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THE FORAMINIFERAL ANALYSIS AS A METHOD FOR DETERMINATION OF SOURCE MATERIAL FOR THE SHERDS FROM THE "ADA TEPE" ARCHAEOLOGICAL SITE, KROUMOVGRAD DISTRICT (EASTERN RHODOPES)

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ABSTRACT. The foraminiferal study is widely used in two aspects – biostratigraphical and paleoecological reconstructions. This article presents the initial results of its application in a new, geoarchaeological aspect – the possibility for determination of the origin of material, used for the pottery production at an archaeological site. By investigation and correlation of the taxonomy and mineralogy of foraminiferal remains from sediments, sedimentary rocks and sherds found at the Thracian sanctuary "Ada Tepe" near the town of Kroumovgrad, an attempt is made to identify the origin (within the site or off-site) of the material (sediments and sedimentary rocks), used for the production of the pottery collected during the archaeological investigations of the site. Thirty samples of heavy mineral fraction from sediments and sedimentary rocks and 169 sherd samples were studied. Two species from altogether only 14 identified (*Globobulimina* sp. and *Globigerina eocaena* Gümbel) were established in both samples (sedimentary rocks and sherds). The presence of one and the same taxa in part of the studied pottery from the Late Iron Age and sediments and sedimentary rocks from the surroundings of the archaeological site suggests local origin of the material used for pottery production. The similarity in the mineralogy and texture of the moulds in some of the studied sedimentary samples also supports the idea that these sediments had been used in the pottery production. The mineralogical features could be used as an additional indicator for the origin of the material and the technology of firing of the studied fragments. The methods proposed here could be successfully used in archaeological research by their further application while using fossil remains of other organismic groups (gastropods; bivalves; plants).

Introduction

Geoarchaeology is of a major importance for the understanding of archaeological record. The majority of interpretations of archaeological material requires a wide application of concepts and methods characteristic for geosciences. Fossils are often used as a "clue" for the chronostratigraphical subdivision of the archaeological record as well as for interpretation of ecological and climatological parameters during the formation of this record. From plants, of great importance are diatoms, spores and pollen, and from animals – ostracods, mollusks (mainly gastropods and bivalves), insects, as well as varied vertebrate remains.

As a whole the foraminiferal research is widely used in two aspects – biostratigraphical and paleoecological reconstructions. The first attempts for biostratigraphical subdivision of sedimentary successions dated from the end of the XIX c., and in the second half of the XX c. are the detailed biostratigraphical schemes, widely used in oil and gas prospecting. During the last four decades foraminifers have turned into one of the most useful groups in the interpretation of ancient sea environments.

This article presents the initial results of the application of foraminiferal research in a new aspect – the possibility for identification of the origin of material used for pottery production found at an archaeological site – the Thracian sanctuary "Ada Tepe" near the town of Kroumovgrad. Due to their small size, foraminifers could be preserved in the sherds and by investigation of the taxonomy and mineralogy of their remains, the source (within the site or off-site) of the material (sediments and sedimentary rocks) for the pottery production could be identified. The present investigation is the first attempt to apply the foraminiferal research in archaeology in Bulgaria.

Geological setting

From geology-structural point of view the studied area belongs to the border area between Kroumovgrad and Dzebel-Zvezdel zones of the Momchilgrad depression of the Eastern-Rhodope structural zone. To the south it is bounded by the NE end of the Kesibir swell. As a whole the studied area is build up by Precambrian crystalline basement and Paleogene-Quaternary sedimentary and volcano-sedimentary cover (Fig. 1). The stratigraphical subdivision used in the present description follows Kozhoukharov et al. (1995a).

The crystalline basement comprises Archaean and Early Proterozoic diverse gneisses, shales and granite-gneisses interbedded by amphibolites, marbles and quartzites composing the Arda and Roupchovo Groups. This crystalline basement is discordantly overlaid by Paleocene red-brown colored breccia-conglomerates, sandstones and clayey siltstones, united in Continental terrigenous-limestone complex (the Kroumovgrad Group). The Priabonian begins with the gray to yellowish polygenetic limy sandstones, conglomerates, clays and marls of the Coal-bearing-sandstone Formation, which overlay transgressively the rocks of the Kroumovgrad Group or the crystalline basement. In most of the cases the Coal-bearing-sandstone Formation is overlaid normally (with transition) by the light (white and light-gray) massive organogenic (reef) limestone of Marl-limestone Formation. Bands of dark-grey thin-bedded marls interbed this limestone.

