THE SOUNDSCAPE IN THE CERÉN TEMAZCAL REPLICA

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Abstract

A large temazcal was constructed at Cerén with solid earthen walls and an earthen dome. Its uniqueness compared to the other earthen architectural buildings attracted considerable interest. Unusual preservation conditions allowed for the construction of a precise replica in the pubic area of the archaeological park. Visitors entering it noted how significantly it altered their voices. Two recordings of sound have been made and analyzed acoustically. The internal surfaces create strong amplifications, while non-favored frequencies die out relatively quickly. The predominant resonance is at 64 Hertz, a tone so low that basso singers can barely achieve it. The internal morphology greatly accentuates voices of mature males, but not those of mature females or children. The acoustical environment may have been utilized by many males for divination, education, curing, rites of passage, or other functions.

Resumen

Un temascal grande fue construido con paredes sólidas de tierra apisonada y un techo de tierra. Su particularidad comparada a otros edificios arquitectónicos de tierra generó mucho interés. Las condiciones de preservación inusuales permitieron construir una réplica muy precisa en el área pública del parque arqueológico. Los visitantes que entran notan cómo se alteran sus voces significativamente. Se han realizado dos grabaciones de sonido para analizar la acústica. La superficie interna crea fuertes amplificaciones, mientras las frecuencias no favorables mueren relativamente rápido. La resonancia predominante es de 64 Hertz, un tono tan bajo que solamente los tenores de ópera apenas lo logran. La morfología interna acentúa grandemente las voces de los hombres adultos, pero no la de las mujeres adultas o jóvenes. El medioambiente acústico puede haber sido utilizado por varios hombres para adivinación, educación, cura, ritos de pasaje u otras funciones.

THE ANCIENT CERÉN VILLAGE

What is now El Salvador was densely populated in the Early Classic period. The immense eruption of Ilopango volcano (Dull, Southon, and Sheets 2001; Dull et al. 2010) toward the end of that period changed the environment from a lush tropical one to a white desert overnight. The eruption evidently occurred late in AD 539 (Dull et al. 2019). The depopulation was essentially complete. A few decades of weathering, plant succession, and faunal recolonization were necessary before people moved in and reoccupied the area. As a part of that reoccupation, a few Maya families established a small village on the left bank of the Rio Sucio, in the Zapotitan valley (Figure 1). Each family used *bajareque* earthen architecture (reinforced wattle-and-daub) to construct at least three structures: a domicile as their principal building, a storehouse, and a kitchen (Sheets 2006). Surrounding each household was an intensive cultivation of seed crops of maize, beans, and squash. Households cultivated special crops in their kitchen gardens. Manioc was grown in special plots south of the village, from which many tons of the tubers had been harvested just prior to the burial of the village (Sheets 2006). The families had occupied the village for a very short time, only a few generations, before it was entombed by the eruption of the nearby Loma Caldera volcanic vent (Sheets 2002). That eruption is dated to the mid-7th Century.

Although the sample is small, each household contributed something as a service to the community. Household 1 maintained the functioning of two religious structures

(Beaudry-Corbett 2002). One was Structure 10, the multi-roomed building used for community celebrations and feasting. The commemoration of the harvest was being

