figure 8. Point-of-view analysis of pictures taken of a dolmen nearby the village Havelte plotted on Googlemaps.com (Y. van Popta 2011).

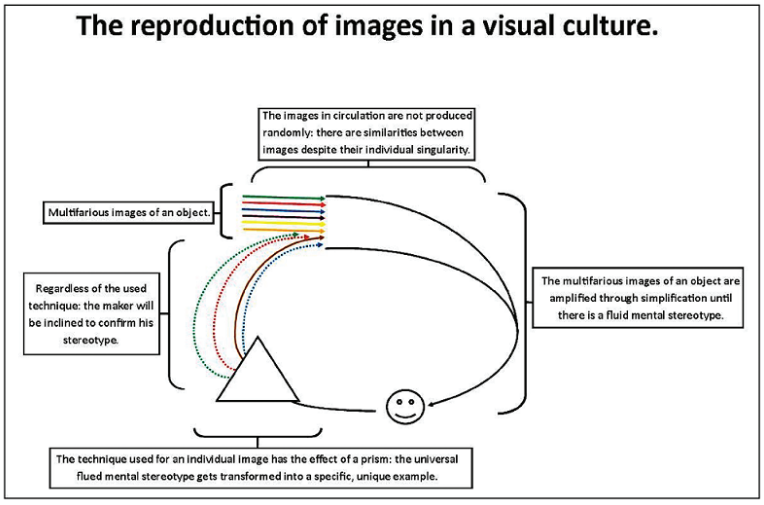


Figure 9. The reproduction-cycle of images in a visual culture (author Thomas van den Brink).
The Dutch landscape artifact called dolmen was the central focus for the current exploration. I was especially interested in how a visual culture exercises influence on the approach its members choose towards the object in the real landscape. As only a few people outside the Netherlands will have seen the specific object in real life, I will shortly conclude with a more international example to show how this theory and methodology could be applied in future cases. The example relates to a world-famous land mark:the Eiffel Tower in Paris. It is used to highlight one of the discussed effects: the distance between the object and the location where most of the photos were made.*

the chosen technique works as a prism: the fluid, cultural determined mental stereotype becomes a specific singular sample. Nonetheless, by doing so, the person contributes to the never-ending pool of dolmen-images. As such, the cycle starts again as this image is part of the collection of images that influence the mental stereotype of others.

As such, mental stereotypes and techniques are equally important but also each other's opposite. The first one leads to convergence (images of the same object looking more similar) while the latter results in divergence (images of the same object looking less similar).

During its lifetime, perhaps over a million images were made of this tower. When these images are compared, it will come forward that there are some important similarities. One of the common

* As the Eiffel Tower is symmetric, it is not suitable to illustrate differences in perspective, as was clearly the case for the dolmen photos.

denominators could be that this landmark is depicted in its entirety. If so, this will have a direct influence on all those persons that are familiar with these images and visit the tower afterwards for the first time. The first over

Whelming experience is the gigantic size of the object: when you approach it, it is almost impossible to see it at a glance from base to top, like you were used to on images.

More specific, when a person plans to make a photo that meets the requirements of his or her mental stereotype of this tower, he or she shall move away from the object until it is possible to make a photo with the tower as a whole. As such, the huge size of the Eiffel Tower enforces a minimal distance to make these kinds of photos. Consequently, as this individual behavior is influenced by a convention it is likely that these choices lead to some kind of collective spatial behavior. When one would plot the locations of all these images around the actual tower, it is thus expected that it would reveal a very clear area where the majority of photos were made.

INTERPRETING THE ARCHAEOLOGICAL RECORD WITH THE AID OF GIS – INSULA 30 AT AUGUSTA RAURICA (SWITZERLAND)

Sven Straumann

Introduction

Within the research agenda of a PhD project at the University of Basel, it is for the first time that GIS has been employed from the start of a post-excavation analysis of the archaeological materials from Augusta Raurica. The project allows gathering valuable experience, both in making available voluminous excavation documentation and in handling this data using ArcGIS software (Straumann 2015).

Augusta Raurica

Once part of the north-west provinces of the Roman Empire, this Roman colonial town lies in the centre of Europe, some 10 km east of Basel, in Switzerland. It was situated at an extremely important transport node and enclosed an area of around 100 hectares, of which about 60 hectares was built up. Augusta Raurica remained the largest and most important settlement in the region for approximately three hundred years (Pfäffli 2010; Berger 2012).

GIS in Augusta Raurica

Although Augusta Raurica has been excavated and studied since the Renaissance, the history of GIS in Augusta Raurica is relatively recent. It developed out of a CAD-supported excavation inventory. We were able to combine the GIS data with the attributes of the archaeological database, IMDAS-Pro.

Since early 2013, the archaeological overall plan of Augusta Raurica has been part of GeoView BL, the new, online interactive map of Canton Basel-Landschaft (www.geoview.bl.ch) (Brombach 2013).

As GIS has become increasingly well-established in Augusta Raurica, its areas of application have grown (Brombach 2010). Today its main uses are: documenting the history of the city, managing excavation results and investigations, and supporting the overall research activity.

The Insula 30 Research Project

Centrally situated in the Upper Town of Augusta Raurica, the block known as Insula 30 was completely excavated between 1959 and 1962 (Berger 1967). Insula 30 is so far the only insula in Augusta Raurica to have been excavated in its entirety. The insula has never been the subject of a comprehensive analysis. Almost the entire area of 3,395 square metres was excavated down to the underlying natural ground, allowing not only the floor plans of the stone-built phases of the town, but also the remains of its timber-built phases of the early 1st century AD to be recorded. As a result, the Insula represents an extremely valuable archaeological source, with great research potential.

Analysis using GIS

A fundamental challenge when analysing the results of archaeological excavations is finding the most efficient way of making available the numerous data and source materials. After the excavation documentation has been initially tidied and archived, it can often be years, sometimes even decades, before it is studied and analysed in detail. This means that, although neatly stored and catalogued, the information on the finds, features and excavation results must first be brought together in a readily available form. It is particularly difficult for a researcher who has not been personally involved in an excavation to link up archive materials stored separately according to media type. It is crucial when analysing excavation results to be able to establish the spatial relationships between structures and then to characterise each structure using every available source of information. Depending on what you want to discover about a particular feature, the required sources will be stored in quite different locations within the site archive. To work efficiently, you will therefore need a strategy which, with the least possible effort, will provide you with an overview of the extensive excavation documentation. Traditional, well-tried solutions include, for example, creating lists and concordances, and photocopying and 'patching together' drawings and photographs. Using these, you can eventually work out plans of the various construction phases. In the end, once the analysis is complete, these are digitalised using drawing software and finally published.

For the analysis of Insula 30 the used procedure turns the traditional working method on its head. All the structures recorded in the original documentation were entered into Augusta Raurica's Geographic Information System at the very outset, by scanning in the original records and then geo-referencing them using the GIS software. The various components of the documentation were thus digitalised before the actual evaluation itself began. The task of producing drawings, including ongoing adjustment and correction, is thus done by the researcher himself, who minutely sifts and evaluates all the records. As a result, there is no need to prepare provisional sketches by hand and "patch together" individual drawings. At the same time as the data for the structural features are being entered into the spatial database, lists are generated using the so-called "attribute tables". Thanks to the GIS facility to link these lists directly with the spatial information, the data can then be used in very versatile ways for different types of searches. Also, once the structural features have been put into the GIS, to-scale plans can be produced at any time and almost at the touch of a button. So the preparatory work of making the excavation documentation available already produces some of the essential components of the final product, such as constructionphase plans, etc.

The chosen strategy not only saves the laborious re-working and incorporation of provisional plans, but also, and more importantly, builds up within the GIS the database which will form the basis for the evaluation. Instead of the knowledge accumulated about individual structural features only being input into the GIS at the end of the research project, it is added as the work progresses, so that the data-set is constantly growing. For the researcher, the GIS software serves not just as an instrument for analysis but first and foremost as a working tool.

In addition, the basic plans accumulated in the GIS and the huge wealth of information stored in the attribute tables is both immediately available and constantly updated for use by the research community.

Methods

Right at the start, all the excavation drawings were scanned into the GIS, geo-referenced and vectorised. At the same time, supplementary data were entered in the so-called 'attribute tables', i.e. the database section of the GIS. An overall map of all the excavated and documented features was thus created. This forms the basis for the analysis and can be constantly updated with further information from the database as the work proceeds; for example, construction phases can be allocated to the mapped structures. It is from the GIS attribute tables that the essential data for the analysis are added to the spatial information. The countless details of data, assignments, measurements and remarks in the attribute tables can be searched at any time or used to generate maps of various types.

Mapping

For archaeological analysis, it is essential to determine the spatial locations of the individual features documented in the excavation records. This is indispensable if the various sources of information are to be linked up. Here too, the GIS are of practical help. For example, the positions from which photographs were taken during the excavation can be mapped in the GIS and linked directly with scans of the photographs themselves (Figure 10). Clicking on a 'photo spot' on the map will thus open the corresponding photograph in a separate window. There is no need to spend time hunting for the analogue photograph in the archive folder.

The same technique can be used for section plans. Clicking on the desired section opens a dialog box where you can select either the section drawing or its description.

As these examples show, the GIS offer a simple way of linking all sorts of documentation components with their spatial locations. The preliminary work of scanning-in and entering the data rewards the user with quick and flexible access to the documentation.

Once the data have been stored in the GIS, many other ways of using them to simplify the archaeological analysis open up.

Density Mapping

The GIS system offers exciting possibilities for analysing not only features but also finds. Whereas mapping finds assemblages from earlier excavations in Augusta Raurica used to be a rather laborious procedure, with GIS it becomes a fascinating process, thanks especially to the many different ways in which the stored information can be used. Once you have entered them in the GIS, it is a simple matter to search for assemblages of finds.

For example, from their upper and lower boundaries, the volumes of find complexes can be calculated. From these, in turn, interesting and revealing density maps can be created. Moreover, it is possible to access the archaeological finds database directly from the GIS database. For example, with a single click, a researcher can see which finds are catalogued under a particular find-assemblage number.

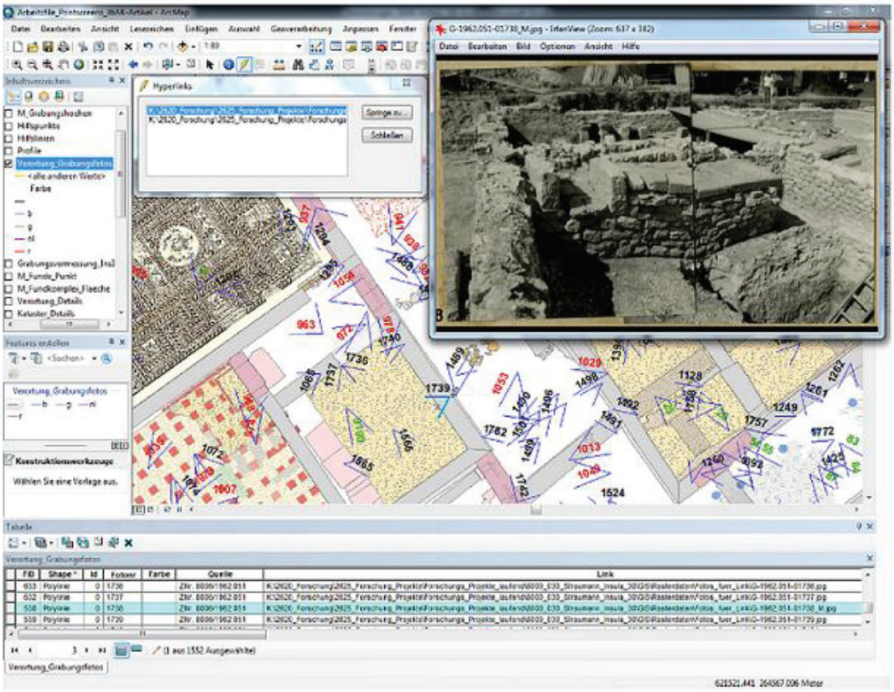


Figure 10. Digital Photomap in ArcGIS (Screenshot).

Of course, you can also simply create find maps with GIS. It takes very little trouble to produce maps with a great deal of information; you might choose, for example, to include the inventory numbers of finds. To help you to form a mental picture of the spatial relationships between finds, you might also create a three-dimensional representation.

Conclusion

These examples show that an analysis supported by GIS, especially in the case of excavations with mainly analogue documentation (for example, old excavations) brings many advantages. Of course, the amount of data available from older excavations does not usually reach the levels generated by an excavation today. Nevertheless, the documentation offers a wealth of information in various analogue media. Digitising the records and integrating them into the GIS system allows the potential of old excavation documentation to be much better and more efficiently exploited.

As a spatial database, the Geographic Information System allows large quantities of data to be quickly accessed. Especially for researchers who have not been personally involved in an excavation, this provides a relatively quick way of obtaining a (spatial) overview (Figure 11). Individual sources of information, such as photographs and drawings, are linked with one another and can be located in three dimensions.

The GIS can be used at any time to search for information, even while the data is still being entered, but especially during the actual work of analysis. It takes only minutes, for example, to search for particular structures or to extract calculations of areas. The whole treasury of data stored in the attribute tables is available to be searched or to generate maps of every type.

Finally, an essential aspect of this method of analysis is its continuing usefulness on many levels. Apart from the "return on investment" for the researcher himself other researchers also benefit. The digitally captured sources and data stored in the GIS are readily, transparently and reproducibly available for anyone in the research community to use for his or her own investigations, and to supplement with further data.

Even though the advantages of the method illustrated here are undoubtedly convincing, there still remains the question of whether the return justifies the investment. Whether using GIS makes sense or not must be decided on a case-by-case basis, depending on the size of the excavation to be evaluated and the questions to be answered. If a project involves studying relationships between excavation results from across a large area – an entire insula in this example – GIS will always be a huge and lasting asset. In excavations which need to be seen as part of a larger whole, linking up with the surrounding features is essential. If all the structural features will finally be stored in a GIS system anyway it makes sense to work with GIS right from the start.



Figure 11. Three-dimensional model of Insula 30 over the topographical model

An archaeological evaluation using GIS offers an attractive alternative to traditional methods. In the end, however, every researcher must decide for him or herself whether it represents a feasible approach for the project and research questions involved. The success of the methods selected for the pilot project on "Insula 30" can only be finally judged once the analysis is complete. GIS opens up new prospects, not only as a working tool for archaeology in general, but, in particular, as an aid for the efficient and ongoing evaluation of excavation results.

PROPERTIES OF ARCHAEOLOGICAL SPATIAL DATA AND THEIR IMPACT ON INTERPRETATION OF ARCHAEOLOGICAL MATERIALS

TsoniTsonev

Introduction

There is no doubt that archaeological spatial data are partial and incomplete. Yet traditional archaeological interpretation schemes are constantly trying to reconstruct invariant relationships understood as perpetuation of a given archaeological culture based on symmetry of presence/absence models of archaeological artifacts, structures, monuments. The theoretical expectations of this kind are that the frequency of occurrence of a given category of artifacts when counted at a large number of sites in a region will outline a center and periphery that will characterize their spatial distribution. This leads to research practices of taking into consideration only the major and most numerous artifacts, structures, and monuments. In most cases interpretations take the form of a linear evolution of a chain of normally distributed archaeological categories. Thus the concept of uniformity of archaeological record gains greater significance at the expanse of its diversity.

A question arises how explanation of partial and incomplete empirical facts contributes to archaeological interpretation. In order to answer it I will provide a novel approach to analyses of these data and will illustrate it with an example. The latter contradicts traditional understanding that the evolution of the flint-knapping techniques and toolkits in the Neolithic in Bulgaria follows "cultural regress" (Gatsov 1992). The results of my analyses suggest that the combination of new subsistence strategies, based on the study of macro-plant remains from a sample of early Neolithic sites (Popova 2009) with the increasing on-site craft specialization, develops both cognitive abilities and learning practices that lead to changes in the entire lifestyle of the early farming communities in the eastern Balkans.

A relational approach to partial and incomplete archaeological data

Generally, the archaeological record consists of disparate events that have little or no direct relations between them. This assumption suggests that particular archaeological categories cannot be expected to be normally distributed along a time-period or within a social-geographic space. I will illustrate this by analysis of the presence/absence (non-symmetrical) pattern of macro-plant remains from a sample of early Neolithic sites in Bulgaria (Figure 12).

For this purpose I constitute a presence/absence data-matrix where I score the presence of a given plant species at a given site by 1 and its absence by 0.01(Table 2).

Thus arranged the data-matrix itself shows that the data cannot be approximated by Normal distribution. This is why a correspondence analysis based on uniform probability distribution is applied. The theoretical expectations are

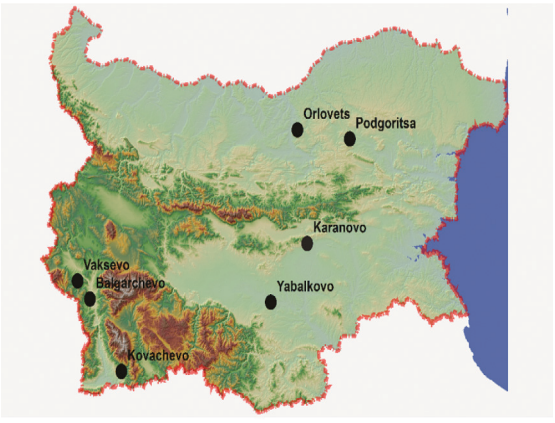


Figure 12. Map of Bulgaria with the early Neolithic sites involved in this study.

Table 2. Data-matrix with the distribution of the identified plant species across the early Neolithic sites.

Plant species	Balgarcevo	Vaxevo	Kovachevo	Orlovets	Jabalkovo	Karanovo
1. *Triticum monococcum*	1	1	1	1	1	1
2. *Triticum dicoccum*	1	1	1	1	1	1
3. *Triticum aestivo/durum*	0,01	1	1	0,01	1	1
4. *Hordeum vulgare*	0,01	1	1	1	1	0,01
5. *Hordeum vulgare v.nudum*	0,01	0,01	1	1	1	0,01
6. *Secale cereale*	0,01	1	0,01	0,01	0,01	0,01
7. *Panicum miliaceum*	0,01	0,01	1	0,01	1	0,01
8. *Avena sativa*	0,01	0,01	0,01	0,01	1	0,01
9. *Lens culinaris*	1	0,01	1	0,01	1	1
10. *Vicia ervillia*	1	0,01	1	0,01	1	1
11. *Vicia sp.*	0,01	0,01	0,01	0,01	1	0,01
12. *Pisum sativum*	1	0,01	1	0,01	1	0,01
13. *Latyrus sativa*	0,01	0,01	1	0,01	0,01	0,01
14. *Pistacia terebinhus*	0,01	0,01	1	0,01	0,01	0,01
15. *Cornus mas*	0,01	0,01	1	0,01	0,01	1
16. *Vitis vinifera ssp. sylvestris*	0,01	0,01	1	1	0,01	0,01
17. *Prunus* sp.	0,01	0,01	1	0,01	0,01	0,01
18. acorn –*Quercus* sp.	0,01	0,01	1	0,01	0,01	1

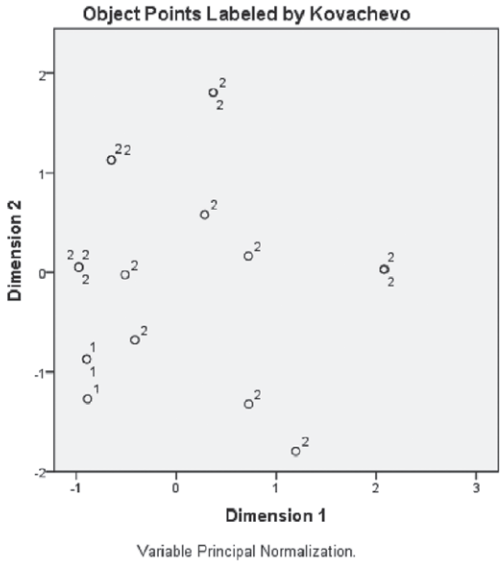


Figure 13. Distribution of variables '1-absence' and '2-presence' within the identified in the Kovachevo site plant species.

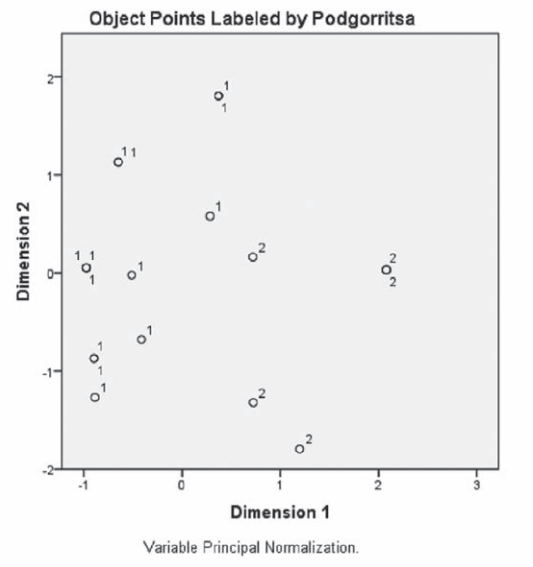


Figure 14. Distribution of variables '1-absence' and '2-presence' within the identified in the Podgoritsa site plant species.

that each plant species has particular frequencies across the sites. This provides the possibility to study the relational character of the presence of the identified species and to approximately reconstruct some of their evolutionary patterns.

The first step of this analysis of data is to check whether such evolutionary patterns are visible in this set of partial and incomplete data. In order to do this two variables are constituted: 1-absence and 2-presence. The question arises as to what types of associations they will form across these data?

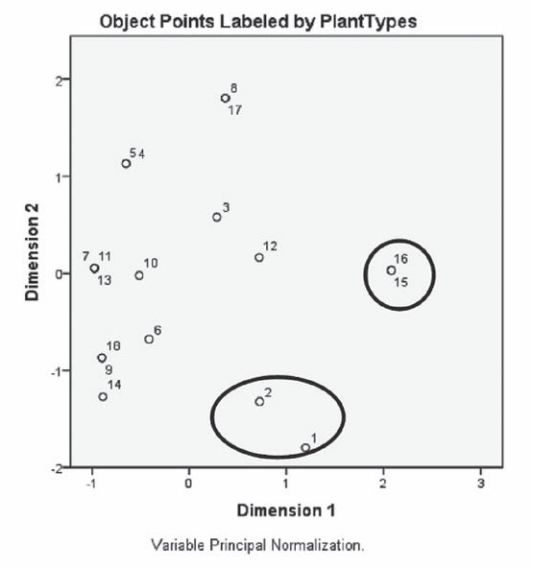


Figure 15. Positive relationship between two stable associations: (1, 2 – Triticum monococcum, Triticum dicoccum); (15, 16 – Vitis vinifera ssp. sylvestris, Cornus mas).

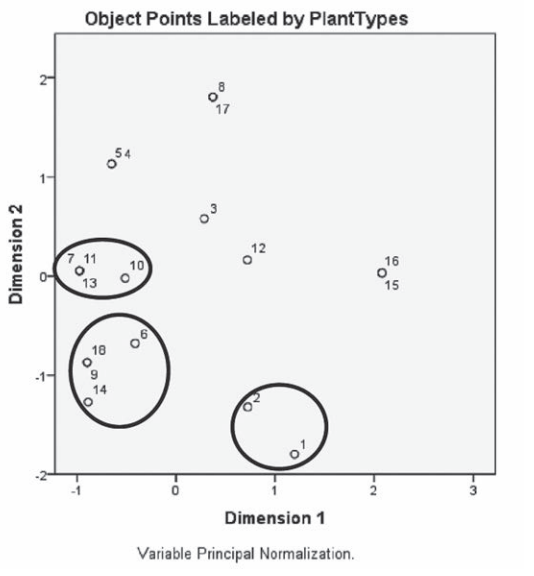


Figure 16. Negative relationships along the first dimension between associations: 1, 2 – Triticum monococcum, Triticum dicoccum; 6, 9, 14, 18 –Secale cereale ,Lens culinaris, Pistacia terebinthus, acorn of Quercus sp.; (7, 10, 11, 13 – Panicum miliaceum, Vicia ervilia, Vicia sp., Lathyrus sativum.

If properly excavated and recorded the sets of these variables should exhibit an even distribution without marked clustering.

In the Kovachevo distribution, these variables (Figure 13) show that variable '2-presence' has both positive and negative associations and contributes significantly to the overall variation. This result suggests that it is worth trying to discover the existing stable associations between particular plant species.

The Podgoritsa distribution shows that the two variables form symmetrical negative association (Figure 14). It suggests the existence of serious epistemological bias in archaeological explanatory schemes due to non-satisfactory excavation practices. The latter is illustrated by the formal symmetry between the presence and absence variables where the 'expected' species (cereals) were systematically identified while the 'unexpected' ones (wild plant species) were not.

In summary these results show that although there is a lack of precise data they bear enough information and may be helpful in assessing how these communities developed strategies for diversification of their resource exploitation.

This conclusion is supported by the results of the correspondence analysis carried out on the same data (Figure 15). They show that there are seven stable associations that emerge from the identified plant species. The first one is the positive association between *Triticum monococcum. Triticum dicoccum*(numbers 1, 2) and the Cornel-tree and wild grape (numbers 15, 16 on the plot). It may correspond to mixed human activities focused on working lowland fields and their hilly margins.

This pattern suggests that there are two alternative strategies. The first one involves growing and collecting *Lens culinaris* (No 9), *Pistacia terebintus* (No 14), acorn (No 18) and rye (No 6). The second involves millet (No 7), *Lathyrus sativum* (No 13), *Vicia ervilia* (No 10), *Vicia sp*. (No 11) (Figure 16). These are overlapping subsistence strategies that may relate human response to small climatic oscillations (10-15 years of average duration) and to systematic land-use in combination of cycles of varying intensity of production and consumption.

The remaining four stable associations may be ascribed to arbitrary (e.g. not related to external climatic influence) human preferences that have local and regional significance. They reveal that people not only usefully adjust to the surrounding environment to their needs but under the influence

of these changes alter their own cognitive space, which allowed them to plan and execute long- and short-term subsistence strategies (Van der Veen 2014).

The first association answers the question how fast the collection of wild plant species increases alongside growing cereals that pre-supposes their subsequent domestication. A linear regression model has been constituted based on the average presence of all cereals in the data-matrix and the average absences of Cornel-tree, wild grape and plums. The result (Figure 17) shows that there is a moderate growth but with considerable local variations based on individual choice of each community.

The next three associations reveal strategies that aim to improve the quality of the expected harvests. They involve growing *Hordeum vulgare, Triticum aestivum/durum* and *Pisum sativum* (Figure 18). The social significance of this strategy can be discerned from the fact that Hordeum was domesticated before wheat (Riehl et al., 2015). The practices of long-term cultivation of Hordeum would entail elaboration of sophisticated knowledge which intensifies individual and community communication that stimulated cultivation of other cereals and growing selected combinations of them according to the local environmental conditions and social demands and dependences.

The analyses of the above show an increasing diversification of subsistence strategies of these early farmers. Also this process of 'on-going diversification' sheds light on interpretation of the evolution of flint-knapping techniques and toolkits during the Neolithic. Because of the lack of precise data, my analysis is based on the common changes in lithic techniques and tool morphology. The latter includes categorization of tool's purpose (single, multiple) in combination of artefacts' techno-typological characteristics, function and provenance of lithic materials. I place these changes in the context of the growing in number and sophistication symbolic expressions of the developed Neolithic communities in the eastern Balkans.

As it was established, the early Neolithic assemblages are featured by the presence of long blades (8-15 cm in length) made by special techniques that were carried out on high-quality flint varieties. Their provenance from Cretaceous limestone strata in northern and northeastern Bulgaria has been established (Nachev 2009). All the other technical and morphological elements are subordinated to this strategy. From this initial stage lithic techniques and toolkits changed and diversified significantly. These changes may be categorized as tendency of production of single purpose tools. Combined burins become rare and each single burin has its own purpose. The same is observed with end-scrapers and microliths which are made by different from the Upper Palaeolithic technique.

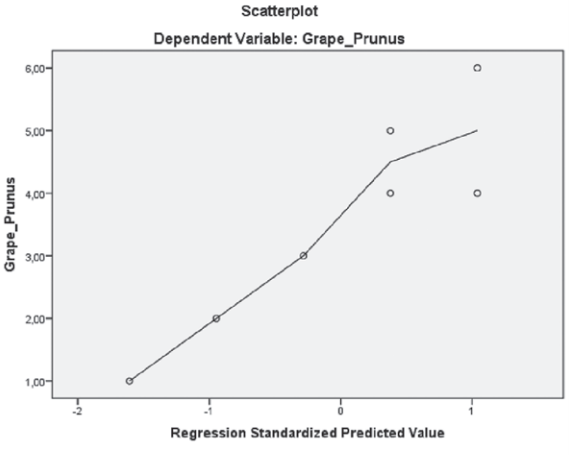


Figure 17.Linear regression model for the growth of wild plant species: wild grape- Vitis vinifera ssp.sylvestris, Cornus mas -Cornel-tree, Prunus sp.-plums.

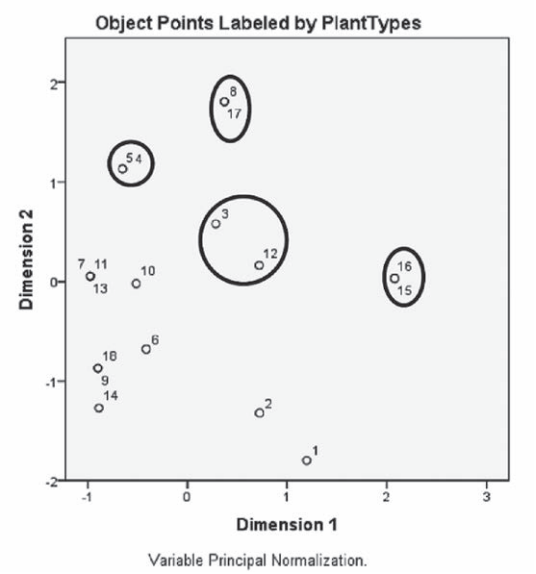


Figure 18.Three negative associations relative to Triticum monococcum, Triticum dicoccum (No8 – oat, No 17 – plum); (No4 – Hordeum vulgare, No 5 Hordeum nudum); (No 3 – Triticum aestivum/durum, No 12 – Pisum sativum).

The domestic (on-site) flint-knapping techniques show significant diversity, especially within the operational chain of exploitation and enlarging of the flaking surface of the nucleuses (Tsonev 2007). Their enormous variety has prominent local particularities and show different technical combinations related to different locales for acquiring raw materials. Thus to these localities, there may have been ascribed symbolic meaning by constituting biographies of local and distant landscapes containing flint outcrops (Tilley, 1994). All this indicates increased on-site craft specialization (Baysal 2013) for working diverse objects including beads, shell, stone ornaments for cloths and small objects of art.

Conclusion

Traditional approaches lead to uniform labeling of these early communities as farmers. The above presented data do not confirm this understanding. Additional data that have not been included in this study support this conclusion. For example, the Eneolithic site – Orlitsa in Bulgaria does not have a single bone uncovered (Boydziev, Boyadziev, 2008). It was shown that the mobility of the Neolithic populations is greater than that of the Mesolithic ones in the Danube Gorges (Boric and Price 2013). The domestication of cereals goes back as far as 23 000 B.C. at the site Ohalo II, Israel (Snir et al., 2015). Early experimentation with domesticated wheat as well as the practice of mobile 'itinerary farming' is observed in Western Europe (Pétrequin and Pétrequin 1988: 31-33).

The key element in all these changes is that the intensification of communication leads to novel cognitive development (novel cognitive cues dispersed within the surrounding landscapes) that enables people to interact with the surrounding world (Roberts, 2015). The early farmers were not passive recipients of novel subsistence practices. They were innovative and active agents with a range of multiple identity practices that not only created novel strategies for engagement with the environment but increased their own dependency on them and, what is most important, developed new cognitive capacity for complex interaction with them.

GENERAL CONCLUSION

In this joint paper it has been shown that space has its own social dimension that can help archaeologists understand how past societies used it to create social meaning and value. The first example reveals how past built environment within the frame of a single settlement sharpens the sensitivity of both its inhabitants and outside visitors to the established public norms of behavior. The next example shows how a visual culture contains mental stereotypes of monumental structures that influence the spatial behavior of modern observers that want to make their own image of these structures. The third example reveals the potential of GIS and 3D representations for analyses and interpretation of the spatial organization of the large urban center from Roman times. The final example provides a critique to the typical understanding of the organization of spatial data in archaeology and offers a way of analyzing both present and absent data in order to extract the maximum information and constitute a coherent interpretation from the otherwise disparate and loosely related data.

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SOCIAL DIMENSIONS OF TECHNOLOGY OF CERAMIC PRODUCTION IN SOUTHEAST BULGARIA IN 6th – 2nd mill. BC[1]

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(Contract DN 10/8 from 16.12.2016, INTERIM SCIENTIFIC REPORT)

ABSTRACT

The article presents activities and data obtained during the first year of the project. The research area encompasses Southeastern Bulgaria with nine main sites included. Object of instrumental research and archeological characteristic are the samples, which are divided into the following groups: denudated rocks, and used for inorganic temper; clays – tectonic and alluvial; ceramics- pottery fragments and burnt remains of stationary equipment; organic fillers, pigments and substances for painting and incrustation, organic residues and impressions of mats and baskets on the pottery bases. . Different methods and analyzes have been applied to solve the problems posed: cartographic analysis and description of the landscape, morphological and typological analysis, dating, instrumental methods, chemical analysis, scanning electron microscopy (SEM), petrographic analysis etc.

СОЦИАЛНИ ИЗМЕРЕНИЯ НА ТЕХНОЛОГИЯТА НА КЕРАМИЧНОТО ПРОИЗВОДСТВО В ЮГОИЗТОЧНА БЪЛГАРИЯ ПРЕЗ VI-II ХИЛ. ПР.ХР.

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РЕЗЮМЕ

В тази статия са представени дейности и данни, получени през първата година от проекта. Цел на проекта е изследването на технологията на керамичното производство през праисторията чрез прилагане на различни инструментални методи и опит за характеристика на социалните аспекти на това производство. Изследователският район обхваща Югоизточна България с включени девет основни обекта. Предмет на това инструментално изследване са образци от глини, керамика, отпечатъци от органични останки върху керамика, пигменти за рисуване, оцветяване и инкрустация, отпечатъци от рогозки и кошници. За разрешаването на поставените проблеми са приложени различни методи и анализи: картографски анализ и описание на ландшафта, морфологичен и типологичен анализ, датиране; инструментални методи; химичният състав на пробите, сканираща електронна микроскопия (SEM), петрографският анализ и др.

[1] The paper presents the interim scientific report of the research project with the same title, funded by the Bulgarian Science Fund, according to Contract DN 10/8 from 16.12.2016.

INTRODUCTION

In this article are presented activities and data obtained during the first year of the project. They don't have concluding character. The basic purpose of the team was the information to be accumulated which is necessary for the creation of a base to be updated in the second year for the project.

This research area encompasses Southeastern Bulgaria with nine main sites included (Fig. 1). In the process of work, it was necessary to include reference materials from other sites, for example Constantia and Chavdarova cheshma near Simeonovgrad and Sokol (Fig. 2); thus the information of them was quite important for solving the tasks, defined in the project. All of them are in Southeastern Bulgaria and enter the research time-span.

The leading institution in preparation of the tests and the accomplishment of the analyses is Sofia University with its departments and the Centre of Archaeometry. Meanwhile, thanks to the increasing popularity of research and the international relationships of the team members, samples are sent for free of charge analyses in the labs of Nottingham, Oxford, Ankara, Istanbul and Athens. Collaboration is expected also with the lab of Archaeometry at the University of Yasi, Romania. In this way we will improve the methodology and widen the area of parallels and correlations. The international collaboration is stimulated by the fact that most archeological sites, included in the Project, are internationally recognizable, i.e. their exploration is of significance for the prehistory of Southeastern Europe and Asia Minor.

The presented results are from those analyses which were finished till 15.12.2017. Only the material from the University of Nottingham, Great Britain, was sent in the beginning of 2018. Many instrumental analyses still in due course but their results will be ready in the first months of 2018.

MATERIALS AND METODS

Structure of the database

Object of this instrumental research and the archeological characteristic are the samples, which are divided into the following groups: denudated rocks, serving for the base of tectonic clay formation, and used for inorganic temper; clays – tectonic and alluvial; ceramics- pottery fragments and burnt remains of stationary equipment; organic fillers, pigments and substances for painting and incrustation; organic residues and impressions of mats and baskets on the pottery bases. This information, presented with texts, photographs (field pictures, microscopic and macroscopic photos) and graphic (maps, scientific drawings, diagrams) type, which are synchronized. The external/internal colour of ceramic fragments is specified through the international standard *Munsell Soil Color Chart*. Digitalization is completed through the programs of Adobe Photoshop, Illustrator and Excel, as well as MIN 5, especially created for treatment of geochemical data. In process is the analyzing of the whole information in Access and GIS.

Specific methods

The aim of this research imposes the necessity of combining of conventional archeological methods for analysis with a wide spectrum of instrumental methods and techniques.

Among the archeological methods we should mention the following: cartographic analysis and landscape description, morphological and typological analysis, dating and cultural attribution, catalog description, macroscopic technological description and graphic records.

Instrumental methods are selected in order to obtain comprehensive information of the multi-step process involved in ceramic production, the function of implements and the different classes of pottery. From technological position, the focus is laid out on the selection and preparation of raw materials, selection of organic and inorganic temper, pottery shaping and decoration until the process of firing.

In order to obtain information on provenance of raw materials and clay matrix, inclusions (non-plastic particles naturally occurring naturally in clays) and tempers (non-plastic materials intentionally

added by potter to the paste) that compose a ceramic body, the mineral and chemical composition of the samples is examined. The character of inclusions and tempers is determined by **microscopic observations (thin-section analysis)**.

Scanning electron microscopy (SEM) gives the possibility by large magnification to observe the texture and the relationships between the minerals in the fired paste. This method also allows identification of plant remains (mats and baskets) used in vessel formation or drying and preserved as imprints on the exterior.

Petrographic analysis is combined with analysis of the chemical compositions of clay samples and pottery fragments. It is studied by **wet chemical analyses** to determine the macrochemical composition" (the contents of SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, etc.). The data from these analyses are used as internal standard for **LA-ICP-MS** analyses to obtain data about the concentrations of microcomponents and of the RRE in particular. The same analyses we use for the clay samples collected from outcrops, too, to correlate the results with these from the ceramic artefacts to establish the source of the raw material. On the base of the chemical composition the clays will be correlated to international rock-standards like North American Shell Composition to obtain a basic information about the geochemical characteristic of the clays.

The mineralogical composition of both clay samples and pottery sherds is studied by **X-ray powder diffraction** (XRD). It is useful to test the results of petrographic groups, defined by thin section, as well as to identify minerals too small to be detected by thin sections and microscope observation. By this method we can establish the firing temperature through the change of the structure of the primary clay minerals and the presence of minerals crystallized during the firing process and exposure to high temperatures (pyroxenes, etc.). The method is also applicable for the identification of minerals used in slip preparation. The pigments and coloring agents used in slip preparation or for pottery decoration (painting, encrustation) will be studied also by vibrational spectroscopic methods, such as **Raman spectroscopy**. The chemical composition of pigments and slips can be further identified by point chemical analysis by using **Scanning electron microscope combined with Energy Dispersive Spectrometry** (SEM-EDS).

Data concerning the modeling techniques can be obtained from the thin section study when peculiarities of the structure are visible (cracks between different elements of the clay are indicators 2 for coil building or slab building techniques; wheel turned vessels can be identified according to the visible orientation of non-plastic particles in the matrix).

The function and use of pottery can be identified by analysis of organic and inorganic residues preserved on the vessel's interior. The method for this investigation is **Gas** and **Liquid Chromatography with Mass spectrometry**.

The described analyses are integrated in the complex study in which the classical archeological methods for ceramic investigations have a leading position – formal and technological classification, synchronic and diachronic analysis, contextual and functional analysis, taxonomy, statistical analysis.