The Priabonian part of the section is completed by a band of intermediate tuffs, tuff-breccias, aleurolithic tuffs, tuffites, marls, sandstones and organogenic limestone belonging to Formation of the first intermediate volcanism. Upwards in the section follow alternating bands of acid and intermediate tuffs, tuffites, tuff-breccias, and organogenic (reef) limestones – all of them of Oligocene age. Three formations were subdivided according to volcanic composition: Formation of the first acid volcanism, Formation of the second intermediate volcanism and Formation of the second acid volcanism.

Quaternary alluvial deposits are outcropping mainly along the valleys of the Kroumovitza and Elbasandere Rivers. They formed the channels as well as the lower, middle and partly the high non-flooded river terraces (Dinkov et al., 1968f). Deluvial, colluvial and eluvial deposits are sporadically distributed and they are of little thickness.

Rich nummulitic and mollusk fauna was established in the Marl-limestone Formation, the Formation of the first intermediate volcanism and the Formation of first acid volcanism (Goranov et al., 1984f; Shabatov et al., 1965f; Dinkov et al., 1968f).

The sediments described above fill the Jebel-Zvezdel (the NE part of Fig. 1) and Kroumovgrad Zone of the Momchilgrad depression. The boundary between these zones is traced by the first occurrence of the Formation of the second intermediate volcanism, characteristic of Jebel-Zvezdel Zone and it follows the north-western slope of Elbasandere River valley. To the south the Momchilgrad depression borders with the NE end of the Kesibir swell composed of Precambrian rocks. The archaeological site "Ada Tepe" is located at the highest point of the "Ada Tepe" hill ridge (altitude 492.4 m) about 3 km south of the town of Kroumovgrad. The area of the archaeological site is composed of the rocks of the Kroumovgrad Group.

Material and methods

The present study is based on the investigation of total 197 heavy mineral fraction samples including 29 heavy mineral samples from sediments and sedimentary rocks and 168 heavy mineral samples from sherds (161 samples) and floor materials (7 samples).

The samples from sediments and sedimentary rocks represent suitable for pottery production eluvial, deluvial and alluvial materials (22 samples) from and around the "Ada Tepe" archaeological site, from the valley's bottom and the slopes of the Kesibir River, Elbasandere River and Kroumovka River, as well as from all Paleogene stratigraphical units in the studied area.

