Acoustic Characteristics of Sacral Thracian Sites

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Abstract: **The purpose of this paper is to present initial results for some acoustic characteristics of sacral Thracian objects in Bulgaria, like tombs, sanctuaries etc. Some modern methods of investigating and archaeoacoustic analyzing are used.**

I. Introduction

In Antiquity, lands, which we now call Balkans and Southeast Europe, were populated by numerous tribes with similar lifestyle and culture, forming two main groups - Greeks and Thracians. By the name Thrace old Greeks called the lands north and northeast of them, right down to the Carpathians and of the two rivers Dnieper and Dniester. Herodotus (Hdt. 5.1.3) sets Thracians as the most numerous people after Indian. According to ancient Greek geographer Strabo, Thracian tribes are 22 and under other researchers - they are about 80 similar tribes forming several internal groups with general basic language and tribal dialect. They are the very first human population in these lands, which namely has begun to displace in the central and western parts of Europe from here [1,4,11].

Figure 1. Schema of the Thracian tribes' location. [12]

The ancient peoples who now call Thracians were not slave owners as Greeks.

A team of Bulgarian Academy of Sciences and other research institutions work on project "Thracians - genesis and development of ethnicity, cultural identities, interactions and civilizational heritage of antiquity" funded by the donation of Petar Mandjoukov. The task is investigation of the acoustic characteristics of the interior of archaeological sites and musical instruments from the Neolithic to the late Middle Ages in Bulgarian lands: search for continuity and continuity. The idea of acoustic surveys of Thracian sacred sites is by Dr. Alexandra Fol [2].

The purpose of this paper is to present initial results for some acoustic characteristics of sacral Thracian sites like tombs, sanctuaries etc. Modern archaeoacoustics, precise measurement and computer methods are used. Of the ten surveyed sites, we will concentrate on Sboryanovo Historical and Archeological Reserve and especially on tomb number 13.

II. Sboryanovo Historical and Archeological Reserve

The Sboryanovo Historical and Archeological Reserve is situated in the western part of the Ludogorsko Plateau of Northeast Bulgaria. It is a complex of age-old villages, sanctuaries, and necropolises. The most noteworthy discovery in it is the Sveshtari Tomb, a Thracian king's sanctuary and necropolis. This site was included among the UNESCO World Heritage Sites in 1985.

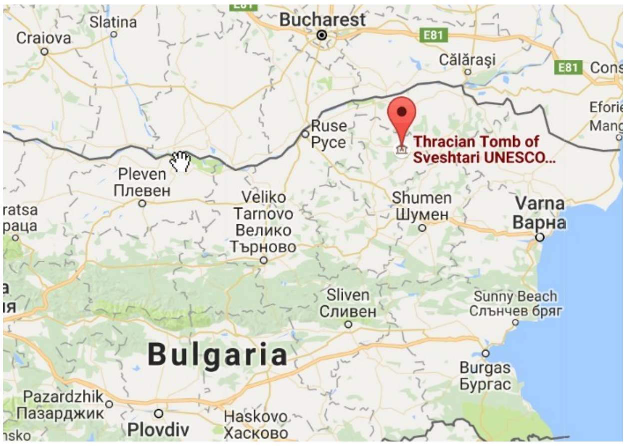

Figure 2. Sboryanovo historical and archeological reserve location.

Mounds 12 and 13 are part of the architectural ensemble of the Sveshtari Tomb under Ginina Mound. They both cover smaller vaulted tombs. They stand out by their symmetrically opening sliding doors, which indicate a specific architectural tradition among the Getae. The tombs in Mounds 12 and 13 date to the end of the 4th – early decades of the 3rd century BC. Only fragmentary remains were found inside: partial human skeletons, sacrificial animals, and other gifts. The tomb under

Mound 12 was destroyed by an earthquake in the early decades of the 3rd century BC [3].

Figure 3. Sboryanovo historical and archeological reserve, the tomb in mound 12 (old photo) [3] .

Figure 4. Sboryanovo historical and archeological reserve, the tomb in mound 12 (actual photo).

Figure 5. Inside mound 13, Archeological reservation Sboryanovo, near to village Sveshtari, Bulgaria

III. SCHEME OF THE TOMB 13 AND INSTRUMENTATION

The scheme of the tomb is obtained by using a laser rangefinder. It is shown on Figure 6,8 and 9.