Expected results

Expected scientific results can be divided into three groups:

- Results, obtained through conventional archeological methods.
- Results obtained by using instrumental methods.

This group comprises the specific data that will be obtained from the natural-scientific analyses and provide information regarding: the raw material source of the pottery production; characteristics of the used clays and admixtures; modeling techniques; firing techniques; organic and inorganic substances used in the coloring of the slip and decoration of the vessels. These data will be used in the creation of a technological database that can be upgraded and developed if/ when the area will be extended by the inclusion of new sites and regions and with the inclusion of new research techniques as well.

Results based on the extracted data in the field of social archaeology.

Expected results in the third group are connected with interpretation of data within the area of humanities. It is obviously too early to sum up all the results.

The obtained data serve as a reference and a basis for the clarification of significant research questions regarding: the relationship between the technology and eco-environment; the level of the technological skills during the different periods and in the different regions; the mechanisms for transmitting and keeping the traditions and for penetration of the innovations, to tracing the direction and intensity in the contacts.

In particular, for the Neolithic period we expect to obtain results about the different types red slip; composition and method for the application of the pigments that are used in the monochrome and polychrome painting; characterization of the thermal processes in the production of luxury ceramics. These results will enable the comparable analysis with Southeast Europe and Northwest Anatolia and will help in establishing the ways that technology had been transferred, the mobility of people and ideas.

For the Bronze Age, we are focused on the color of the slips (intense black; raspberry-red; etc.); the innovations in the thermal techniques (adding grog); the substances used for the incrustation in various techniques (incised; corded ware; *Furchenstich*) typical for different stages of the period. We expect to establish the characteristics of the local production for every region and periods (examined in the project) and thus to be able to identify imports and local imitations. We also expect during the second year of our work to obtain results that can be interpreted in terms of the consumption of time and effort spent on the pottery production; the specialization of the production and its characteristics as a separate and independent craft.

For this purpose we will broaden our activity in three directions: selection of new samples; inclusion of new sites, both in Bulgaria in neighbor regions; and use information from similar areas of investigation – geomorphology, paleogeography, paleoclimatology, and other.

Sample description

Spatial distribution in micro-regions and objects (Figs.1-2)

As it is already said, the research is limited in Southeastern Bulgaria, which is divided into the following sub-regions and micro-regions:

The middle and a part of the lower valley of the Maritsa River, with Yabalkovo and Voden as main sites. The list is extended with the sites of Constantia and Chavdarova cheshma near Simeonovgrad, dated to the EBA and Early Neolithic respectively. Materials from Constantia are included because of the presence of probable imports from Northwest Anatolia, dating from the end of the 3rd mill. BC. Ceramics from Simeonovgrad (Chavdarova cheshma) has direct parallels with the materials from Yabalkovo. During the first year of the project samples were analysed from Yabalkovo (EN), Constantia (EBA 3) and Dana bunar 1 (ECh/LCh).

The middle valley of the Tundzha River.

Here the two main sites included in the project are the open air settlements known as Chokoba 18 and Chokoba 18A during the transitional period from the Late Neolithic to the Early Chalcolithic and in the Bronze Age.

The valleys of the Ovcharitsa and Sokolitsa rivers, flanking the north part of the Sakar mountain North. The basic sites are the sites of Kliselika, Madrets and Galabovo (Fig. 2).

Sveti Iliya hills. Tell Sokol is located in the southern slopes of the hills. The site has been included in the project for two reasons. First, this is the only mound from the first half of the 3rd mill. BC with on-going fieldwork research, and, second, the site is located in an area rich in graphite deposits. In the first year samples have been taken from pottery fragments and various clay installations.

Chronological distribution

The chronological framework of the project is from the beginning of 6th to the end of 2nd mill. BC, that includes the periods of Early, Middle and Late Neolithic (EN, MN, LN), Early and Late Chalcolithic (ECh and LCh), Early, Middle and Late Bronze age (EBA, MBA, LBA).

EN – Yabalkovo and Kliselika

MN – Yabalkovo

LN/ECh – Chokoba 18A;
ECh – Dana bunar 1, Madrets
LCh – Madrets, Galabovo, Dana bunar 1
EBA – Madrets, Sokol, Galabovo and Constantia
EBA 3/MBE – Galabovo
MBA – Chokoba 18
MBA/LBA – Chokoba 18A.

Archeological context of the selected fragments

The materials included in the project come from settlement sites and not from necropolises and sites of supposed ritual functions (sanctuaries). This is due to the fact that pottery in the latter types of sites has more specific functions and quite often is manufactured or selected especially for the rituals. Most of the settlements are investigated in the recent past i.e. there is reliable field documentation. Some settlements however are investigated more than 40 years ago (for example Constantia) and many of the details about fieldwork cannot be recovered. In spite of this are selected fragments because of their high scientific value (imports, ceramics thrown on a pottery wheel). The rest of the samples are with a certain context and come from pits, houses or secure closed complexes, for example ditches. Consequently, the information value of the samples given for analysis is high and the results can be defended with sure evidence from the sphere of field archeological documentation.

Types of samples

Subject to analysis are samples taken from denudated rocks, clays, pottery and remains of stationary equipment. The following signature has been used: abbreviation of the name of the site – type of the sample (clay, ceramic fragment, burnt clay) – date of the sample – number of the sample. For example: SMG_S.BA_008 refers to: tell Galabovo (SMG) – ceramic fragment/sherd(S), Bronze Age (BA), number 008.

Rock outcrops (Fig. 3)

Four samples have been taken from several places – from Sveti Iliya hills, north from Sokol, from the modern quarry south from Yabalkovo, from the hills north from Chokoba site and from the northern slopes of Sakar mountain. As the analyses haven't been finished, the results will be announced in the final report.

Clays (Figs. 3, 4, 5)

Eighteen samples from clay sources have been taken for provenance analysis.

Yabalkovo. The geomorphology of the region of Yabalkovo has already been studied and the base data are published, so they won't be repeated here. The research was carried out in 2010-2012 by Ph. Machev, D. Vangelov, L. Klain and V. Vangelova. Their data will be included in the final report and it will be explicitly stated, that those analyses are done prior to the project. We consider that because the authors participate in this project as well, their re-execution is not justified or reasonable.

Yabalkovo-profile, cut by the road connecting the villages Yabalkovo and Krum; coordinates: 42° 3'48.00"N, 25°29'11.00"E; approximately 740-750 m from the EN site of Yabalkovo. The terrain represents a low hill, above the old riverbed of the Maritza. The samples were taken at around 1.50 m below the top of the profile.

Yabalkovo-Sector North; approximate coordinates: 42°03'50.95"N, 25°28'39.07"E; sample has been taken from the area of the EN settlement. A small section has been made to the virgin soil (dark yellow sediment), from where the sample was taken, at round 0.30 m under the earliest EN settlement.

Yabalkovo-modern quarry, S/SE from Yabalkovo village; coordinates: 42°3'32.37"N, 25°27'32.99"E. The quarry is situated around 1.5 km W-SW from the central part of the prehistoric site. Five samples were taken, defined by the different coloring and structure of the clay and the rocky base.

Yabalkovo-South. In the land of the neighboring village of Kasnakovo archeological excavations are taking place, reaching the level of the virgin soil. The site is known in literature as "Sanctuary of

the nymphs", Kasnakovo; coordinates of the site: 42° 0'13.91"N, 25°30'7.55"E. The sanctuary stands at around 6.5 km S-SE from the central part of Yabalkovo site.

Sokol, Nova Zagora district. The region north from Sokol village is built of Paleozoic granitoids, which are fossilized and subsequently slightly altered. In addition, in the process of weathering and decomposition, they are cracked and form blocks with sizes of several dozen centimeters, which are easy to extract and use as a building material (Fig. 3.1). On a few of the fragile fault zones are developed tectonic rocks – cataclasites and ultracataclasites – tectonic clay, which is quite fine. This is a result mostly from the kaolinization of feldspar, a basic rock-forming material in the granitoids (Fig. 3.2-3). In their weathering these rocks disintegrate fast and form the so-called "grus" or sand from the basic rock-forming minerals. In the kaolinization process of the feldspar, it is often mixed with a clay weld and during hard rain it is exported in flood cones, which are most suitable for its exploitation. Characteristic for these rocks are also the quartz stems and quartz is a very hard mineral that could be used in many ways.

Chokoba, sites 18 and 18A. The region is built in its hilly part from upper cretaceous volcanic and hypoabyssal rocks (andesite, dacite and latites), which are distinguished by strength and cracks, a result of the decomposition and compression and extensive tectonic deformation. The preserved harder rock fragments are suitable for extraction and procurement and trough the fault zones, as a consequence of the crushing of the rocks, it is possible to reach fossilized and ultracatalasites (tectonic clay). In the locality of "Ostar kamak" and west from it are found traces of extraction activities. This conclusion is based on the difference of effect of the exogenous processes on the rocks or more precisely the formation of "patina" (a level of surface weathering or such in shallow penetrating micro-cracks), which have been determined by:

- natural weathering, distributed on large areas;
- small areas with traces of contemporary anthropogenic activity and lack of patina;
- those with a small effect on the exogenous processes.

On the basis of the duration of those processes and by analogy with other sites it could be concluded that the natural weathering or the penetrating patina date from 70-65 Ma, since when they have been brought on the surface, several decades for the current weathering with no traces of patina and several thousand years for the slightly patinated areas, all this suggesting the extraction of raw material a few thousand years ago, taking into account also the morphology of the natural erosion and the anthropogenic interference in the lay.

Chokoba 18 site is located on one of the segments of the contemporary neotectonic fault zone, dividing the hilly northern part, built by volcanic rocks with age 90-88 Ma, from the southern plane part of continental deposits with ages around several thousand years. This fault is followed by satellite synthetic zones. One of them, north of the hill "Ostar kamak", appeared to be 15 m thick and filled with tectonic clay created by the intense crushing of igneous rocks. It is probable that those clays are susceptible to extraction and processing.

Between those two faults is developed a system of sidelong faults with a downgrading of the western blocks. Tectonic clay is also visible in one of these faults, but more importantly, it drains water, which is captured and with a very good drinking quality. As we take into consideration the trend of reduction of flow of natural springs nowadays, it can be suggested the presence of other springs during the existence of the settlement. The presence of neotectonic system suggests an intense seismic activity as well.

Madrets. There are two tell sites in the vicinity of Madrets village. Tell Kliselika is located in the immediate vicinity of the main stream of river Sokolitsa, which shows an intense indent in an old overflowing terrace. This corresponds to the data for the region for tectonic sinking in the region with speed from approx. 1mm/y and morphologic manifestation of active faults on the slope of the hills south of the village. They are presented by a system of faults with a downgrade of the north blocks on the main orientation of the conjugated couple faults in the region – west-east, steep slopes on the south coast of the river and flat at north. The steep south slopes are located with indentation, a result of skew of the main cuts with rotation and lowering in their south-western edges, which besides the

fault speaks about a shifting component of translation. This explains also the zigzag geometry of the mainstream and its position in different parts close to the south or north slope and the meandering character is caused by the characteristic for the transtensive areas with the presence of saw cuts, the formation of small pull-apart pools, in which all the boards are active, but not at the same time.

The presence of those saw cuts and on the slope north of the river confirms the rotation of blocks between the conjugated couples of faults and the formation of local depot centers. This is characteristic for the whole region as it falls in the borders of the Maritsa zone of shearing, for which is proved a right shifting component. The high seismic activity in the region of the site is also proof for the contemporary activity of the faults and the common trend of sinking.

North of the settlement mound next to the river (Kliselika) are established traces of paleo-mainstream, which could be interpreted as: a) an old river bed; b) traces of temporary floods; c) constant migration of the mainstream as a result of the compensation of the accommodating space and temporary floods. It is proved by the big watershed upstream, the steep slopes, the lack of "traps" for territorial material, its inconsistent distribution and the discharge of the river during low water periods. This presupposes during hard rain, on one side floods in the terraces and on the other the formation of debit flows or high waves.

The situation is similar in the located just east alluvial pull-apart pool in the region of Vladimirovo village, after which the river enters in a region with a higher lay, created by Paleozoic granitoids with a metamorphic border and Triassic territorial rocks. These rocks form the mat are strongly weathered and offer a rich influx of territorial material as a consequence of intense erosion and the transportation during hard rain at long distances.

Traces of similar spills with sedimentation of big amounts of terrigenous material are observed east of the second settlement mound (Madrets 1), as well as on the terraces over which the mound is located. The higher terrace reaches the base of the upper settlement mound, which could be interpreted as discharge and overflow of large areas. The small displacements between these terraces (0.5 – 1.5 m) and the additionally developed on top of them local draining system indicates fast draining of the water as a consequence of some kind of cataclysm or a similar event connected to draining, probably an earthquake. Generally, floods are a very fast and dynamic process, while the drainage is much more time consuming and even longer or permanent overflows are possible, and their draining is caused only by a cataclysm. This could be confirmed by shallow drills of the terraces and an analysis of the sediments from the core.

The region is very interesting as an object for research of contemporary geodynamic processes, but it need further attention. These results are from the preliminary terrain observations and treatment of satellite pictures and for more factual results is necessary a more detailed terrain work.

The clay samples are submitted to wet chemical and LA-ICP-MS analyses. The objective is to compare them with the ceramic artifacts and to determine the provenance of clay sources used in pottery manufacture. Because the results from the examination of the clays were received too late, they are not processed in detail. They are presented in Table 1. The same can be said about the pottery samples. The results of their geochemical analyses are presented in Table 2.

Pottery samples

Pottery samples selected for petrographic and chemical analyses of the clay paste are taken from the following sites:

- Yabalkovo (EN) -25 fragments
- Chokoba 18 A (LN)-31 fragments
- Constantia (EBA) – 18 fragments
- Madrets (EBA) – 1 fragment
- Galabovo (EBA-MBA) – 31 fragments
- Chokoba 18 (MBA)11 fragments
- Chokoba 18A (MBA-LBA) – 6 fragments

One aspect of pottery technology is the use of woven and plaited goods, such as baskets and mats

in the production process. Samples of pottery fragments (pot bases) with mat/basket impressions were selected from one of the sites included in the project:

Dana bunar 1 (ECh-LCh) – 28 ceramic fragments

For identification of organic temper in clay paste, samples were taken from the following sites:

- Yabalkovo (EN) – 25 pieces of burnt clay used in the construction of houses and stationary equipment
- Dana bunar 1 (ECh-LCh) – 28 ceramic fragments
- Sokol (EBA) – 15 pieces of burnt clay used in the construction of stationary equipment
- Chokoba 18 (MBA) – 50 pieces of burnt clay used in the construction of stationary equipment
- Chokoba 18A (MBA-LBA) – 25 ceramic fragments

Samples of colored slips and pigments:

- Yabalkovo (EN) – 8 fragments with red slip (Ya_S.EN_018-025), from them 3 with white (Ya_S.EN_019-021), 3 with dark (Ya_S.EN_023-25) and 1 with polychrome (Ya_S.EN_022) painted decoration; 1 fragment with chequer board pattern and white incrustation (Ya_S.EN_009); 1 fragment, coated with red ochre(?) on the interior and supposed black painting (Ya_S.EN_012);
- Constantia (EBA) – 4 fragments with red slip /Con_S_001-003, 012/;
- Galabovo (EBA/MBA) – 2 fragments with red slip /SMG_S.BA_028, 031/ and 1 fragment with white incrustation (SMG_S.BA_027);
- Chokoba 18A (LBA) – 1 fragment with probable dark painting (Ch18A_S.BA_006).

It is supposed that some of these fragments are imports, which is subject to proof or rejection by instrumental methods.

RESULTS

Archeological analysis – technology and classification

Archeological activities are carried out in the field and in the lab.

Terrain work with specialists geologists include localization, mapping and testing of resourcing areas for each of the micro-regions included in the research. The places selected for testing are described, photographed and mapped.

Study work

Work with collections of ceramic materials from the sites included in the research, was carried out in three stages: selection of fragments, macroscopic description– and systematization. It is performed a technological and formal characterization of the ceramic fragments, from which are taken probes for analysis. Collections are stored in the museums of Sliven and Haskovo, archeological base Sokol and archeological base in the village of Mineralni bani, Haskovo district.

Selection. With purpose of obtaining adequate information from the investigations of fragments, through which to reconstruct the cycle of ceramic production during the respective age, a careful selection of the materials was done. All ceramic fragments were selected from secure archeological contexts and so-called "closed complexes" – situations, undisturbed by later periods – for each of the sites (Fig. 6).

Macroscopic description of ceramics. These fragments are characterized in detail in several aspects – technology, formal classification and decoration. For each site, included in the first year of the project is created a separated database. The compiled lists of selected materials are in MS Word and Excel. Also pending is the compiling of a catalogue with data-base in MS Access.

Ceramic technology. Fragments are separated in technological groups on the basis of technological attributes – wall thickness, clay fabric and temper, surface treatment. There are five basic groups of inclusions in clay paste (fine and coarse sand, tiny rock particles, mica and organic fillers) as they are described in concentration, visible in the fracture of the fragments. In the presence of additional coating (slip) of the pots, the description is on the basis of two criteria: colour and thickness (fine,

medium -thick, dense). Surface treatment is described as follows: unsmoothed, smoothed (unevenly smoothed; well-smoothed); burnished (matt, polished in stripes, evenly), polished. The surface colour and the colour of the fracture are defined with the help of Munsell Soil Color Chart.

Classification of ceramics. Samples are selected amongst individual fragments, which can be reliably defined in terms of category, shape and size.

Analysis of decoration. A grouping has been done according to the technology of decoration, the position of motives and compositions of decorative elements and the correlation between the last technological and formal groups.

The documentation of the selected materials included their technological description, graphic and photo documentation (Figs. 7-40). The applied illustrations present information for ceramics' manufacture of each object, its dating and cultural specifics.

Tests' preparation for lab analyses. Selection is done, signing of the corresponding specimen, selection of the most suitable method of analyses and choice of the most suitable place (surface) for preparation.

Macroscopic identification of mixtures. Types of temper. To define mixtures in clay mould, added by potters, investigations are laid out the mineral component of ceramic artifacts. Mixtures are characterized by a few criteria: size, shape, quantity and character. They are inorganic – minerals or fragments of rocks, organic (traces from plants, shells and bones) or anthropogenic, for example "grog" (grounded fragments from already fired ceramic pots). Identification of organic mixtures.

Archaeometric studies

Instrumental methods used in first year of the project.

Petrographic analyses. 33 thin cross sections are prepared, which are studied by optic microscopy (Figs. 41, 42). This method is used to examine the mineralogical and microstructural composition of ceramics.

Wet chemical analyses. This classical method is used to identify the macro chemical components of clays, taken after testing of rooted areas and of clays, from which are manufactured ceramic pots (chart 3, 4).

Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) analysis. It examines the concentrations of microelements and especially REE in analyzed ceramics and in clay samples (chart 3, 4).

Scanning electron microscopy. The method is used for identification of organic and inorganic admixtures in the clay fabric (Figs. 43.2; 45).

X-ray diffraction analyses is used to obtain information on the variety of minerals and colorant agents used in the preparation of coloured slips and in painted and incrusted decoration of vessels (Figs. 43.3, 44).

Gas and liquid chromatography and mass spectrometry (organic residue analyses). Organic residue analysis is initiated on a series of pottery samples from EN Yabalkovo, yet we are still expecting the results.

Institutions and laboratories

Sofia University "St. Kliment Ohridski" offered its facilities and laboratories for the realization of the project, as follows:

• Laboratory for preparation of rocks and mineral samples for ceramic petrography – it is equipped with a full set of crushing machines for sample preparation and separation of mono- mineral samples.

• Laboratory for microscopic analysis – preparation of petrographic thin sections and analysis with polarizing and electronic microscope and X-ray microprobe.

• Laboratory for x-ray diffractometry supplied with an x-ray apparatus TUR-M62.

Chemical laboratory – performs chemical analysis of rocks and minerals through wet silicate analysis

• Laboratory for Raman spectroscopy

• Laboratory for electronic microscopy
• LA-ICP-MS laboratory (in consortium with Geological institute at BAS)
• Centre of Archaeometry – coordinating organ between different labs, as well as between members of the team of different scientific departments. Equipped with storage and working rooms.

Apparatus for a fee is used for the following analyses: scanning electron microscope (Faculty of Physics, SU), LA-ICP-MS (GI at BAS), Gas and liquid chromatography (Faculty of Chemistry, SU). All analyses are made by members of the team.

Interim results

Clays

Geochemical investigations of clays and ceramic fragments.

Clay sources analysed during the first year of the project are from the vicinity of the EN site of Yabalkovo, from the land of Kasnakovo (in the valley of the Maritsa River), from the region of Sokol (Sveti Iliya heights), from the region of Chokoba (in the Tundzha River valley) and from the region of Gudzhova tell near the village of Madrets in the valley of the Sokolitsa River, north slopes of the Sakar mountain (Fig. 2). The results are presented in diagrams from figures 46 and 47, which summarize the details from Table 1. It is possible to define two groups of clays from the areas of Sokol, Chokoba and Madrets, on one hand, and from Yabalkovo and Kasnakovo, on the other.

Clays from the first group (red dots) show higher contents of alkaline components (Na_20 + K_2O).They form a cluster, which is pulled towards the top of the diagram. The second group of clays marked in green dots (Yabalkovo and Kasnakovo) is also similar in chemical composition and form quite a "compact" cluster. It is obvious that clusters do not match (Fig. 47.1). The two groups vary significantly in their chondrite-normalised REE pattern. The first group is characterized by a deep negative Europium anomaly (Eu anomaly), due to the low contents of CaO (Fig. 47.1). Clays from the second group, marked in green squares, are characterized by a shallow negative Eu anomaly, which is result from the higher contents of CaO (Fig. 47.2).

Correlation clays – ceramic fragments

Geochemical analysis is made on 26 ceramic fragments from the sites of Galabovo, Constantia, Chokoba18A and Madrets, all dating from the Bronze Age (Table 2).The results allowed the distinction of a group of six samples (Con_S_007 to Con_S_ 012). All of them derive from Constantia. No samples of clays from the region are taken (this will be a task for 2018). The chemical composition of the fragments differ significantly from that of the others, expressed in the high amounts of CaO (up to 17.91 %). This is not specific of clay rocks in the valley of the Maritsa. The total of the main petrogenic oxides in the six tests is quite low (up to 70%). It means that a high amount of carbonate minerals is present in the clay (probably calcite – $CaCO_3$). Higher contents of Sr (up to 599 ppm) in these samples may be due exactly to this reason but it might also be a result of the presence of the mineral Celestine, containing strontium sulfate ($SrSO_4$). Another distinctive feature of the six samples is the high concentration of REE, which are marked with green triangles in the figures (Figs. 46.2; 47.3). Yet another is the existence of a deep negative Ce anomaly, which is not established either in sampled clays or in any of the rest sampled pottery sherds. Beside this, the ratio of AL_2O_3 to SiO_2 in these tests separates them from both the fragments and the clays in the region (Fig. 46.3).

So far, we can assume that the six sampled vessels are not locally manufactured. Moreover, they do not constitute a homogeneous group, thus a heterogenic origin cannot be excluded, i.e. if these pots are imports in Constantia, they have been produced in different centers.

Pottery analysis

Galabovo (SMG_S.BA_031).

Two red-slipped fragments were analyzed with XRD method. The results however show there is no difference in the mineral composition of the coating and the clay matrix. The main materials are quartz, muscovite and plagioclase (Fig. 43.3). Non-destructive Raman spectroscopy was applied for control testing. The spectrum confirmed the results made by XRD. There are no visible peaks specific for substance with crystal structure, which could have been used as a clay colorant. In some

fragments, even macroscopic, is seen difference in coloring in the cross-section, yet no boundary is observed in the SEM image (Fig. 43). Thus, the coloring results most probably from the firing process. It is concluded that the same clay matrix is used both for the slip and for the pot, yet in the former it is purified in order to receive smoother and impermeable surface. Petrographic analysis was carried out on a selection of pottery fragments, macroscopically divided is the following technologicalgroups:

Group I-II – fine and semi-fine pottery

From this group 11 thin sections were prepared and analyzed under microscope (Fig. 41, SMG S.BA 001 to SMG S.BA 018). Analysis shows that rocky particles constitute ca. 90% of the fabric and the remaining part is clay. Mineral particles are mostly from feldspar (plagioclase and potassium feldspar, the latter is often identified as microcline) and quartz. White mica is rarely observed. The inclusions are shown as mono-mineral fragments and more rarely as poly-mineral aggregates (rocky pieces). Their size is irregular, as sometimes is above 2 mm. Their shape is predominantly angular which shows that they are probably crashed rocky pieces, mixed with clay. Rounded grains (river sand) are rare. No particular orientation of the inclusions is observed, however it seems that the larger ones are concentrated in the inner part of the cross-section.

Group III – semi-coarse pottery The fragments of this group are from thick-walled vessels. Five thin sections are prepared and analyzed (Fig. 41, SMG_S.BA_ 020 to SMG_S.BA_024). The mineral composition of the fabric is the same, however, the maximal size of the inclusions is larger (up to 4 mm) and polymineralic aggregates are more often present.

Yabalkovo

The investigations of ceramic fragments from Yabalkovo are made by X-ray diffraction phase identification analysis (XRD).

The object of analysis is the white substance on four ceramic fragments – samplesYa_S.EN_009, Ya_S.EN_019, Ya_S.EN_020, Ya_S.EN_021. In the first case the substance is used for incrustation, and in the rest – for painting, applied over the slip of the vessels. The results show that the mineral used in the preparation of the white pigment is calcite ($CaCO_3$). It is possible that white marbles were grounded as limestone (sedimentary rocks, built from calcite) most often are grey in colour. In one of the samples (Ya_S.EN_019) is established also the presence of talc and clinochlore. These two minerals are characteristic of altered ultrabasic rocks, i.e. they are much softer and probably that's why they have been a suitable substance for preparation of white paint (Fig. 44).

Chokoba 18

The petrographic analysis is based on 11 thin sections prepared on ceramic fragments from Chokoba 18 (Fig. 42). As opposed to the Galabovo samples, the clay matrix is quite fine. The rocky and mineral particles are with much smaller sizes. Rarely are seen such with size up to 2 mm and more. Another characteristic is the predominance of metamorphic rocks and the mineral composition is as a whole quite more diversified. Except quartz and plagioclase are established epidote particles and inclusions from low metamorphic and altered volcanic rocks.

Sokol

Research of spherical inclusions in the clay paste, macroscopically defined as looking like metal nodules. Microscopic analysis showed that these inclusions have the shape of a sphere, 3 to 6 mm in size, with two clearly separated parts. The inner part seems like a core, which is quite harder and more compact and has an outer shell, which is more fragile and with more porous texture (Fig. 45.1). These specifications are seen quite well under scanning electron microscope (Fig. 45.2). With the help of SEM/EDX analysis was created a spectrum for establishing the presence of chemical elements in the central part and the periphery (Fig. 45.3-4). The analysis shows predominant presence of Mn and little quantity of K and Ca. High contents of oxygen points to a manganese oxide. The inclusions are probably present in the initial clay. If it is of Oligocene age, the chemical composition is easily explained.

Oligocene age is known in geology for its manganese-bearing deposits. The manganese ore deposit 'Obrochishte' in NE Bulgaria is formed in Lower Oligocene sediments, and there manganese occurs in the shape of concretions of different size. It may be supposed that due to the high temperature (up

to 800 C) during the firing process, the manganese mineral has been melted down and today we are seeing it as a slag-like nodule (Fig. 45.4). The periphery of the inclusions has a much more specific and rich chemical composition (Fig. 45.3). Analysis of this content shows that it is for clay and it probably is from the resource, used for the making of object.

Data from archaeobotanical analysis

Organic remains in clays Tempering clay with organic fillers (especially plant remains) is of particular importance for the prehistoric pottery production. Little attention has been paid so far to the botanical identification of the organic temper. On the other hand, the analysis of fibre remains may produce valuable data for the reconstruction of different ceramic recipes, as well as for the exploitation of natural resources.

The samples subject to analysis are studied by optical microscopy NOVEX (30x magnification). Microphotographs are taken with a USB Digital Microscope (20x-200x magnification). Samples from pottery fragments and burnt pieces of stationary household equipment are selected from several sites: Yabalkovo, Chokoba, Sokol, Dana bunar 1.

Yabalkovo. The studied material from the Early Neolithic settlement includes pieces of burnt remains from house walls and stationary equipment. The observation revealed negative imprints of small twigs, stalks and seeds.

The results demonstrate that in the preparation of the clay fabric are used mainly dry stalks of different cereal crops (straw). Probably left accidentally after threshing, there were preserved also a few grains mainly of barley (*Hordeum vulgare),* einkorn *(Triticum monococcum)* and club wheat *(Triticum aestivo-compactum)*. Weeds are presented with brome grass (*Bromus* sp.) and annual meadow grass (*Poa annua*) (Fig. 48, 4-6).

Sokol. Samples have been taken from the remains of burnt stationary equipment (bins and granaries), excavated in the EBA layer of the tell (Fig. 45). Microscopic observations show high concentration of organic mixtures, with a dominant presence of barley (*Hordeum vulgare*). Different parts of the ear are added to the clay paste – grains, chaff, spikelet bases (Figs. 50, 51).

Dana Bunar 1. For the purpose of the project 28 ceramic fragments have been selected and studied (Fig. 52). On the surface of three of them are identified negative imprints of barley grains (*Hordeum vulgare*) and cereal chaff (*Triticum* sp.). The negatives of rye (*Secale* sp.) are found in two fragments (Figs. 53, 54).

Chokoba. The investigated materials from MBA-LBA are from sites 18 and 18A. They include thick- walled pottery fragments and pieces of burnt daub and remains of household equipment (Fig. 55). During the firing process organic filler is partly or completely destroyed, leaving negative imprints in the fabric. Daub pieces from Chokoba 18A contain mainly straw and cereal grains (*Triticum* sp.), as well as small negatives from burnt chaff (Fig. 56).

Traces of plant remains were found on daub pieces and ceramic fragments from Chokoba 18. Daub pieces contain imprints from einkorn (*Triticum monococcum*), emmer (*Triticum dicoccum*) and club wheat (*Triticum aestivo-compactum*), barley (*Hordeum vulgare*), rye (*Secale cereale*) and brome grass (*Bromus sp*.) (Fig. 57, 1-3). Again barley is best represented among the organic fillers. On the surface of the ceramic fragments and in the fresh fractures is established the presence of club wheat, cereal chaff (*Triticum* sp.) and barley (*Hordeum vulgare*).

The quantity of the investigated ceramic fragments and daub pieces from the different sites varies, that is why it is difficult to make a final conclusion. The results show a dominant presence of admixtures from different parts of wheat plants and barley.

Mat and basket impressions on pottery bases

The impressions give information for the technique of pottery manufacture and especially for the process of shaping and drying of pots prior to firing. The final results will be laid down in the PhD thesis of M. Andonova. Here a brief summary of the preliminary analysis is given.

Object of this research are 27 samples of pottery bases, with imprints of mats and/or baskets from the Chalcolithic layer of Dana Bunar 1.Two types of weaving techniques are presented: open/faced simple twinning with circular orientation and plain/checker weave with square orientation. In

circular items the passive elements, sourced from the centre, which initiated the weave, will be called warp, the active elements, which are twined in intervals between warps and are coiled from the centre towards the periphery – weft. In plaits with square orientation, passive elements will be called ribs, and active elements – weft.

The bases with imprints of circular weaves were subject to defining of the minimum or maximum possible diameter of the base and the weave. The minimal size was assumed according to the outer preserved arc, formed by the coiling of the weft, when it doesn't match the terminus of the pot base. The maximum diameter is established when the terminus of the pot base is present; in both cases were used graphic arcs for the establishment of the diameter.

In the macroscopic description of the types of weaves and elements casts were prepared from the negative impressions with the help of dental wax, heated to a maximum of 300° C. After that, an analysis with stereoscope and cold LED light was undertaken, as well as SEM images at low vacuum conditions of two fragments of each type of weave.

Mats/baskets with circular organization. Most of the studied material from Dana Bunar 1 consists of fragments or whole bases of ceramic pots with imprints of mats or baskets, made by open twining with circular orientation (18 out of 27 samples). In several cases the centre of the weave is preserved, the one that initiates the weaving: those are samples №, 3, 4, 9 and 16, as well as partially preserved centre in №17 and 19. The cases, in which we can presume that the edge of the woven object is present, are rare – for example in №14 and 15b. Some observations allow the assumption that at least in some case shallow containers made of plant materials were used in the process of shaping the body of the vessels.

The dominant weaving technique is open simple twining, with one exception – fragment №6, which has an impression from a weft-faced simple twining (Fig. 58.1). In the cases of open simple twining a square centre is present with an even number of initial stakes, placed at right angle, from where the actual stakes start, around which the weft strands are twined in a spiral. Several samples demonstrate the direction of weave – from left to right in the mark, which would be reciprocal in the original weaved object. In almost all cases of circular weaves, the stakes are hidden from the coils of the weft and thus their section and diameter remains invisible. The weft of all circular weaves is with circular section, which allows the measurement of its diameter. The diameter of the weft in almost all of the samples varies slightly from 2 to 3 mm, with one exception – №15b, where it is 5 mm. Several weaves (i.e. №3, 4 and other) are extremely regular and the size of the weft doesn't change, it keeps its value around 2 mm in diameter, with a constant, growing from the center to the periphery, interval between the stakes. Others are not so precise and their wefts' diameters vary, as well as the interval between warps is irregular (e.g. №1, 15b).

Precisely the weft is the main evidence, allowing speculation about the plant materials chosen. It has to be noted that no actual plant remains were recorded, but some of the impressions allow extrapolation of the plant morphology. In the cases of wefts with lower diameter values of diameter, with the help of stereoscope in combination with SEM images, there are clearly distinguishable vertical grooves, parallel to one another (Fig. 59). These common morphologic features (section, diameter, longitudinal ridges and grooves) of the leaf and/or stem, are in support of monocotyledonous plants, whose leaves and stems have a circular transverse section and their epidermis is saturated with parallel grooves along the leaves and the stem. Representatives of the monocotyledonous flora, traditionally exploited in basketry, could be types from the families *Poaceae, Cyperaceae, Juncaceae*. This list could be narrowed among those types, spread in the modern flora of the Balkans, in comparison with the available paleobotanical data and ethnographic fieldwork data. In the case of sample №15, the higher diameter (5mm), as well as the plain surface of the weft imprints could be explained in many ways but it could also testify for the use of dicotyledonous plant with a circular cross section. Those could be young twigs of similar diameter, chosen among several types of trees, spread in the Balkan flora, from the families *Salicaceae, Aceraceae, Fagaceae Betulaceae, Cornaceae, Malvaceae* and other.

Rectangular weaves. Without exception, these items are made in plain weave, where each weft goes alternately over and under each warp rib (1:1). The weave is quite dense and compact, with

the exception of fragments №21, 22, 24 and 27, where there is a greater distance between the ribs and the weft is less compact. It has to be noted that fragments №20, 23, 25 have extremely well preserved impressions of weaved structures (Fig. 60). The width of the weft varies between 5 and 11 mm in those fragments and in several places a doubling of the weft is recorded with the purpose of maintaining the desired width. All imprints represent flat cross-section and parallel grooves, again characteristic for the monocotyledonous plants.

As with circular weaves, here too actual plant remains are missing, but only the imprints of epidermal tissue of the plant leaves (Fig. 61). The transverse section of the leaf and its width, as well as the pronounced distance between the grooves, could be in favour of the choice of broad-leaved plants, for example from the families *Typhaceae* and *Poaceae*. Traces from rotation on the bases are not present and this allows the assumption that the pots have been placed on the plaited structures in the process of drying.

From a chronological point of view, the available evidence suggests that rectangular weaves are almost exclusively associated with Early Chalcolithic pottery, while the impressions of circular mats/baskets are mostly on pottery from complexes dated to a later stage of the Early Chalcolithic and the Late Chalcolithic. Whether this reflects a local/regional preference or it has a chronological meaning, could be judged after comparisons of the data from Dana bunar 1 and those from other Chalcolithic sites.

Identification of lipids

The testing of organic remains in cooking pots (so-called organic residue analysis) gives basic data for their use. In the first year of the project, samples are given from Yabalkovo (EN) – 2 fragments (Ya_S.EN_004 and 011). The results are positive. Gas-chromatography gives the presence of highly molecular organic compositions, which identification with mass-spectral analysis is forthcoming in 2018.

CONCLUSION OF THE INTERMEDIATE RESULTS AND PERSPECTIVES FOR THE DEVELOPMENT OF THE PROJECT

In conclusion of the report, it could be underlined that the work on the project is developing successfully and the accumulation of the necessary empirical data is in an advanced stage. It is early for interpretation. The main reasons are at least two – not all fields of the matrix are filled and not all tests undertaken in 2017 have presented their results. In addition, the team foresees an expansion of the scope of the work in several directions. There is now reason to doubt, that the chosen instrumental methods, the stages of work and the pace of processing of the field information and so on, will not lead to positive results.

Concluding the work made through the year, we reach the opinion, that it's necessary to develop the research in two directions: 1) further research of those objects, which exhibit have a potential for diachronic ("vertical") analysis within the stages of one era or between the different prehistoric ages;

2) increasing of the territorial range within the region with the attachment of new sites. With the purpose of correlation the data with the neighboring territories is necessary the inclusion of data from the western parts of the upper Thracian lowland; with East of Trace and Northwestern Anatolia; with the Bulgarian seaside at East and with North Bulgaria (Central and Northeastern). Enlargement is envisioned of the data base with the inclusion of information from the objects Nova Nadezhda, Chavdarova cheshma (Simeonovgrad), Aşağı Pınar (Kırklareli) and Hoca çeşme, Troy and other. It is possible the inclusion of data from the region the Marmara sea (Aktopraklık) and from the Black sea – Sozopol and Kiten. The correlation of the data in north could lean on the ceramic from objects of the sites north of Stara planina – for example Dzhulyunitsa – Early Neolithic (Veliko Tarnovo region) and Belokopitovo – Late Bronze age (Shumen region).

"The expansion" of the project in those directions will be made in the established time and financial constraints, object of Contract DN10/8 from 16.12.2016.

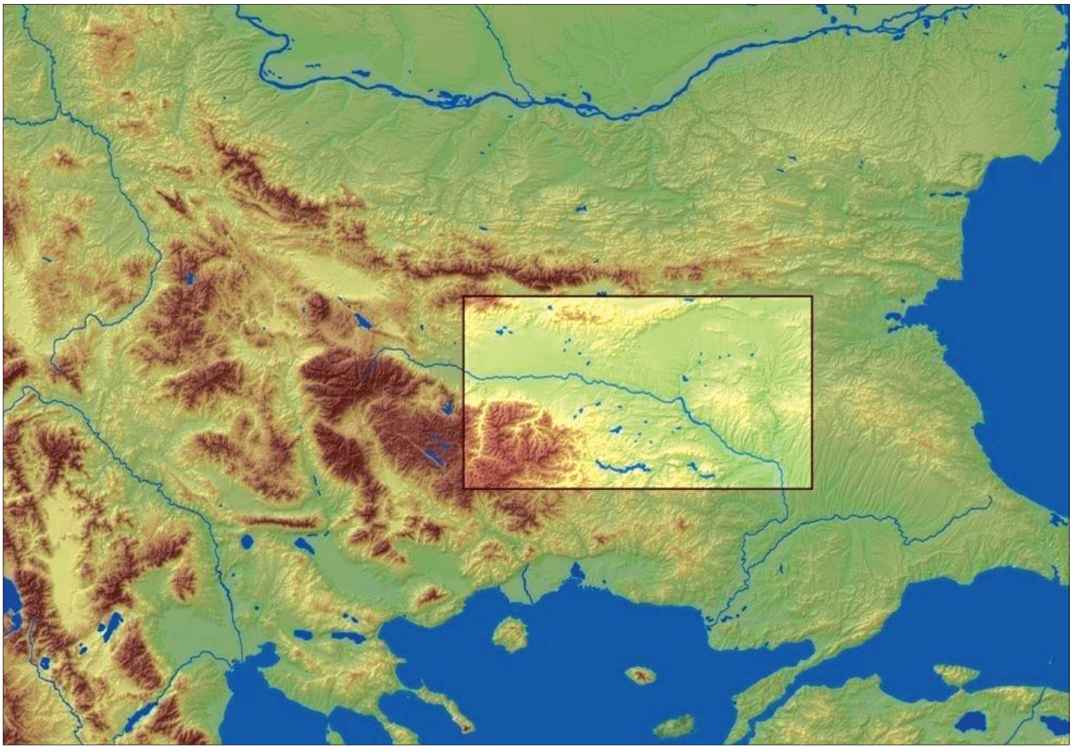


Fig. 1. Map of Bulgaria with the study area (highlighted).