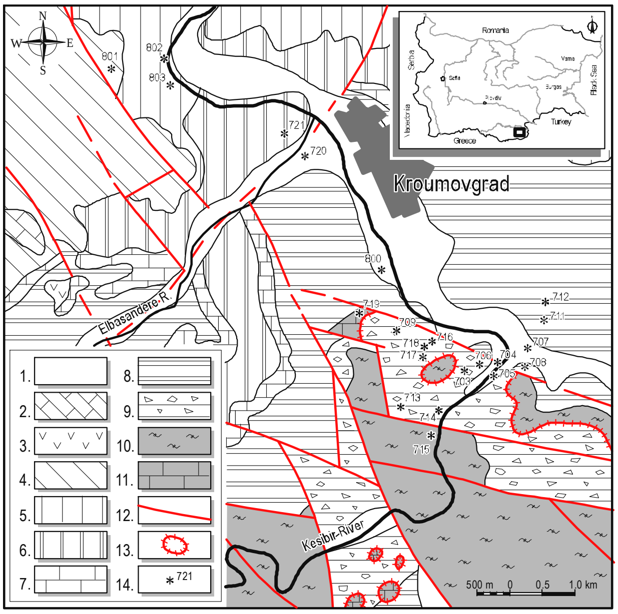

Fig. 1. Geological map of the studied area (after Kozhoukharov et al., 1995b) with the location of the samples from sediments and sedimentary rocks outside the area of rescue archaeological investigations at the "Ada Tepe" archaeological site, Kroumovgrad district: *Quaternary*: *1* – alluvial deposits; *Oligocene* (*2-5*) Formation of second acid volcanism, *2* – organogenis (reef) limestones; Formation of the second intermediate volcanism (*3-4*), *3* – andesites, andesite-basalts, *4* – intermediate tuffs, tuffites, tuffo-breccias and organogenic reef limestones; Formation of the first acid volcanism, *5* – acid tuffs; *Priabonian* (*6-8*), Formation of the first intermediate volcanism, *6* – intermediate tuffs, tuffites, tuff-breccias, tuffo-sandstones, marls and organogenic limestones, *7* – Marl-limestone Formation, *8* – Coal-bearing-sandstone Formation; *Paleocene*, *9* – Continental terrigenous-limestone complex; *Precambrian* (*10-11*), *10* – alternation of diverse gneisses, shales, granite-geneisses, amphibolites and quartzites, *11* – marbles; *12* – fault; *13* – olistolith; *14* – location and number of a sedimentary sample

Seven of the sedimentary samples characterize different archaeological-stratigraphical levels from the area of rescue archaeological investigations of "Ada Tepe" archaeological site, while a single sample represents material from the inner filling of the wall of the oval-shaped stone-built structure (Fig. 2).

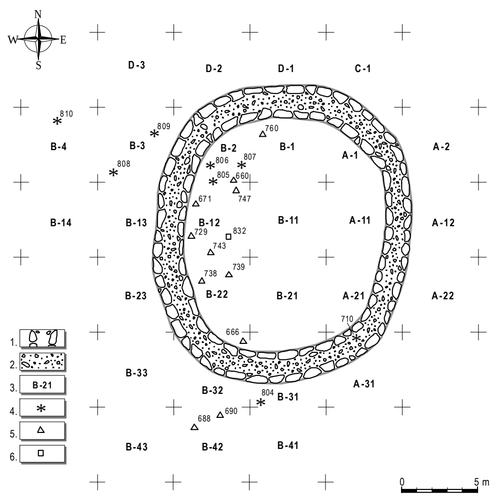

Fig. 2. Sketch of the area of rescue archaeological researches of "Ada Tepe" archaeological site, Kroumovgrad District, with the location of the samples from sediments and sherds containing foraminiferal remains: archaeological structures (1-2) 1 – inner and outer stone-built structure of the wall of the oval-shape structure; 2 – inner infill of the wall; 3 – number of the square; 4 – number of the sedimentary sample; number of ceramic sample (5-6) 5 – from the Late Iron Age; 6 – from the Late Bronze Age

Part of the sedimentary samples from the area of the archaeological investigations and the sherds were collected by G. Nehrizov, while the other part of the sedimentary samples was collected by D. Zlatanov.

Initial heavy mineral concentration of the sedimentary samples was lead in the field by standard water pan washing and the obtained heavy mineral concentrate was dried under temperature of 20°C. The rock and pottery samples were disintegrated and initially concentrated and dried in the lab. All obtained dry heavy mineral concentrates (field and lab) went through magnetic separation, heavy liquid (bromoform – $CHBr_3$, relatively weight 2.89) separation, and electromagnetic separation (5A, 25V). After the heavy liquid separation every sample was cleaned by ethyl alcohol and dried under temperature of 35°C. As a final result magnetic (m), electromagnetic (em) and non-magnetic heavy mineral fractions from every sample were obtained.

The micropaleontological content of all fractions was studied by binocular stereomicroscope MBS-9. Foraminiferal taxonomical determinations followed the Loeblich & Tappan's (1988) classification. The microphotographs were made in the Central Laboratory of Mineralogy and Crystallography "Acad. Ivan Kostov" of the Bulgarian Academy of Sciences by Scanning Electron Microscope "Philips SEM-515" (U_{op} = 25 kV). For this purpose foraminiferal specimens were fixed on a metal holder and covered by thin gold layer.