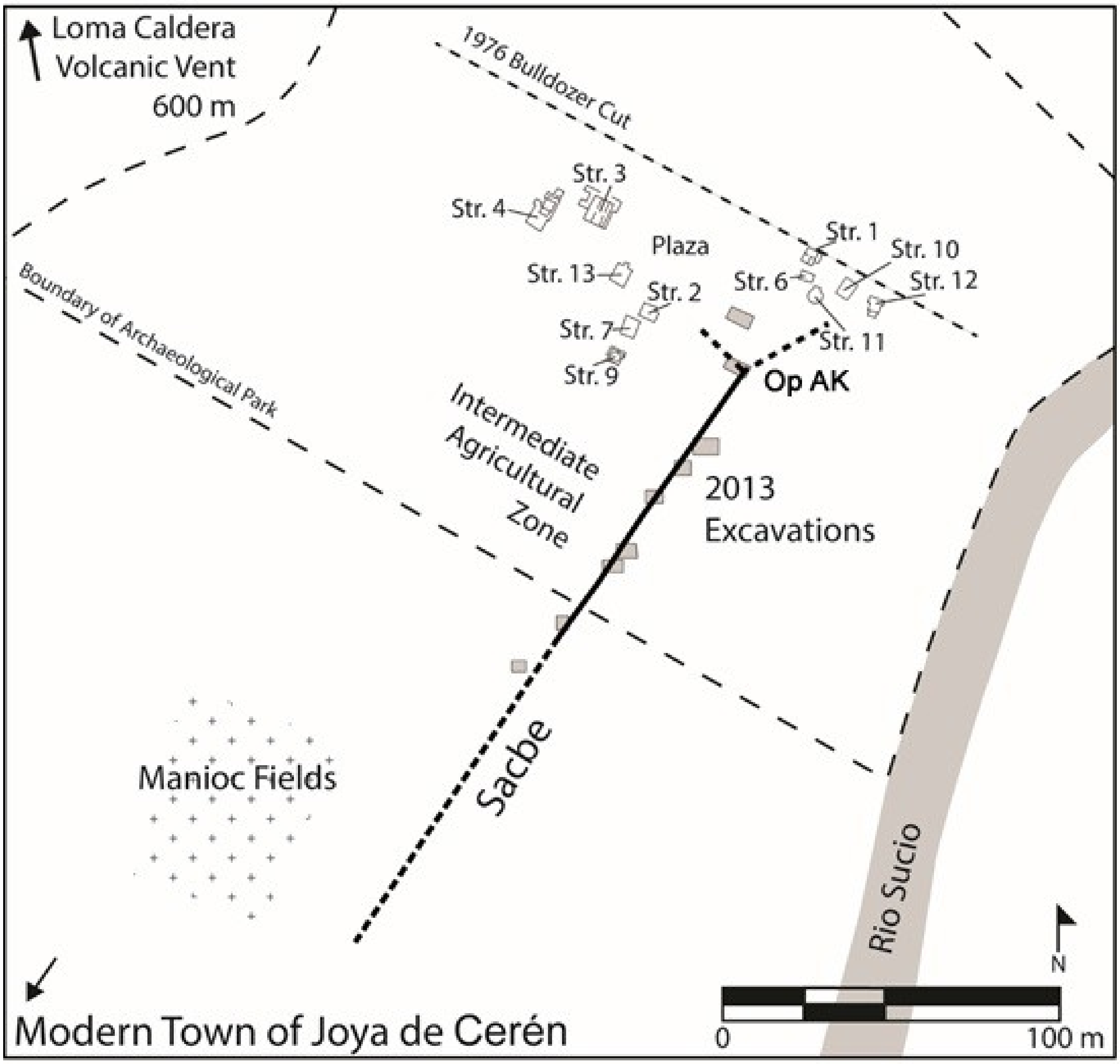

Figure 1. Map of the Cerén site. Structure 9 is the temazcal. The replica was built at the northern end of this map, where visitors could enter it and experience the acoustic effects on their voices.

conducted when the Loma Caldera eruption occurred. Household 4 cultivated specialty crops in abundance sufficient to supply the village with their needs (Sheets 2006). They grew some 70 agave plants for fiber for twine and rope, abundant chili, guayaba fruit, and cane for vertical reinforcements of the bajareque architecture. It is the service relationship to the community by Household 2 that is the focus of this article. They maintained a temazcal, a sweatbath or sauna, for use beyond their household needs.

Household 2

Brian McKee was in charge of the 1989-1996 excavations of Household 2 (McKee 2002a). He encountered a domicile (Structure 2), a storehouse (Structure 7), a temazcal (Structure 9), a midden, and agricultural fields surrounding the structures. The kitchen has yet to be discovered. This household shared many characteristics with the others, by using the earthquake-resistant bajareque architecture that was oriented to 30 degrees east of north, building functionally specific structures, and being largely self-supporting in food production. Each household produced a commodity in excess of what they needed for their own consumption, for exchange within and outside the community, and Household 2's part time craft specialization was painted gourds (Sheets 2006). All the buildings had hip roofs of grass thatch, meaning they were pitched in four directions. The roofs extended about 1.5 meters beyond the walls of the domicile and the storehouse, more than doubling the area covered, therefore providing considerable shaded and dry area outside the buildings. The abundance of artifacts was striking, with the household on track to have an inventory of about 70 complete ceramic vessels, if the kitchen can be found and excavated (Sheets 2006). Obsidian knives were abundant, and stored in the thatch of the roofs in predictable locations, as a means of child-proofing their residences and protecting the cutlery.