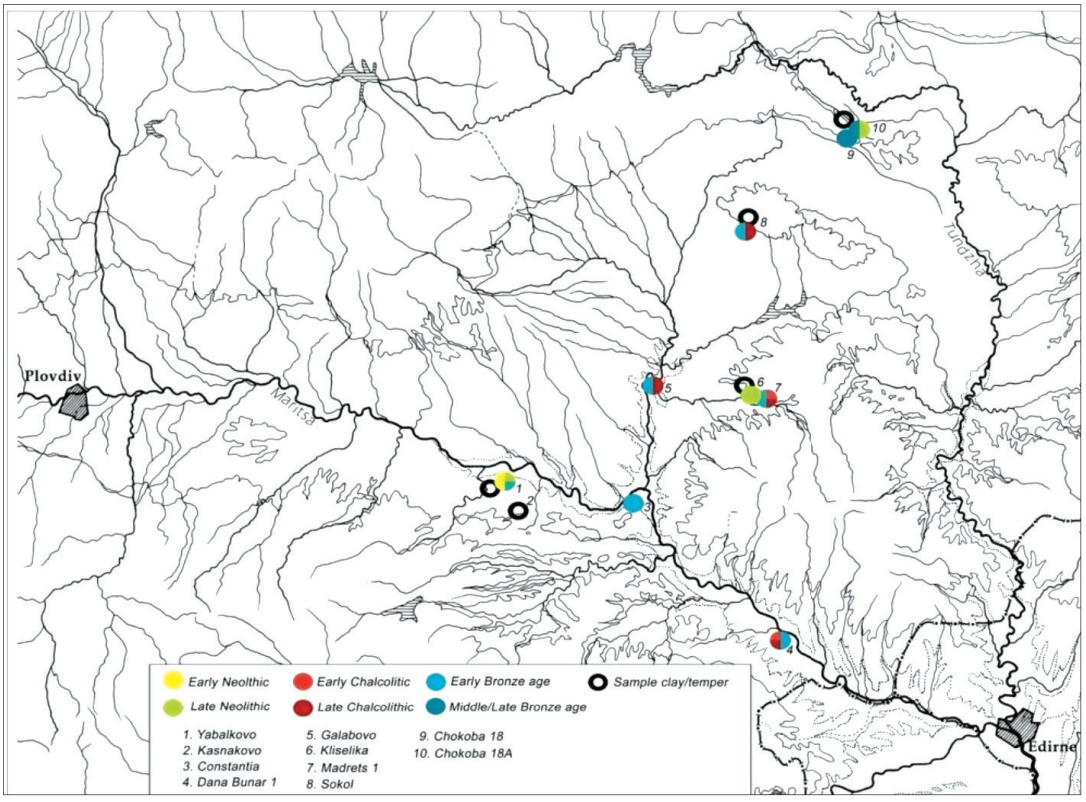
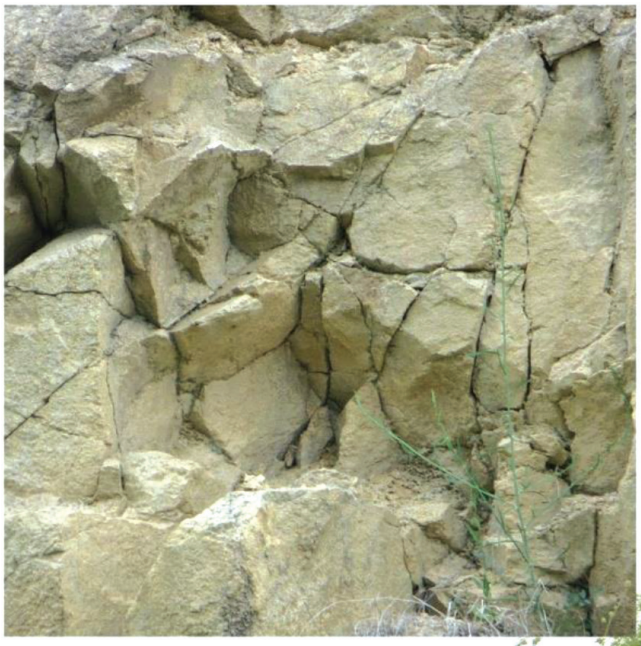


Fig. 2. Map of Upper Thracian lowlands with sites included in the project.



1. Granitoide cracks in the area of Sokol



2. Fault zones of tectonic clay



3. Fault zones of tectonic clay

Fig. 3. Granitoide cracks and fault zones of tectonic clay in the area of Sokol.



Sample Ya_R_01



Sample Ya_R_02



Modern quarry in the area of Yabalkovo

Fig. 4. Provenance of clay samples from the area of Yabalkovo.

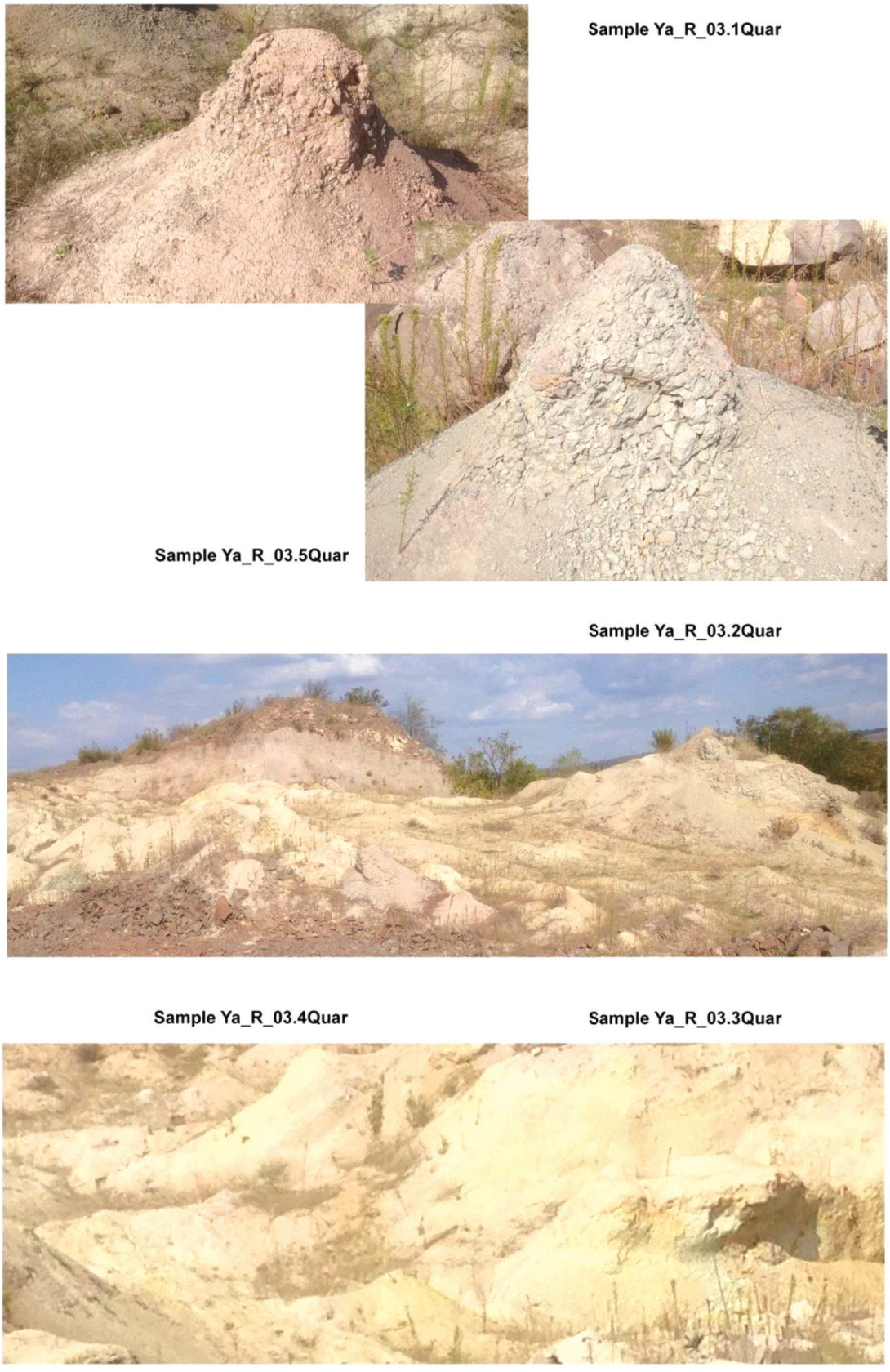


Fig. 5. Provenance of clay samples from the area of Yabalkovo (modern quarry samples).



Fig. 6. Work with pottery collections. Selection of sherds for analyses.

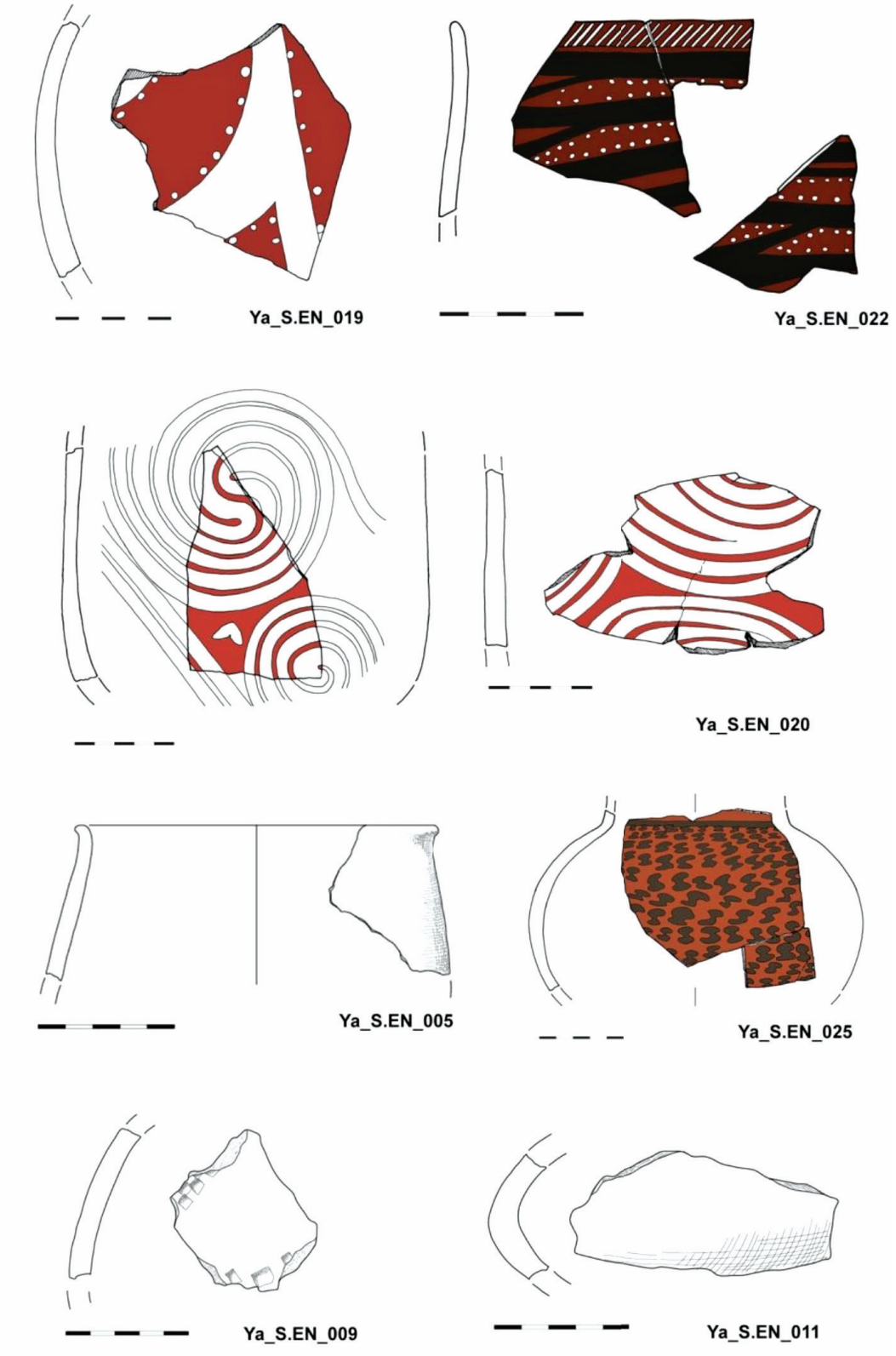


Fig. 7. Pottery sherds from Yabalkovo, Early Neolithic.

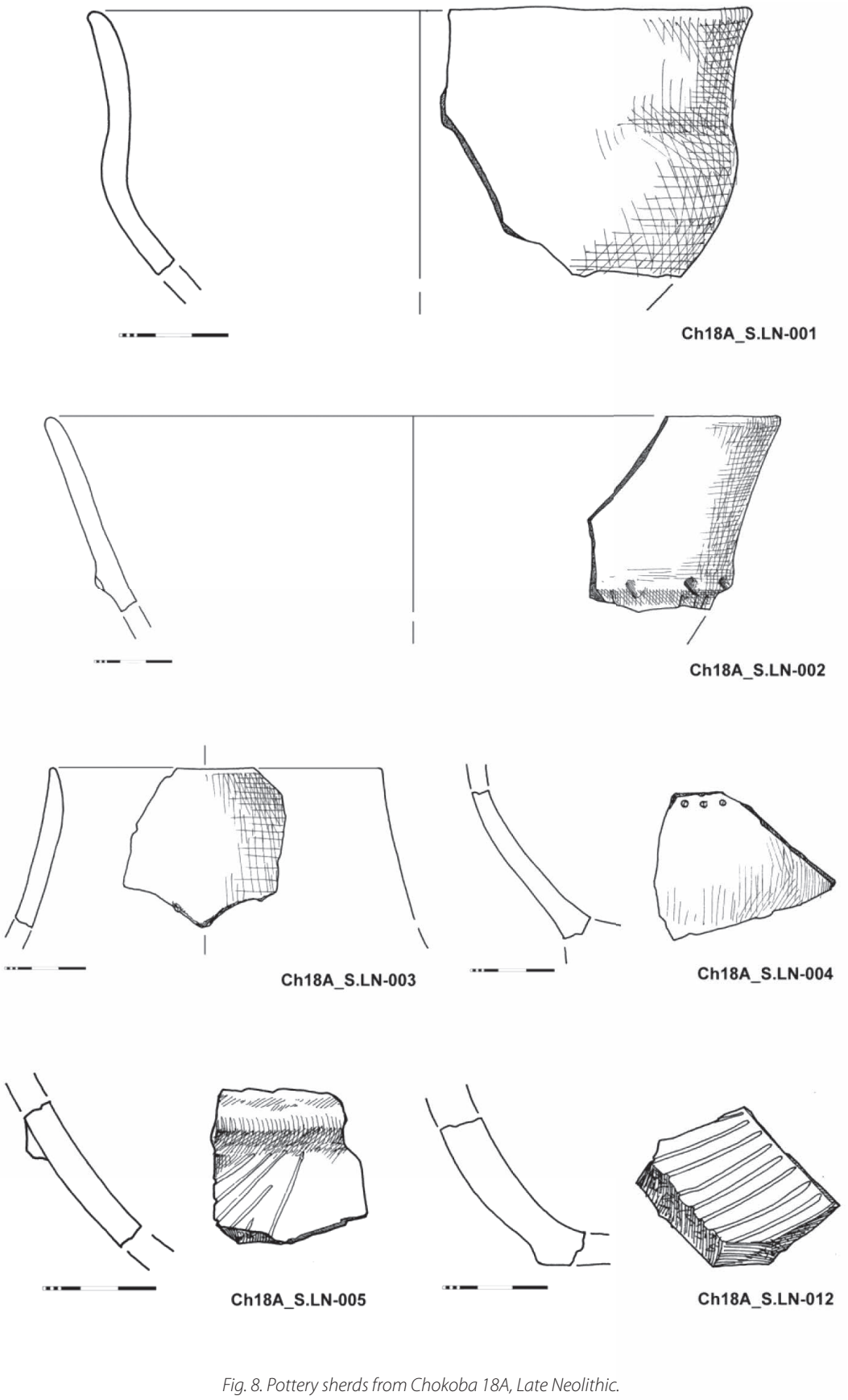


Fig. 8. Pottery sherds from Chokoba 18A, Late Neolithic.

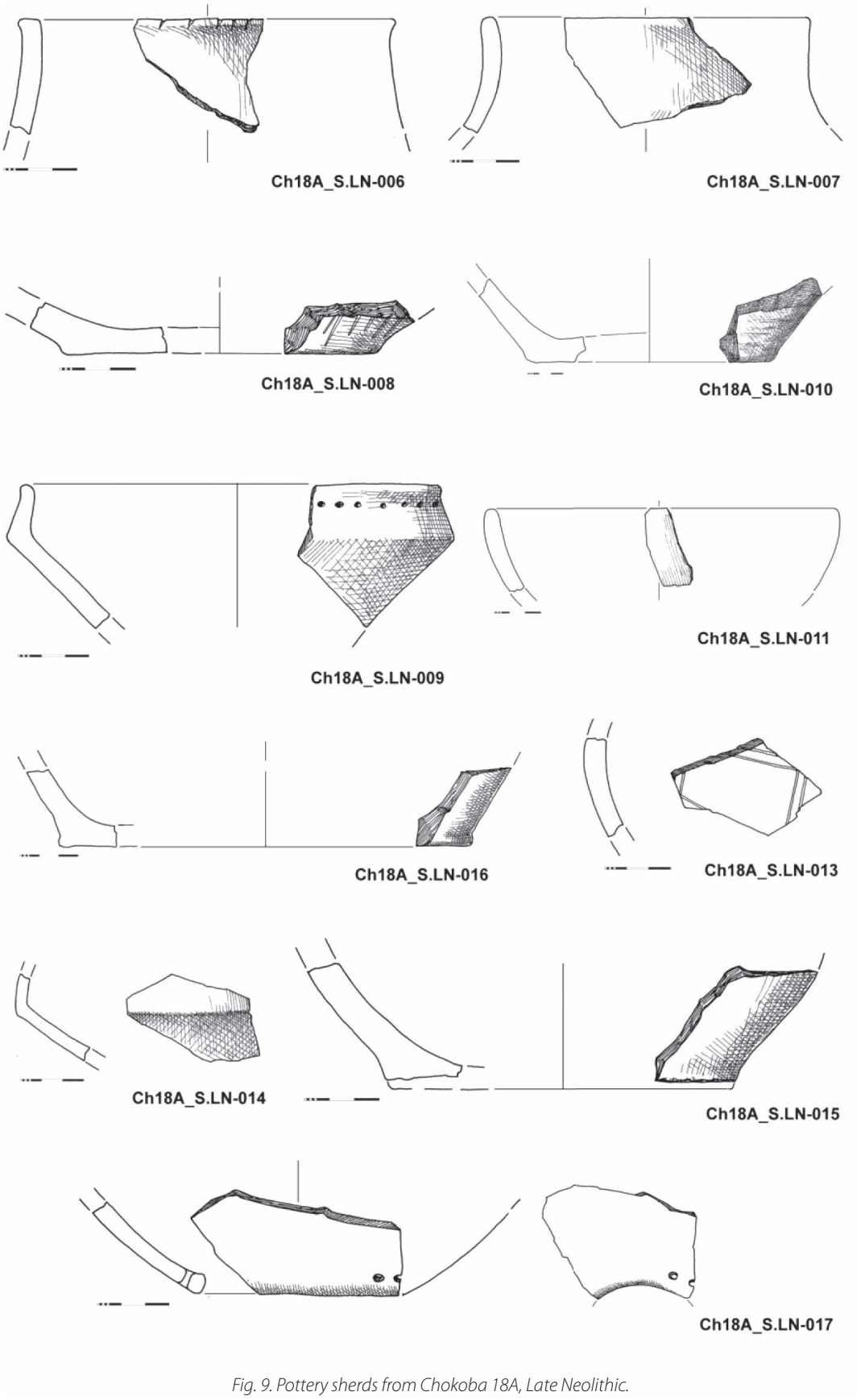


Fig. 9. Pottery sherds from Chokoba 18A, Late Neolithic.

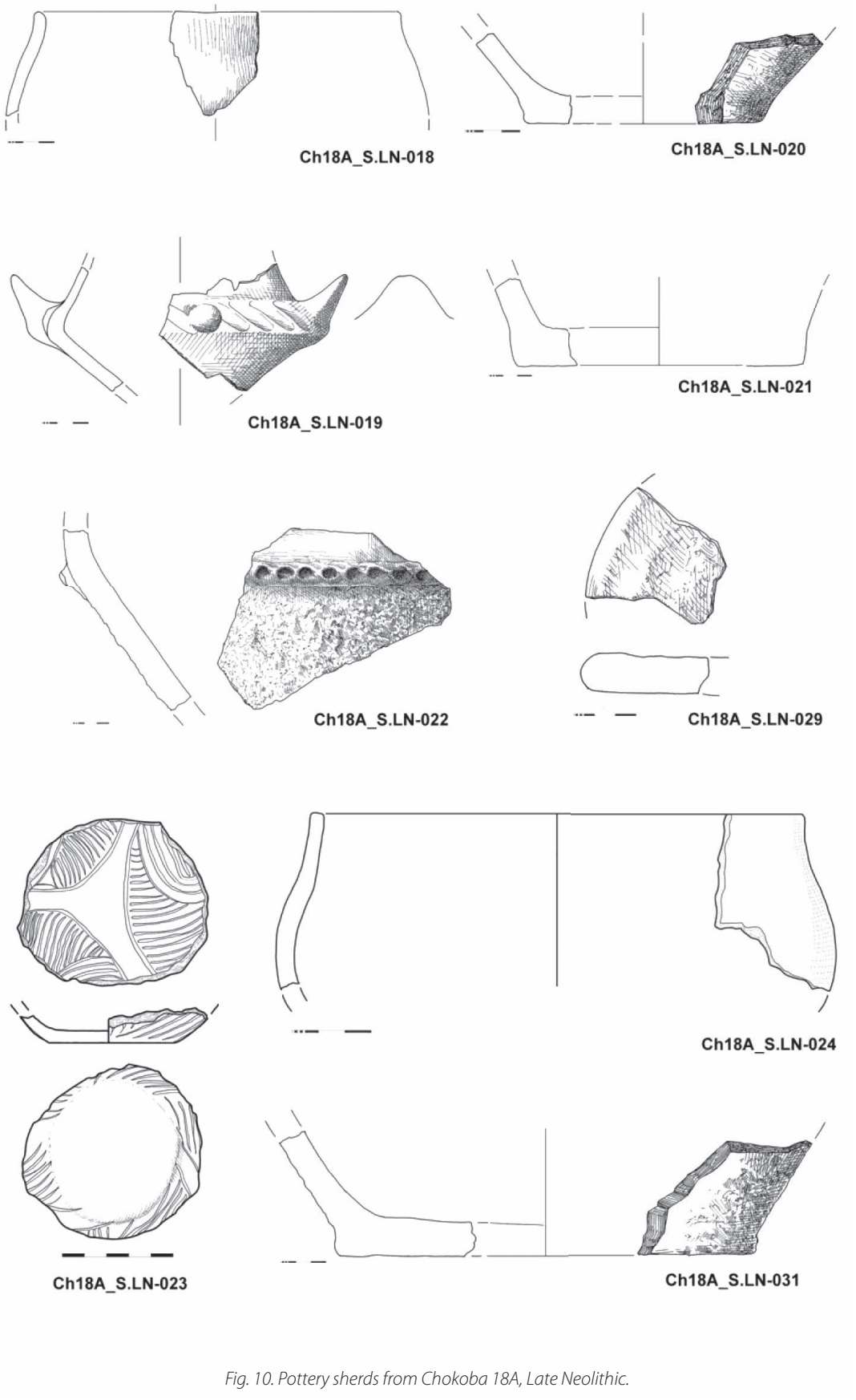


Fig. 10. Pottery sherds from Chokoba 18A, Late Neolithic.

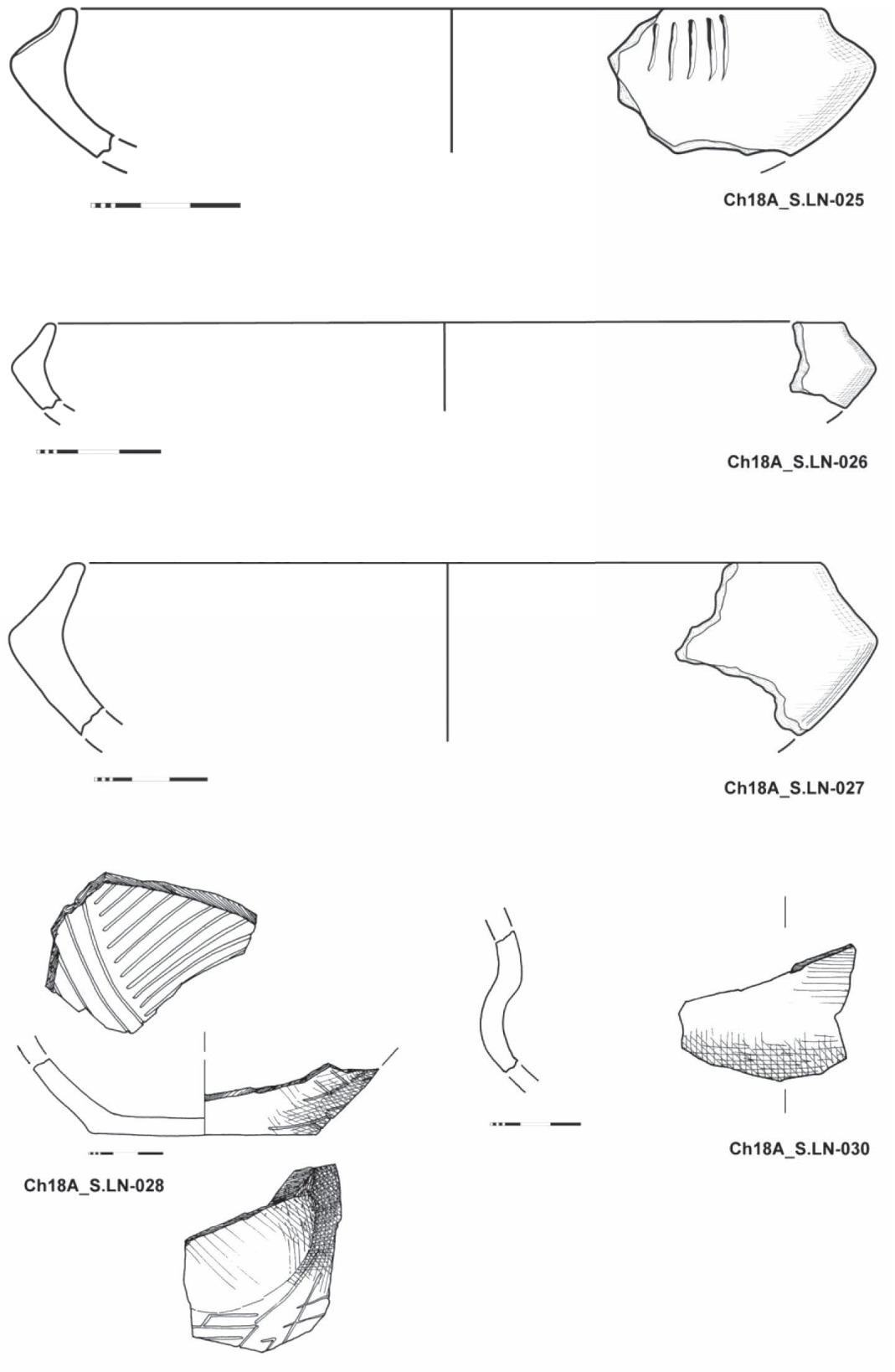


Fig. 11. Pottery sherds from Chokoba 18A, Late Neolithic.

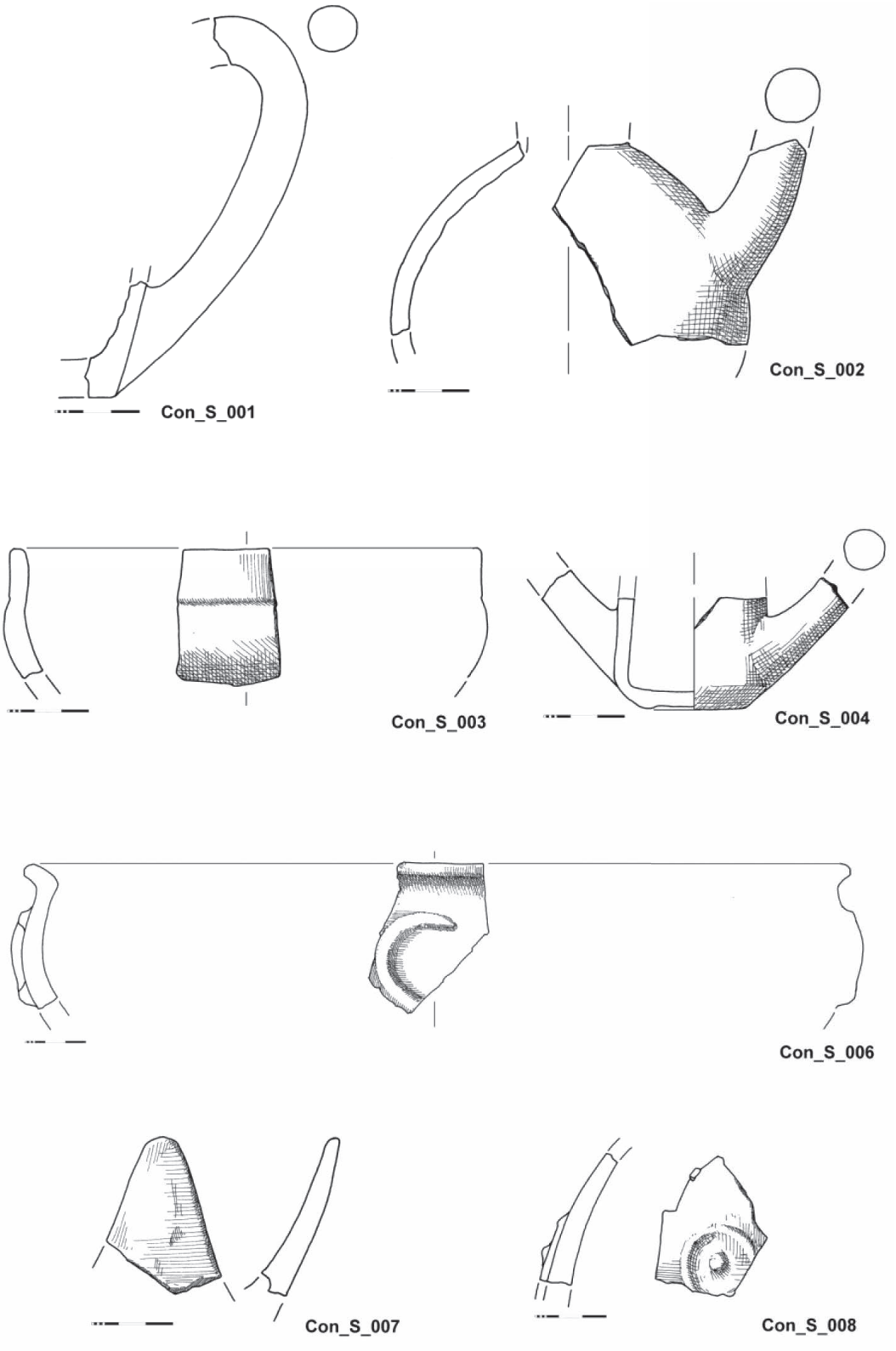


Fig. 12. Pottery sherds from Constantia, Early Bronze Age.

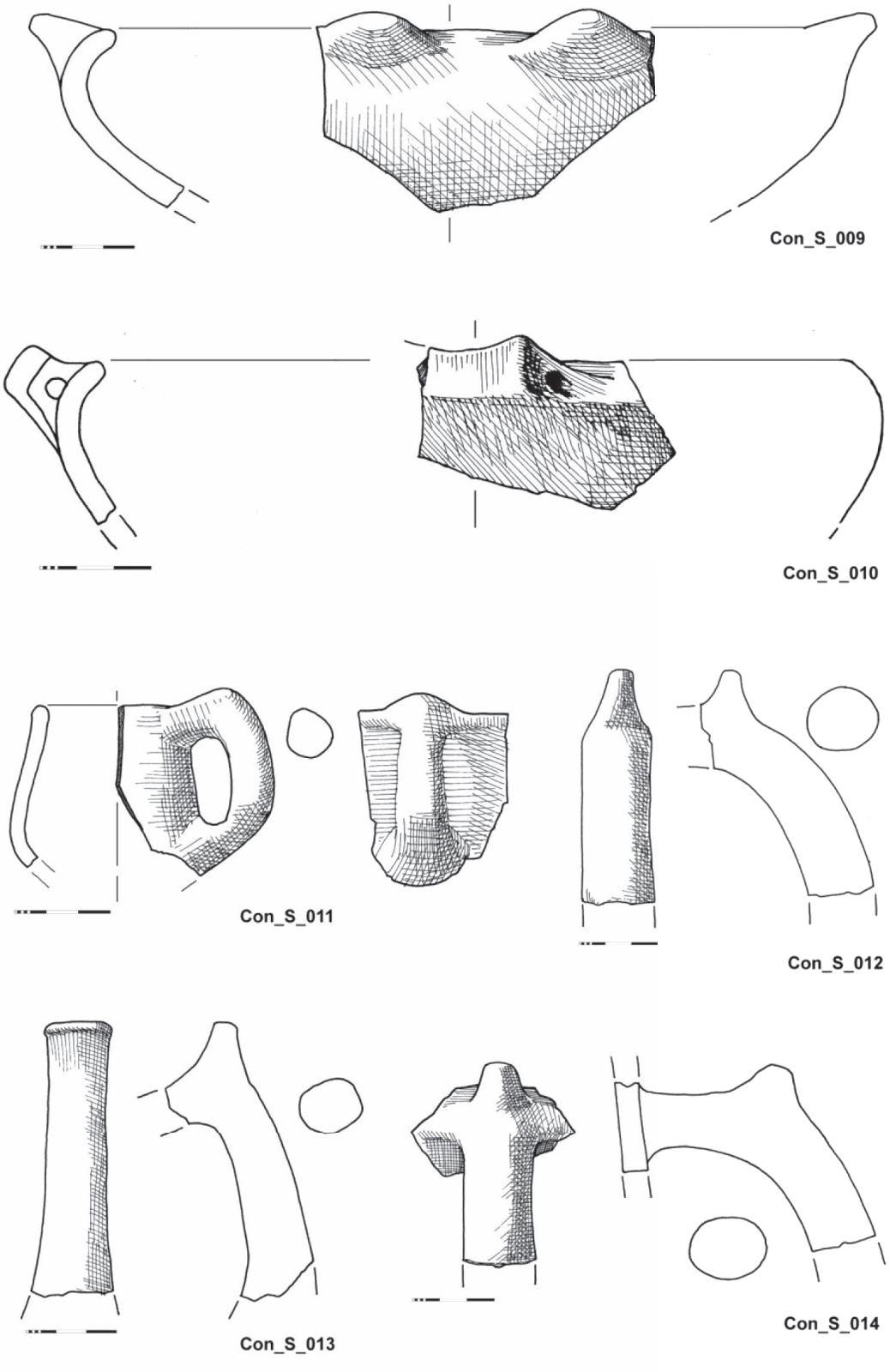


Fig. 13. Pottery sherds from Constantia, Early Bronze Age.

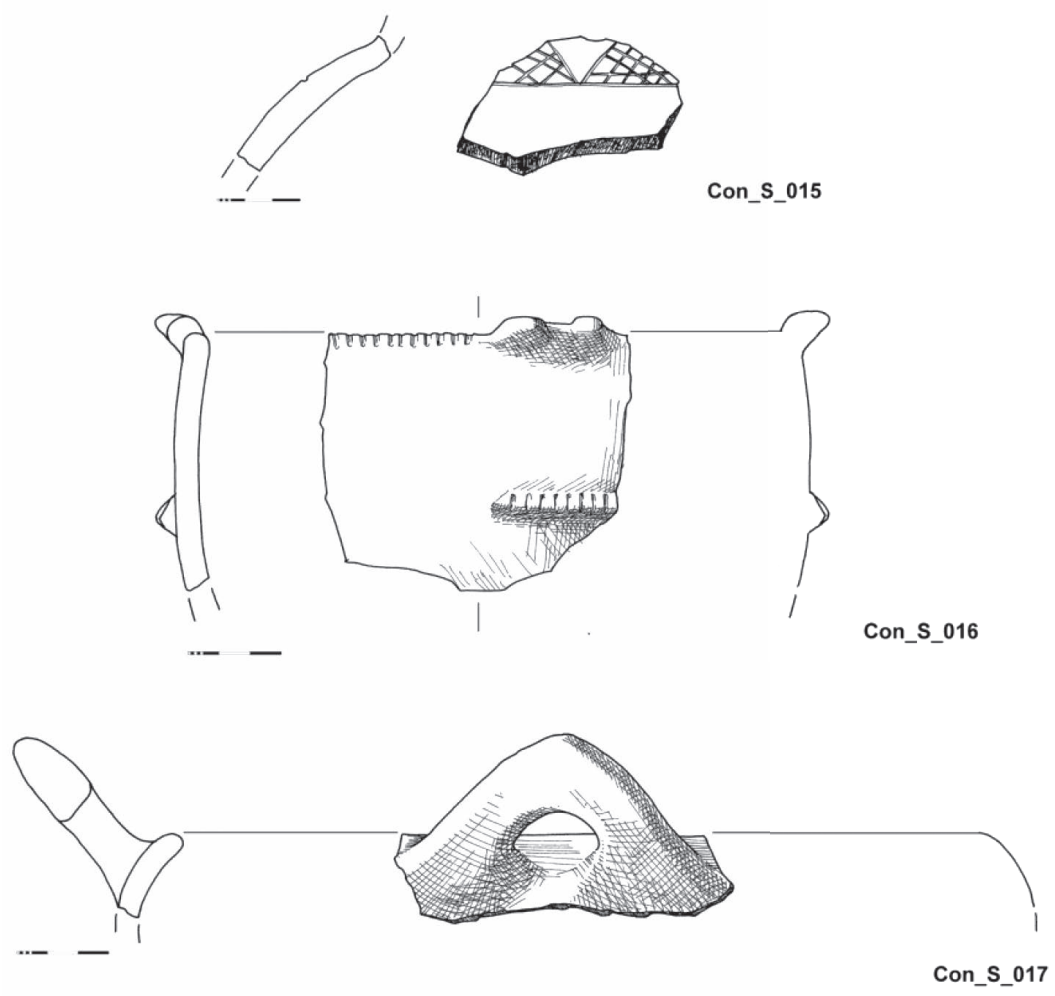


Fig. 14. Pottery sherds from Constantia, Early Bronze Age.