For investigation of the mineralogical composition and the internal texture of the fossil moulds some of them were mounted in polyester resin and polished sections were prepared. They were studied by polarization microscope Amplival Carl Zeiss. The precise mineralogical diagnostics was made using X-ray diffraction analysis (Cu-filter, 40 kV, 30 mA, 0.5°/min). The dating of the studied sherds is based on the field archaeological data.

Results

The study of the paleontological contents of heavy mineral samples revealed the presence of fossil remains of three groups – foraminifers, gastropods and bivalves. The present investigation was focused on the representatives of the first group only.

Taxonomical composition and structure of the foraminiferal assemblages

Foraminifers were established in a sample from sediment (AT-705-m – Table 1), 3 samples from sedimentary rocks (AT-711-em, AT-717-em, AT-721-m, AT-721-em and AT-721-nm) and 9 samples from pottery fragments (Table 2). The study of samples from sediments and sedimentary rocks revealed low taxonomical diversity. Specimens of 14 species in total were found, as in 2 of the samples (AT-705-m и AT-717-em) only indeterminable single specimens were observed. 11 species were established in sample AT-711-em, and 8 species – in sample AT-721-(m, em, nm). 5 species were identified in both samples (Table 1).

The assemblage of sample AT-711-em is dominated by 3 species planktic foraminifers (58% of total number of specimens) - *Globigerina corpulenta* Subbotina, *Gl. eocaena* Gümbel и *Gl. officialis* Subbotina. Benthics are strongly dominated by representatives of *Globobulimina* sp. (87%). By more of 1 specimen are represented *Bathysiphon* sp. 1 (5%), *Fursenkoina* sp. (4%), *Bathysiphon* sp. 2 (2%) и *Lenticulina* cf. *inornata* (d'Orbigny) (2%), while the other established species occur as single specimens only. In respect of the wall texture the assemblage is dominated by hyaline taxa (96%). No milioline tests were found.

Table 1

Distribution of the foraminiferal taxa in the samples from sediments and sedimentary rocks

N	Taxon	Number of sample			
		AT-705	AT-711	AT-717	AT-721
1	*Bathysiphon* sp. 1		♦		♦+
2	*Bathysiphon* sp. 2		♦		♦+
3	*Bathysiphon* sp. 3				♦+
4	*Dendrophrya* sp.		♦		
5	*Siphotextularia* sp.				♦+
6	*Lenticulina* cf. *inornata*		♦		
7	*Globobulimina* sp.		♦		♦+
8	*Fursenkoina* sp.		♦		♦+
9	*Cibicidina* sp.		♦		
10	*Cibicidoides* sp. 1		♦		♦+
11	*Cibicidoides* sp. 2				•♦+
12	*Globigerina corpulenta*		♦		
13	*Globigerina eocaena*		♦		
14	*Globigerina officialis*		♦		
15	undeterminable	•		♦	

• magnetic heavy mineral fraction (m); ♦ electromagnetic heavy mineral fraction (em); + nonmagnetic heavy mineral fraction (nm)

The assemblage of sample AT-721-(m, em, nm) is entirely composed of benthics. The most important amongst them are *Globobulimina* sp. (37% of the total number of specimens), *Bathysiphon* sp. (26%) and *Fursenkoina* sp. (10%), while the other species are represented by single specimens (Fig. 4a). As a whole the assemblage is dominated by hyaline taxa (63% of the total number of specimens), as no milioline tests were established.

The samples from pottery fragments are characterized by very low taxonomical diversity. Only 2 species were identified (Table 2), as 94% of the determinable specimens are represented by *Globobulimina* sp. and in sample AT-666-nm only a specimen of *Globigerina eocaena* Gümbel was found. As a whole only single specimens were established in the samples. An exception is sample AT-671-m containing 15 specimens.