Experimental set-up includes:

- Pressure-field Microphone Type 4193 Brüel&Kjær, available in Transducer Electronic Data Sheet (TEDS) combinations with the classical Preamplifier Type 2669 with an individual calibration; Dynamic Range: 19 … 162 dB, Sensitivity: 12.5mV/Pa.
- Compact Data Acquisition Unit 3560B Brüel&Kjær, for outdoor use that consist: Dyn-X input modules with a analysis range exceeding 160 dB and automatic detection of front-end hardware and transducers − supports IEEE 1451.4-capable transducers with TEDS (Transducer Electronic Data Sheet); output TCP/IP protocol communication - RJ 45 connector complying with IEEE−802.3100baseX; Multiframe Control option;
- Base software PULSE 12 for CPB (Constant Percentage Band) analysis 2 channels; 5-channel Time Capture; PULSE Bridge to MATLAB®
- MathWorks Software - MatLab&Simulink, toolboxes for FFT and Wavelet analysis.
- Sinusoidal signal and random noise generator 1027, Brüel&Kjær.

Figure 6. Microphone position in camera of mound 13 Archeological reservation Sboryanovo, near to village Sveshtari, Bulgaria

Figure 7. Measurement unit “in situ” in King mound (actual photo).

Through the equipment, mentioned above, typical measurements for architectural acoustics were carried out in mound 13.

IV. Some Results and Discussion

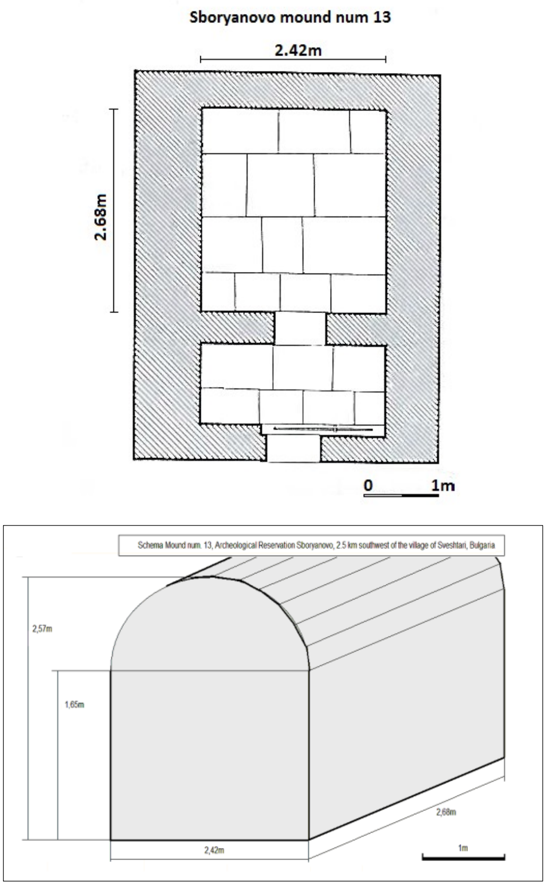

Figure 8. Scheme of the camera of mound 13, archeological reservation Sboryanovo, Bulgaria

It is known, that the acoustics of the room behaves quite uniformly in frequencies above 200 Hz and it is described by its reverberation time RT60 very well. However, in low frequencies (below 200 Hz), the discrete resonances in room will be dominated. [9]
Approximation of the camera by cuboid give us Fig.9.

We can calculate rectangular room first modes,
Length: $l_x = 2.68\text{m}$, Width $l_y = 2.43\text{m}$,
Height $l_z = 2.3\text{m}$

$$f_i = \frac{v}{2}\sqrt{\frac{n^2}{l_x^{\,2}} + \frac{p^2}{l_y^{\,2}} + \frac{q^2}{l_z^{\,2}}}\,.$$

num	n	p	q	Mode	Frequency Hz
1	1	0	0	Axial	64,3
2	0	1	0	Axial	71,2
3	0	0	1	Axial	74,9
4	1	1	0	Tangential	95,9
5	1	0	1	Tangential	98,7
6	0	1	1	Tangential	103,3
7	1	1	1	Oblique	121,7

No modal boost: 1Hz to 64Hz.
Room modes dominated 64Hz to 176Hz.
Diffraction and diffusion dominated 176Hz to 704Hz.
Specular reflections and ray acoustics prevail: 704Hz to 20000 Hz, see [10].

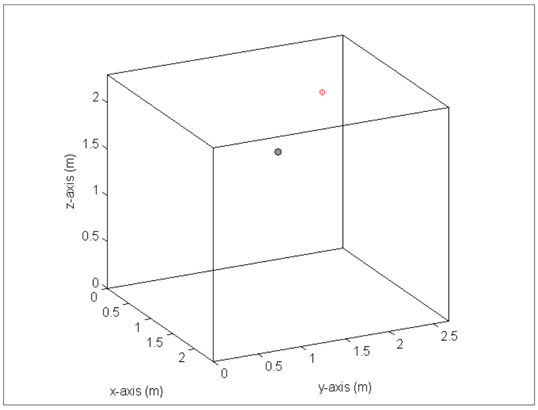

Figure 9. The microphone is on the center of the camera. The location of the source can be seen too.

