

Archaeoacoustic Analysis of an Ancient Hypogeum in Italy

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ABSTRACT: Abstract - The archaeoacoustic properties of an ancient hypogeum in Cividale del Friuli (North Italy) were studied. A series of experiments took place over a one year period to establish its acoustical resonant properties. A number of male and female singers were used and a resonance of 94Hz and 103Hz was discovered in two of the hypogeum's six chambers. The best frequency response was obtained when male singers were positioned inside a 'sound node' that was discovered in both chambers. The term "node" refers to the point in the interior space of the chamber where the greatest acoustic resonance effect is achieved. Later the effects of a frame drum were studied in one of the two chambers. Although it had an average frequency response of 55Hz, the drum was able to activate the chambers resonance of 103Hz from its harmonics. The research demonstrated the male voice was more successful in stimulating the resonance than a female voice, as the required resonant frequencies commonly fall within the male vocal range. This study demonstrates that archaeoacoustics is an interesting emerging field capable of analyzing ancient sites, utilizing different study parameters to those usually used in archaeology. Research in this field is re-discovering lost technology that operates on the human emotional sphere.

KEYWORDS: Archaeoacoustics, Cividale del Friuli, Hypogeum.

Introduction

Archaeoacoustics is part of an emerging interdisciplinary approach to which can add another dimension to classic archaeological techniques. It could for example be used to establish why a particular ancient site was considered sacred, or why an ancient structure was built with a particular type of stone. Through archaeoacoustic analysis, it is possible to demonstrate there was some knowledge of acoustic phenomena, which could for example have been used, in ancient rituals [2, 3, 4, 19] in the Neolithic and later periods.

Research over four years by SBRG has shown ancient people were able to utilize sound to obtain different states of consciousness, without the use of drugs or other chemical substances. Further, they were able to detect and make use of natural phenomena to enhance this effect [2, 3, 4, 19].

This mystery is far from being solved, however the technology hidden in these temples underneath apparently crude architecture, suggests builders used their knowledge of the resonance phenomenon thousands of years ago.

In this paper the comparison between a well know hypogeum in Malta (Hal Salfieni) and another one in Italy (Cividale del Friuli Hypogeum) is presented. Even though they are very different in size both have some similarities, for example each hypogeum has three levels, which was the starting point for this research.

The Maltese Hal Salfieni Hypogeum

The Maltese archipelago is made up of two main islands in the Mediterranean: Malta and Gozo. Between them are two small islands, Comino and Cominotto, and to the South there is a small rock called Filfla. According to academic archaeology, the first time man arrived on the islands was in 5,200 BC. Through archaeological excavations and the use of carbon 14 dating, the construction of megalithic complexes has been placed in Malta and Gozo around 3,600 BC [25]. Many researchers have tried to analyze and study the architecture of the Maltese temples, the most widely known were: Zammit, Ugolini, Ceschi and the British archaeologists Trump and Evans.

Hal Salfieni hypogeum is an underground complex carved from limestone. It is a United Nations Educational, Scientific and Cultural Organization (UNESCO) heritage site, accidentally discovered in 1902 during construction work. The complex consists of a system of chambers and passages that consists of three distinct underground levels, reaching a maximum depth of approximately 11 meters and covering an area of approximately 500 square meters². At first glance this immense work appears to be the result of a well-organized and advanced civilization, yet visitors are told the rock has been excavated using only simple flint or bone tools by farmers over hundreds of years.

The architecture of this hypogeum features a curved shape. Inside, it is remarkable to see the rock excavations of the chambers

which would have allowed other more spontaneous and rational solutions, full of arches, vaults and domes [26].

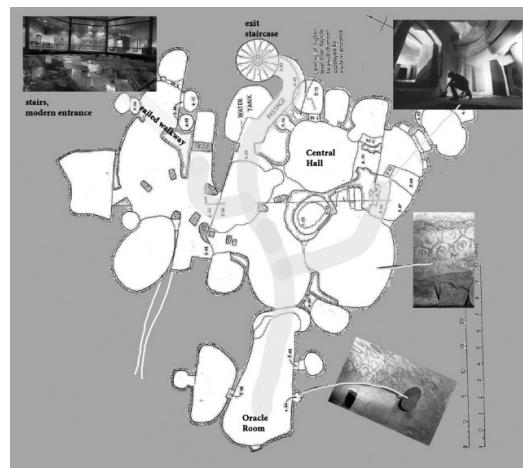


Fig. 1 – Map of the Maltese Hypogeum Hal Salfieni

The Maltese hypogeum played two roles, first as a sanctuary, possibly dedicated to the worship of the Mother Goddess; the second as a burial place, as evidenced by the remains of thousands of skeletons with their ornaments and their pottery[6].