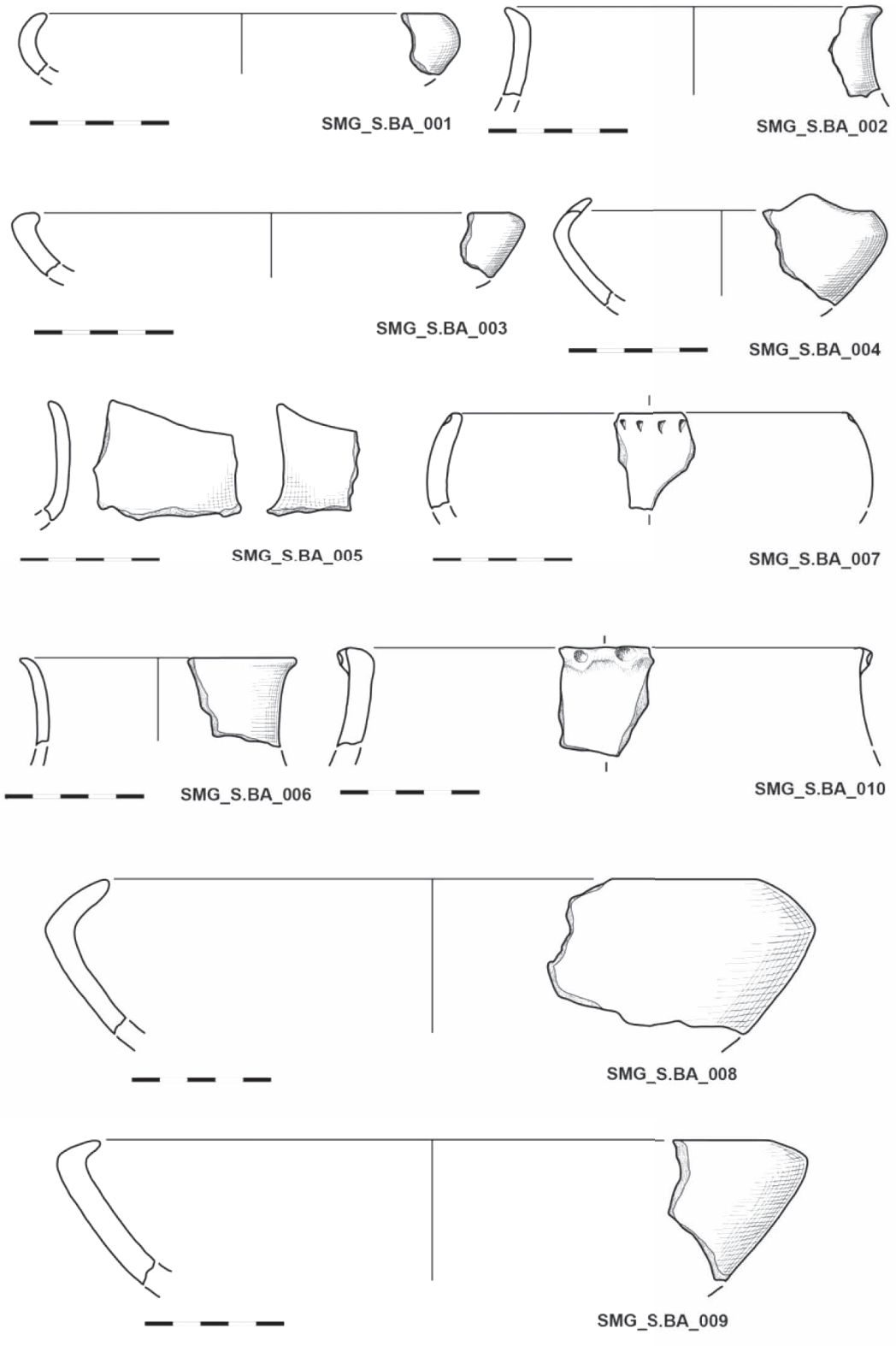


Fig. 15. Pottery sherds from tell Galabovo, Early and Middle Bronze Age.

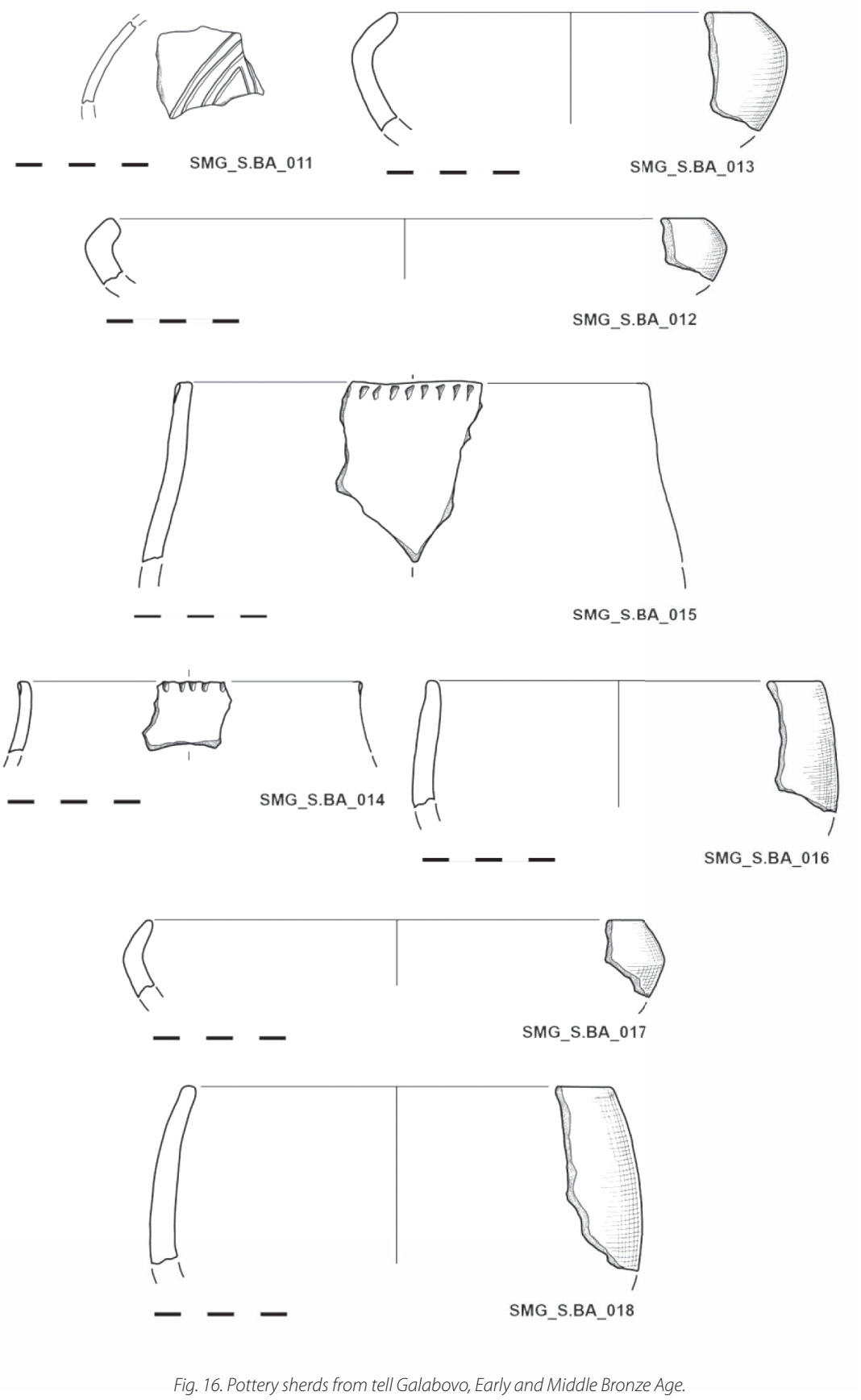


Fig. 16. Pottery sherds from tell Galabovo, Early and Middle Bronze Age.

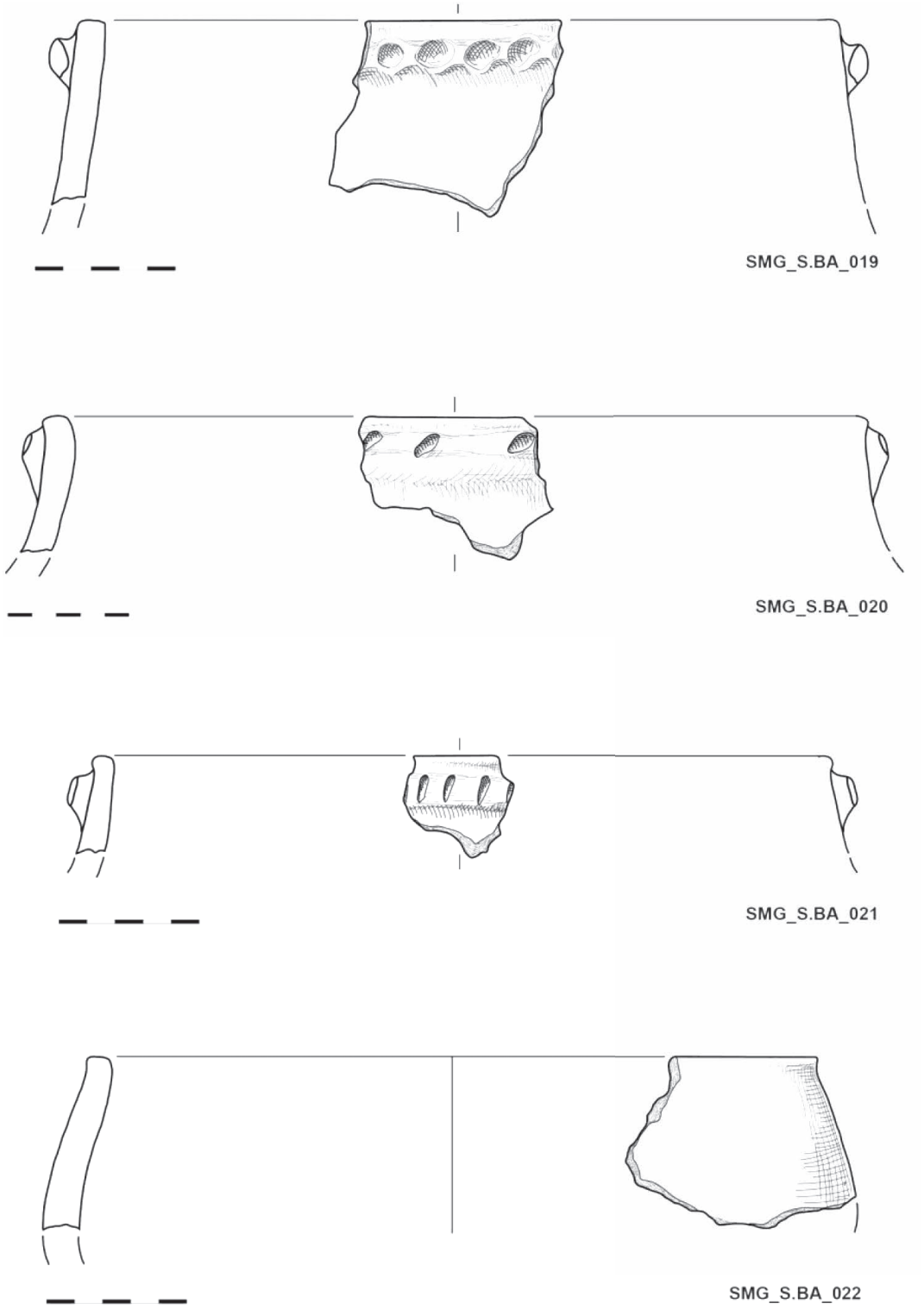


Fig. 17. Pottery sherds from tell Galabovo, Early and Middle Bronze Age.

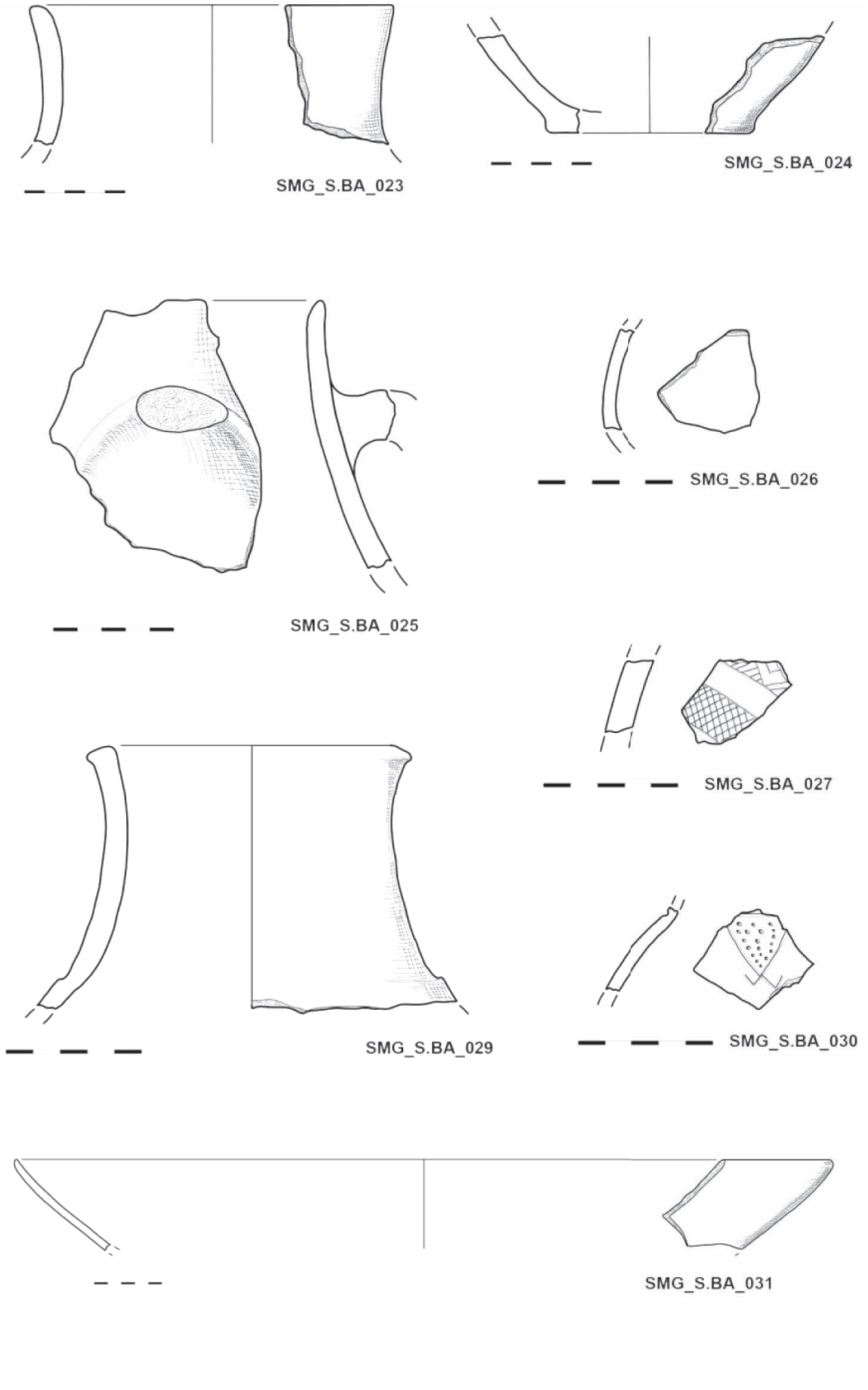


Fig. 18. Pottery sherds from tell Galabovo, Early and Middle Bronze Age.

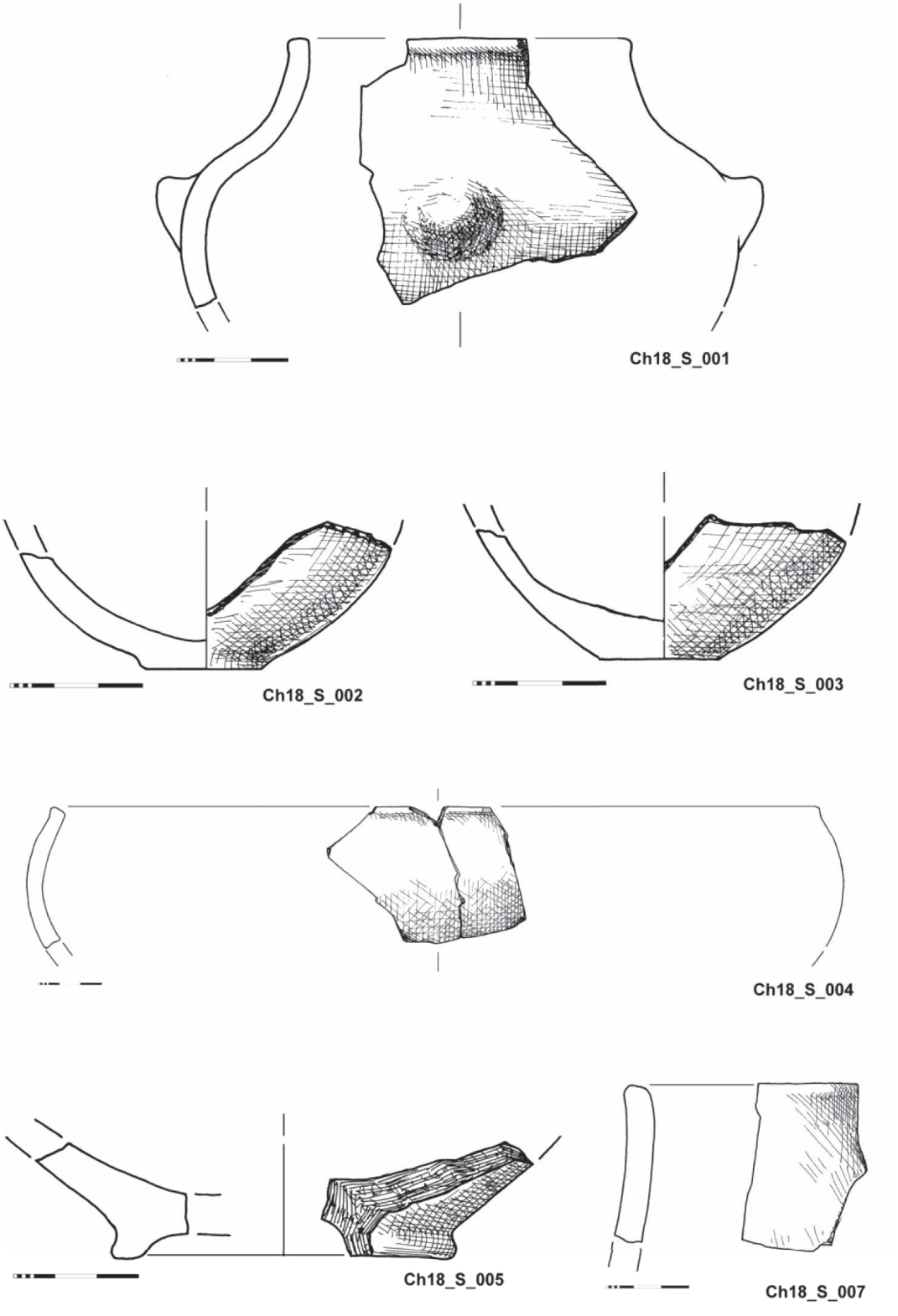


Fig. 19. Pottery sherds from Chokoba 18, Middle Bronze Age.

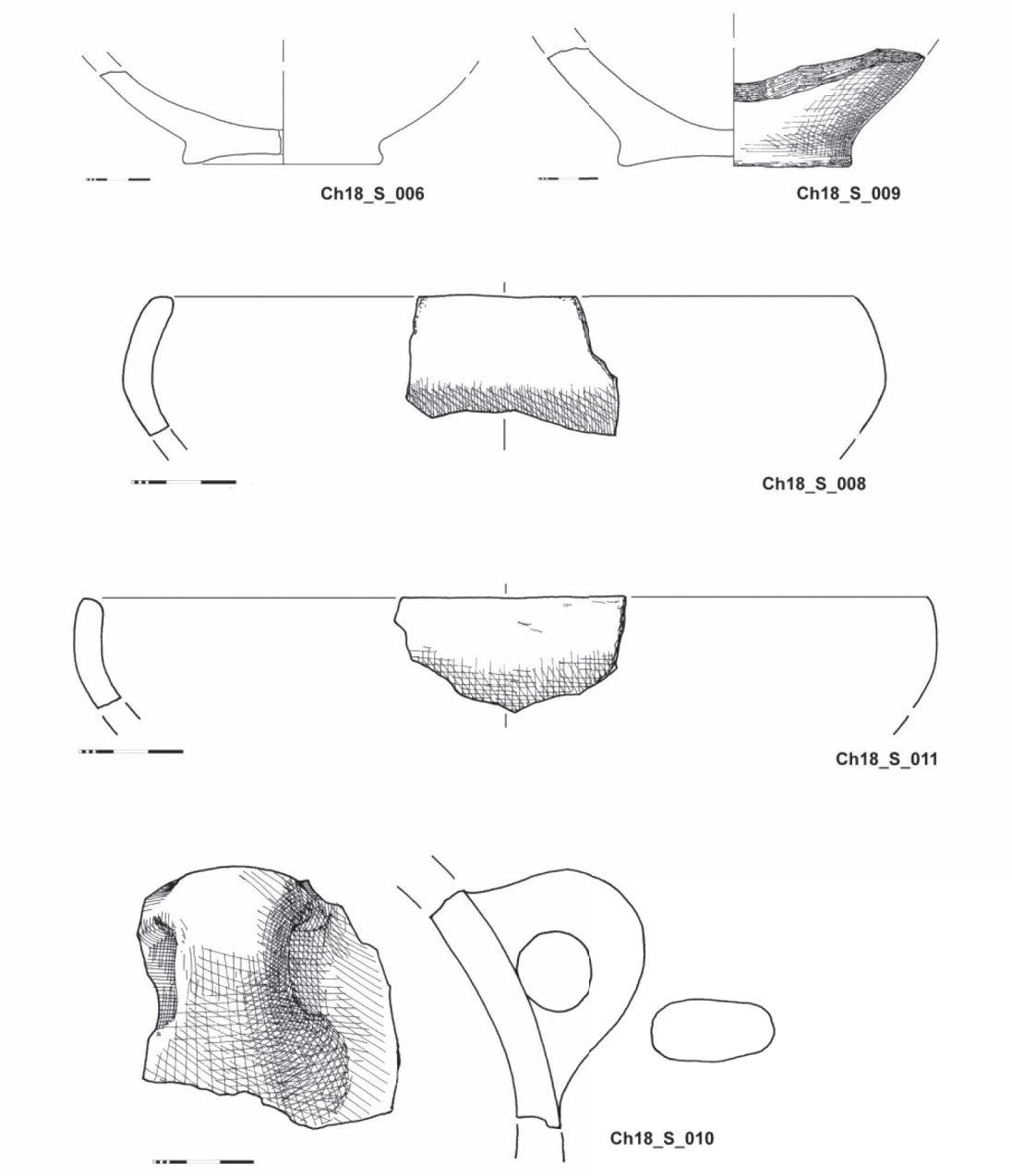


Fig. 20. Pottery sherds from Chokoba 18, Middle Bronze Age.

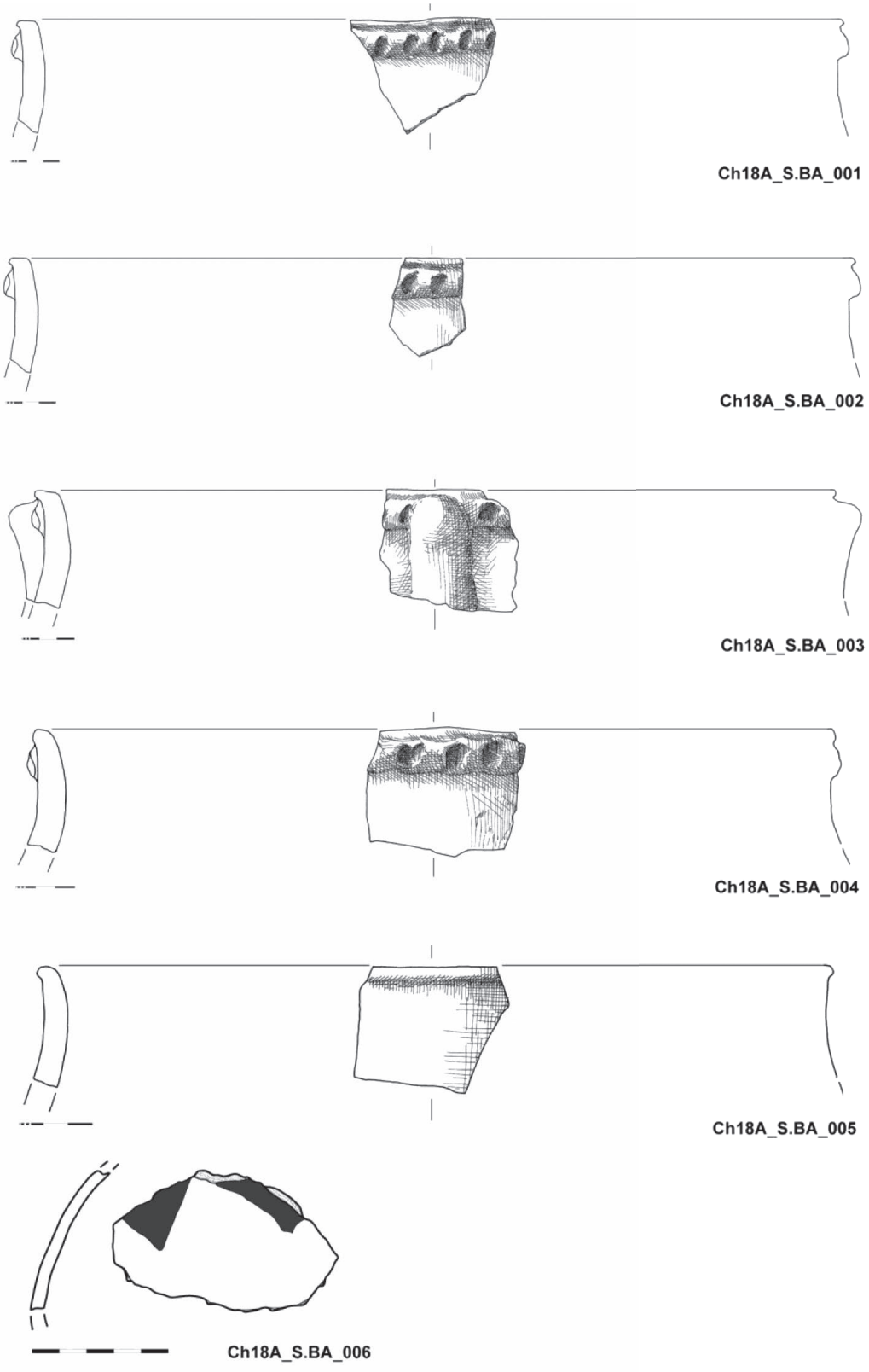


Fig. 21. Pottery sherds from Chokoba 18A, Middle and Late Bronze Age.

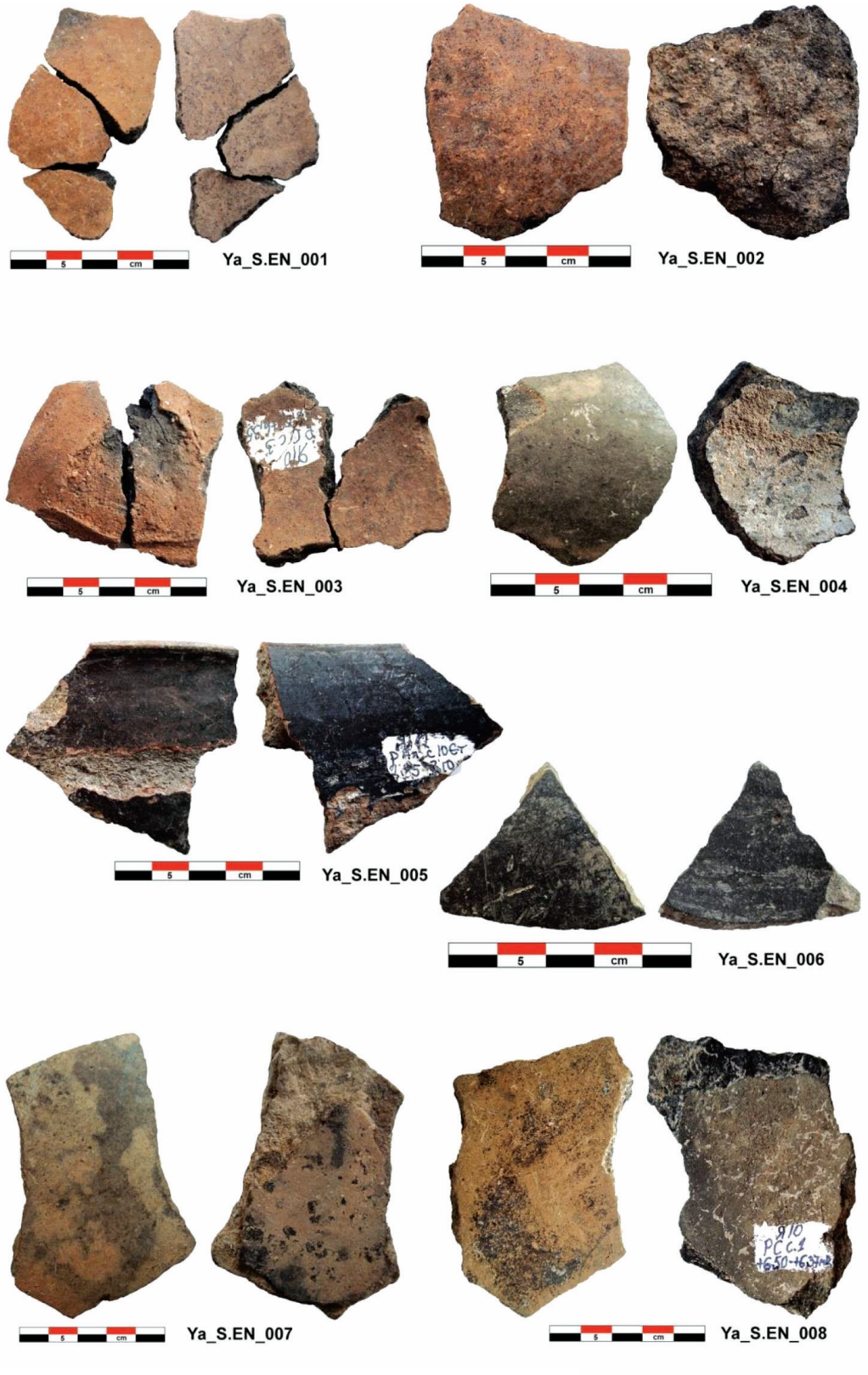


Fig. 22. Pottery sherds from Yabalkovo, Early Neolithic.

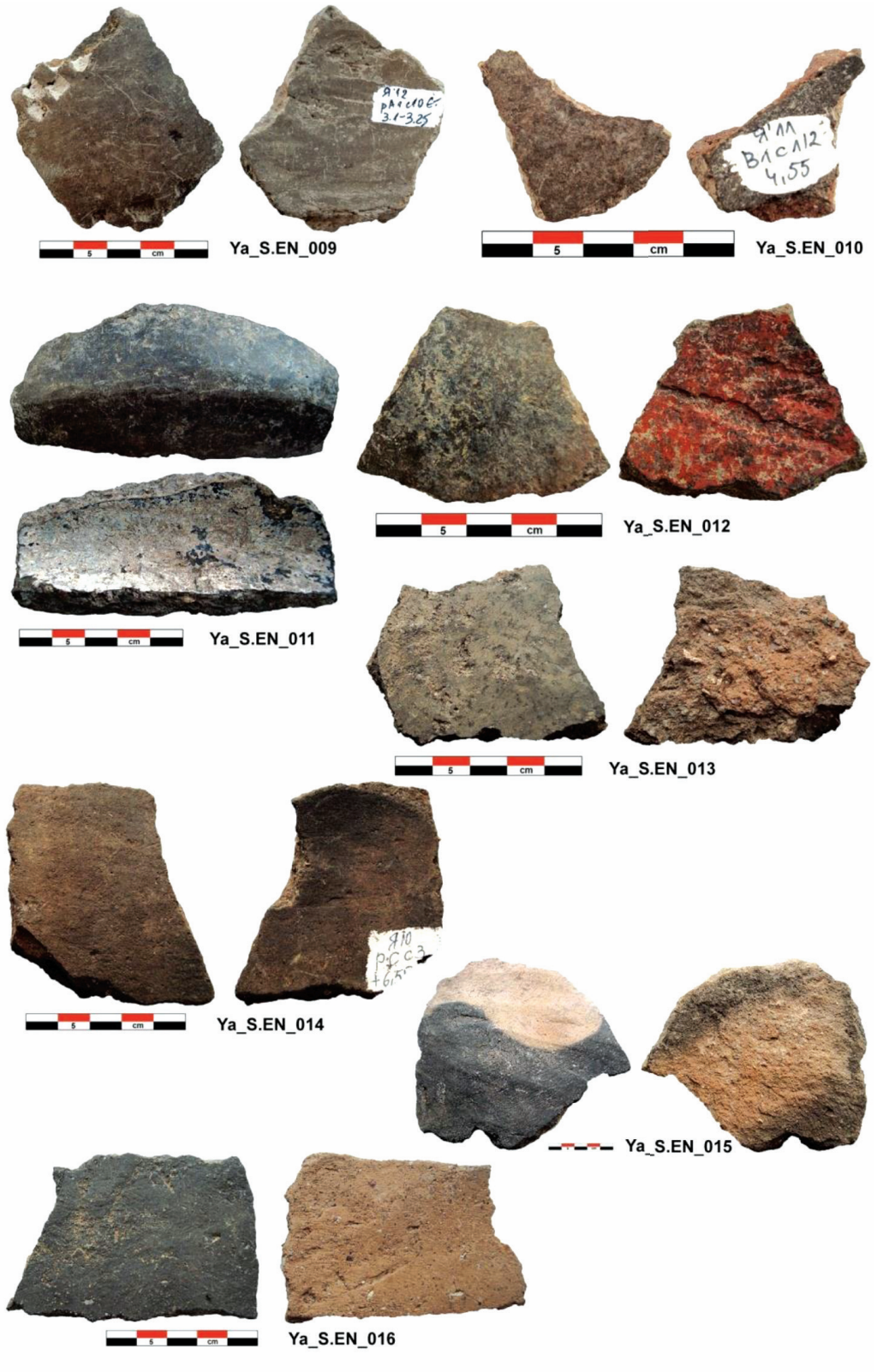


Fig. 23. Pottery sherds from Yabalkovo, Early Neolithic.

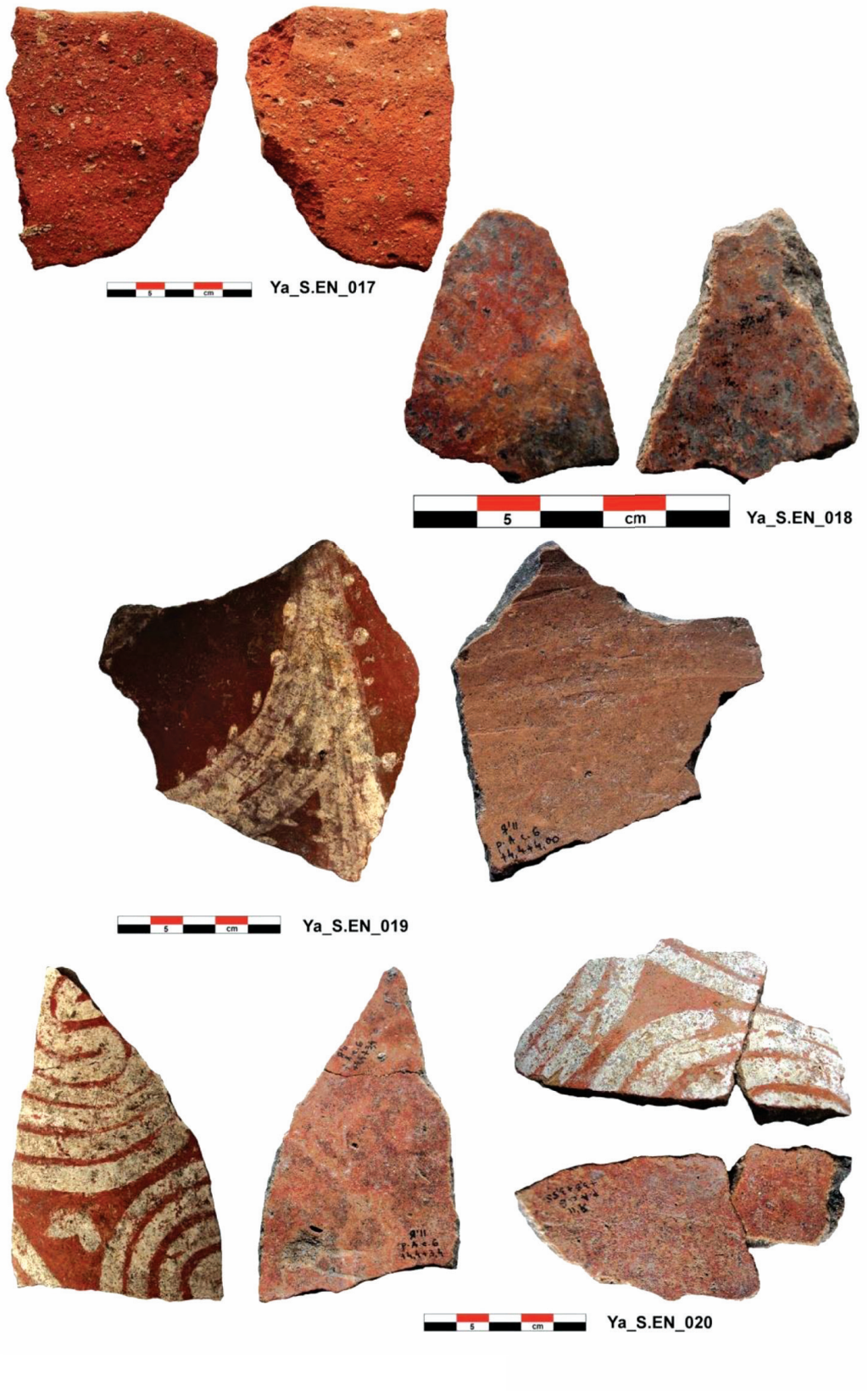


Fig. 24. Pottery sherds from Yabalkovo, Early Neolithic.

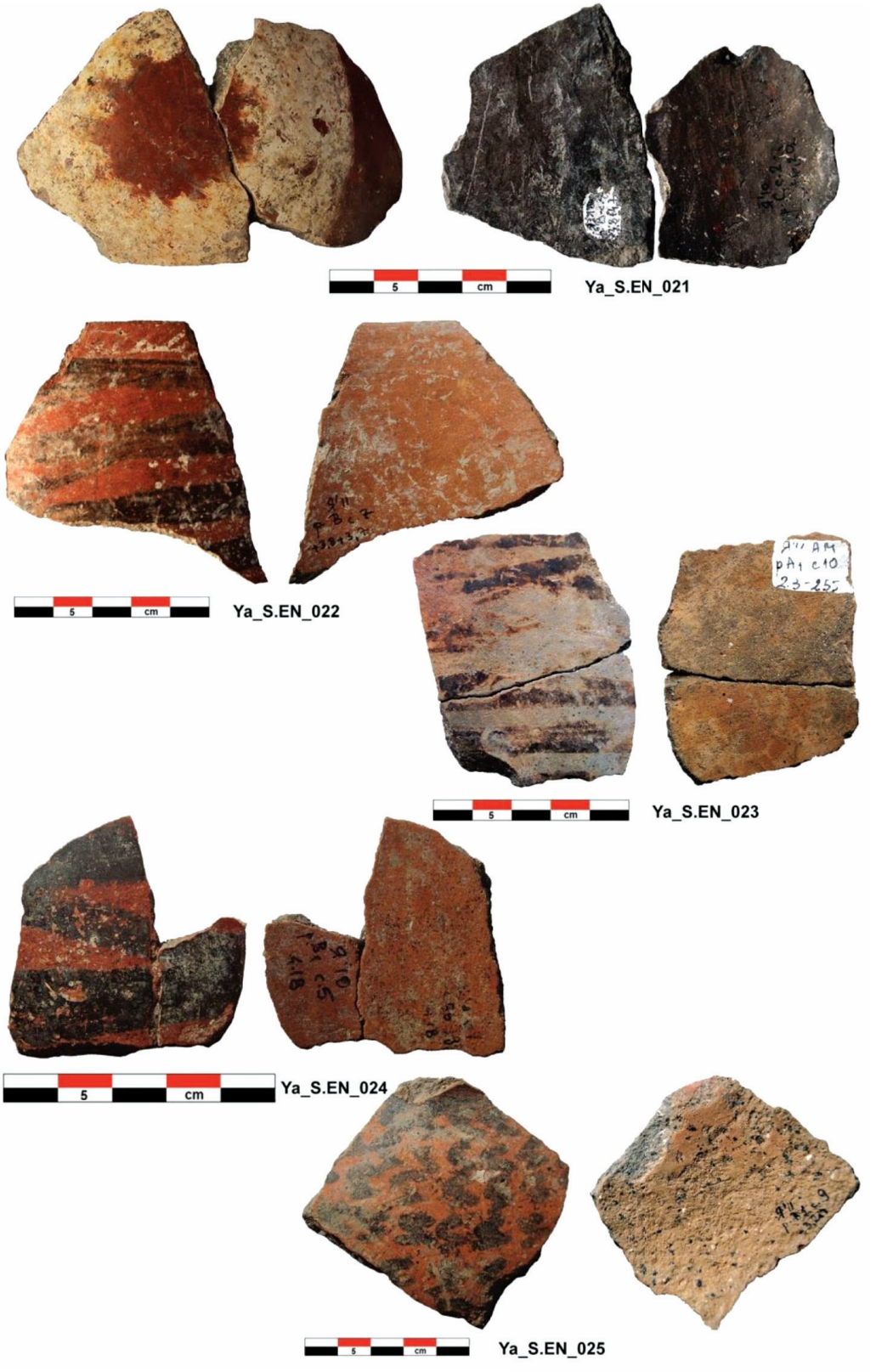


Fig. 25. Pottery sherds from Yabalkovo, Early Neolithic.