The storehouse is the closest household building to the temazcal (McKee 2002a), and in addition to proximity, six meters, it revealed some stored items of functional significance to sweatbath functioning. It had an unusual number of water carrying and storage vessels, ollas, for pouring water over the firebox to make steam, and likely for rinsing off after exiting the building. It also contained pine kindling/firewood, and was the only storehouse with it. It also held the items common to the other storehouses: ceramic vessels of all sizes and functions, obsidian knives, grinding tools, gourds storing wood ash, a jade celt, iron and mercury-based pigments, and other items (McKee 2200a). As with the other households, Household 2 was awash with material culture, in contrast to the temazcal to its south.

THE TEMAZCAL: CONSTRUCTION, FORM, BURIAL, AND EXCAVATION

During Brian McKee's 1990 excavations south of Structure 7 (McKee 2002b), a very broad bulging upward was noted in volcanic Unit 9, which is about half way between the present ground surface and the Classic period ground surface. The same Unit 9 bulging was noted the year before when excavating down to the large building of Structure 3. Removing the remaining tephra units revealed the structure itself. The

Figure 2. The Temazcal at Cerén. The earthen architecture with the dome was protected by a thatch roof. Two lava bombs penetrated the roof and dome, damaging them, but allowing tephra to support other portions of the dome.

grass thatch of the roof that protected the earthen dome and walls had collapsed on the building.

Because of the uniqueness and fragility of the dome, McKee (2002b) had to excavate down through two areas where lava bombs destroyed the dome (Figure 2) while he was hanging upside down from scaffolding. The lava bombs landed after the first component of the eruption had coated the building with fine moist tephra. Thus, they penetrated the dome when the airspace within it was still intact. Accompanying the lava bombs were airfall cinders that began to fill that airspace. Later tephra units landed and filled the airspace below and around those holes, fully filling the inside of the structure. At first glance we were discouraged by the damage. However, we later realized that had the lava bombs not penetrated the dome and allowed for tephra support of unaffected portions of the dome, it would have fully collapsed into small fragments, rendering reconstruction of the dome shape impossible, and therefore the accurate construction of a replica impossible. The still intact portions of the dome, on all four sides, allowed its precise reconstruction of the replica.

The very first step in constructing the sauna, toward the end of the 6th century, was to create a low mound of clay, higher in the center, and broader than the final building, which allowed for rainwater running off the roof to drain away from the building. It also created a slight slope from the firebox downward to the entrance and beyond, to allow water poured on the firebox to exit the building. The second stage of construction was to build a square, solid adobe platform, which formed the seating floor inside the building and the external bench surrounding half of the exterior. That surface is penetrated on the north side by a narrow entryway that can be negotiated only on hands and knees. It ends at the domed firebox.

The next step in construction was to create the solid rammed-earth walls, and finish their tops with a cornice running around all four sides. Short earthen columns were added at each corner, to support horizontal beams, with poles running upward to maintain the grass thatch of the roof. The thatch roof extended well beyond the building walls, and covered the bench on the front and sides. The roofed area beyond the building walls was greater than that over the building itself.

Prior to constructing that protective roof, the dome was built. The first stage was to take canes from all four walltops to the center, each bent enough to create the internal reinforcements prior to mudding the top and the underside. After mudding, the result was a smooth dome.

During dome construction, a perforation was made above the entrance, and encircled with a rim that appeared somewhat like a donut. It had an informal clay plug in it when excavated, but we believe that plug would be removed after the fire had fully heated the firebox. It would have been smoky inside, but opening that vent would allow smoke to escape. Then water poured on the firebox created stream, and people could enter and utilize the temazcal. It is likely a temporary door could be placed in the entryway, but there is no direct evidence of this.