It has been hypothesized that the holes in the ground in front of the entrance could have been used to collect the libation of animals destined for sacrifice, or for solid offerings with rope being run through the holes [6].

The holes in the walls of the interconnecting chambers are attributable to the possible practice of the oracles. It is plausible that some sort of priest or priestess took advantage of the echo and resonance phenomenon in this location, to answer anonymously any questions that were asked [24]. The most interesting example attributed to this practice, is the one inside the Hypogeum, speaking from a niche carved inside a room, (the Oracle chamber) where the voice is greatly amplified and deepened.

Recently, in this chamber, SBRG along with other researchers and with the help of the Old Temples Study Foundation (OTSF), found a double resonance frequency at 70Hz

and 114Hz. Ancient Maltese musical instruments were played inside and it was found that a frame drum was able to stimulate the resonance of the Oracle chamber by its harmonics, provided a strong sound pressure was applied. These chambers may well have served as centers for social or religious events, so the chamber cavities' resonance might have been intended to support human ritual chanting to achieve mystic states of consciousness.

The Cividale del Friuli Hypogeum, Italy

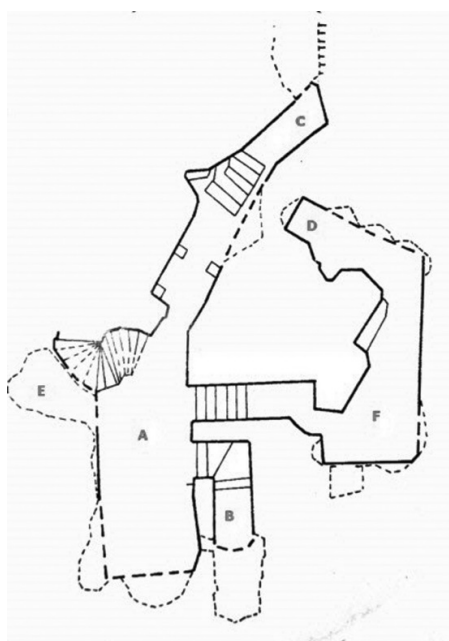


Fig. 2 - Map of the hypogeum of Cividale del Friuli

Cividale del Friuli is an ancient town in the North-East of Italy Founded by Julius Caesar with the name of Forum Julii. It was also the capital of the Longobard Kingdom after the fall of the Roman Empire. In this area there were various settlements that date from the Neolithic Age period [22].

Some historians believed that during the Iron Age, a hypogeum that is found here was used as a depository for funerary urns, others say it was used as a prison during the Roman or Lombard period. Of interest to archaeoacoustic researchers is that this hypo-

geum has some unexpected acoustical properties similar to the Hal Saflieni Hypogeum in Malta.

Cividale del Friuli Hypogeum has a number of underground spaces on three different levels carved out of the conglomerate. Its shape looks rough to a careless eye, but despite the alterations over the centuries, the builders made full use of the shape of the rooms to enhance its acoustical properties, which for example could be utilized during prayers and mystic songs.

This underground complex could have been derived from a natural cavity running along the rocky riverbank of the Natisone river.



Fig. 3 – The riverbank of Natisone river where the hypogeum is located below the houses

There are three big and disturbing masks carved on its walls in the style of the Gallic civilization, similar to the remains of sculptures found in Gallic graves in France known as *têtes coupées*. There are also niches carved by different builders that are perfectly dry, they may well have been used as a mortuary at a later date. In respect of the other chambers they are wet and would therefore have been unsuitable for such use. It is assumed that some of the hypogeum rooms functioned as water tanks and used for ceremonial rites of uncertain origin. However, the true function and origin of this underground structure, unique in Friuli, remains a mystery. It is certain that the underground has been remodeled over successive

periods, however none of the other hypotheses have been supported by historical evidence.

The structure consists of a tall central chamber that is reached through steep descending steps. At the beginning of which is the only window that gives access to the Natisone riverbank, the rest of the structure being completely underground. Three corridors lead off from the central chamber and contain niches and seats of various heights. Many of which appear to have been dug with a pick at a later period.