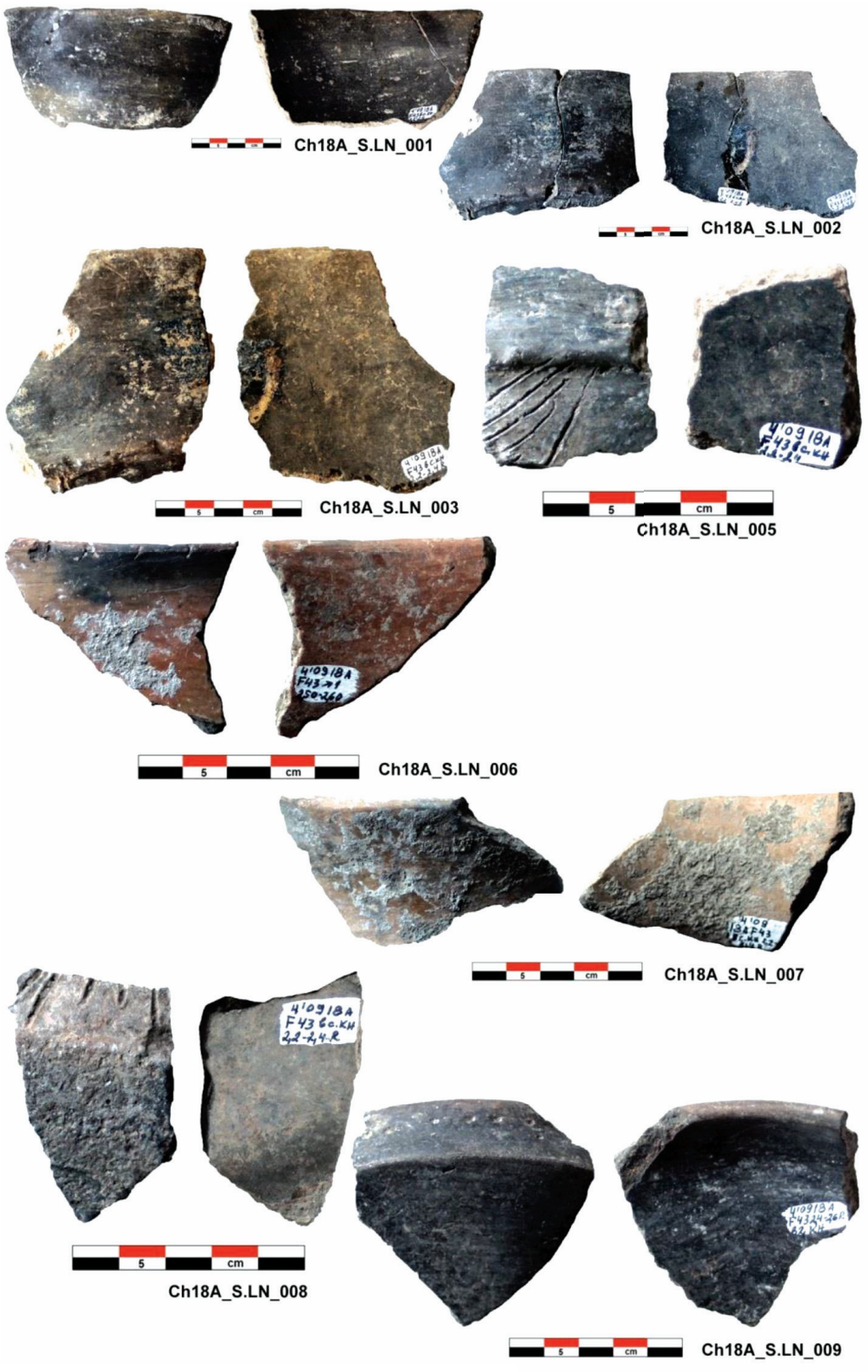


Fig. 26. Pottery sherds from Chokoba 18A, Late Neolithic.

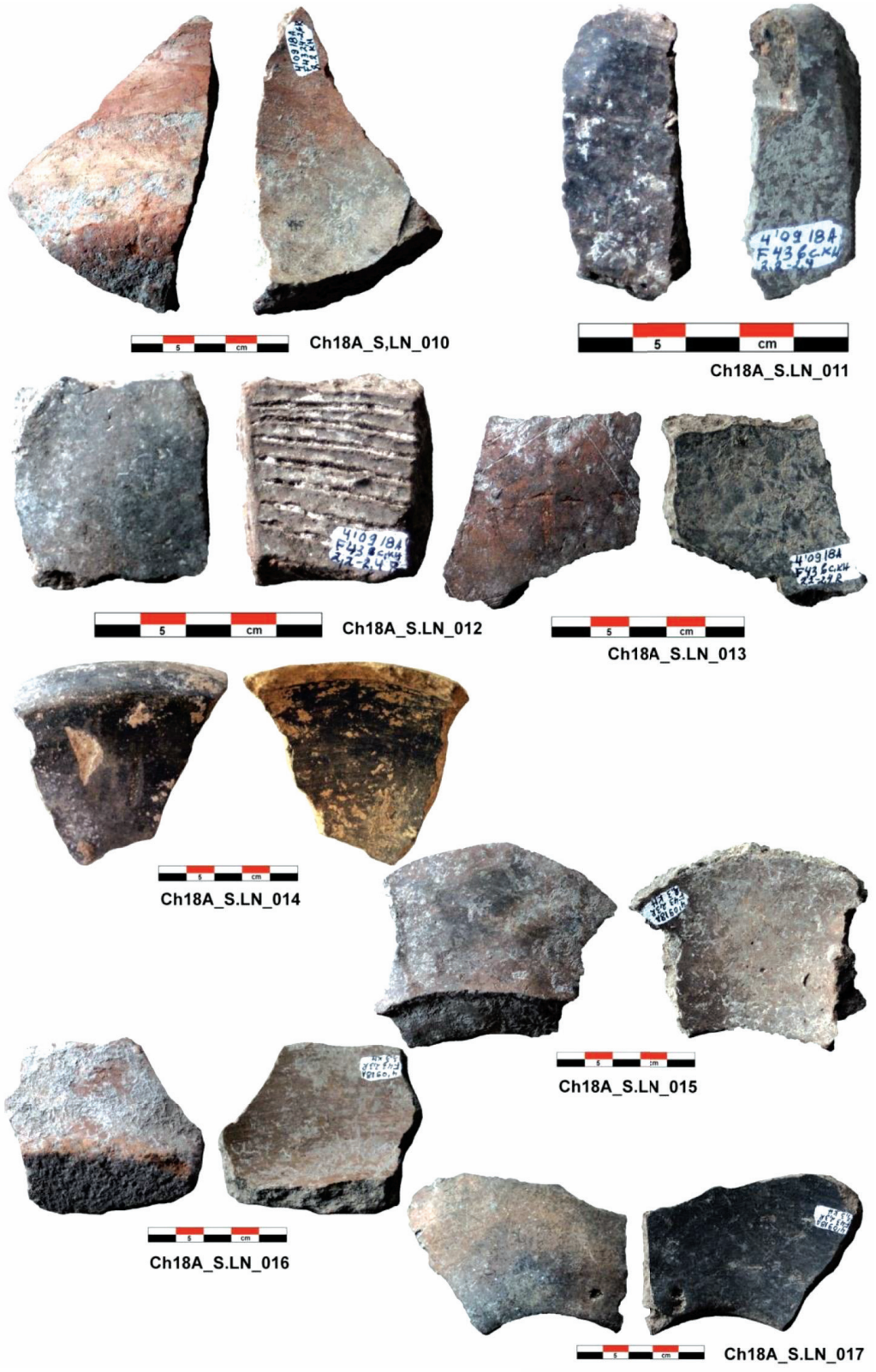


Fig. 27. Pottery sherds from Chokoba 18A, Late Neolithic.

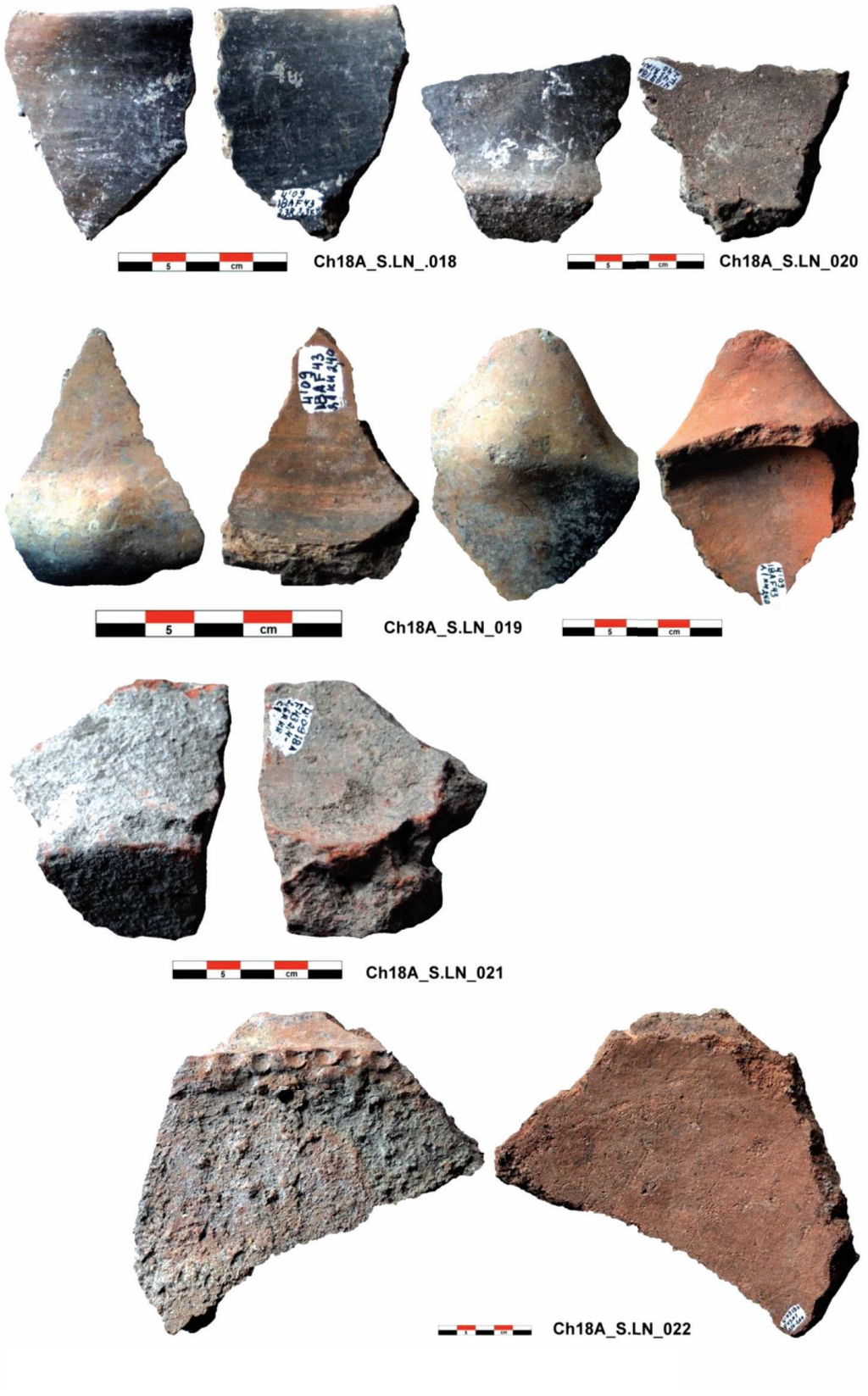


Fig. 28. Pottery sherds from Chokoba 18A, Late Neolithic.

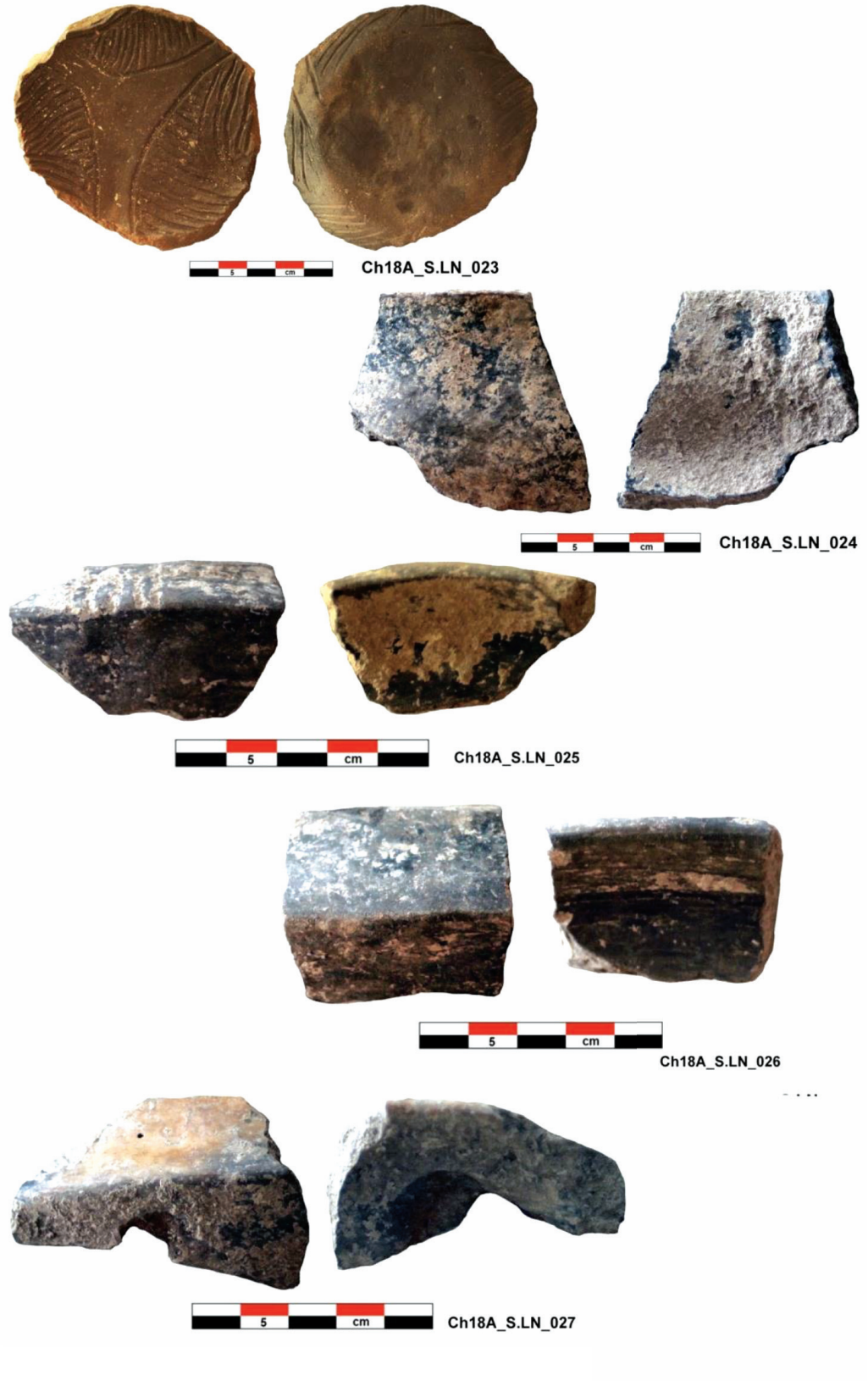


Fig. 29. Pottery sherds from Chokoba 18A, Late Neolithic.

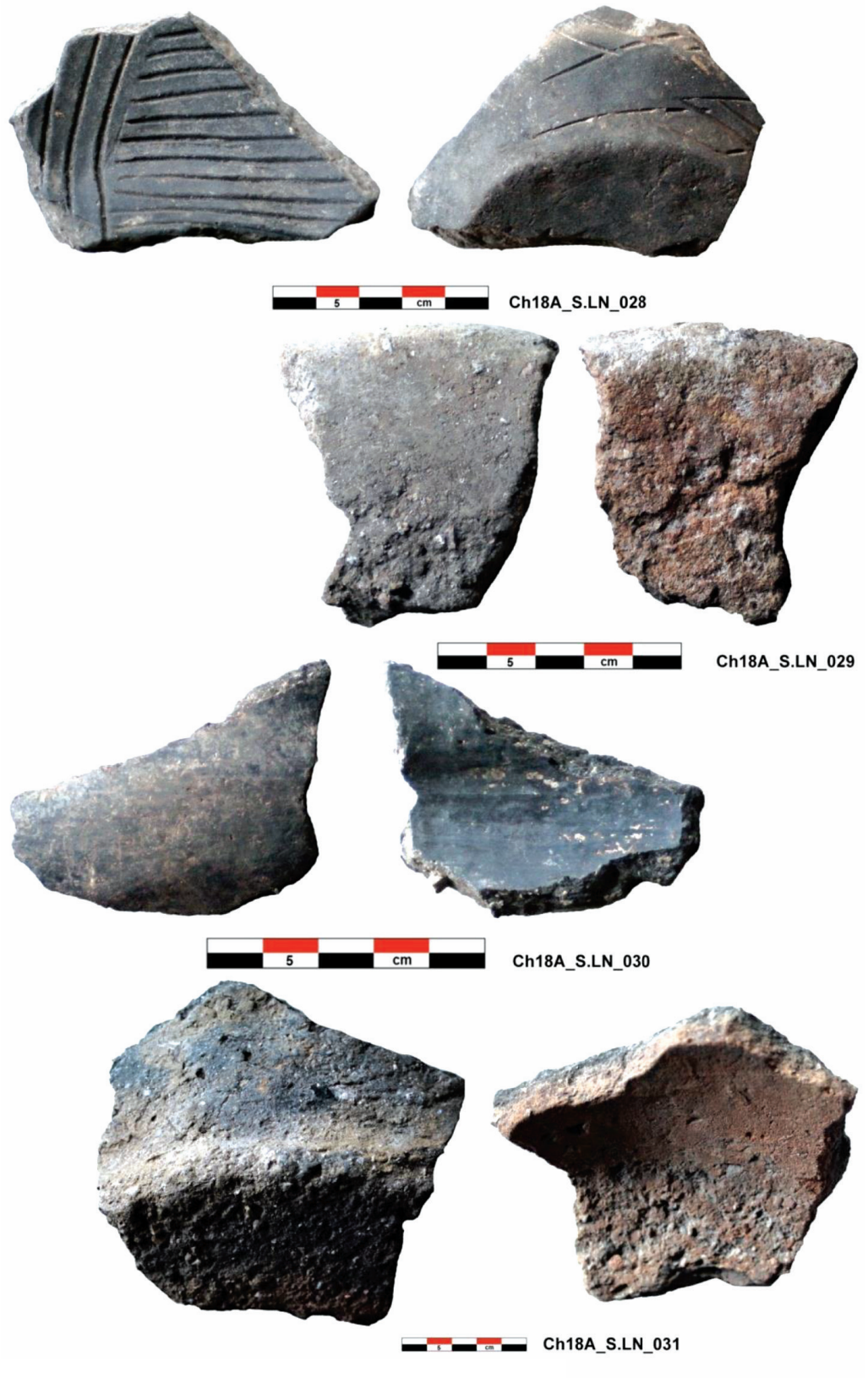


Fig. 30. Pottery sherds from Chokoba 18A, Late Neolithic.



Fig. 31. Pottery sherds from Constantia, Early Bronze Age.

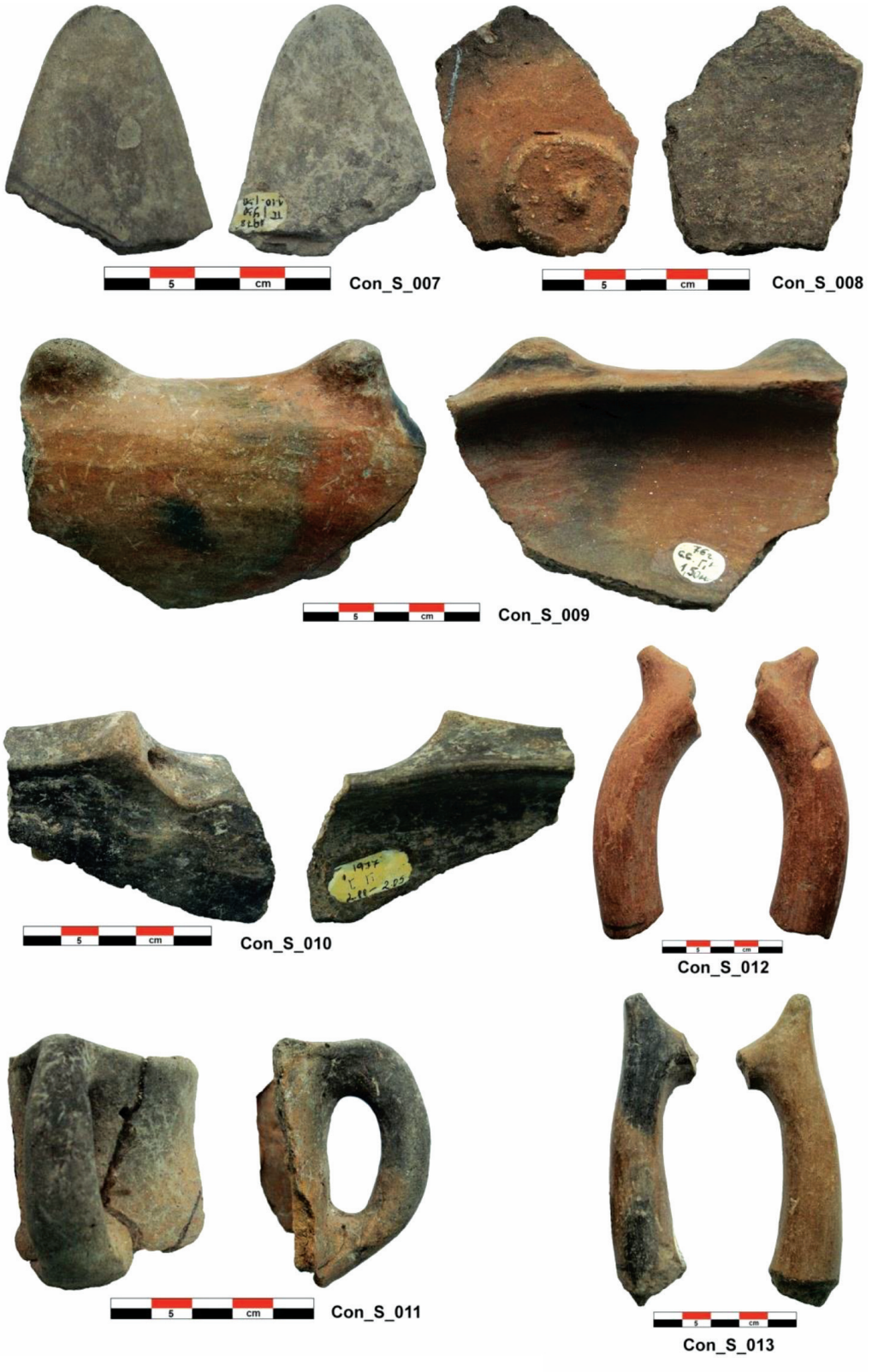


Fig. 32. Pottery sherds from Constantia, Early Bronze Age.



Fig. 33. Pottery sherds from Constantia, Early Bronze Age.

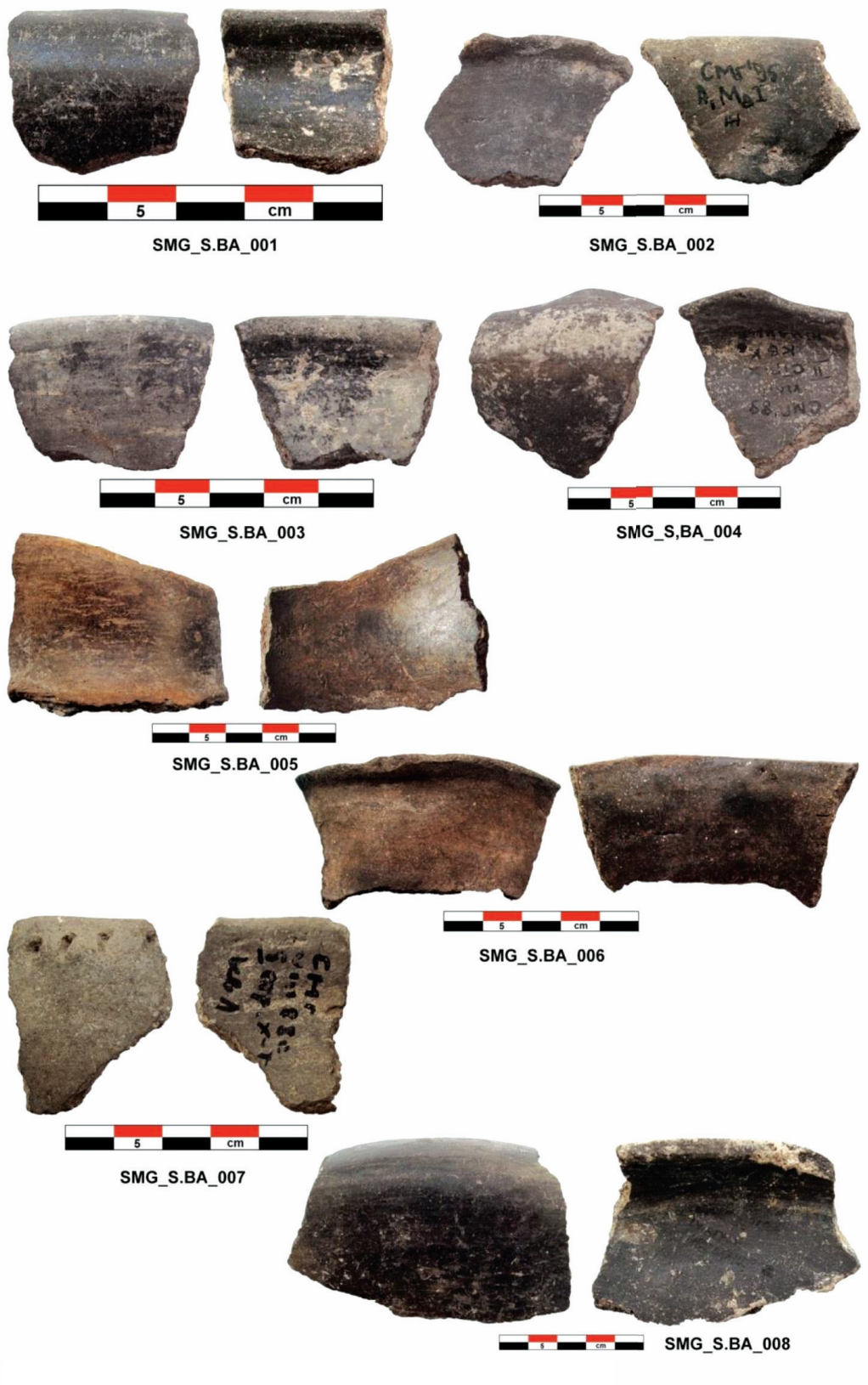


Fig. 34. Pottery sherds from tell Galabovo, Early and Middle Bronze Age.

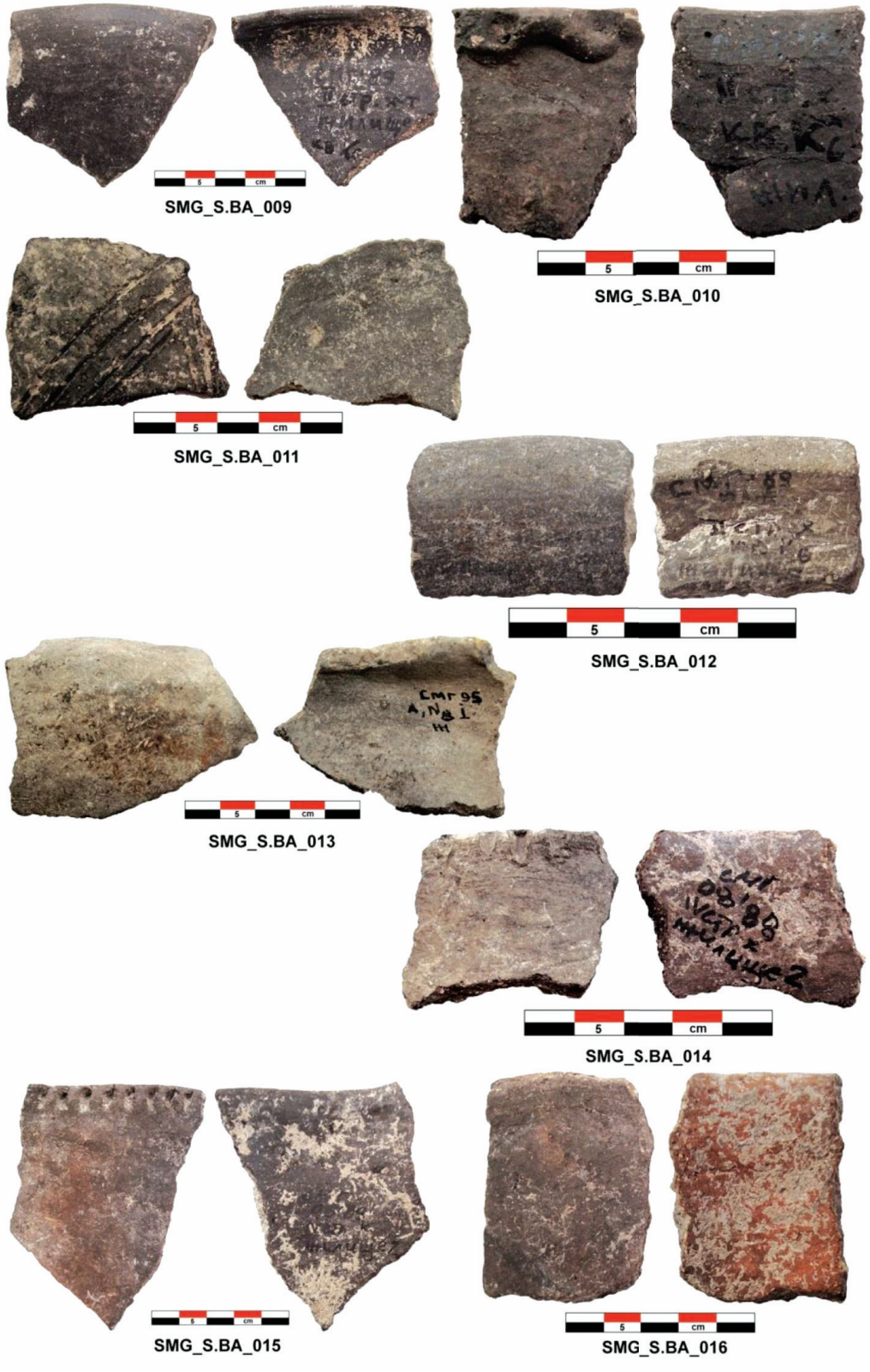


Fig. 35. Pottery sherds from tell Galabovo, Early and Middle Bronze Age.

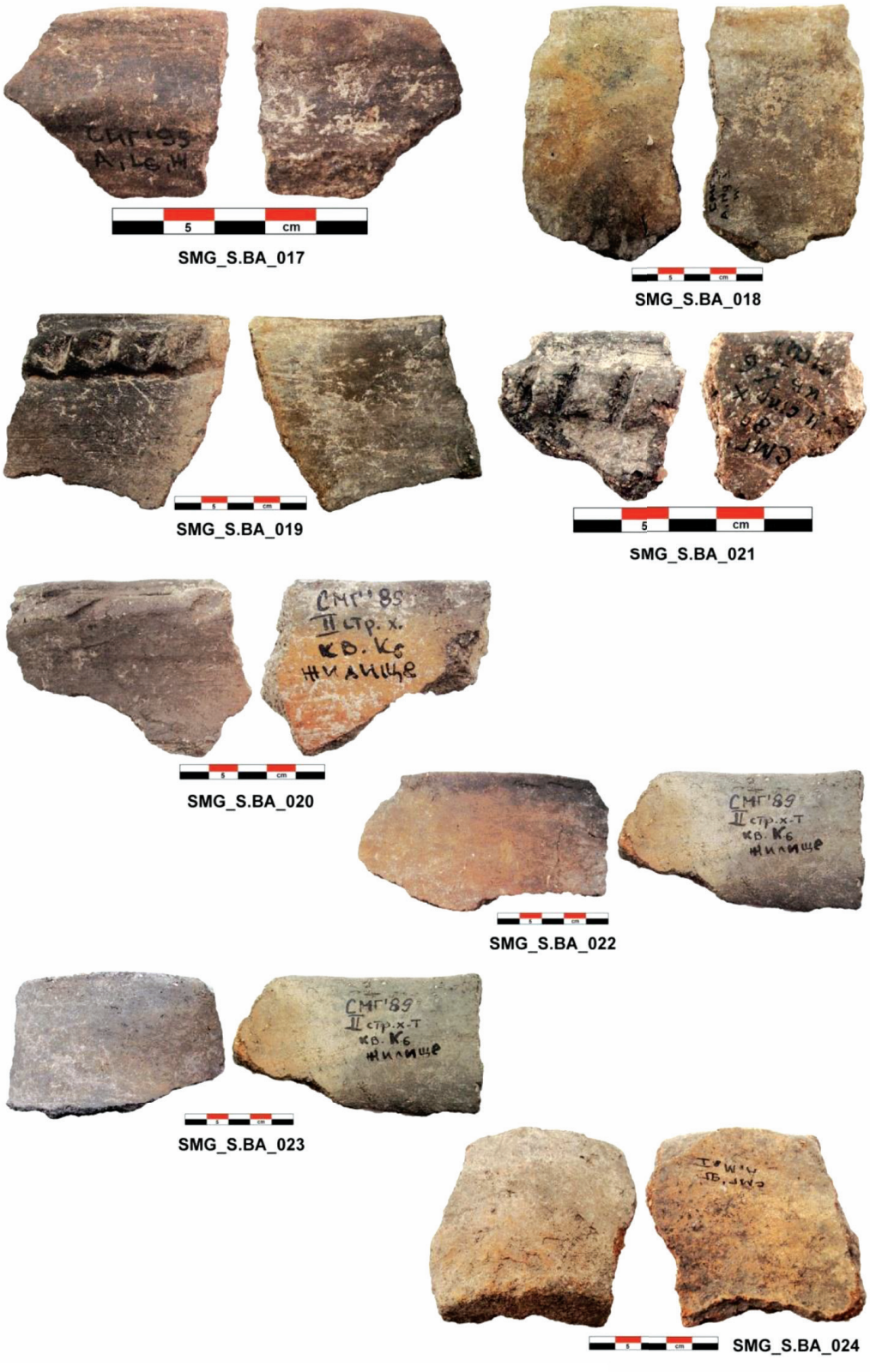


Fig. 36. Pottery sherds from tell Galabovo, Early and Middle Bronze Age.

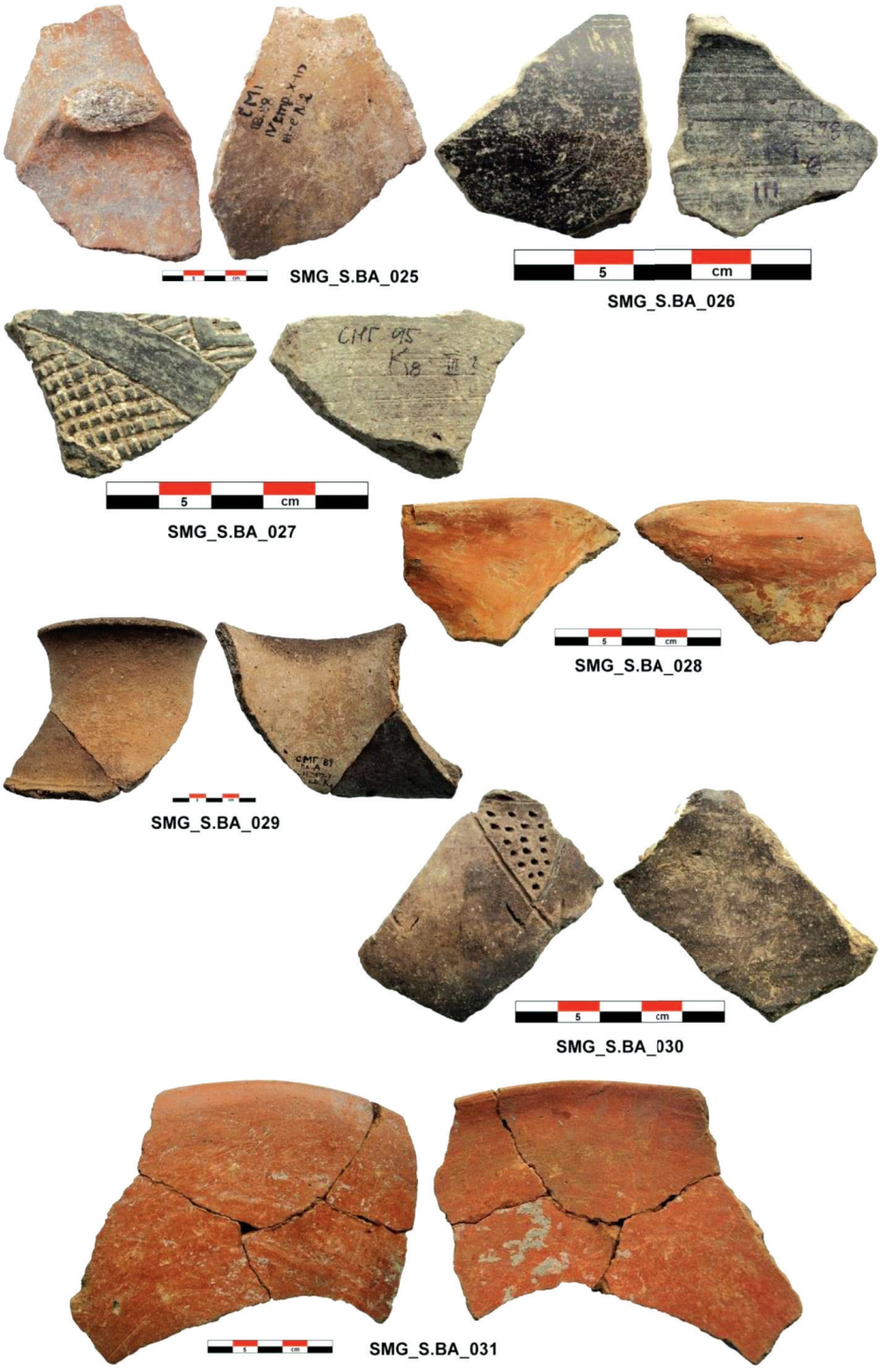


Fig. 37. Pottery sherds from tell Galabovo, Early and Middle Bronze Age.