First we estimate the reverberation time RT60 of the camera by impulse measurement techniques. The pistol shot and balloon boom were made for obtaining the impulse response of a camera. The signals are collected by microphone 4193 Brüel&Kjær and PULSE data acquisition unit 3560B, [6]. Sample frequency $Fs = 2^{16}$ samples per sec. On Fig.10 it can be seen, that the RT60 is about 0.56sec.

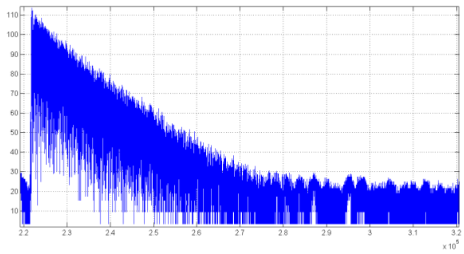

Figure 10. Signal pistol shot decay waveform (microphone in the centre of camera), RT60 is about 0.56sec, frequency of simples is 65536Hz

If we considered that sound velocity $v \approx 343m/s$, (the temperature about 20deg Cels. or 68deg Far.), and the sample frequency Fs is 65536Hz, then the one sample is equal to 5.23E-3 meter, or 5.23mm.

The scalograms (Continuous Wavelet Transforms) are applicable to estimation of impulse responses [5,7,8].

The signal's waveform in time and scalogram (Continuous Wavelet Transform - CWT, Daubechies wavelets) are illustrated on Fig. 11.
The zoomed in time first parts of the same signal waveform and its scalogram are shown on the Fig. 12 and 13.

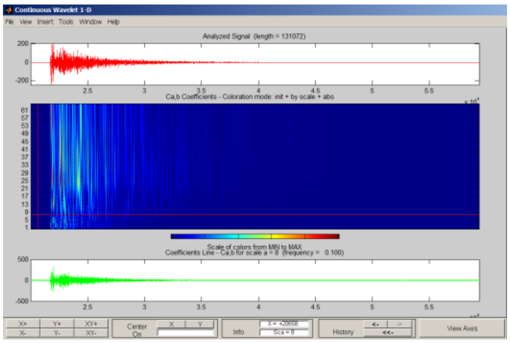

Figure 11. The shot waveform in time and its scalogram. The signal is collected by microphone 4193 Brüel&Kjær and PULSE data acquisition unit 3560B.

From the CWT, shown on Fig. 12, it can be seen the structure of maxima for the first reflections. In fact, these are the first 12 milliseconds, or 766 samples (or 4.01 meters).

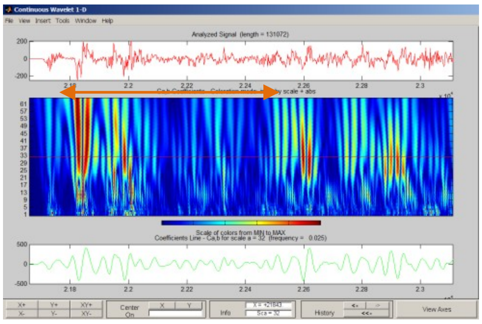

Figure 12. Scalogram of a shot waveform first 12 milliseconds, 766samples (or 4.01meters)

The structure of the first 3.8 milliseconds of the shot waveform can be seen on Fig. 13.

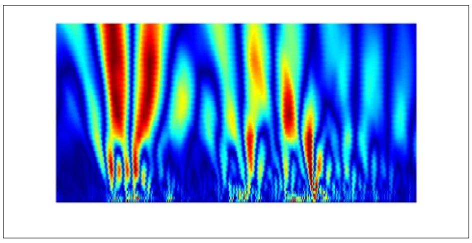

Figure 13. Scalogram of the shot waveform - first 250 samples or about 3.8 ms (or 1.31m).

V. Conclusions and Future Works

The initial and partial processing of the results allows the following conclusion:

- Almost certainly, in the chambers of Thracian mounds were performed rituals that were accompanied by music and speech.
- Obtained modes in the range of 64 to 176 Hertz allow us to assume that the voices were mostly male voices.

In the future, the authors plan to analyze specific resonances in the sonic and in the infrasonic ranges in this and in the other Thracian sacral sites. The results will be useful in archeology and archaeoacoustics.

In a very short time, the authors will conduct the experiment of recording of ancient music, performed by significant Bulgarian musicians by models of typical ancient Thracian musical instruments like lira, guitar, ancient flute etc.

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