The interior seating area was covered with lajas, i..e. flat-fracturing exfoliated andesite slabs. They were covered with a 1-2 cm thin layer of Ilopango TBJ volcanic ash. It is possible the TBJ tephra was replaced after each use, or it might have been there for ceremonies recalling that immense eruption/disaster.

THE REPLICA, AND INITIAL ACOUSTIC STUDY

The senior author of this article began suggesting the construction of a replica, or replicas, of the ancient buildings in the early 1990s, to various Salvadoran government officials. So many visitors stated how fascinated they were with the ancient structures that they wanted to get closer to them. Of course, they cannot be allowed to touch the originals, so building at least one replica was agreed-upon for many years. No action was taken for two decades, for lack of funds, until Corsatur (Corporacion Salvadoreño de Turismo) offered to fund the project in 2012. Visitors, archaeologists, and government officials all agreed that the temazcal was the building to replicate. Fortunately, Modulare Arquitectos, one of the finest of Salvadoran architectural firms, was awarded the project in June of 2012. The architect Jose Roberto Ortiz Novoa, the leading architect of the firm, took responsibility for the project. The engineer Hector Cardoza was in charge of the construction. Ortiz submitted the proposal to Secultura (Secretaria de Cultura a la Presidencia) in July. That consisted of text, plans, sections, and elevations of the replica, and a schedule of work. Secultura examined those materials and checked them for accuracy to the original building, and gave the approval to proceed in August. Actual construction of the replica began in October, and was finished 3 November 2012.

The replica (Figure 3) is quite precisely faithful to the original in exterior and interior morphology and measurements, reconstructing it to its condition prior to the Loma Caldera eruption. The beginnings of this acoustics project were shortly after its construction, when the senior author of this article entered the replica, and noted how fundamentally it changed his voice. He noted how much lower in pitch his voice sounded while inside, compared to speaking outside of it. To explore the nature of the acoustic effects, in 2017 he made

Figure 3. The Temazcal replica. It is located in the public access area of the archaeological park, so people can enter it and experience the acoustic phenomena.

an initial sound recording of his voice outside the replica, continuing to inside, and then back outside, for comparative purposes. He used a Sony Panasonic DSC RX100M4. He took that recording to the Physics Department of the University of Colorado, and consulted with Michael Thomason, with results published in Sheets and Thomason (2020). Thomason investigated the unique sound inside the structure due to its size, shape (especially because of the domed ceiling), and the hard surfaces.

Thomason was the first to do a spectral analysis of the decay of speech inside the temazcal and identified the frequencies most prominent in that decay as related to the natural resonances of the enclosed volume. In addition, he identified the interaction of the two lowest, slowly decaying modes that the spoken word excited as the source of the amplitude modulation they exhibit.

His research was able to attribute conclusively the resonances to the geometry and materials of the interior of the temazcal by comparing recordings made inside the structure with those made immediately outside, using the same talker.

Thomason identified numerous topics for potential future analysis. For instance, the reflectivity of the wattle-and-daub surfaces of the original could be compared to the reflectivity of the replica. The number of people inside should affect the acoustics. Spoken versus singing voices, and musical instruments such as Classic period "ocarinas" (fired clay flutes) should be employed and studied. More sophisticated recordings could be done, with multiple microphones, to explore the two and three dimensional standing waves.

Following the groundbreaking research by Michael Thomason, Sheets turned to Robert Mahoney, an acoustician. Mahoney loaned Sheets a more sophisticated sound recording instrument than what he used originally, a Tascam DR-40 Linear Pulse Code Modulation recorder. The results of Mahoney's research are presented in the following section.

THE SECOND RECORDING AND ACOUSTICAL ANALYSIS

An English acoustician, Hope Bagenal, divided auditoria into two groups: those enclosed spaces, like caves and rooms, versus those in the open air (Forsyth, 1985). Enclosed spaces evolved into venues for music, like concert halls, while open air spaces, more favorable to the spoken word, were the forerunners of the theater.

What makes the acoustics of the temazcal, a small and tightly enclosed space, so intriguing? Sounds originating within the space are altered, sustained and them decay in strikingly remarkable ways. Subjectively sounds seem to linger for an unusually long time while their timbres grows darker as they fade away. There are strange rapid variations in the strength of some components of the decaying sound and, depending upon location, the sound source seems larger than life as if it was amplified by the temazcal.