Fig. 38. Pottery sherds from Chokoba 18, Middle Bronze Age.

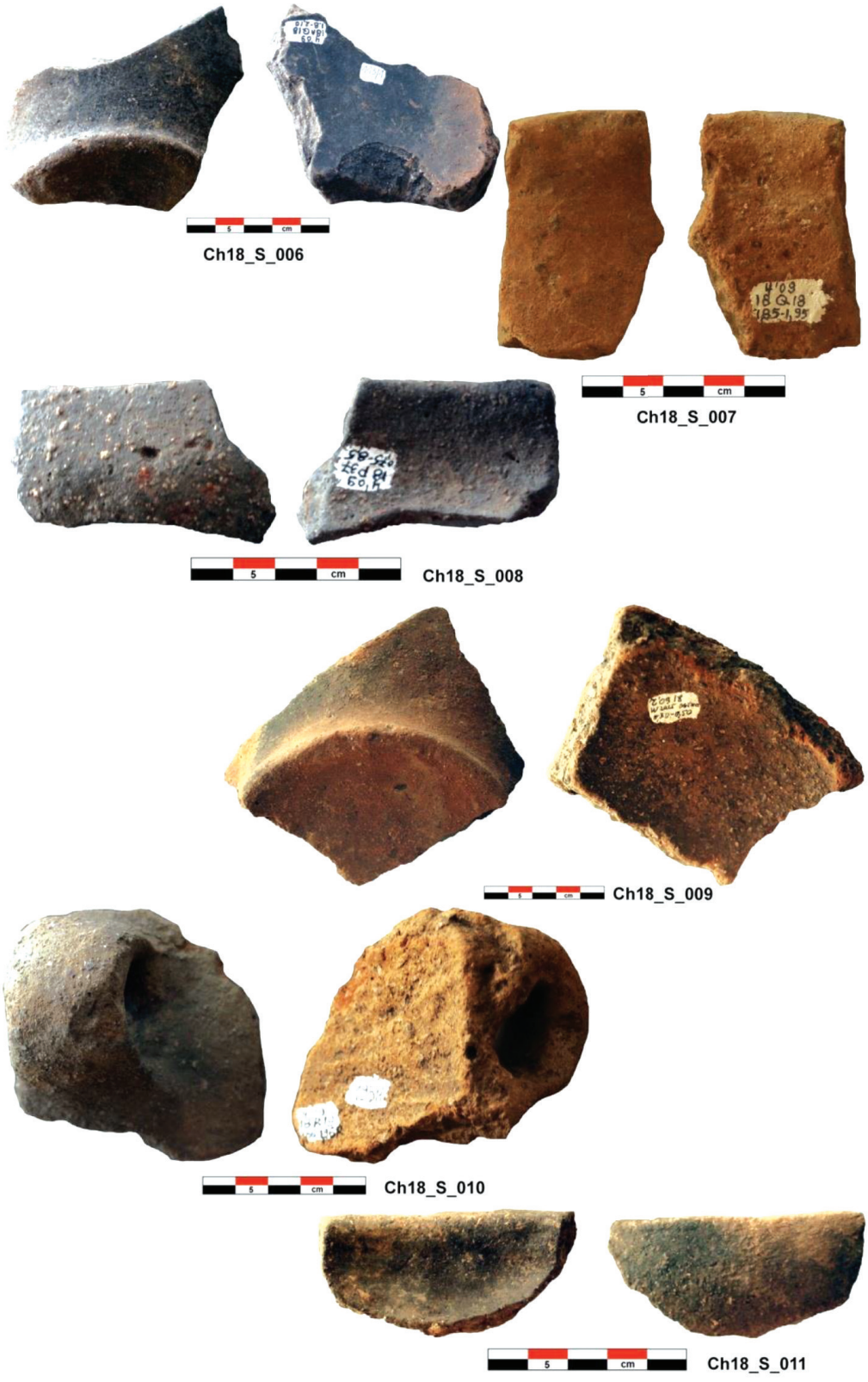


Fig. 39. Pottery sherds from Chokoba 18, Middle Bronze Age.

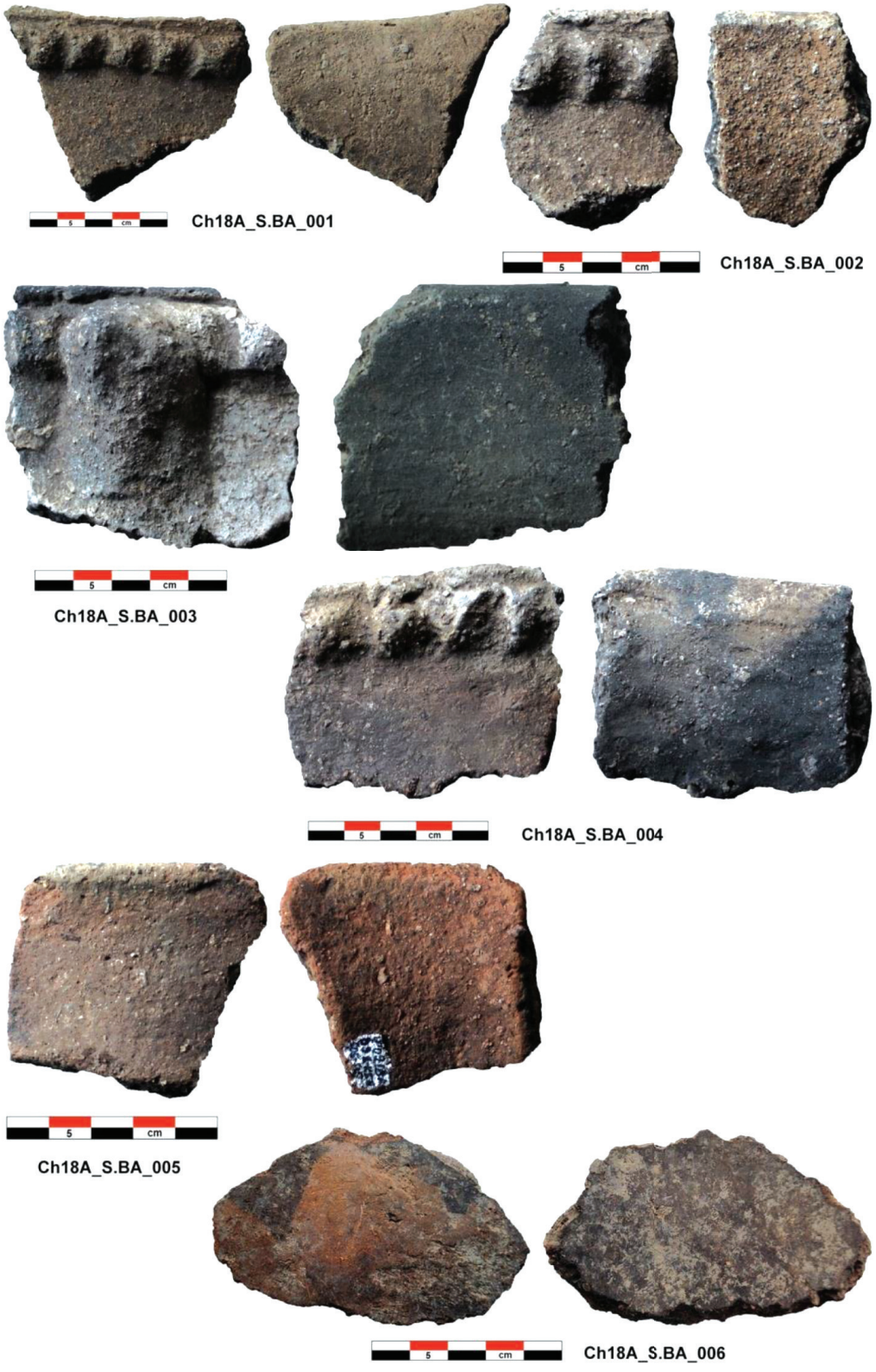


Fig. 40. Pottery sherds from Chokoba 18A, Middle and Late Bronze Age.

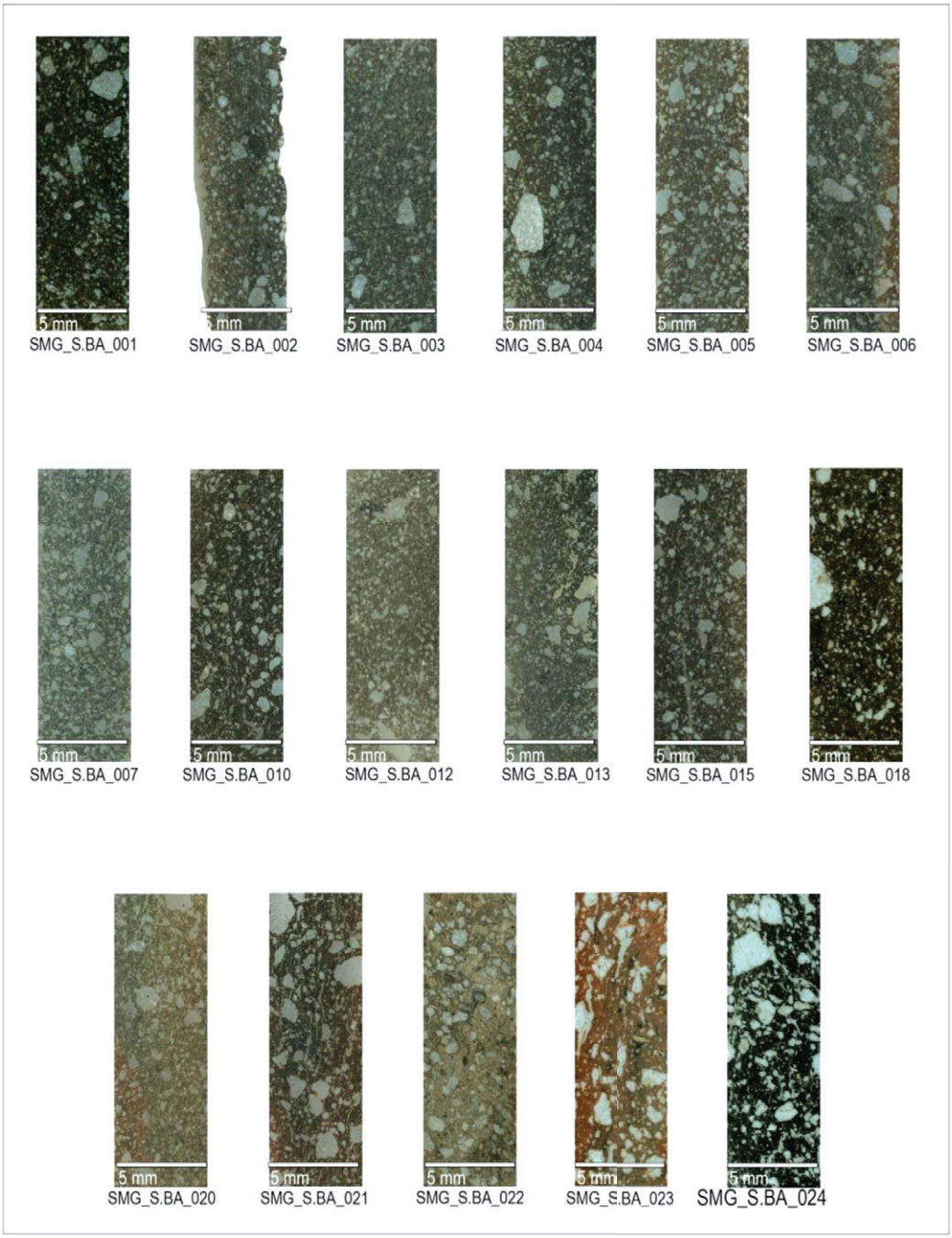


Fig. 41. Thin section macrographs of pottery samples from tell Galabovo, Early and Middle Bronze Age.

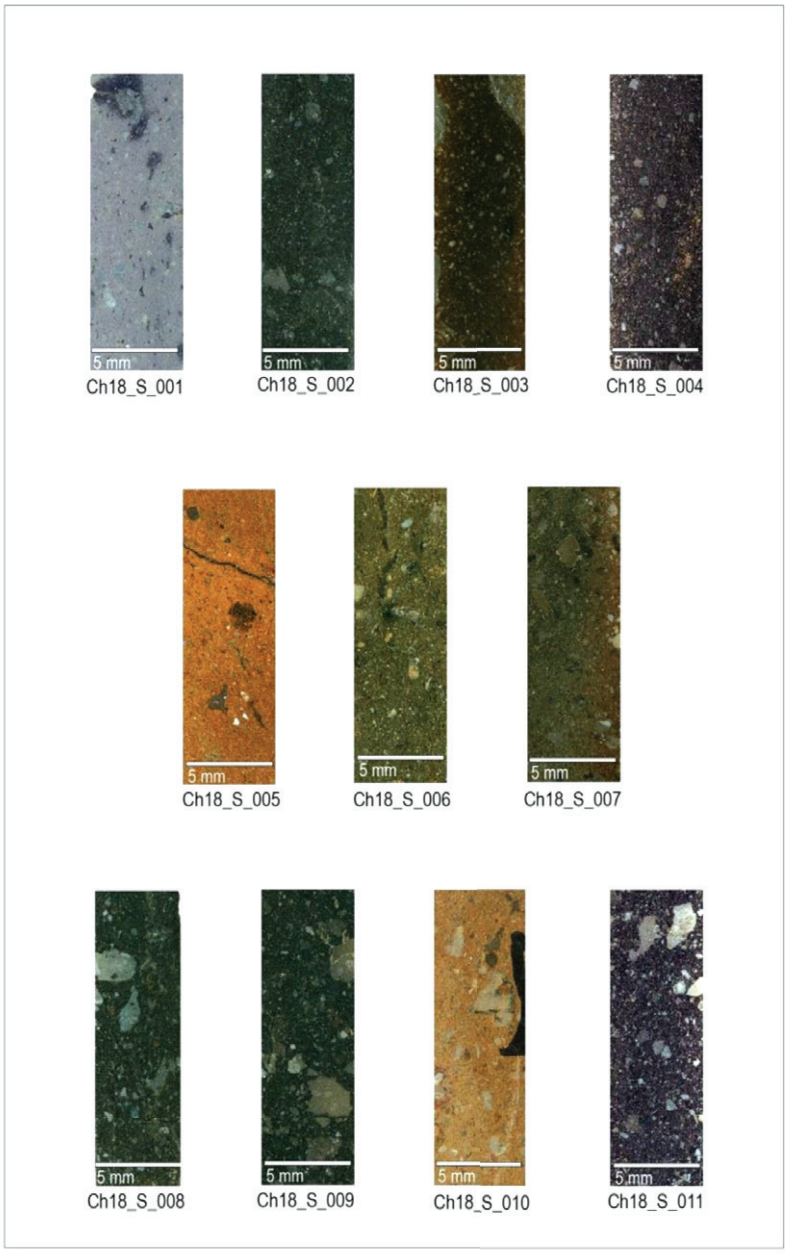


Fig. 42. Thin section macrographs of pottery samples from Chokoba 18, Middle Bronze Age.



Fig. 43.1. Thin section SMG_S.BA_031

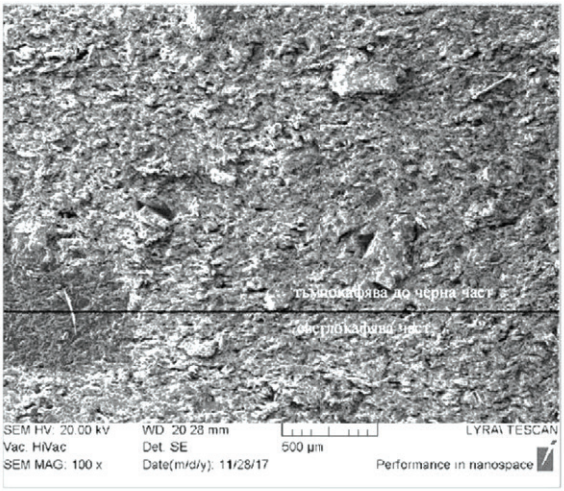


Fig. 43.2. SEM image of sample SMG_S.BA_031

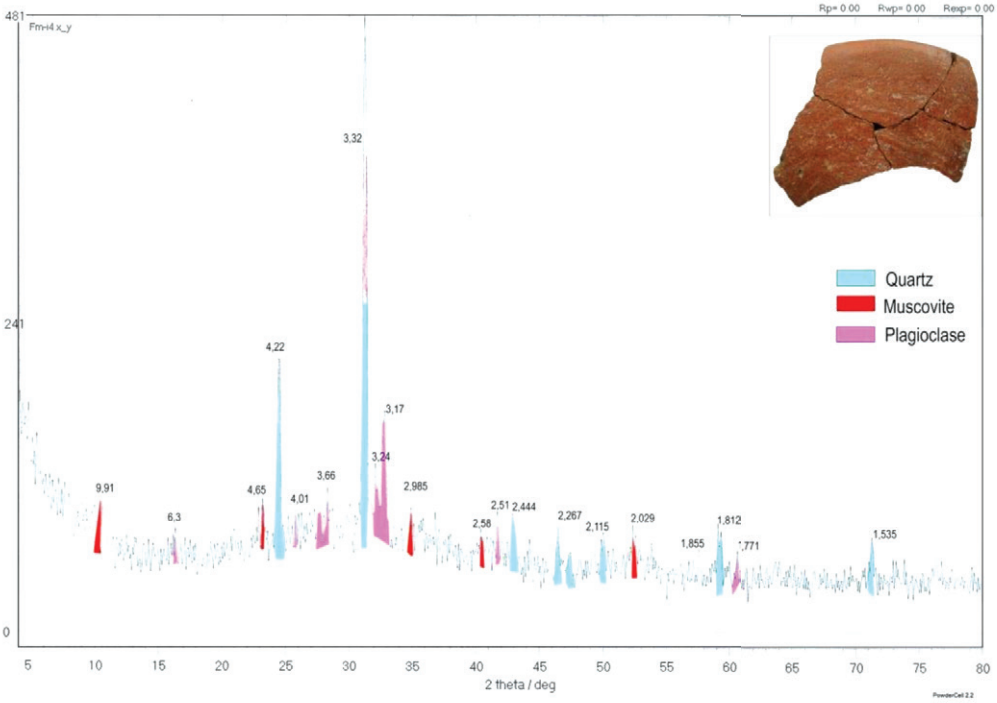


Fig. 43.3. XRD analysis of red slip from sample SMG_S.BA_031

Fig. 43. Instrumental analyses of a red-slipped sherd (SMG_S.BA_031) from Galabovo: thin section (top left), SEM image (top right), XRD analysis (bottom).

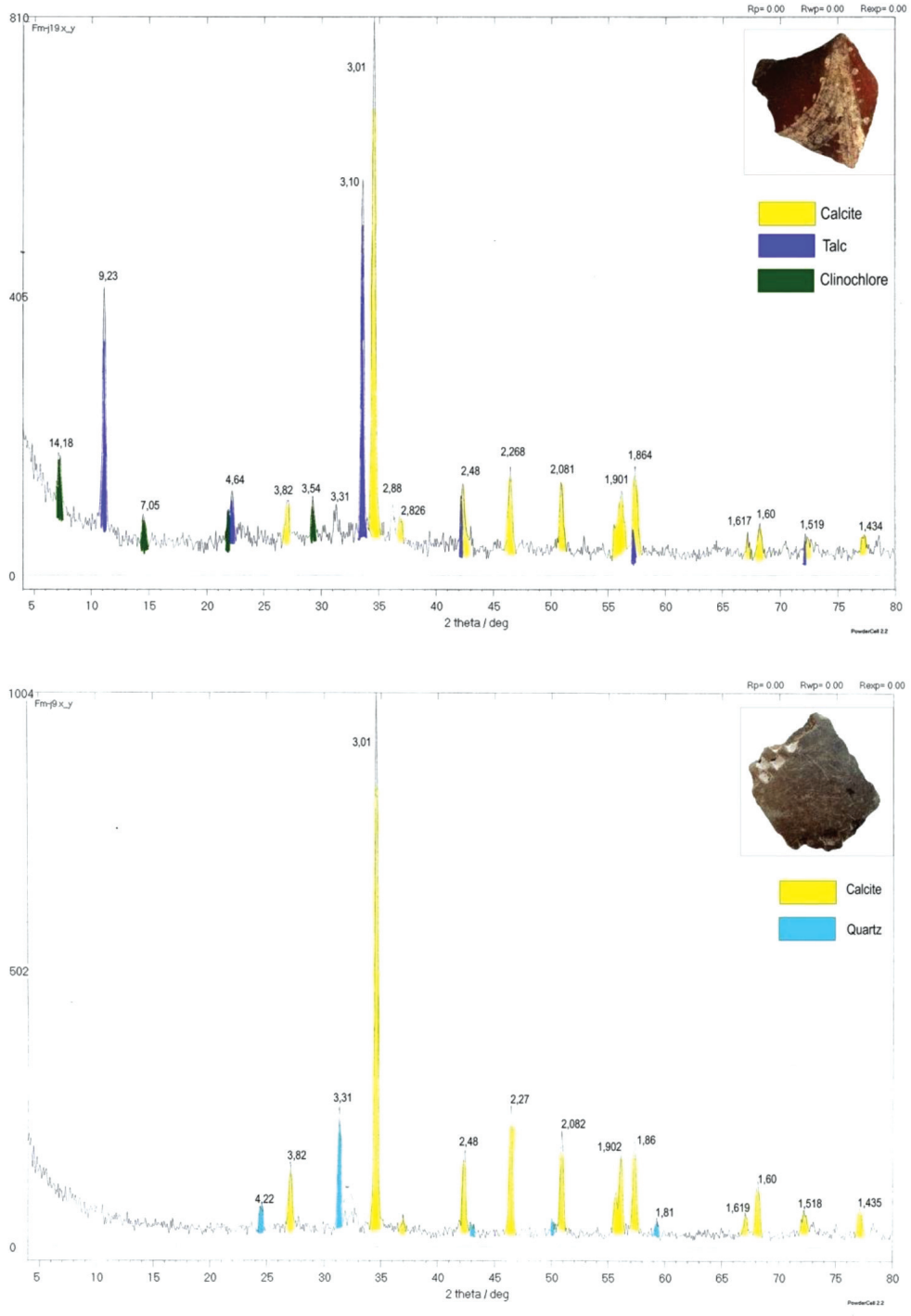


Fig. 44. XRD of white pigment from a white-on-red painted sherd (Ya_S.EN_019, top) and of white incrusted sherd (Ya_S. EN_009) from Yabalkovo, Early Neolithic.

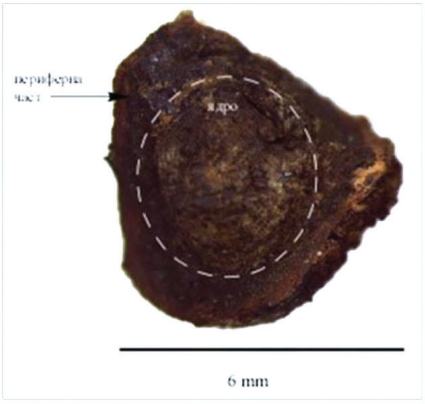


Fig. 45.1. Microphotograph of an 'inclusion'

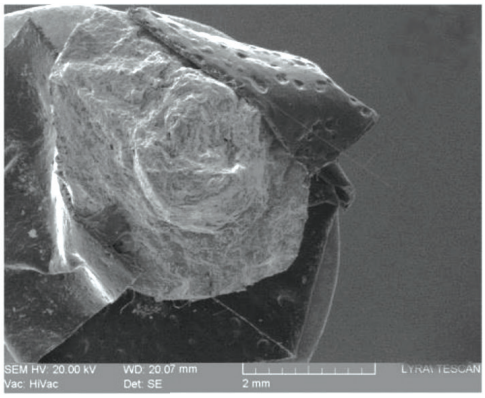
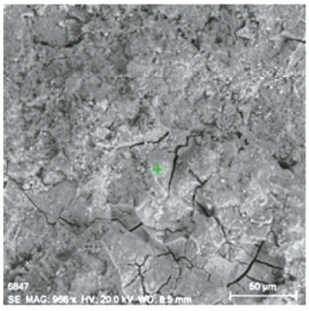
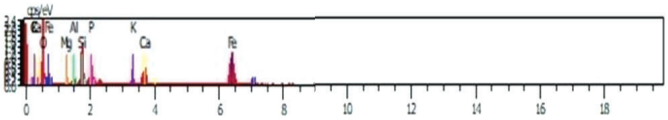


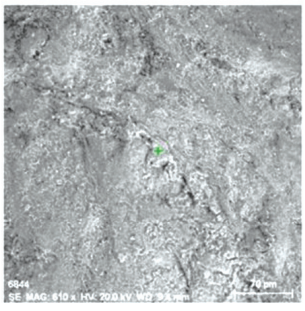
Fig. 45.2. SEM photo

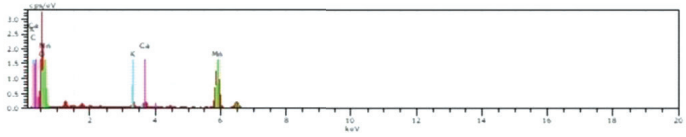




El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error [%]
O	8	K-series	40.76	43.01	60.54	5.6
C	6	K-series	5.99	6.32	11.85	1.5
Fe	26	K-series	27.45	28.96	11.68	0.8
Si	14	K-series	6.87	7.25	5.82	0.3
P	15	K-series	4.83	5.10	3.71	0.2
Ca	20	K-series	4.66	4.92	2.77	0.2
Mg	12	K-series	2.03	2.14	1.98	0.2
Al	13	K-series	1.21	1.28	1.07	0.1
K	19	K-series	0.98	1.03	0.59	0.1
Total:			94.78	100.00	100.00	

Fig. 45.3. EDX spectrum and semi-qualitative analysis of the periphery zone





El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error [%]
O	8	K-series	50.13	59.23	81.67	6.6
Mn	25	K-series	31.13	36.78	14.77	0.9
C	6	K-series	0.88	1.04	1.92	1.0
Ca	20	K-series	1.29	1.52	0.84	0.1
K	19	K-series	1.20	1.42	0.80	0.1
Total:			84.63	100.00	100.00	

Fig. 45.3. EDX spectrum and semi-qualitative analysis of the central zone

Fig. 45. Instrumental analyses of an "inclusion" in a clay object from Sokol, EBA.

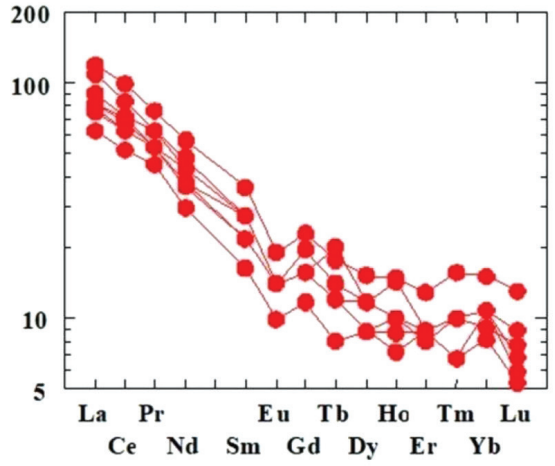


Fig. 46.1. Chondrite-normalized REE pattern of clay samples from Chokoba, Sokol and Madrets

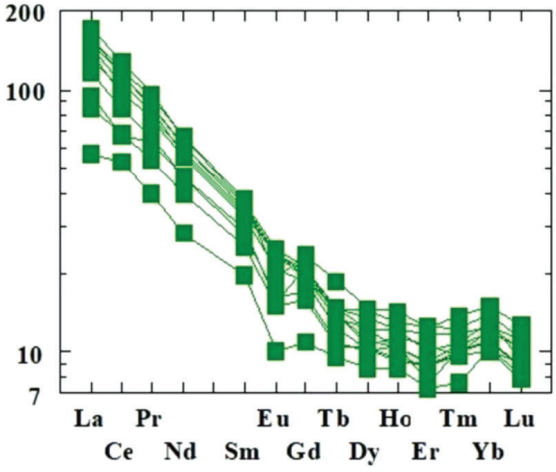


Fig. 46.2. Chondrite-normalized REE pattern of clay samples from Chokoba, Sokol and Madrets

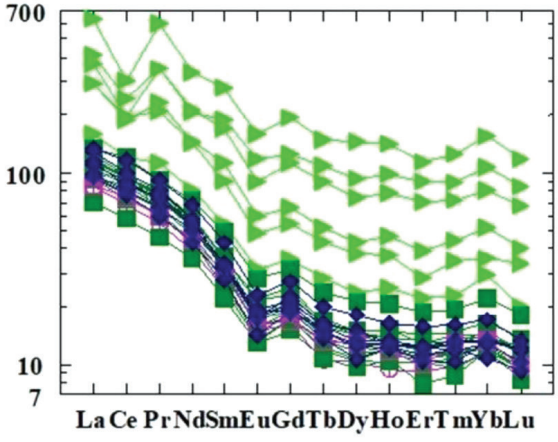
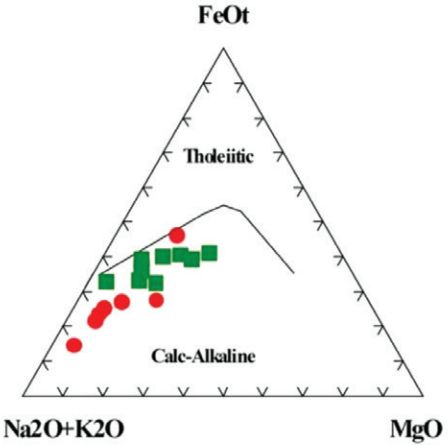
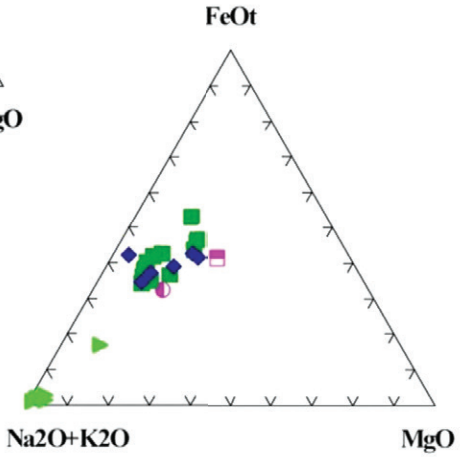


Fig. 46.3. Chondrite-normalized REE pattern of pottery sherd samples

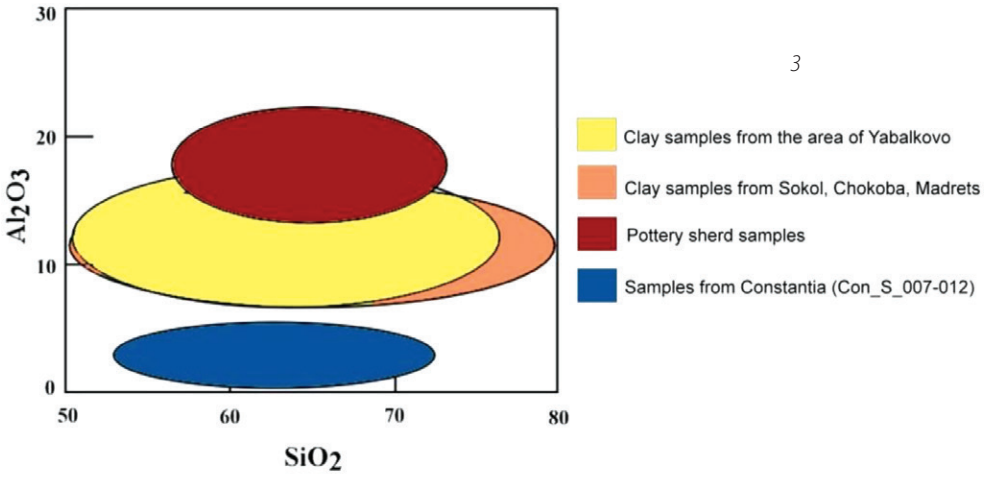
Fig. 46. Chondrite-normalized REE pattern of clay samples and pottery sherds.



1

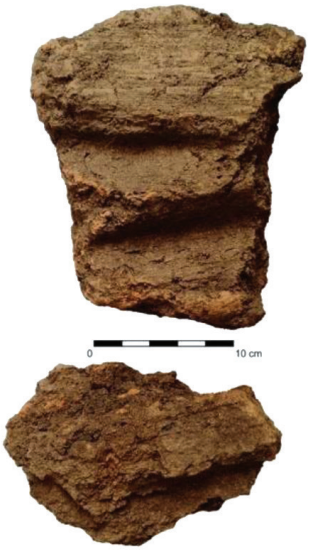


2



3

Fig. 47. AFM and binary diagrams: 47.1. AFM diagram of clay samples (top); 47.2. AFM diagram of pottery sherds (middle) and 47.3. Binary diagram SiO_2-Al_2O_3 (bottom).



1. Wall plaster with imprints of wooden posts



2. Wall plaster with imprints of stems and twigs



3. Wall plaster with imprints of chaff and *Triticum aestivum* grains



4. Close-up photo of stem imprints



5. Close-up photot of stem imprints



6. Close-up photo of stem imprints

Fig. 48. Wall plaster with organic inclusions from Yabalkovo, EN.

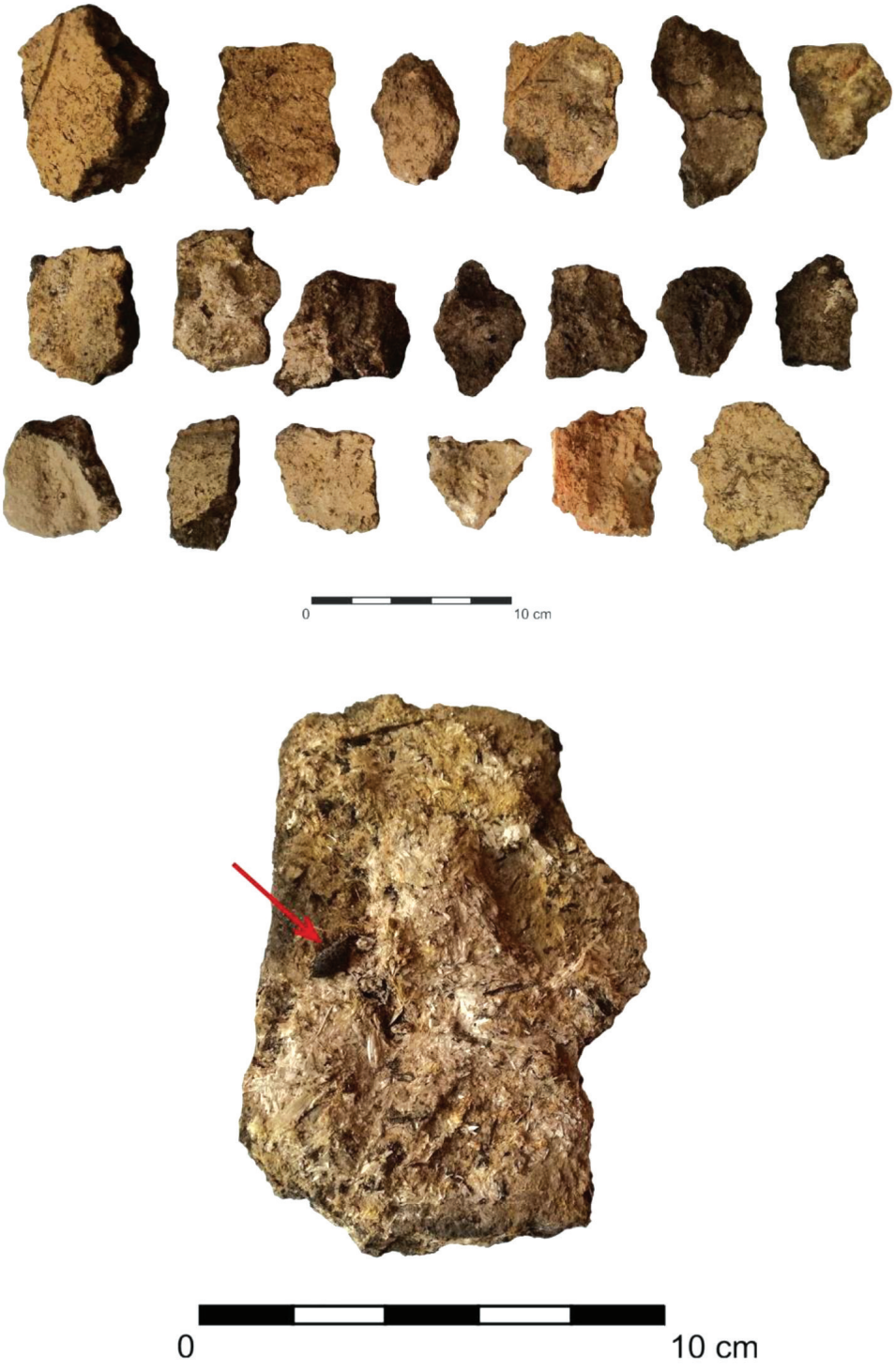


Fig. 49. Burnt clay debris with organic inclusions from tell Sokol, EBA.

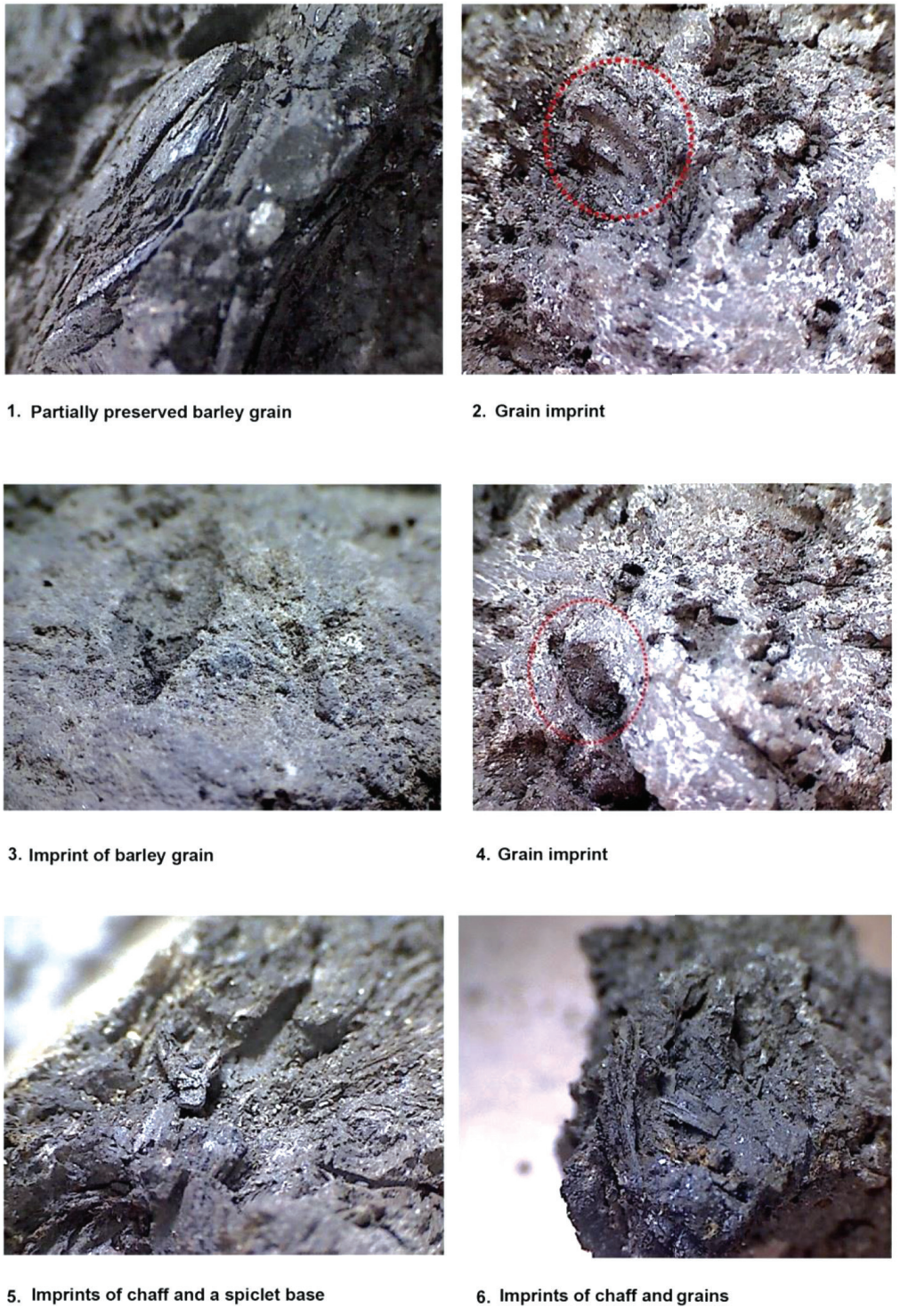


Fig. 50. Close-up images of organic inclusions in ceramic sherds and burnt clay from tell Sokol, EBA.