Table 2

Distribution of the foraminiferal taxa in the samples from sherds (symbols as in Table 1)

Taxon	Number of sample								
	AT-660	AT-666	AT-671	AT-688	AT-690	AT-729	AT-738	AT-747	AT-832
Globobulimina sp.			•	•					
Globigerina eocaena		+							
undeterminable	♦				♦	•	♦	♦	♦

Microfossils occur as moulds, filled and unfilled tests. In the samples from sediments and sedimentary rocks the filled tests (55% of total number of specimens) prevail over the moulds (44%), while the unfilled tests are in low number (1%). All agglutinated taxa are represented by moulds (excepting *Siphotextularia* sp. from sample AT-721-nm), as well as all specimens of *Globobulimina* sp. The other hyaline taxa occur as filled tests.

The shared samples are strongly dominated by moulds (89% of the total number of specimens) of *Globobulimina* sp. while *Globigerina eocaena* Gümbel is represented by filled test.

Mineralogical composition of the moulds

The general heavy mineral characterization of the samples containing moulds as well as the mineralogical characterization of the moulds from all samples is shown on Fig. 3.

The sedimentary samples that contain foraminifers form two groups (Fig. 3a). The first one, including samples AT-705, 711 and 717, is characterized by dominance of electromagnetic heavy mineral fraction. The other two heavy mineral fractions are poorly represented or missing. The second group includes only one sample – AT-721. It is dominated by the magnetic heavy mineral fraction while the other two fractions compose up to 15%.

In the majority of the fossiliferous sherds, the three heavy mineral fractions occur in almost equal amounts (Fig. 6a). As an exception, samples AT-671, 690 and 832 are dominated by electromagnetic heavy mineral fraction.

The microscope and X-ray diffraction investigation (Table 3) showed that the moulds are generally composed of 5 mineral phases – pyrite, magnetite, goethite, siderite and hematite. The mould texture is dominated by goethite and pyrite. The other mineral phases are subsidiary.

The most widely distributed are moulds with matrix composed predominantly of goethite (Fig. 4a). As a rule this type of moulds are more fragile. Its matrix is porous, rarely dense. In the majority of samples relics of fine-grained pyrite forming pseudointerstitial texture are observed in this matrix. Only in single moulds from samples AT-(671, 688, 705 and 729)-m the relics are of magnetite (Fig. 3b). Very small-sized grains of magnetite were observed in the moulds from sample AT-717, but there is a lack of criteria about their genesis. The porous goethitic moulds are often enriched with carbonate. In the test walls and septa it shows light green-yellowish inner reflex, characteristic for siderite (Fig. 4b).

Fewer moulds are predominantly composed of pyrite. It is fine-grained, fine-crystal and it composes two types of aggregates: (*i*) entirely composed of "fresh" (unchanged) pyrite (Fig. 4c) and (*ii*) pyrite aggregates in initial stage of change into goethite and hydrogoethite. The changes are mainly along the periphery of the aggregates or closed to the preserved septa (Fig. 4d) or form well pronounced zones of hydrohematite along the whole periphery of the mould.

In rare cases moulds composed of unchanged magnetite were observed. They were found only in sample AT-721-m. More widely distributed are magnetite moulds with pore-pronounced oxidized periphery (Fig. 4e) or moulds with advanced mushketovitization of magnetite, in which only the aggregate kernel is unchanged (Fig. 4f).

According to the mineralogical composition of the moulds the pottery samples form three groups (Fig. 3b): (i) samples with pyrite moulds altered in low degree (including samples AT-666 and 739); (ii) samples containing magnetite moulds partly altered into goethite (including samples AT-671, 688 and 729) and (iii) samples containing predominantly goethite moulds.

Table 3
Results from X-ray diffraction analysis of fossil moulds

AT-711		AT-729		JCPDS**			
Fossil moulds (from sediments)		Fossil moulds (from pottery)		Magnetite (19-629)		Pyrite (6-710)	
I/I_o	d(Å)	I/I_o	d(Å)	I/I_o	d(Å)	I/I_o	d(Å)
1*	2.903	9	2.698	3	2.967	9	2.708
10	2.508	1*	2.442	10	2.532	6	2.428
4	2.067	1*	2.171	2	2.099	5	2.212
		1	1.887			4	1.915
		10	1.656			10	1.633