The difference between interior and exterior spaces is entirely a matter of reflections. In the open air – especially where there are few reflective surfaces and those that are present are acoustically absorbent to a high degree – sounds are almost completely devoid of reflections. Sound is heard once and only once by a listener before the energy is completely carried away and contributes nothing further to the overall impression.

The acoustics of enclosed spaces, on the other hand, are the result of reflections that in turn are determined by the extent of the enclosed air volume, the geometry of the room boundaries, and the degree to which the energy of sound waves incident on these boundaries is absorbed or reflected.

Where the cubic volume of a room is large and the geometry is not highly irregular, the room boundaries are inherently far apart. Consequently, sound waves radiating from a source encounter the room boundaries less often than is the case where the cubic volume is small and boundaries are much closer together.

Regardless of the volume of a space, when a sound wave encounters a room boundary some of its energy is lost. How much depends on the absorptive properties of the boundary. Materials with a high degree of absorption are generally porous or highly flexible, like thatch, pine needles on a forest floor, sand or loose soil, etc. Highly reflective materials are dense and heavy and without fine surface porosity like pavers of densely grained stone or plastered walls.

If room boundaries are highly absorptive, then the interior geometry and spatial arrangement of the surfaces are less significant factors in the overall acoustics. When sound energy is absorbed at each reflection, the strength of a continuous sound cannot build up. Once the sound stops, it fades away very quickly. Indeed, in small spaces where sound waves encounter many highly absorptive boundaries in very quick succession the acoustics can closely approach those of open-air conditions.

Where room boundaries are highly reflective not only do continuous sounds build up strength over time and persist after the sound source stops, the interior geometry can add some additional extraordinary effects. That is what makes spaces like the temazcal so intriguing.

Every closed or partially enclosed space with even slightly reflective surfaces will exhibit "room modes" or "room resonances." These are the specific frequencies at which standing waves arise more or less quickly when excited by sound sources that contain energy at those favored frequencies. These standing waves will increase in strength over time, (which we hear as increasing loudness), so long as the sound source is continuous. When the sound source stops, the energy of these frequencies will be absorbed by the boundaries much more slowly than the energy of non-favored frequencies. This causes the favored tones to linger on. In the case of the temazcal, this "lingering" is quite pronounced. This is why the timbre of sounds inside the temazcal seem to evolve and grow darker as they fade away.

For even slightly irregular spaces, the calculation of these resonances is challenging, and not at all intuitive, either mathematically or visually. However, for simple geometries the math is much simplified and visualization is not difficult. A simple geometry similar to that of the temazcal – at least in terms of its geometry in plan – is a parallelepiped. This is a six-sided space with a rectangular floor plan and an identical ceiling plan bounded by perpendicular walls on all four sides.

The room boundaries of a parallelepiped are such that waves reflected from them are sent back in a direction that is exactly opposite of that from which they arrived which results in the creation of standing waves, even for sounds of very short duration.

Planar parallel surfaces, dihedral edges (e.g. floor/wall and wall/ceiling intersections at right angles) and trihedral corners where surfaces are acoustically reflective are particularly good conditions for standing waves. A good visual analogy to the parallel planar surfaces are the "infinite" reflections one can see in barbershop mirrors. The wave reflection that takes place at the intersecting planes of dihedral edges is analogous to a billiards player making a bank shot (Figure 4).

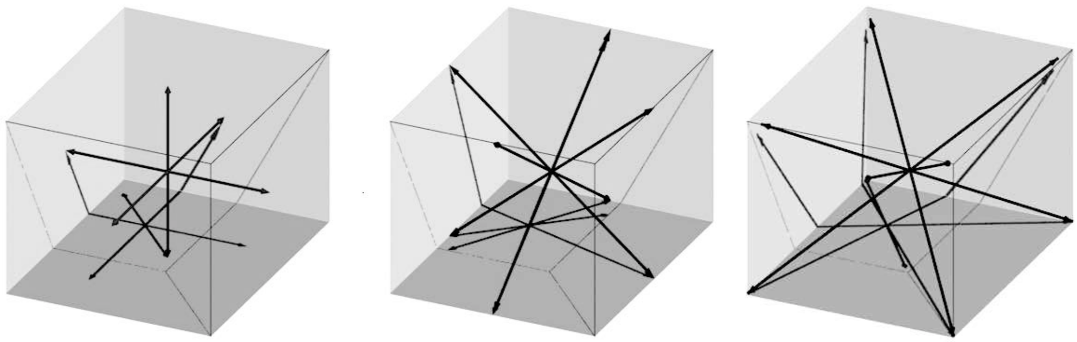

Figure 4. Room modes of a parallelepiped: planar, dihedral and trihedral.