1. Carbonized barley grain



2. Partially preserved spikelet base



3. Ceraeal grain with partially preserved hulls



4. Imprints of barley grains



5. Part of a barley spikelet



6. Imprints of chaff and grains





7. Carbonized barley grain

Fig. 51. Close-up images of organic inclusions in the ceramics from tell Sokol.



Fig. 52. Pottery sherds with grain imprints from Dana Bunar 1, Chalcolithic period.



Fig. 53. Close-up images of organic inclusions in the ceramics from Dana bunar 1.



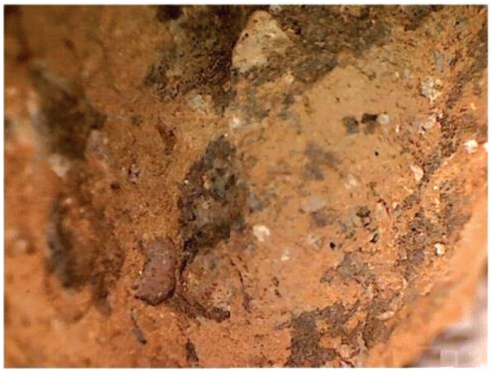
Fig. 54. Close-up images of organic inclusions in the ceramics from Dana bunar 1.



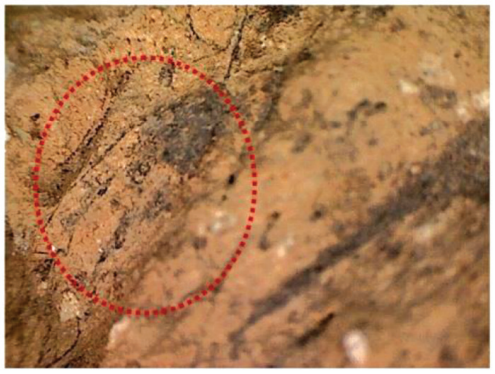
Fig. 55. Pottery sherds from Chokoba 18 and 18A, MBA – LBA.



1. Grain imprint



2. Imprints and blanks of decayed organic material



3. Imprints and blanks of decayed chaff



4. Blanks of decayed organic material



5. Imprint of a rye grain seed



6. Imprints of grains and chaff

Fig. 56. Close-up images of organic inclusions in ceramic sherds from Ckokoba 18 and 18A.



1. Stem imprints



2. Imprints of cereal grains



3. Imprint of barley grain



4. Blanks of organic material



5. Grain imprint



6. Grain imprint

Fig. 57. Close-up images of organic inclusion in ceramic sherds from Chokoba 18 and 18A.

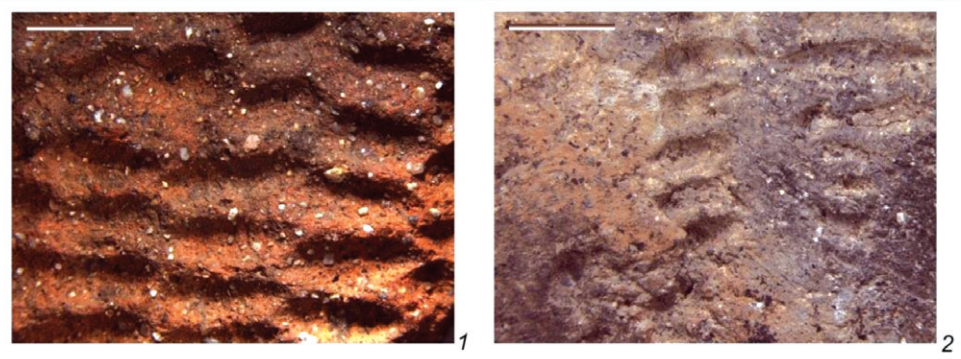


Fig. 58. Mat impressions: 53.1. Fragment No.6 – weft-faced simple twining; 58.2. Fragment No.17 – open simple twining.

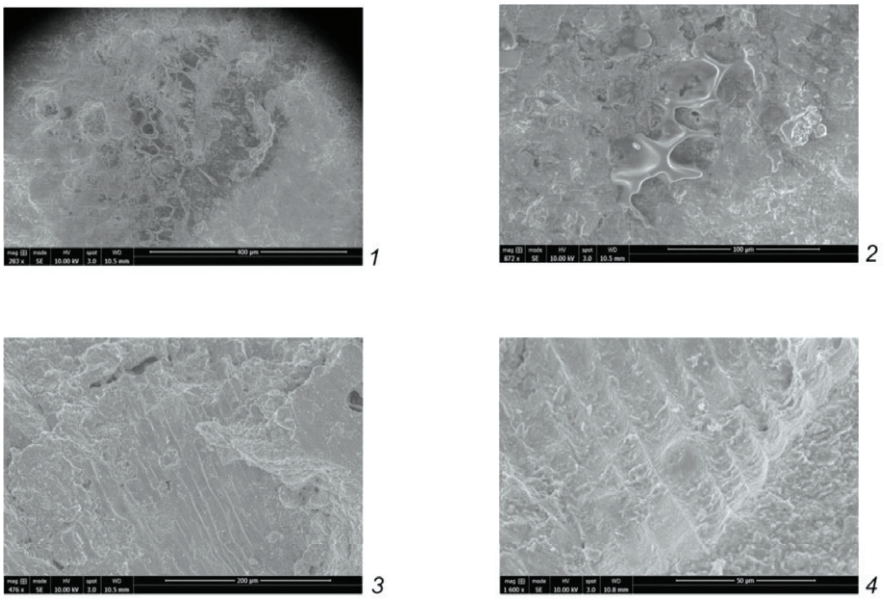


Fig. 59. Fragment No. 19: 1 and 2 – non-diagnostic cell walls of plant tissues; 3 and 4 – parallel grooves in the imprint of a leaf/stem of monocotyledon plant.

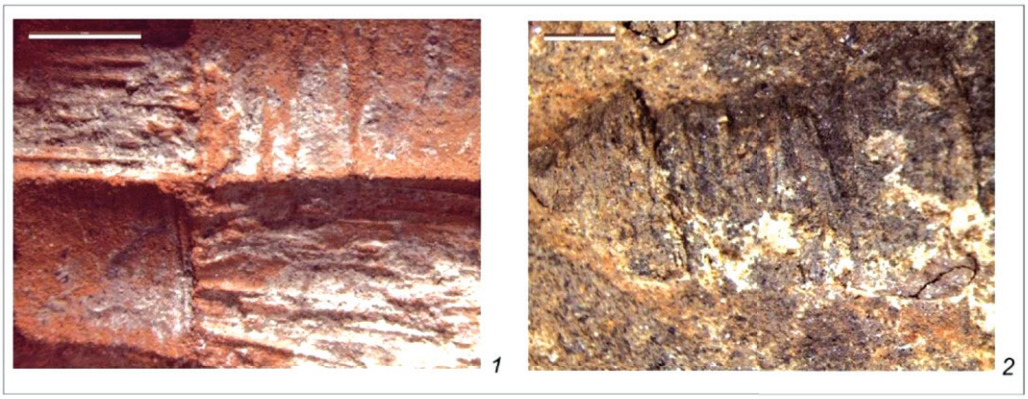


Fig. 60. Plain weave: 1. Fragment No.20; 2. Fragment No.23.

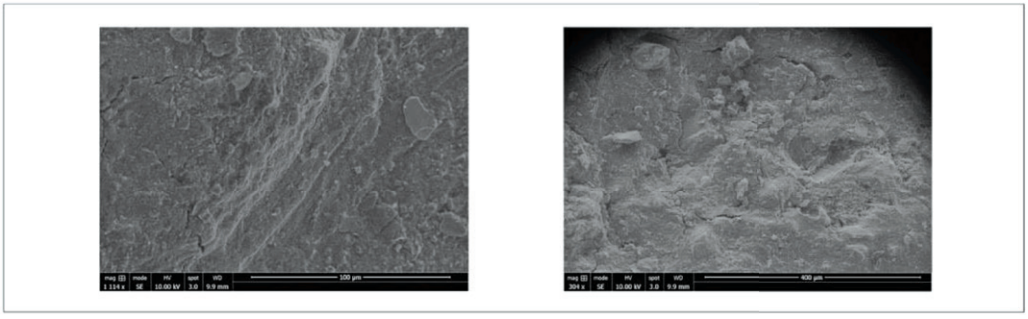


Fig. 61. Fragment No.20: parallel grooves on a flat-section leaf.

Table 1. Chemical composition of samples from clay deposits

	Ya_R_01	Ya_R_01a	Ya_R_02	Ya_R_03.1	Ya_R_03.2	Ya_R_03.3	Ya_R_03.4	Ya_R_03.5	Ks_R_01	Ks_R_02	S_R_01	S_R_02	S_R_02a	S_R_03	Ch_R_01	Ch_R_02	M_R_01	M_R_02
SiO2	42,27	59,85	62,92	52,88	49,95	51,65	49,83	54,49	62,55	53,44	69,24	63,82	69,27	69,87	60,39	61,89	66,85	65,92
TiO2	0,47	0,71	0,54	0,68	0,63	0,64	0,57	0,69	0,46	0,66	0,23	0,25	0,17	0,40	0,58	0,74	0,56	0,63
Al2O3	14,38	20,92	19,38	19,39	18,70	19,03	17,25	20,27	12,76	15,66	16,06	20,20	18,81	17,33	16,33	17,83	15,09	17,77
FeO	3,36	4,64	3,60	4,69	3,77	4,40	3,59	5,07	2,78	4,00	1,74	2,20	1,43	2,44	3,65	4,41	2,64	2,21
MnO	0,11	0,05	0,11	0,06	0,08	0,04	0,06	0,06	0,11	0,11	0,02	0,08	0,05	0,06	0,10	0,12	0,09	0,08
MgO	1,60	0,64	1,18	1,77	1,43	2,82	2,08	1,54	0,72	2,66	0,60	0,92	0,59	0,73	1,41	1,48	0,92	0,72
CaO	18,14	5,35	2,29	6,76	9,89	5,48	7,96	3,83	9,93	10,91	0,46	1,23	1,15	0,56	1,81	1,10	2,58	2,60
Na2O	1,49	4,03	1,91	2,30	2,39	1,54	1,57	2,18	1,07	1,06	2,38	2,35	2,76	2,67	2,85	1,20	1,71	3,30
K2O	1,87	4,85	3,31	2,95	3,80	1,98	1,88	4,92	2,51	3,48	3,35	5,70	5,27	3,77	2,78	2,45	3,36	3,24
P2O5	0,27	0,49	0,46	0,50	0,48	0,54	0,49	0,49	0,20	0,22	0,10	0,22	0,20	0,10	0,14	0,10	0,71	0,24
сума	83,95	101,55	95,71	91,99	91,12	88,11	85,28	93,54	93,10	92,21	94,19	96,96	99,70	97,92	90,05	91,32	94,50	96,71
Ba	2494,49	3420,73	765,03	3743,70	3452,75	2569,57	3168,21	2934,53	470,23	637,27	318,85	501,04	446,60	477,64	450,41	492,86	712,03	643,64
Rb	63,45	157,03	162,03	131,35	145,84	103,64	111,94	204,94	127,31	164,62								
Sr	785,33	1244,27	287,99	1133,45	1063,01	894,52	840,59	992,19	99,51	119,18	83,87	91,11	101,26	114,71	225,91	143,58	221,51	298,98
Cs	4,45	5,86	8,12	16,16	4,07	27,36	23,24	5,98	13,29	15,60	4,25	6,81	6,28	3,22	2,18	5,51	3,58	2,70
Ta	0,68	0,78	1,44	0,78	0,78	0,71	0,72	0,74	0,98	1,14	1,86	2,17	2,43	1,21	0,51	0,96	0,88	1,17
Nb	11,22	13,36	23,34	11,99	11,76	11,78	10,85	12,76	10,35	13,35	14,12	17,79	17,99	11,85	7,34	15,47	11,30	13,55
Hf	4,17	6,38	5,54	5,64	5,17	4,52	4,76	5,64	4,70	4,07	2,92	3,27	2,67	3,27	4,16	6,78	5,00	6,02
Zr	168,59	244,62	231,84	210,71	204,33	187,62	171,13	205,34	178,13	155,24	101,69	90,45	84,77	125,16	166,33	268,11	187,42	232,02
Y	19,94	21,13	29,19	24,17	22,49	19,23	26,91	21,53	15,10	26,69	14,58	20,74	17,80	19,55	19,69	29,57	20,68	21,10
Th	19,58	30,93	20,44	25,37	24,94	27,82	25,36	26,74	8,46	12,53	9,11	11,01	10,02	9,14	13,13	12,87	10,01	9,44
U	3,86	6,64	2,49	7,77	16,23	10,61	8,96	6,99	2,79	2,10	2,13	7,09	3,40	1,71	2,51	2,68	2,86	3,45
Cr	45,94	47,39	69,56	31,04	30,74	33,17	34,68	35,72	81,54	94,33	35,95	38,52	<30.94	47,37	55,01	112,80	62,04	62,34
Ni	16,06	<13.83	28,98	<12.87	<13.85	<9.78	<11.36	18,36	26,89	36,85	<10.93	<11.56	<11.0	15,35	17,23	38,79	25,34	13,67
Co	10,10	12,46	10,37	12,36	16,00	15,29	9,76	17,36	12,49	13,50	3,16	5,62	2,83	7,46	11,97	14,28	8,40	7,68
Sc	13,91	15,31	12,07	15,79	15,12	16,82	13,67	16,78	12,02	11,76	9,77	9,22	8,80	11,30	16,45	15,91	12,39	12,74
V	105,61	188,47	96,21	160,59	161,28	160,92	143,86	168,89	86,16	102,45	40,87	62,23	27,79	69,86	138,73	121,42	67,61	68,15
Pb	47,74	77,8	35,46	82,62	85,19	80,58	80,32	84,4	23,2	26,21	31,70	89,69	84,96	22,84	13,60	20,13	20,23	21,70
Zn	40,90	57,14	54,95	53,95	81,95	52,95	51,13	98,19	37,59	80,14	24,22	59,86	45,43	36,00	48,56	60,24	79,19	36,54
Ga	14,04	18,75	19,02	16,44	15,99	16,98	15,45	18,14	13,30	18,55	15,79	24,74	24,36	17,65	13,46	17,42	16,24	17,47
Ag	<0.37	<0.38	<0.37	<0.38	<0.39	<0.33	<0.36	<0.36	<0.44	<0.45	<0.38	<0.46	<0.41	<0.45	<0.28	<0.38	<0.31	<0.35
La	37,37	54,46	50,06	50,35	46,15	42,56	43,85	48,30	18,40	30,22	20,42	26,19	24,17	24,89	34,88	38,41	28,93	25,98
Ce	66,10	100,36	92,41	88,95	83,58	78,67	75,63	89,59	41,91	62,59	41,16	52,81	49,07	49,39	65,51	77,61	57,36	55,80
Pr	7,46	10,71	10,50	9,63	9,33	8,70	8,82	9,80	4,46	7,04	4,53	5,98	5,60	5,70	7,36	8,57	6,74	6,32
Nd	27,24	38,39	38,58	35,94	33,25	31,95	34,12	35,72	16,40	27,01	16,49	22,44	20,80	22,01	28,01	33,07	25,13	24,87

Table 1 (cont.) Chemical composition of samples from clay deposits

	Ya_R_01	Ya_R_01a	Ya_R_02	Ya_R_03.1	Ya_R_03.2	Ya_R_03.3	Ya_R_03.4	Ya_R_03.6	Ks_R_01	Ks_R_02	S_R_01	S_R_02	S_R_02a	S_R_03	Ch_R_01	Ch_R_02	M_R_01	M_R_02
Sm	5,08	6,77	7,06	6,45	6,17	6,05	6,32	6,72	3,63	5,42	3,17	5,14	4,15	4,37	5,30	6,61	5,35	5,12
Eu	1,17	1,73	1,37	1,70	1,68	1,47	1,66	1,65	0,71	1,10	0,68	1,11	0,85	0,95	1,08	1,35	1,00	1,06
Gd	4,25	5,40	6,06	5,00	5,17	4,82	5,32	4,88	2,81	5,32	3,09	4,16	3,69	3,94	3,96	5,89	4,19	4,70
Tb	0,54	0,69	0,93	0,67	0,70	0,62	0,74	0,73	0,48	0,74	0,44	0,63	0,63	0,58	0,58	0,88	0,59	0,67
Dy	3,43	3,82	5,00	4,21	3,68	3,49	4,60	4,19	2,94	4,90	2,57	3,87	3,39	3,41	3,36	5,24	3,48	3,76
Ho	0,75	0,72	1,00	0,84	0,80	0,65	0,85	0,73	0,60	0,91	0,46	0,69	0,60	0,58	0,68	1,04	0,69	0,71
Er	1,72	2,05	2,76	2,26	2,41	2,01	2,64	2,09	1,63	2,80	1,53	1,81	1,53	1,92	2,05	2,87	2,17	2,02
Tm	0,30	0,29	0,41	0,33	0,29	0,29	0,35	0,32	0,23	0,37	0,21	0,27	0,21	0,24	0,27	0,47	0,29	0,31
Yb	2,03	1,86	2,78	2,40	2,29	1,88	2,32	2,20	1,90	2,63	1,51	1,69	1,62	1,74	2,08	2,78	1,98	1,99
Lu	0,30	0,31	0,43	0,32	0,35	0,27	0,38	0,35	0,28	0,38	0,18	0,26	0,23	0,24	0,32	0,44	0,31	0,29
Au	0,29	<0.21	<0.20	<0.16	<0.19	<0.16	<0.17	<0.13	<0.20	<0.19	<0.16	<0.18	<0.19	<0.24	<0.13	<0.16	<0.15	<0.16

Table 2. Chemical composition of samples from pottery

Kod	Con_S_001	Con_S_002	Con_S_003	Con_S_004	Con_S_005	Con_S_006	Con_S_007	Con_S_008	Con_S_009	Con_S_010	Con_S_011	Con_S_012	Con_S_013	Con_S_014
SiO2	59,89	63,17	69,65	68,32	67,35	70,72	70,61	54,25	69,70	64,88	67,23	62,30	65,61	60,68
TiO2	0,94	0,74	0,58	0,68	0,70	0,55	0,10	0,09	0,11	0,11	0,13	0,26	0,71	0,91
Al2O3	20,21	19,09	14,58	17,06	19,42	15,58	2,15	2,64	2,33	2,37	3,19	5,09	17,59	19,33
FeO	6,14	5,33	3,10	3,43	4,18	2,85	0,07	0,13	0,09	0,09	0,13	0,26	3,67	5,30
MnO	0,09	0,06	0,08	0,05	0,13	0,10	0,08	0,07	0,06	0,04	0,07	0,07	0,08	0,11
MgO	2,43	2,34	0,74	1,25	1,93	0,89	0,08	0,35	0,10	0,10	0,15	0,15	0,95	1,28
CaO	3,01	2,68	1,72	1,89	1,88	1,23	7,70	17,91	4,87	4,20	4,99	3,90	2,11	2,81
Na2O	1,63	1,65	1,05	1,99	1,95	1,18	6,69	8,33	5,15	4,12	4,14	1,99	1,63	2,29
K2O	2,95	2,88	2,88	3,09	3,34	3,14	0,06	0,06	0,08	0,07	0,10	0,14	3,42	3,75
P2O5	0,34	0,18	0,36	0,12	0,15	0,16	0,14	0,82	0,12	0,09	0,24	2,20	0,42	0,51
сума	97,62	98,12	94,75	97,89	101,05	96,40	87,69	84,68	82,59	76,07	80,37	76,35	96,17	96,97
Ba	1273,55	829,01	1138,92	594,69	921,92	989,75	633,29	1031,39	535,09	388,20	570,08	770,44	1300,43	1063,80
Rb	118,95	116,78	101,97	102,45	142,78	115,29	364,69	396,56	302,95	263,82	217,40	151,91	126,27	105,76
Sr	269,50	201,63	199,18	174,36	289,00	196,20	388,34	599,92	353,84	318,08	468,62	701,86	273,75	375,68
Cs	11,67	6,21	3,85	4,99	8,24	5,12	53,96	32,17	29,96	20,78	12,17	9,89	4,11	3,56
Ta	1,12	1,01	1,09	0,86	1,09	1,02	12,39	6,16	5,90	4,64	2,88	1,90	1,20	0,85
Nb	15,54	12,11	16,24	11,19	15,85	12,54	118,77	61,98	71,67	50,15	38,49	22,03	15,20	13,05
Hf	6,57	4,39	6,30	4,64	4,93	3,96	64,82	23,36	36,87	21,99	14,86	10,14	5,75	5,10
Zr	254,83	173,87	247,70	173,82	194,70	165,72	601,69	279,15	522,75	396,37	383,67	310,10	218,41	199,17
Y	29,25	26,64	23,29	18,74	27,48	21,50	190,27	144,98	126,51	78,96	65,42	45,89	24,48	29,66
Th	15,73	10,94	10,54	7,87	18,43	11,74	94,81	58,66	53,66	37,16	37,82	19,78	17,12	12,33
U	4,35	2,18	2,39	2,46	4,02	1,96	23,13	18,93	15,85	8,54	7,19	3,97	2,90	2,15
Cr	177,21	229,08	70,91	80,18	144,62	71,47	354,55	1061,89	249,51	252,58	216,83	143,32	82,77	75,35
Ni	56,87	131,69	26,67	27,18	76,18	28,44	216,33	705,67	142,18	88,41	91,88	40,99	28,55	33,06
Co	18,26	20,59	9,13	9,32	15,90	11,11	87,38	167,03	60,52	33,88	32,39	24,54	11,06	16,04
Sc	21,75	20,73	12,32	14,42	16,13	12,84	112,95	129,05	62,52	52,95	33,00	27,50	14,68	18,16
V	151,21	132,54	88,29	101,34	111,19	71,24	358,17	414,23	301,82	238,28	215,53	173,34	104,82	176,57
Pb	28,30	22,00	20,47	18,33	41,06	25,49	131,91	84,91	90,39	65,00	65,65	42,66	19,75	17,49
Zn	84,34	88,53	55,56	58,06	74,83	53,66	286,21	344,60	236,24	138,65	141,99	124,73	52,99	65,37
Ga	17,92	17,81	14,21	14,87	19,59	16,26	121,55	108,87	79,16	62,54	43,23	30,19	19,41	20,25

Table 2 (cont.) Chemical composition of samples from pottery

Kod	Con_S_001	Con_S_002	Con_S_003	Con_S_004	Con_S_005	Con_S_006	Con_S_007	Con_S_008	Con_S_009	Con_S_010	Con_S_011	Con_S_012	Con_S_013	Con_S_014
Ag	<0.67	<0.578	<0.54	<0.71	<0.656	<0.75	<8.80	<3.31	<3.55	<2.91	<1.73	<0.801	<0.57	<0.54
La	39,05	31,11	29,86	22,71	40,27	29,62	203,22	118,31	132,89	92,58	93,57	51,02	33,58	36,11
Ce	73,68	61,52	66,99	45,86	76,23	85,67	235,66	153,76	191,24	147,77	155,36	95,69	68,11	74,30
Pr	9,05	7,36	7,25	5,19	8,41	6,73	67,08	39,15	39,25	25,95	23,52	12,48	8,08	8,38
Nd	34,09	29,06	27,48	20,76	31,07	25,35	192,18	120,24	123,97	84,56	83,05	46,40	30,14	33,44
Sm	6,62	6,02	5,42	4,12	6,01	5,19	51,38	35,00	31,39	20,58	16,79	10,06	5,95	6,59
Eu	1,56	1,25	1,13	0,92	1,24	0,95	11,17	8,41	6,29	4,27	3,44	2,23	1,19	1,53
Gd	6,35	5,30	4,46	3,87	4,84	4,30	49,11	32,41	28,79	16,82	13,99	9,07	5,19	5,98
Tb	0,83	0,81	0,67	0,54	0,79	0,63	7,43	5,38	4,42	2,57	2,15	1,40	0,68	0,86
Dy	5,04	5,06	4,01	3,27	4,79	3,62	49,78	32,24	25,58	15,06	13,02	8,11	4,24	5,13
Ho	1,06	0,95	0,79	0,74	0,90	0,83	9,92	6,86	5,46	3,26	2,59	1,75	0,81	1,05
Er	2,92	2,62	2,33	1,78	2,85	2,20	25,76	20,40	15,77	8,74	6,37	4,98	2,48	3,22
Tm	0,42	0,41	0,35	0,26	0,38	0,33	3,79	2,67	2,16	1,33	1,05	0,69	0,35	0,44
Yb	2,67	2,57	2,25	2,15	2,78	2,27	29,00	19,77	14,92	9,58	6,66	5,49	2,25	3,07
Lu	0,39	0,42	0,32	0,32	0,39	0,31	4,01	2,89	2,27	1,38	1,15	0,68	0,33	0,46
Au	<0.29	<0.15	<0.15	<0.18	<0.12	<0.21	<3.22	<1.37	<0.94	2,42	<0.59	<0.29	<0.24	<0.24
Pb	28,30	22,00	20,47	18,33	41,06	25,49	131,91	84,91	90,39	65,00	65,65	42,66	19,75	17,49

Table 2 (cont.) Chemical composition of samples from pottery

Kod	Con_S_015	Con_S_016	Con_S_017	Con_S_018	SMG_S.BE_026	SMG_S.BE_027	SMG_S.BE_028	SMG_S.BE_029	SMG_S.BE_030	SMG_S.BE_031	M_S.BE-001	Ch18A_S.BE_001
SiO2	67,54	69,81	71,45	67,77	64,48	61,86	64,41	64,59	63,92	61,37	55,83	64,45
TiO2	0,66	0,58	0,54	0,96	0,91	0,68	0,79	0,67	0,72	0,77	0,78	0,53
Al2O3	19,08	18,32	16,92	20,54	17,77	19,57	18,29	17,02	21,77	19,09	15,77	17,23
FeO	4,17	3,40	2,88	5,78	3,63	4,48	5,42	4,76	3,75	4,32	5,35	3,89
MnO	0,08	0,07	0,06	0,14	0,14	0,08	0,08	0,10	0,07	0,07	0,11	0,09
MgO	1,16	0,99	0,92	1,52	1,14	1,43	2,49	2,42	1,18	1,82	3,99	2,07
CaO	1,92	1,70	1,24	1,74	2,50	2,36	3,37	5,03	2,19	3,43	7,05	1,71
Na2O	1,58	1,80	1,42	1,50	2,16	1,63	2,18	1,57	2,72	1,39	1,29	2,84
K2O	2,87	3,21	3,18	2,08	2,80	4,07	2,66	2,69	3,21	3,51	2,87	3,20
P2O5	0,23	0,21	0,15	0,17	0,28	0,56	0,17	0,13	0,15	0,20	0,26	0,27
сума	99,29	100,09	98,75	102,20	95,83	96,73	99,85	98,98	99,69	95,96	93,30	96,29
Ba	757,46	835,74	897,11	787,43	1052,88	2222,10	678,25	578,52	620,67	822,42	818,02	732,93
Rb	123,73	113,03	123,08	88,11	118,16	167,71	97,34	103,35	135,08	123,27	114,71	98,28
Sr	183,84	218,99	199,49	143,79	302,90	403,73	436,83	207,66	215,38	224,57	265,67	223,09
Cs	4,95	4,58	5,60	5,54	3,78	6,92	4,70	4,34	4,67	6,42	6,89	2,87
Ta	0,90	0,88	1,19	0,91	1,74	1,23	0,84	1,00	1,71	1,02	0,77	0,41
Nb	13,48	12,56	13,07	13,56	18,95	15,98	11,50	11,98	19,03	14,09	11,15	6,81
Hf	7,48	4,88	5,10	6,34	8,40	6,10	4,90	3,56	6,71	4,97	4,22	3,92
Zr	286,41	188,09	184,48	243,71	326,52	222,28	186,64	125,75	241,88	183,09	168,68	145,83
Y	25,97	23,46	21,26	40,05	33,88	23,87	24,57	22,81	27,38	26,55	23,56	19,98
Th	12,99	14,94	12,42	10,58	13,69	26,56	11,55	12,18	13,13	12,69	10,10	10,38
U	2,74	2,38	2,58	2,30	4,78	7,44	2,57	1,52	4,17	2,97	1,95	2,05
Cr	107,27	87,27	56,51	101,99	79,36	74,12	118,04	238,94	73,69	107,50	395,68	52,89
Ni	44,70	25,48	27,46	44,99	27,81	34,36	55,55	184,20	29,05	42,86	243,59	27,44
Co	11,95	10,50	9,20	18,46	14,75	13,83	19,77	20,60	8,44	16,54	24,40	12,54
Sc	15,31	12,02	12,45	21,45	14,62	18,64	20,23	17,47	14,95	17,35	21,86	15,76
V	112,22	94,02	80,13	163,20	104,85	132,96	181,76	105,45	89,26	128,36	130,57	124,32
Pb	21,46	37,47	24,16	13,54	23,38	60,17	31,11	26,07	20,74	20,9	26,09	17,62
Zn	59,18	46,92	57,26	73,54	70,05	67,73	97,07	76,46	199,61	82,56	96,83	76,35
Ga	19,35	18,34	17,90	21,61	19,00	19,06	16,80	17,39	24,50	20,70	17,51	14,30

Table 2 (cont.) Chemical composition of samples from pottery

Kod	Con_S_015	Con_S_016	Con_S_017	Con_S_018	SMG_S.BE_026	SMG_S.BE_027	SMG_S.BE_028	SMG_S.BE_029	SMG_S.BE_030	SMG_S.BE_031	M_S.BE-001	Ch18A_S.BE_001
Ag	<0.61	<0.43	<0.55	<0.54	<0.43	<0.35	<0.42	<0.47	<0.45	<0.40	<0.60	<0.44
La	37,33	37,45	29,98	42,70	42,74	41,93	31,23	30,21	36,49	35,46	27,64	27,19
Ce	74,50	72,01	57,63	96,07	91,60	78,55	63,17	60,16	66,76	71,33	57,99	53,44
Pr	8,78	8,08	6,82	10,27	10,24	9,09	7,27	6,65	8,39	8,24	6,63	6,06
Nd	33,78	30,49	25,88	41,47	39,80	33,74	28,87	25,13	32,38	31,13	25,73	23,12
Sm	6,77	5,86	4,61	9,16	8,02	6,00	5,90	5,08	6,18	6,16	5,60	4,62
Eu	1,23	1,11	0,93	2,00	1,64	1,31	1,24	1,02	1,26	1,37	1,14	1,06
Gd	5,78	4,84	4,44	8,10	6,91	4,94	5,33	4,74	5,77	5,39	4,32	4,07
Tb	0,83	0,73	0,59	1,19	1,00	0,73	0,72	0,68	0,81	0,79	0,66	0,53
Dy	4,93	4,41	3,59	7,27	6,28	4,26	4,37	3,64	5,15	4,54	4,30	3,52
Ho	0,96	0,88	0,72	1,45	1,14	0,85	0,89	0,88	0,90	0,93	0,82	0,66
Er	2,95	2,37	2,30	4,15	3,54	2,33	2,79	2,50	2,74	2,82	2,23	2,01
Tm	0,38	0,34	0,29	0,58	0,48	0,31	0,35	0,36	0,39	0,40	0,38	0,30
Yb	2,61	2,34	2,18	4,11	3,17	2,50	2,36	2,00	2,48	2,46	2,45	2,09
Lu	0,38	0,35	0,28	0,61	0,45	0,40	0,35	0,31	0,40	0,41	0,33	0,30
Au	<0.23	<0.11	<0.19	<0.16	<0.15	<0.16	<0.16	<0.23	<0.18	<0.13	<0.15	<0.20
Pb	21,46	37,47	24,16	13,54	23,38	60,17	31,11	26,07	20,74	20,90	26,09	17,62

ADVANTAGES AND DISADVANTAGES OF BRICKS AS A MATERIAL FOR ARCHAEOMAGNETIC STUDY

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ABSTRACT

Three collections of bricks were archaeomagnetically studied – Roman bricks (taken from the Diocletianopolis city wall, present Hissarya), Turkish bricks (coming from a mosque excavated on the territory of „40 Saint Martyrs" church, Veliko Tarnovo) and bricks with inscription (found also on the territory of „40 Saint Martyrs" church). The bricks differ significantly according to their shape and size. The main aims of the study were: 1) to determine the geomagnetic field elements (inclination and intensity); 2) to evaluate the magnetic anisotropy effect; 3) to verity the reliability of previously obtained archaeomagnetic determinations for Hissarya bricks (involved in the Bulgarian archaeomagnetic database); 4) to demonstrate the reliability and capabilities of archaeomagnetic dating method using bricks with well-known manufacturing date.

The rock-magnetic experiments performed indicate that the magnetic properties of all bricks are suitable for archaeomagnetic study. This is a consequence of the fact that bricks are usually baked at high temperatures (above 700°C) so they always carry a stable full TRM.

The inclinational data obtained show unacceptable scatter for the Turkish bricks and mean inclinational value was calculated only for the Roman bricks and the bricks with inscription. The magnetic anisotropy corrections applied do not improve the dispersion observed for none of the collection studied. Therefore, it can be concluded that these bricks were not strictly arranged along their long narrow sides during their production and obviously, this dominates the magnetic anisotropy influence. It is suggested that the Turkish bricks were situated in the furnace much more randomly compared to the other ones. There is a good internal consistency among the archaeointensity results obtained for the different collections and the magnetic anisotropy does not affect significantly the final mean results. The repeated archaeomagnetic study of the referent site Hissarya confirms its old inclinational determination but changes the old intensity result. Based on all the archaeointensity data received for the Roman bricks it can be suggested that some of the bricks in the construction of Hissarya fortress were reused (they were baked at least in two different periods).

Archaeomagnetic dating was performed only by one geomagnetic field element (intensity) for the studied Turkish bricks and by two geomagnetic field elements (inclination and intensity) – for the bricks with inscription. The dating intervals obtained on 95 percent probability level (2σ) are: 1817 – 1894 AD (Turkish bricks) and 1833 – 1894 AD (bricks with inscription) as they ended with the last year of the Bulgarian archaeomagnetic dataset. The archaeomagnetic dating interval obtained for the Turkish bricks indicate that they were produced rather in the end of the Ottoman ruling than in the end of XVII – beginning of XVIII century. This does not contradict the archaeological data. The maximum of probability density distribution for the bricks with inscription is around 1880 AD and agree quite well with the year of their production – 1888 AD. It should be considered that dating by all geomagnetic field elements (impossible for bricks materials) in the most cases produces narrower and more precise archaeomagnetic dating intervals compared to dating by one or two geomagnetic field elements.

The Turkish bricks and the bricks with inscription are included as new referent points with their archaeological dates in the Bulgarian archaeomagnetic database. With the new study of the Roman bricks an important correction for the referent site Hissarya was done. This demonstrates the importance and requirement of regular revision of the available archaeomagnetic dataset especially with regard to the old results.

Key words: archaeomagnetism, bricks, magnetic anisotropy, Diocletianopolis, Veliko Tarnovo

ПРЕДИМСТВА И НЕДОСТАТЪЦИ НА ТУХЛИТЕ КАТО МАТЕРИАЛ ЗА АРХЕОМАГНИТНО ИЗСЛЕДВАНЕ

Мария Костадинова-Аврамова

РЕЗЮМЕ

Обект на настоящото изследване са три колекции тухли, различаващи се съществено по форма и размери – римски тухли (от крепостната стена на Диоклецианопол, гр. Хисаря), турски тухли (от турска джамия, разкрита на територията на църквата „Св. 40 мъченици", гр. Велико Търново) и тухли, върху които е щампирана точната дата на тяхното производство (от територията на църквата „Св. 40 мъченици"). Основните цели на изследването са: 1) да се определят елементите на земното магнитно поле (инклинация и интензитет); 2) да се оцени ефектът на магнитната анизотропия върху получените резултати; 3) да се провери достоверността на включените в археомагнитната база данни стари резултати за обекта в Хисаря (получени по много по-малобройна колекция и чрез прилагане на много по-малко лабораторни експерименти); 4) да се демонстрират възможностите на археомагнитния метод чрез датиране на тухли с известна дата на производство.

Според резултатите от направените магнитно-диагностични лабораторни експерименти и трите вида тухли имат подходящи за археомагнитно изследване магнитни свойства. Това до голяма степен е свързано с факта, че при изпичането тухлите винаги се нагряват до много високи температури, което е основна предпоставка за придобиването на стабилна пълна термоостатъчна намагнитеност.

Данните за инклинацията на древното геомагнитно поле показват неприемливо „разхвърляне" за турските тухли, поради което среден резултат за тази характеристика е определен само за римските и щампираните тухли. След въвеждането на поправка за влиянието на магнитната анизотропия, наблюдаваното „разхвърляне" не се подобрява за нито една от колекциите. Следователно то най-вероятно е следствие от не достатъчно прецизно подреждане на тухлите в пещта по време на изпичането, а не толкова ефект от магнитна анизотропия. Може да се предполага, че най-внимателно в пещите са били редени щампираните тухли, а най-хаотично – турските. Стойностите, определени за археоинтензитета като цяло имат много добра вътрешна съгласуваност и за трите колекции като отчитането на магнитната анизотропия не ги променя съществено. Повторното изследване на римски тухли от крепостта Хисаря показа, че вследствие на малкия брой образци, при първото изследване, е получена много по-висока и очевидно нереална стойност за палеоинтензитета (резултатът за инклинацията се потвърждава). От всички данни за археоинтензитета би могло да се допусне, че при строежа на крепостта Хисаря са били използвани тухли, изпечени в различни моменти от време.

Археомагнитно датиране е направено по един геомагнитен елемент (интензитет) за турските тухли и по два (инклинация и интензитет), за щампираните. Дефинирани са следните датируеми интервали: 1817 – 1894 г. (турски тухли) и 1833 – 1894 г. (щампирани тухли). И в двата случая краят на интервалите съвпада с края на археомагнитния ред от данни. Полученият за турските тухли времеви интервал предполага, че е по-вероятно те да са били произведени в края на Османския период, отколкото в края на XVII – началото на XVIII. Това не е в противоречие с археологическите данни. Полученият за щампираните тухли времеви интервал е в много добро съответствие с годината на тяхното производство – 1888 (максимумът на разпределението на плътността на вероятността на получения археомагнитен датируем интервал е около 1880 година). Важно е да се отбележи, че датирането по трите геомагнитни характеристики (неприложимо в случай на тухли), в повечето случаи стеснява получаваните археомагнитни датируеми интервали.

Изследваните три колекции тухли са включени в Българската археомагнитна база данни като реперни точки с археологическите им дати. Повторното изследване на тухлите от крепостта при Хисаря даде основание да се направи една много важна корекция в базата данни, което показва колко важно може да се окаже в някои случаи преразглеждането на старите резултати.