Fig. 4 – One of disturbing heads in the hypogeum carved in the conglomerate



Fig. 5 - The stairs leading to the first level: (chamber A of the map)

In the Iron Age this region was inhabited by the Veneti population (in Latin Heneti), an Indo-European people who lived throughout North-Eastern Italy [22]. During this period the area surrounding Cividale del Friuli was strongly influenced by the Illyrian people

along with other ancient populations from the Balkans [22]. It is therefore plausible that some of their customs were adopted by local people, such as the Mother Goddess cult [21] and other rituals connected with the esoteric underworld. The period in which the hypogeum was built is difficult to determine, but it could be as far back as the Bronze Age. This hypothesis was striking and in parallel with archaeoacoustic researches conducted in the South of England and Bosnia-Herzegovina by SBRG [2]. Other researchers detected the resonance phenomenon in the Maltese underground temples [23], so it was important to test the Cividale structure from an archaeoacoustic point of view to verify this theory.

Materials and Methods

Initially, a preliminary study examining every chamber of the Cividale hypogeum with electronic sound generators was carried out following a procedure established by PEAR [8]. Once the resonant frequency was identified, a 'node of resonance' was discovered which provided the optimum position to achieve a resonance effect, allowing sound to expand throughout every chamber. After this initial study, the conditions present in ancient times were recreated using both male and female singers.



Fig. 6 – One of the digital recorders (Tascam DR-680) used during the audio analysis of Cividale del Friuli Hypogeum

SBRG's recording equipment consisted of dynamic high-end recorders extended in the ultrasound field with a maximum sampling

rate of 192KHz (Tascam DR-680) or sampling rate of 96KHz (Tascam DR-100 and Marantz PMD661 equipment). Microphones with a wide dynamic range and a flat response at different frequencies (Sennheiser MKH 3020, frequency response of 10Hz - 50.000Hz) with shielded cables (Mogami Gold Edition XLR) and gold-plated connectors were also used.

Ultrasensitive omnidirectional microphones (Aquarian H2a-XLR Hydrophone, frequency response from 10Hz to 100.000Hz) were used to accurately obtain any possible resonance response from the water at the bottom of chamber B. This type of microphone has a wide bandwidth and is used by sea biologists to hear whale song up to a distance of several kilometers. Sound transmits very quickly in water, with the body of water acting as a reflector capable of capturing the resonant vibrations [2].

The correlation between the sound source and response of the chamber was verified at the same time as the singers voice vibrations were being correlated to the response of the chambers.

The analysis was carried out using computer audio programs. PRO TOOLS version 9.05 software for Mac was used to overlap and mix the various recorded tracks; Praat program version 4.2.1 from the University of Toronto and Audacity open-source program version 2.0.2, both for Windows PC, were used for analyzing.

Before recording a spectrum analyzer (Spectran NF-3010 from the German factory Aaronia AG) was used to search for electromagnetic phenomena present in the surrounding environment which could potentially have a negative influence on the results. All records were performed in accordance with the SBSA Standard Protocol [5] and were taken several times during the night where the risks of noise from human activity on the surface was lower.

The singers performed a repertoire of ancient chant and overtone singing. It was found that mantras and modulated frequencies excited the surrounding structures at particular frequencies, typical of various mystical songs and prayers.

If the Hypogeum of Cividale del Friuli is considered to be a temple of Mother Goddess of Iron or possibly Bronze Age origin, rituals would normally have been conducted by a priestess [21]. For this reason it has been compared to the more widely known Hypogeum of Hal Saflieni in Malta which may have been dedicated to the Mother Goddess. But if priestesses did conduct rituals in this structure, it seems counterintuitive that the only way to stimulate the resonance effect was through a male voice. Surely if this hypothesis is correct, there must be other ways to activate this?



Fig. 7 - The high sensitivity Sennheiser MKH 3020 microphone

An acoustic instrument that may have been available to the priestesses in this period was searched. Wind instruments were discarded as the tone was too high, instead a frame drum sometimes referred to as a "shamanic drum" was used. Such drums are used today in Celtic music of Northern Europe as well as for shamanic rituals and is found in many cultures throughout the world. It is a drum with one head, built on a circle of solid wood on which is stretched an animal skin, typically goat or deer, but skins can also be derived from different animals, depending on the area and culture. These skins are

stretched on the wooden circle when wet and pulled tight with ropes to reach the right amount of tension whilst drying. Typically they range in diameter between 30 to 50 cm, and usually have a handle on the back. This can be made from ropes or parts of skins cut into strips and then tied, or with a wooden cross that allows it to be held firmly with one hand whilst the other is free to strike it using a wooden or leather beater. There are still a large number of craftsmen who can make such drums, with different patterns on the skin producing a unique tone, which must be dry to produce the correct sound. If the skin becomes damp from moisture, it vibrates less causing a change in tone and must be dried to obtain a purer sound. The tone can also vary depending upon where the beater strikes the skin, for example at the periphery the tone rises, but there is also a decrease in sound pressure that can be exerted. A frame drum made from goat skin with a diameter of 50cm was used during the experiment.