The distances among the room boundaries that fulfill these conditions are very important because sounds whose wavelengths match these dimensions are very strongly sustained and constitute the “room modes” or “room resonances”

It is important to consider what “matching” the dimensions between reflecting conditions implies. A match occurs for all frequencies whose wavelengths are one-half the dimension, exactly the dimension, one and half times the dimension, two times the dimension, and so forth. Expressed mathematically if c is the speed of sound, the relationship between frequency, *f,* and wavelength, λ, is $f = c/\lambda$. If D is the dimension that gives rise to standing waves and N = 1, 2, 3, …, then the resonant frequencies that exist for that particular set of reflecting surfaces is $f_N = N \times (c/2D)$.

D of course is different for all the various conditions of planar, dihedral and trihedral conditions, but nevertheless in every case it can be derived from the length, width and height of the parallelepiped. If the three possibilities for D are instead represented by *p,*

q, r, and the integers, 1, 2, 3 … for each mode are given by l, m, and n, then the general formula for the resonant frequencies of all possible modes is:

$$f_{lmn} = c_0 /2\ [(l/p)^2 + (m/q)^2 + (n/r)^2]^{1/2}$$

The resonant frequencies that result in any one condition form a harmonic series where each is an integral multiple of the lowest fundamental frequency. Whether due to cultural conditioning or some more universal cause, this series is considered inherently musical. It generates the musical intervals we call an octave, then a perfect fifth, a perfect fourth, a major triad, a somewhat flat dominant seventh and then begins a diatonic major scale.

It is important to note that this harmonic series that creates the resonances will arise for each and every case in which the geometrical and absorptive conditions are met. And if all the relevant dimensions, p, q, r, do not have simple relationships to one another (1:1, 1:2, 1:3,…) they will not be harmonically consistent.

It is also worth noting that even if such simple relationships existed, one could not “play along” in tune with these resonances with customary western instruments. Contemporary instruments are usually tuned to a reference pitch such as A= 440, 441 or 442 Hz, whereas the overtone series of the space in question may not align with those reference pitches. Moreover, the tones produced by western instruments are based on equal temperament whereas the harmonic series that characterizes the tones enhanced by the temazcal follow a Pythagorean temperament.

How perceptible all these resonances are depends on a large number of factors. First, the resonant frequencies must be present in the source of the sound – while the potential for room resonances always exists, they will not arise without proper excitation. Second, the audibility of the modes depends on their strength, which in turn is related to how absorptive the room boundaries are; the more reflective the more quickly will sustained sounds build up and the more slowly they will decay. Under the best conditions, even if the resonant frequencies are only weakly present in the sound source, they could build up to clearly audible levels over time.

Yet another very significant factor is spacing between the various room modes. The effect of widely spaced room modes is easily experienced. If in a small, hard shower stall one sings a *glissando* (a tone that slowly sweeps over a broad range of tones) you will hear some that suddenly leap out very strongly. The same exercise in a bare but even moderately large unfurnished room will still excite the room modes but since they are close together, they are much less remarkable.

So far the discussion has not addressed the ceiling geometry and materials. One observation is that having a plastered ceiling exposed to interior sound rather than a thatched underside of a roof would alone create an unusual condition because of the vastly different absorptive/reflective properties of the two materials.

The concave shape of the ceiling creates conditions that are significantly more complex to analyze compared to the case of a planar horizontal ceiling. Additionally, the floor of the structure is also far from a simple plane, because of the firebox in the center. People inside the the temazcal complicate the geometry further. Nonetheless, it is worthwhile to consider the effects of the concavity on sounds heard inside the space. This analysis moves away from considerations of standing waves and on to geometrical acoustics or ray tracing (Figure 5).