*very thin or with low intensity reflex; **Joint Committee on Powder Diffraction Standards (JCPDS) (1980)

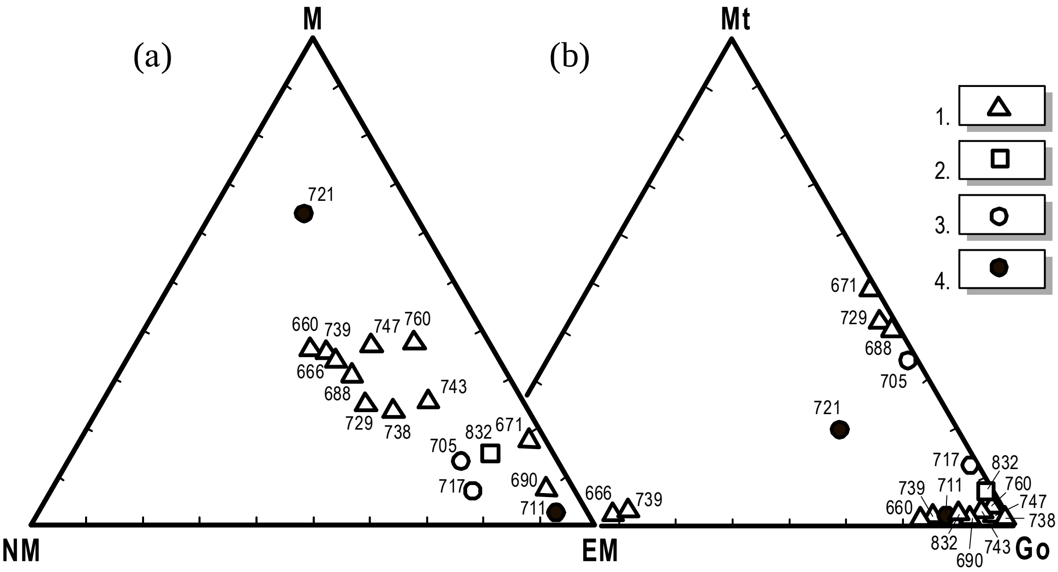

Fig. 3. M-EM-NM diagram (a) of the heavy mineral samples and (b) Mt-Go-Py diagram of the mineral composition of the fossil moulds: M – magnetic heavy mineral fraction; EM – electromagnetic heavy mineral fraction; NM – nonmagnetic heavy mineral fraction; Mt – magnetite; Go – goethite; Py – pyrite; pottery fragments: 1 – from the Late Iron Age; 2 – from the Late Bronze Age; sedimentary samples: 3 – sediments, 4 – sedimentary rocks