INTRODUCTION

Archaeomagnetism is an interdisciplinary geophysical approach, which can be used as a reliable dating tool in archaeology (Kovacheva et al. 2004, 1563-1479; Kostadinova, Kovacheva 2008, 511-522; Ben-Yosef et al. 2010, 7-9; Aidona, Kondopoulou 2012, 839-842; Herve et al. 2011, 153-154;

Prevosti et al. 2013, 2696-2700; Casas et al. 2014, 861-864; Kostadinova-Avramova et al. 2014, 44-47; Tema et al. 2015, 501-504; Ech-Chakrouni et al. 2015, 578-593). The physical background of archaeomagnetic methodology is based on backed clay capability to acquire a thermoremanent magnetization (TRM) during its cooling in a weak magnetic field from temperatures above 400°C. This TRM contains information about the direction (I – inclination and D – declination) and the intensity (F) of the inducing magnetic field (Earth's magnetic field existing during the final cooling). The accumulation of sufficient amount faithful archaeomagnetic determinations, coming from well dated (with other methods) archaeological sites, enable local secular variation curves (SVCs) to be build and used for dating purposes. The basic feature of Bulgarian archaeomagnetic database is the intention of simultaneous determination of the three geomagnetic field elements from the same materials and the fact that it covers almost the entire prehistoric and historic periods (Kovacheva et al. 2014, 79 – 94).

The preferable materials for archaeomagnetic studies are different baked clay remains found *in situ* because they allow all the geomagnetic field elements (inclination, declination and intensity) to be restored. From displaced materials, only the geomagnetic field intensity can be determined. More specific and complicated is the situation with bricks. When the bricks are used in a kiln construction, they can be oriented and studied as *in situ* materials. In this case, it should be considered the sample`s position and spatial distribution of firing temperatures inside the kiln. If in some parts of the kiln, relatively lower (less than 500-600°C) firing temperatures were achieved, the bricks will retain information for two firing moments – the moment of their production and the last usage of the kiln. The latter could complicate the undertaken archaeomagnetic investigation without making it impossible. When the bricks are collected from some building constructions (not burned), their archaeomagnetic study will fix only the time of brick' manufacturing. Two geomagnetic field elements could be defined for such samples – inclination and intensity. The result for the ancient inclination, however, can be obtained only if the bricks were arranged precisely in the furnace along their long narrow side during their baking.

Regardless of whether the bricks were secondary baked or not, there are two important factors, which can affect the carried TRM – magnetic anisotropy and cooling rate effect. The magnetic anisotropy in bricks is due to mechanical alignment of magnetic grains during the treatment of clay in the moulding process. Many studies (Aitken et al. 1981, 53-64; Lanos 1987, 985-1012; Garcia et al. 1997, 89; Chauvin et al. 2000, 117-129; Hus et al. 2002, 1319-1331) show that sometimes the magnetic anisotropy effect is quite important. It could be responsible for significant deviations between the TRM vector and the vector of the ancient geomagnetic field and thereby, to distort the archaeomagnetic determinations. It is proven that magnetic anisotropy affects the archaeointensity results of bricks in less extend compared to pottery (Jordanova et al. 1995, 49-58; Kovacheva et al. 2009,730-731*).* Although, it seems that quite often the application of magnetic anisotropy corrections improves the inter-sample consistency and gives more precise archaeomagnetic evaluations (Chauvin et al. 2000, 134; Hill et al. 2007, 476-478; Kovacheva et al. 2009; 731; Tema 2009, 213-223).

Three brick collections were archaeomagnetically studied with the following aims: 1) to determine the geomagnetic field elements (inclination and intensity); 2) to evaluate the magnetic anisotropy effect; 3) to verity the reliability of previously obtained archaeomagnetic determinations for a referent site Hissarya; 4) to demonstrate the reliability and capabilities of archaeomagnetic dating method using bricks with well-known manufacturing date.

MATERIALS AND METHODS

1. Description of the collections studied

The first collection consists of 13 Roman bricks taken from the Diocletianopolis city wall (present Hissarya), from which 71 standard (8 cm^3) cubic specimens (subsamples) were cut. A small brick collection coming from the same archaeological site was archaeomagnetically studied many years ago

(in 1969) when archaeomagnetism started to develop in Bulgaria. Having in mind the small number of samples and the fact that archaeomagnetic methodology was considerably improved thereafter, the verification of these old results (involved already in the Bulgarian archaeomagnetic database) is quite important. The second collection includes 26 Turkish bricks from a mosque excavated on the territory of „40 Saint Martyrs" church, Veliko Tarnovo and 214 standard cubic specimens. According to the archaeologists, the Roman bricks were more probable produced during III-IV century AD or earlier, while the Turkish bricks were baked at the earliest in the end of XVII – beginning of XVIII century AD and no later than the Turkish slavery Liberation (1878). The third collection, containing only 2 bricks (found also on the territory of „40 Saint Martyrs" church) and 12 cubic specimens, is quite small, but each brick has an inscription of its manufacturing year – 1888 AD. Consequently, the study of this small collection can serve as a good example of the reliability and capabilities of archaeomagnetic dating method.

The bricks included differ considerably according to their shape and size. The Roman bricks are larger and better formed than the Turkish ones. The bricks with inscription have dimensions similar to these of the Turkish bricks but they are significantly thicker in comparison to the Roman and Turkish bricks.

2. Laboratory procedures

The success of an archaeomagnetic study strongly depends on fulfilment of several conditions: 1) the materials have to carry a stable thermoremanent magnetization; 2) the mineralogical changes during laboratory heating experiments have to be negligible (less than 10 percent); 3) the prevailing magnetic particles have to be in appropriate domain sizes (single or close to). That is why in the last years rock-magnetic experiments are obligatory part of each archaeomagnetic investigation. A regular set of laboratory analysis (Kovacheva, Jordanova 2001, 685-696; Kostadinova-Avramova et al. 2014, 37-42) were done for selected specimens:

- **viscous cleaning** – all subsamples;

- **demagnetization with alternating field (AF demagnetization)** – five Roman, four Turkish and one brick with inscription;

- **thermal demagnetization of isothermal remanece induced along three orthogonal directions in a sample (3IRM test)** (Lowrie 1990, 159-162) – five Roman, five Turkish and one brick with inscription;

- **thermal demagnetization of isothermal remanece with subsequent magnetization at room temperature after each heating step (SIRM test)** (Van Velzen, Zijderveld 1992, 79-90; Jordanova et al. 2003, 146-158) – five Roman, five Turkish and one brick with inscription;

- **Thermomagnetic analysis** – five Roman, four Turkish and one brick with inscription;

- **Lowrie and Fuller test** (Lowrie, Fuller 1971) – six Roman, four Turkish and one brick with inscription.

ROCK MAGNETIC RESULTS

The results of the rock-magnetic experiments carried out, lead to the conclusion that the investigated materials are appropriate for archaeomagnetic study. The calculated viscosity coefficient values (Sv) are highest for the bricks with inscription (the most Sv values are above 9 percent) and lowest for the Roman bricks (Sv values vary from 2 to 10 percent with a maximum of 6 percent) – Fig. 1. The obtained Sv values for the Turkish bricks are between 6 and 10 percent with a maximum of 8 percent. Generally, the observed high Sv values are explained by insufficient firing of the materials in the past or/and the presence of high quantities fine unstable magnetic particles of supperparamagnetic (nano) sizes. Obviously only the second explanation should be considered for bricks. The available secondary viscous remanence was easily removed with applying of low (5-10 mT) alternating fields – Fig. 2 (the quick alignment of the experimental points is obvious on the left upper plot). From 3IRM test and thermomagnetic analyses can be concluded that the magnetic mineralogy of Turkish bricks and

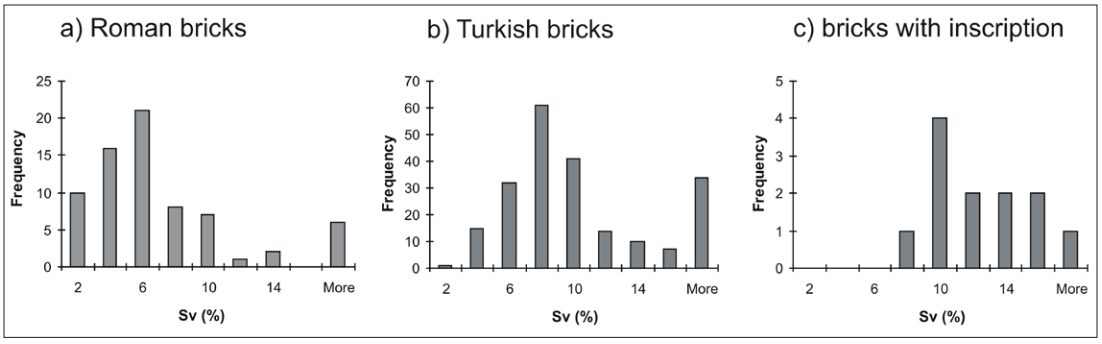


Fig. 1. Frequency distribution of the viscosity coefficient Sv: a) Roman bricks b) Turkish bricks and c) bricks with inscription

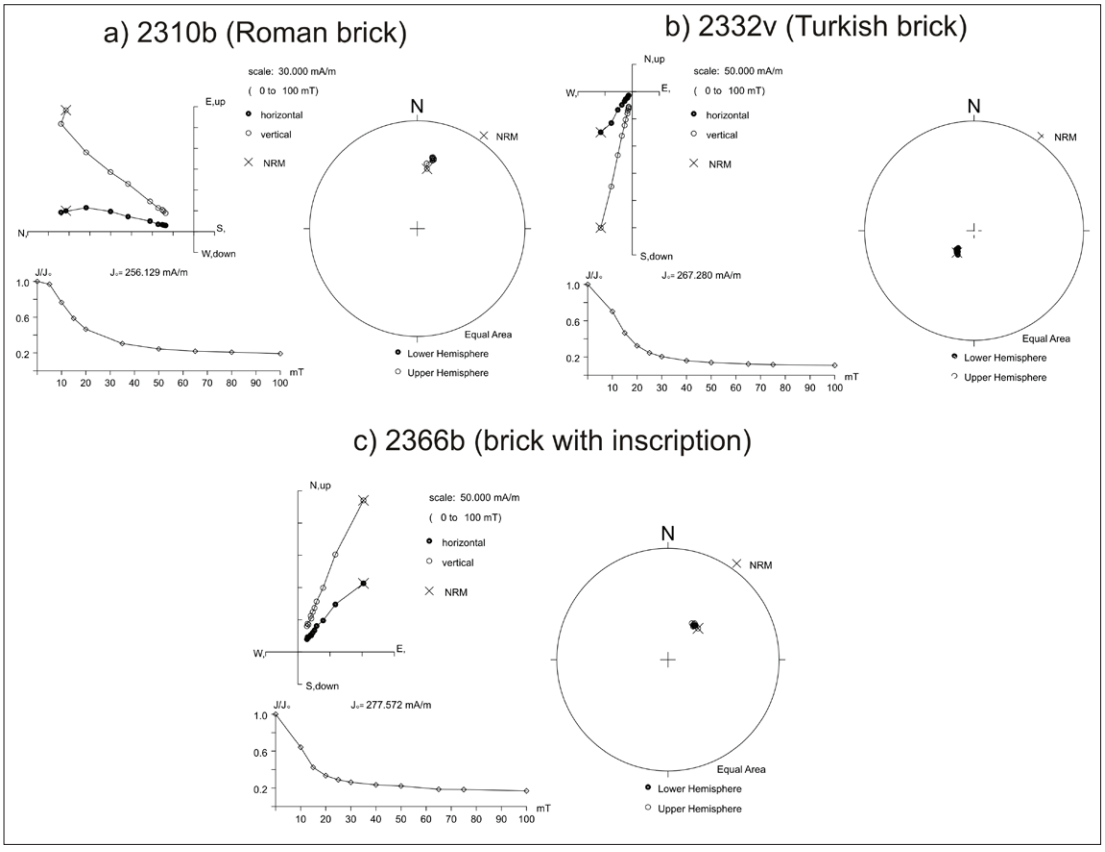


Fig. 2. Typical examples of AF demagnetization: a) Roman brick b) Turkish brick and c) brick with inscriptions. In all graphs, a cross marks the initial values of the measured remanence.

the bricks with inscription is quite similar and magnetically soft minerals prevail – *titanomagnetite/magnetite* and *maghemite* (Fig. 3b, c and Fig. 4b, c). This similarity suggests a common origin of the clay used for their production. In contrast, in the Roman bricks a significant amount of high coercivity minerals (*goethite*, *hematite* and *epsilon iron oxide*) are detected (Fig. 3a; Fig. 4a; Lopez-Sanches et al. 2017). The thermomagnetic analyses and SIRM tests carried out indicate that overall there are no strongly expressed magnetic mineralogical transformations during laboratory heating (Fig. 4, b, c; Fig. 5). The magnetic susceptibility (K) monitored during 3IRM and SIRM tests confirms the stability of magnetic mineralogy (Fig. 3; Fig. 5). Lowrie and Fuller tests failed for the Roman bricks because of the significant presence of high coercivity magnetic minerals (the test is applicable only for magnetite type minerals). For the other two brick collections, bimodal (Fig. 6a) and single (Fig. 6b) domain sizes of magnetic carriers are supposed (Dunlop 1983).

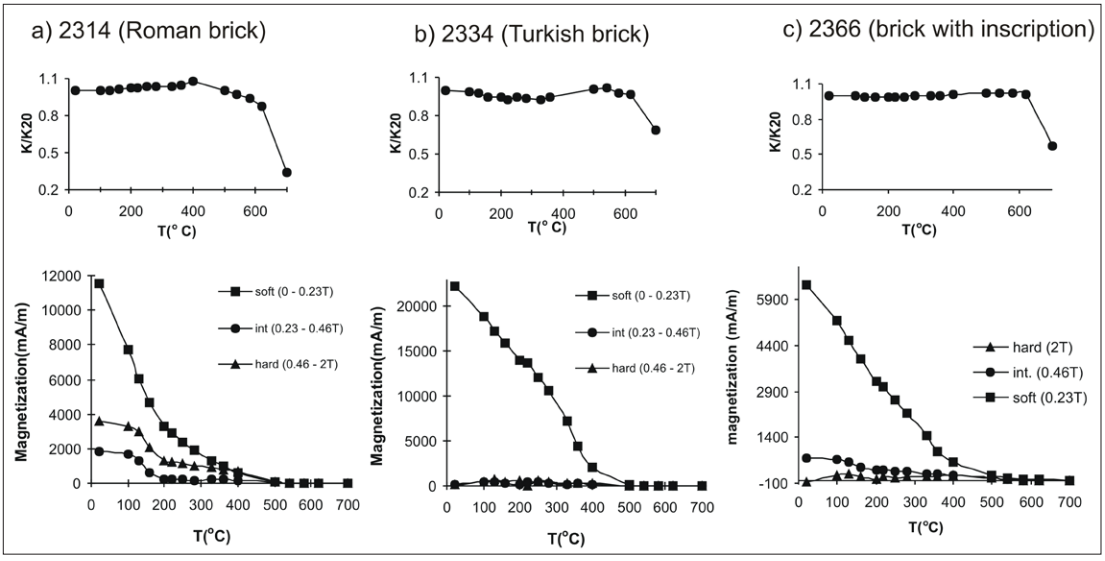


Fig. 3. Typical examples of 3IRM test: a) Roman brick b) Turkish brick and c) brick with inscription. The upper graphs show the behaviour of magnetic susceptibility (K) during the thermal demagnetization. K was measured at room temperature after each heating step.

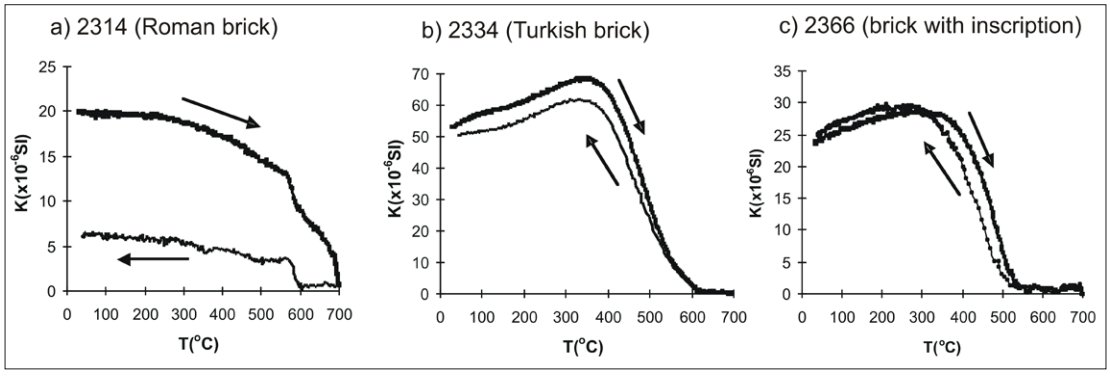


Fig. 4. Typical examples of thermomagnetic analyses: a) Roman brick b) Turkish brick and c) brick with inscription. The magnetic susceptibility behaviour was constantly monitored during the heating and cooling cycles.

According to the rock-magnetic results, 40 specimens were carefully selected for archaeointensity (F) determination – 18 Roman, 20 Turkish and 2 bricks with inscription. The classical Thellier method (Thellier, Thellier 1959) was applied (Fig. 7). During the experiment, the magnetic susceptibility at room temperature was measured at each heating step to monitor if any mineralogical changes occur. With few exceptions, the variations in this parameter are acceptable (less than 10 percent). Three additional archaeointensity determination experiments were done by Dr. Fabio Donadini for the old previously investigated collection from Hissarya (Roman bricks) using Coe protocol (Coe, 1967).

MAGNETIC ANISOTROPY AND ARCHAEOMAGNETIC DETERMINATIONS

The influence of magnetic anisotropy on archaeomagnetic determinations was evaluated using **anhysteretic remanence anisotropy tensor method** (Kostadinova-Avramova 2009, Chapter III. 2). Owing to the similarity of AARM and ATRM tensors, anisotropy of anhysteretic remanence (AARM) can be used as a substitute of thermoremanent (TRM) anisotropy. Thereby, the thermally induced mineralogical alterations are avoided.

The obtained results show that, for samples with a higher degree of remanence anisotropy, expectedly, higher anisotropy corrections are observed. The Roman bricks are more anisotropic

than the Turkish ones and the bricks with inscription (Kostadinova-Avramova 2009, Chapter III. 2). The magnetic anisotropy affects archaeointensity in less degree than inclination, which agrees well with Kovacheva et al. (2009, 730-731).

All archaeomagnetic results obtained are summarized in Table 1. In the first column the numbers of accepted/all measured specimens are given. The mean inclination for each independently oriented sample is calculated as an average of the values measured for the relevant subsamples after the corresponding cleaning. For the Roman and Turkish bricks the scatter between the inclinational data obtained for the different samples is significant (Table 1a and b). The comparison between uncorrected and corrected for the magnetic anisotropy effect I values is given in columns 2 and 3 of Table 1. Although, the individual determinations for the inclination shift significantly in few cases as a result of this effect, the average I value per collection does not changes considerably. Hence, the applied corrections for the magnetic anisotropy effect (third column in Table 1 – I_{corr}) do not improve the inclinational dispersion. Therefore, the most probable explanation for the observed scatter is the assumption that Roman and Turkish bricks were not arranged exactly along their long narrow sides during their baking. Nevertheless, after the rejection of two results (2310 – the lowest and 2314 – the highest I value – Table 1a), an acceptable final value for the Roman bricks is determined (after magnetic anisotropy correction): $\mathbf{I_{corr} = 53.0^o \pm 4.1^o}$ (given in bold at the end of Table 1a). For the Turkish bricks, however, the scatter between the results is so high that it is impossible to determine any mean inclination (Table 1b). The two bricks with inscription have quite similar inclinational values and gives averaged result: $\mathbf{I_{corr} = 55.1^o \pm 1.6^o}$ (after magnetic anisotropy correction).

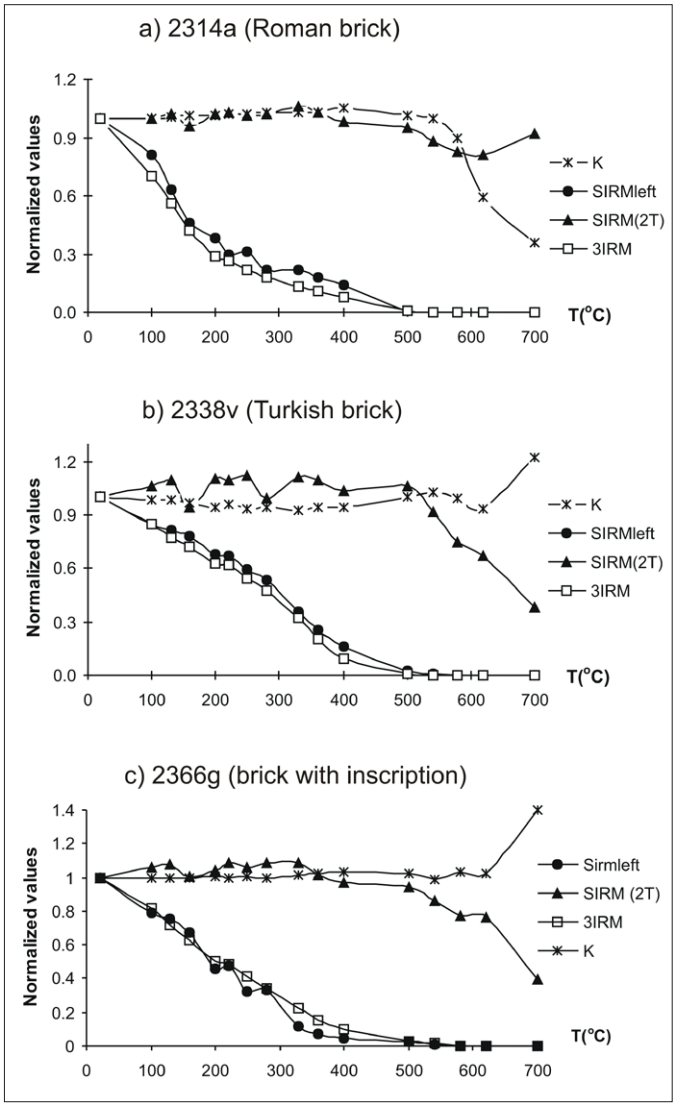


Fig. 5. Typical examples of SIRM test: a) Roman brick b) Turkish brick and c) brick with inscription

The studied Turkish bricks are much more numerous in comparison to the other two brick collections but nevertheless, only for them the inclinational results are inacceptable. Therefore, it can be concluded that Turkish bricks were arranged in the furnace more randomly and imprecisely during their production compared to the other ones.

The obtained archaeointensity (F) values are also given in Table 1 before and after magnetic anisotropy corrections (column 5 and 7) with the corresponding errors (column 6 and 8). The temperature intervals used for the intensity determination are shown in column 4. The final F value (given in bold in Table 1) for the Roman bricks is calculated from 10 accepted results corrected

Table 1. Summary of the archaeomagnetic determinations obtained: a) Roman bricks, b) Turkish bricks and c) bricks with inscription. № – sample`s number; I (I_{corr}) – magnetic inclination (in degree) before (after) magnetic anisotropy correction; Tmin – Tmax – temperature interval used for F determination; F and σ (F_{corr} and σ_{corr}) – the obtained archaeointensity value and its corresponding error (in microtesla) before (after) magnetic anisotropy corrections.

a) Roman bricks							
№	**I°**	**$I°_{corr}$**	**$T_{min} – T_{max}$ (°C)**	**F (μT)**	**σ (μT)**	**F_{corr} (μT)**	**σ_{corr}(μT)**
2305 (7/6)	47.9	48.6					
2306 (8/8)	51.8	53.7		rejected			
				rejected			
2307 (6/6)	61.2	58.2	20 – 430	64.20	1.33	59.71	0.93
			20 – 320	64.01	5.60	54.47	0.85
2308 (3/3)	53.5	53.9	20 – 370	64.01	2.86	61.58	0.96
2309 (4/4)	55.8	58.5		rejected			
				rejected			
2310 (5/5)	*43.4**	-	100 – 320	60.50	1.49	57.23	0.94
			20 – 320	62.79	2.59	59.27	0.94
2311 (5/5)	47.5	48.3					
2312 (3/3)	64.0	58.7					
2313 (5/5)	47.0	49.0	20 – 430	63.40	2.10	61.50	0.97
			20 – 430	62.30	1.87	62.92	1.01
2314 (5/5)	*64.6**	*63.5**		rejected			
2315 (6/6)	61.4	60.4	130 – 460	57.61	2.90	58.30	1.01
			130 – 460	57.04	3.05	58.18	1.00
2316 (7/7)	49.8	48.8	100 – 620	61.34	2.44	63.12	1.03
				rejected			
2317 (7/7)	56.7	56.8	100 – 320	*74.53**	*1.14*	*76.99**	*1.03*
			100 – 320	*74.56**	*2.82*	*78.66**	*1.06*
Average	**54.2**	**53.0**		**62.10**	**2.11**	**59.42**	**2.66**
St. dev.	**6.1**	**4.1**					

b) Turkish bricks							
№	**I°**	**I_{corr}**	**$T_{min} – T_{max}$ (°C)**	**F (μT)**	**s (μT)**	**F_{corr} (μT)**	**σ_{corr}(μT)**
2329 (6/6)	55.2	56.2	100 – 370	39.47	0.46	39.23	0.46
2330 (6/6)	44.9	44.1					
2331 (6/6)	47.4	48.1					
2332 (7/7)	70.5	69.9	130 – 460	45.38	0.84	44.70	0.83
2333 (6/6)	47.5	47.4	100 – 430	45.87	1.33	45.55	1.32
2334 (6/6)	57.6	58.8					
2335 (6/6)	43.2	40.7	100 – 430	42.41	0.80	43.39	0.82
2336 (6/6)	41.4	40.5	100 – 370	39.28	0.99	39.59	1.00
2337 (6/6)	40.1	40.5	100 – 460	45.84	1.26	45.89	1.26
2338 (6/6)	51.0	50.9	100 – 370	48.73	1.71	47.85	1.68
2339 (6/6)	53.3	56.6		rejected			
2340 (6/6)	40.8	38.5	130 – 430	52.74*	2.42	53.69*	2.46
2341 (6/6)	40.8	40.0					
2342 (6/6)	53.7	53.6	100 – 370	42.98	0.84	43.50	0.85

2343 (7/7)	42.3	43.3					
2344 (6/6)	63.5	63.6	20 – 370	41.91	1.60	41.11	1.57
2345 (5/5)	44.1	41.5					
2346 (6/6)	47.3	48.4					
2347 (6/6)	35.7	36.7	20 – 460	41.99	0.88	42.03	0.88
2348 (6/6)	43.4	42.7	20 – 370	39.93	1.91	40.53	1.94
2349 (6/6)	43.4	42.6					
2350 (6/6)	51.8	-	200 – 370	48.01	1.45	46.91	1.42
2351 (6/6)	40.3	39.7		rejected			
2352 (7/7)	41.9	41.3	100 – 370	40.88	0.69	42.60	0.72
2353 (6/6)	51.9	51.7					
2354 (5/5)	36.8	37.3					
2355 (6/6)	39.4	39.2					
2356 (6/6)	57.0	55.3					
2357 (6/6)	49.8	47.2					
2358 (6/6)	48.9	48.3		rejected			
2359 (6/4)	53.5	55.1					
2360 (6/6)	49.8	49.2					
2361 (6/6)	60.8	61.4	100 – 280	39.74	1.30	39.90	1.30
2362 (6/6)	70.7	70.6					
2363 (6/6)	42.1	41.6	100 – 320	46.67	2.59	47.04	2.61
2364 (6/6)	52.8	52.2	100 – 370	42.67	0.91	42.71	0.91
Average	**48.7**	**48.4**		**41.95**	**2.53**	**42.13**	**2.45**
St. dev.	**8.6**	**9.0**					

c) bricks with inscription							
№	**I°**	**I_{corr}**	**T_{min} – T_{max} (°C)**	**F (μT)**	**σ (μT)**	**F_{corr} (μT)**	**$σ_{corr}$ (μT)**
2365 (6/6)	55.5	53.5	100 – 460	44.58	1.41	44.60	1.41
2366 (6/6)	57.7	56.7	100 – 460	44.01	2.10	44.40	2.12
Average	**56.6**	**55.1**		**44.40**	**0.26**	**44.54**	**0.06**
St. dev.	**1.6**	**1.6**					

for magnetic anisotropy $\mathbf{F_{corr} = 59.42 \pm 2.66\ \mu T}$ (Table 1a). For 6 subsamples the experiment failed (Table 1a, Fig. 7a). For two sister specimens the determined F values are two high (sample 2317, Table 1a, with italic and asterisk) and they were not taken into account in the final mean intensity calculation.

The old archaeomagnetic determinations for the Roman bricks (obtained in 1969 and included in the Bulgarian archaeomagnetic database) are $\mathbf{I = 52.1^o \pm 4.4^o}$ and $\mathbf{F = 71.88 \pm 9.72\ \mu T}$. It is obvious that the old I value is very close to the newest one but the old F value, determined with an objectionable error (9.72 μT), is too high. The later is not surprising considering that the old archaeointensity mean value were calculated using only 4 results varying from 57.08 to 82.74 (difference of more than 20 μT – Table 2, column 3, samples 596, 597, 604, 608). It was mentioned above that additional archaeointensity experiments were performed for three specimens taken from 1969 collection in 2008. The results are very close to the newest F determinations (Table 2, column 3, values given in bold). It is interesting that the old Roman brick collection also gives two very high intensity values (samples 596, 608 – Table 2) which are comparable with the excluded from the present collection F values (sample 2317, Table 1a). In this context, it can be supposed that some of the bricks in the construction of Hissarya fortress are reused (they were baked in different time). Taking into account the accepted inclinational and intensity values for both Roman brick collections

(Table 1a, Table 2) the final archaeomagnetic determinations for the referent site Hissarya were obtained: **I = 53.27° ± 3.88°** and **F = 59.91 ± 2.29 μT** and an important correction was done in the Bulgarian archaeomagnetic database (Kovacheva et al. 2014, 83).

For the Turkish bricks three archaeointensity determination experiments were unsuccessful (sample 2339, 2351, 2358) and one F value is substantially higher (sample 2340) – Table 1b. The other 16 intensity determinations are in very good agreement and the final (magnetic anisotropy corrected) F value is $\mathbf{F_{corr} = 42.13 \pm 2.45\ \mu T}$.

Table 2. Summary of the old (1969) archaeomagnetic determinations of Hissarya bricks. The three new archaeointensity evaluations (the same collection) obtained in 2008 are given in bold.

No	I°	F (μT)	σ (μT)
596	68*	79.76*	5.00*
597	58.0	57.08	3.00
	58.0	**65.15**	**2.82**
598	46.5		
599	rejected	**59.11**	**2.54**
600	54.6		
601	45.0	**62.02**	**1.84**
602	55.3		
603	53.7		
604	53.0	60.90	3.00
605	57.0	rejected	
606	55.0		
607	48.5		
608	47.0	82.74*	5.00*
609	52.0		
Average	**52.6**	**61.09**	**2.43**
St. dev.	**4.5**		

The two bricks with inscription practically give the same value for F and the final intensity determination (after magnetic anisotropy correction) is: $\mathbf{F_{corr} = 44.54 \pm 0.06\ \mu T}$ (Table 1c).

ARCHAEOMAGNETIC DATING

Archaeomagnetic dating for the studied Turkish bricks was performed by one geomagnetic field element (intensity) and for the bricks with inscription – by two geomagnetic field elements (inclination and intensity) using RenDate software (Lanos 2004, 43-82). The final archaeomagnetic determinations (intensity value for the Turkish bricks; inclination and intensity values for the bricks with inscriptions) are compared to the corresponding reference curves (updated in 2002 year) for the time interval 1500 – 1900 AD (Fig. 8a and b). The calculated dating intervals on 95 percent probability level (2σ) are: 1817 – 1894 AD for the Turkish bricks and 1833 – 1894 AD – for the bricks with inscription (Fig. 8). The archaeomagnetic dating interval obtained for the Turkish bricks (Fig. 8a) suggests that these bricks were produced rather in the end of the Ottoman

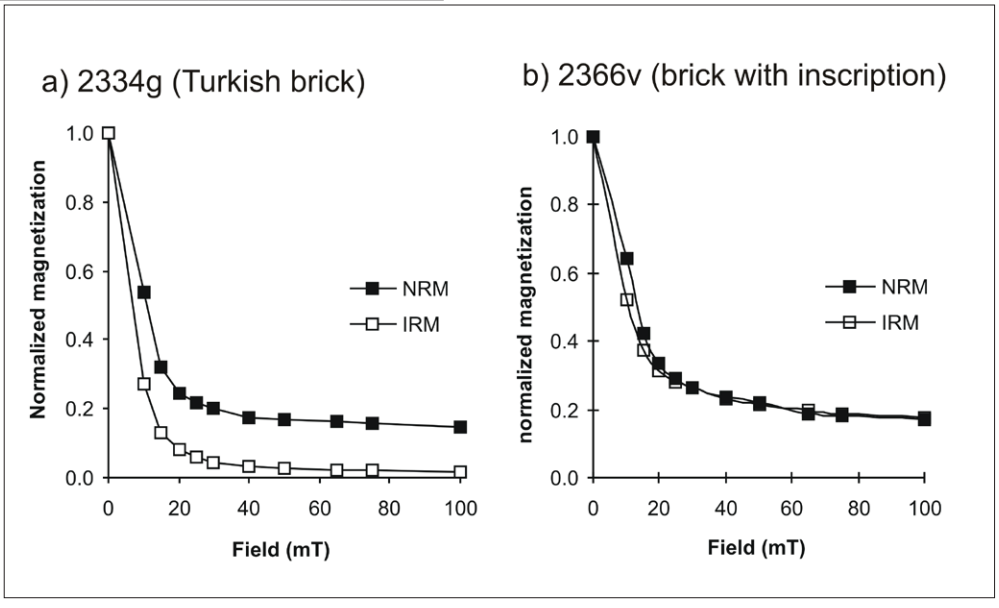


Fig. 6. Typical examples of Lowrie and Filler test: a) Turkish brick and b) the brick with inscription

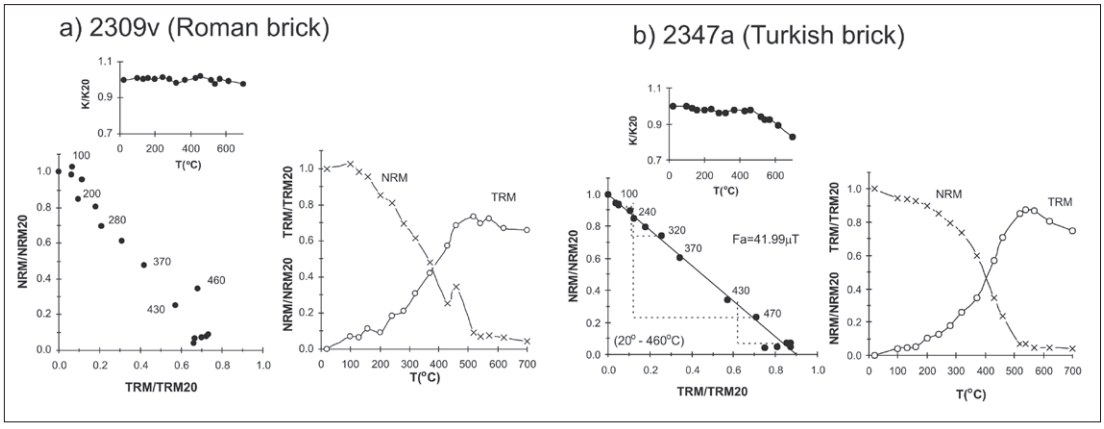


Fig. 7. Examples of Thellier experiment: a) Roman brick (failed) and b) Turkish brick (successful)

ruling (1878) than in the end of XVII – beginning of XVIII century. The maximum of probability density distribution for the bricks with inscription is around 1880 AD (Fig. 8b) and agrees quite well with the year of their production – 1888 AD. It should be noted that 1894 (the end of the archaeomagnetic dating intervals obtained for both brick collections) is the last year in the Bulgarian dataset used for the reference curves calculations. If direct geomagnetic field measurements were taken into account, in both cases wider dating intervals would be obtained. It is worth remarking that dating by all geomagnetic field elements (impossible for bricks materials) in the most cases produces narrower and more precise archaeomagnetic dating intervals compared to dating by one or two geomagnetic field elements. Archaeomagnetic dating for the Hissarya bricks cannot be done because the old determinations of this referent site participate in the Bulgarian secular variation curves. It is important to underline that archaeomagnetic dating of any site could be performed only before its involvement in the database.

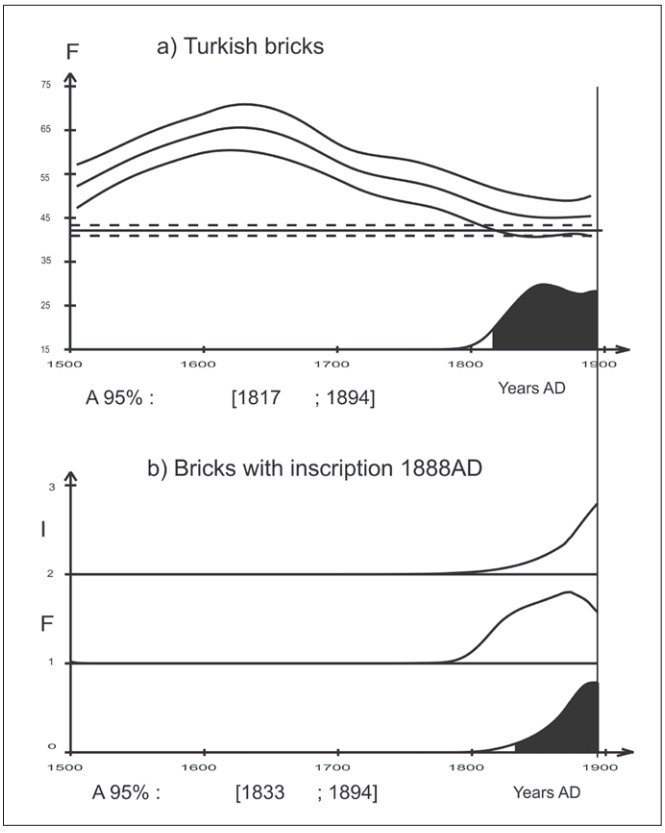


Fig. 8. Archaeomagnetic dating: a) Turkish bricks (only by intensity determination) and b) bricks with inscription (by inclination and intensity).

The precision of each archaeomagnetic dating depends not only on the accuracy of the experimental archaeomagnetic results but also from the accuracy of the reference curves used. In turn, the accuracy of the reference curves depend on the number of the included reference points and on the accuracy of their input dates. That is why each local database requires a constant updating and improvement. With the new study of the Roman bricks an important clarification for the referent

site Hissarya is done (the old intensity determination is revised and the old inclination is confirmed). The Turkish bricks and the bricks with inscription are included as new referent points with their archaeological dates in the Bulgarian archaeomagnetic database.

The cooling rate effect that was mentioned above as another important factor for archaeointensity determination is a subject of another investigation (Kostadinova-Avramova and Jordanova, 2019). Having in mind that the Bulgarian database consists of archaeointensity data uncorrected for this effect, the dating procedure is properly carried out.

CONCLUSIONS

1. The magnetic properties of the studied brick collections are suitable for archaeomagnetic study. The bricks are usually baked at high temperatures (above 700°C) so they should carry a stable full TRM. Additional advantage of bricks is that they are always well consolidated. That is why it is quite easy to be cut at subsamples without any water glass impregnation (the latter is obligatory procedure before cutting of fragile baked clay materials).

2. Great disadvantage of bricks is the fact that if they are not found *in situ* (after their final cooling) it is very difficult to obtain a reliable result for the ancient inclination and it is impossible to determine the declination of the past geomagnetic field. The establishment of the directional geomagnetic field elements is not easy even when the bricks can be oriented. The magnetic anisotropy and cooling rate factors could be combined with the possible presence of multi-component TRM.

3. The applied magnetic anisotropy correction on the archaeomagnetic determinations (inclination and intensity) obtained do not change significantly the final mean results and do not improve the inter-sample consistency for none of the studied brick collection. The individual corrections over the palaeointensity results are less in comparison to these for the inclination.

4. The repeated much more detailed archaeomagnetic study of the referent site Hissarya confirms its old inclinational value but changes the old intensity result. This illustrates the importance and requirement of regular revision of the available database especially with regard to the old results.

5. The reliability of archaeomagnetic dating is proved by the investigation of bricks with inscription.

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