Fig. 8 – The drum used during the experiment in Cividale del Friuli Hypogeum at the entrance of chamber D

Results

A series of experiments took place over a one year period using different male and female singers to establish the acoustic resonant properties of the hypogeum. A resonance effect was discovered in two of the hypogeum's six chambers, both of which are understood to retain much of their original shape. The best frequency response was found when male singers were positioned

inside the 'sound node', a small truss on the end wall in the two chambers that enhanced the resonance effect. It would appear to have been carved specifically to enhance the resonance at these lower frequencies.

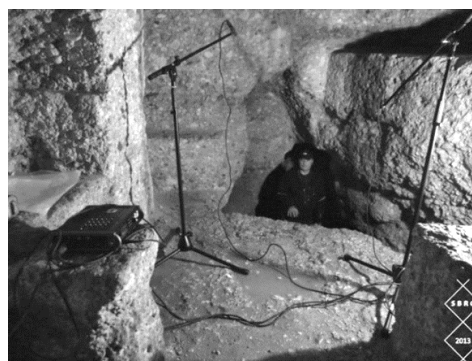


Fig. 9 - The entrance to chamber C which seems to have retained the original shape and has demonstrated a conspicuous resonant effect

On several occasions, a female singer was used, including a mezzo-soprano whose lower local range reached 150Hz however, this was insufficient to stimulate the resonance. The resonance response begins at lower infrasonic frequencies rising up to 94Hz for chamber C or 103Hz for chamber D.

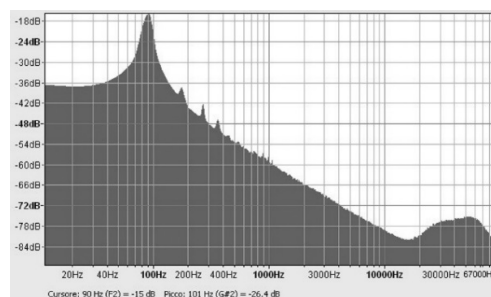


Fig. 10 - The logarithmic plot of the resonance effect in chamber C. The hump between 30KHz and 90KHz is due to increased sensitivity of the Sennheiser microphones at these frequencies, but this is not an anomaly. No ultrasounds have been found in the Cividale del Friuli hypogeum so far

The difference between the effect of the male and female voice is evident when comparing their respective graphs. For example, with the female voice a hole appears in the same range of audible frequencies as the male.

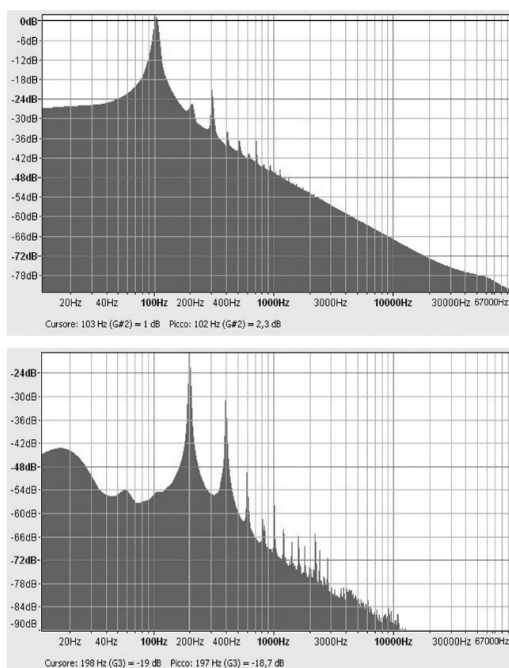


Fig. 11 - Top: the harmonious appearance of the graph from chamber D, with a male voice stimulating the resonance at 103Hz. Bottom: the detectable graph of chamber D with a female voice. The dominant feature is around 198Hz, the hole in the low frequency range between 20Hz up to 200Hz is clearly shown in the graph

Chamber E located below the access stairs, had no resonant effect, neither did chamber B. Their shape is completely different from the other rooms, indicating these could have been created or modified at a later period.

A frame drum was also played inside chamber D, the greatest resonance effect was achieved when it too was placed inside the sound node however, this also dramatically decreased when moving away from it. The frame drum used had an average resonance frequency of 55Hz when beaten at the center, yet the room responded with a resonance of 103Hz. The later response would have been triggered by the drums harmonic vibrations and sound pressure waves.

The drum had an average resonance frequency of around 55Hz when beaten at the center. However, as previously mentioned, its sound characteristic can be affected after a prolonged stay in a moist environment

such as that found in Cividale del Friuli Hypogeum. This meant that at the start of the experiment the drum worked more efficiently than after prolonged exposure. The drum used in this experiment was placed at the end of the chamber D, with the greatest effect achieved by playing the drum in the sound node previously identified, about half meter from the bottom of the chamber and one meter above the ground.