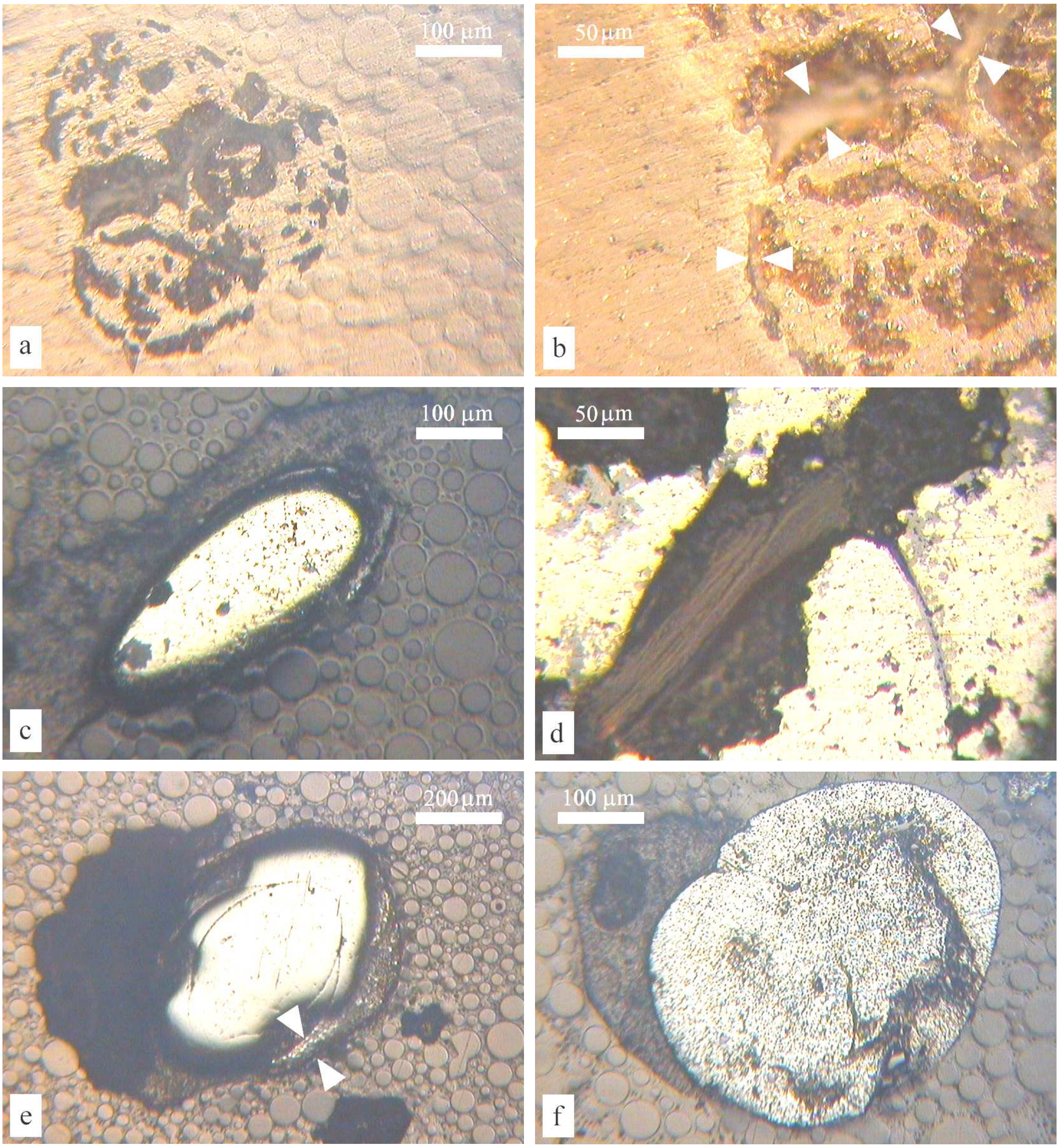

Fig. 4. Microphotographs of polished preparation of fossil moulds from sedimentary and pottery samples: (*a*) – general view of fossil moulds build up mainly by porous goethite (dark grey), among which are visible small pyrite (light grey) grains; (*b*) – detail of (*a*) demonstrating composed by siderite septa and outer walls of the fossil shell (between the arrows); (*c*) – fossil mould, completely build up by "fresh" (unaltered) pyrite; (*d*) –fossil mould, composed by fine grained pyrite with initial stage of alteration in hydrohematite near to the septum of the fossil shell; (*e*) – build up by magnetite fossil mould with oxidized periphery (between arrows); (*f*) – mushkevitovitizied fossil mould

Discussion and conclusion

As could be seen from the data presented in the previous chapter, only 2 species occur in both samples from sediments and sedimentary rocks and from shred samples – *Globobulimina* sp. и *Globigerina eocaena* Gümbel. Characteristic feature of the sherd samples is the lack of agglutinated forms as well as the majority of hyaline taxa. *Globobulimina* sp. is presented by moulds in both sedimentary samples and pottery fragments, while *Globigerina eocaena* Gümbel occurs as filled tests. The first species was established in both sedimentary samples containing determinable specimens, while the second one was identified in only sample AT-711, which is from the surroundings of the archaeological site.

The mineralogical characteristics of the moulds allowed us to conclude that most of them were originally composed of fine-grained pyrite or magnetite. Subsequently these minerals were altered to a different degree, as the most frequent result was their almost entire replacement by porous goethite or hydrohematite with single pyrite or magnetite relict grains preserved in it. The pseudo interstitial texture is a result of the alteration of the pyrite and magnetite from the center of the grains to their periphery.