The resonance effect decreased dramatically the further away we moved from this point. Graphical analysis of the recorded files shows two distinct peaks (fig. 12), the first from the frame drum, the second from the chamber. The logarithmic plot of the recordings also shows the presence of two peaks of intensity with the chambers frequency response being 103Hz. Similar peaks were found when analyzing the male voice when it matched the chambers resonance, with an initial peak of 55Hz, the same as the average frequency of the frame drum. The sound response of the chamber is equal in volume to the sound pressure exerted by the drum. There are also higher harmonics present but at a lower volume.

By drumming at a certain rate, the chamber almost continuously vibrates. These vibrations are composed of frequencies which are capable of interfering with brain [19].

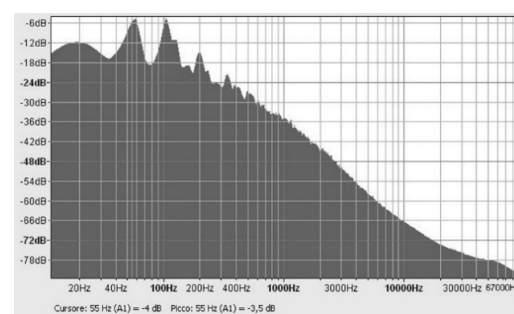


Fig. 12 - The logarithmic graph that come out from the analysis of the recordings : two peaks of the same volume are evident, one determined by the sound of the drum (first from left) and one from the chamber



Fig. 13 - Chamber B of Cividale hypogeum has a different shape to that of chambers C and D. Therefore it is likely it was modified in later periods or had another purpose. SBRG are also studying if the basin is filled with water, if it is possible to obtain a sound response

Discussion

With a male voice achieving the resonant frequency, a response in the infrasound and low frequency bands is obtained (fig. 10 and fig. 11 top). The male voice is reflected back from the structure in a low tone, as happened in the hypogeum of Hal Saflieni, Malta. This is not ordinarily possible to achieve using a female voice (fundamental frequency for male voices has a range from 77 Hz to 482 Hz, for female voices the range is from 137 Hz to 634 Hz [20]). Fig. 11 (below) shows a big hole where any frequencies could be reflected back. Therefore ordinarily only a male priest would have been able to trigger the resonance phenomenon and low frequency response. However if this was at one time an underground temple of a Mother Goddess, a priestess could obtain the resonance response using a drum beaten at the right pace and at the right location (acoustic node). It is conceivable that any onlookers present, could be sitting on the seats carved into the rock in several places close to the celebrant. This research also verified sound travels easily within the hypogeum.

There are many scientific papers that evidence mechanical vibrations have a positive or negative influence on human health and perception [3]. Any severe or artificial extreme imposed on the sonic environment has

a profoundly destabilizing effect on the human body. However, natural low vibrations with an absence of high pressure can have a positive influence on human health, for example by enhancing human perception [3,16,18,19]. Also some people perceive very low frequency sounds as a sensation rather than a sound. In contrast, at sufficiently high volumes inaudible infrasound can create feelings of awe or fear in humans, in some cases resulting in a misplaced belief that some strange or supernatural event is taking place [18]. This could explain the mystical feeling that some people have when they are in an ambient environment full of these frequencies in deep meditation during a sacred rite, but of course this also happens in other historic "sacred sites" that have the same natural tonal characteristics.

Conclusion

With two chambers (C and D) having a strong resonance effect (94Hz and 103Hz), it is clear that the builders of Cividale del Friuli Hypogeum were aiming to achieve some sort of mystical state during their ceremonies. Other chambers that were subsequently modified for use as a mortuary or a prison had no resonance properties. The similarity with the technology of Hal Saflieni Hypogeum suggests the construction of the Italian hypogeum could be backdated to a similar time period as the Maltese hypogeum, but this needs further verification. The small truss found on a wall inside two of the chambers (which resonates when stimulated by use of a male singing or praying voice) appears to be an example of knowledge of the physical resonance phenomena. It is possible to stimulate the resonance phenomenon also by using a percussion instrument, and this is an important anthropological discovery. If as hypothesised this was indeed some sort of Mother Goddess temple, a priestess would have been able to utilise the resonance phenomenon by using a drum without the need for a male voice. This would have amplified the effect

of any rituals by enhancing the psyche of the participants. This suggests the builders of these sites had some sort of knowledge of this process and the age of this structure could be dated back to Bronze or Iron Age.

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