Amongst the samples from sediments and sedimentary rocks pyrite moulds were established in sample AT-711. In sample AT-721 the moulds are in small number and most of them are altered. In the other two samples, representing alluvial and deluvial materials from the near surroundings of the archaeological site, the moulds are composed of strongly altered magnetite or they are entirely goethitic. The predominance of pyrite moulds in sample AT-711 is possibly influenced by the lithology of the sampled rocks – gray-black marls of the Coal-bearing-sandstone Formation. In the sampled sandstones from the same unit (AT-712) fossils were not found. The other three fossiliferous sedimentary samples are from sandy materials. They are dominated by goethite moulds. Entirely magnetite moulds were established only in sample AT-721, representing eluvial material from tuff-sandstones of Formation of the first intermediate volcanism.

The mineralogical characteristics of the moulds from pottery fragments allowed us to divide them to three groups. In two of them the fossil moulds are composed mainly by pyrite and magnetite. The similarity of mineralogical content and structure moulds in some of the sedimentary samples from the studied area (for example samples AT-711 and 721) poses a question about the possibility these sediments to have been used as raw materials for preparation of the pottery. Additional argument for this hypothesis is the occurrence of one and the same taxa in both sedimentary and pottery samples. For instance *Globobulimina* sp. occur in the pottery samples AT-668 and 671 as well as in the sedimentary samples AT-711 and 721, while *Globigerina eocaena* Gümbel – in pottery sample AT-666 as well as in sedimentary sample AT-711.

The occurrence of goethite moulds in the pottery could be explained by the technology of their production and more precisely, of their firing. On the other hand goethite moulds occur in considerable amount in the sedimentary samples. That is why it is risky to use them as indicators for the technology of firing or to refer the raw material to some of the sampled sediments or sedimentary rocks.

Of great interest is sample AT-690 representing fragment of pithos with geometric ornament. Its heavy mineral characteristics and the mineralogical features of the established moulds resemble almost entirely those of the moulds from samples AT-711 and 717, representing the sediments and sedimentary rocks in the near surroundings of the site. Such a similarity was observed between samples AT-671 and AT-705.

The available archaeological data dates the majority of the fossiliferous pottery fragments to the Late Iron Age. The foraminiferal fauna established in them is the same as this from the nearby sediments and sedimentary rocks and on the base of this fact we supposed that the source material for the pottery was of local origin. Only one of the pottery samples (AT-832) was dated to the Late Bronze Age, but the lack of determinable fossil microfauna did not allow us to correlate it to the other fossiliferous pottery samples.

It has to be pointed out that the samples were not processed according to the classical methods for foraminiferal research described by Stancheva (1981), which could explain the occurrence of undeterminable foraminiferal remains in some of the sherd samples. Because of this reason we cannot conclude if the source material is or is not from sedimentary and sedimentary rocks of local origin. On the other hand it is possible that the methods applied in disintegration of the pottery fragments have led to destruction and loss of paleontological material. Of great interest is the study of the other fossil fauna (gastropods and bivalves) in the sedimentary and pottery samples which could elucidate the origin of the source material used for the pottery production.

The study of the taxonomical and mineralogical composition of the foraminiferal remains in pottery and sedimentary samples from the area of the Thracian sanctuary "Ada Tepe" near the town of Kroumovgrad allowed the following conclusions to be made:

- the paleontological data derived from the foraminiferal research revealed taxonomical resemblance between the microfossil fauna in part of the studied sherds from the Late Iron Age and sediments and sedimentary rocks from the near surroundings of the archaeological site, which is an evidence for local origin of the raw material;
- the mineralogical characteristics of the moulds could be used as additional indicator of the origin of raw material and the technology of firing of the studied pottery fragments;
- the methods suggested here could be successfully applied in archaeological investigations by study of additional fossil remains (gastropods, bivalves, fossil flora);
- the value of the results could be increased by processing of the samples following the classical methods for microfossil extraction.

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