In the strictest sense, amplified sound is sound that is stronger because some external energy source has increased the strength of the original sound. However, in a colloquial sense amplified sound may mean sound that is stronger than would normally be expected regardless of the mechanism by which the sound was strengthened.

Ray-tracing is an analysis tool that assumes sound waves act like particles and respect all the rules of optical reflection, in particular that the reflections are specular, that the angle of incidence equals the angle of reflection. While not strictly true, this simple analysis tool shows how for positions that might reasonably be taken by a person speaking or singing and by a person listening the dome is of such a size that a great deal of energy would be focused on listeners symmetrically opposite to the singer/speaker.

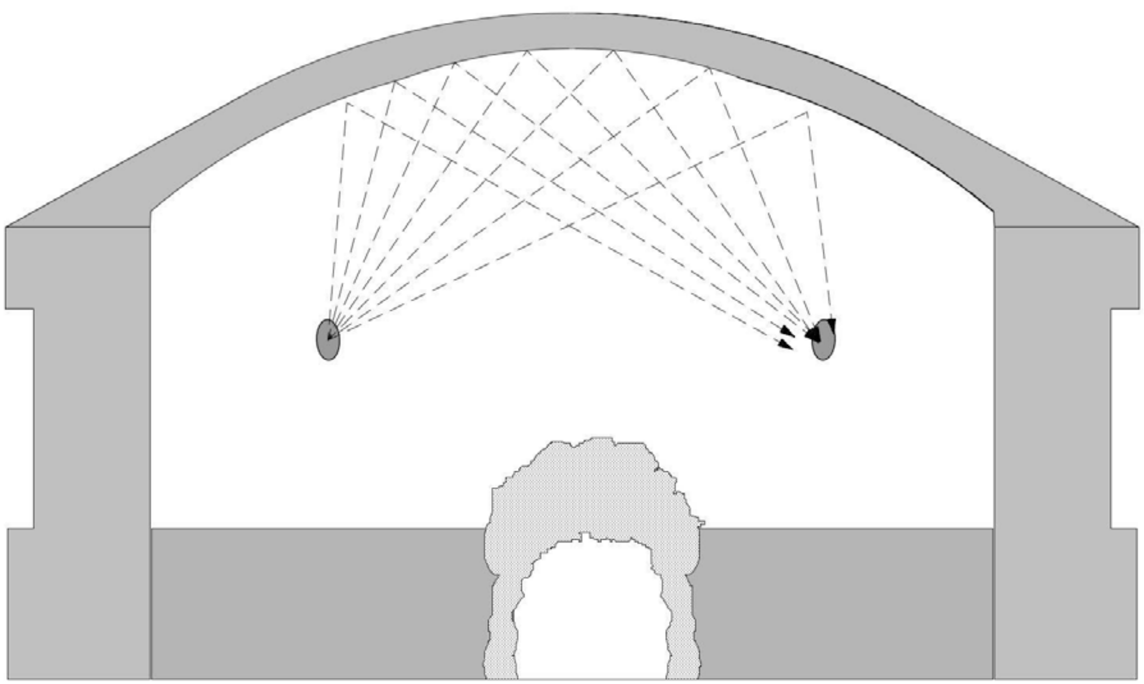

Figure 5. Ray tracing study illustrating effects of concave underside of the dome.

Taken all together, the very small scale of the temazcal, the square plan and overlapping resonances, the reflective and focusing ceiling geometries, it is quite likely that for people who lived largely out-of-doors, or in thatch-roofed household buildings, the acoustics of the tightly enclosed temazcal would have provided an extraordinary experience.

A comprehensive measurement of the room modes of the temazcal would be a complex procedure involving a great many measurements using controlled positioning of both sound sources and measurement locations. However, by examining reverberation times at various frequencies we can learn something with a much simpler test that proves to be highly informative.

A large balloon was burst inside the temazcal and the resulting sound decay was recorded with a digital recorder (Tascam DR-40). The recording was analyzed using Amadeus Pro software that produced the sonogram shown in Figure 5. The vertical axis is frequency, the horizontal axis is time and the sample is six seconds long (Figure 6). The greatest energy is shown in white. Note the various frequencies listed for which the rate of sound decay was much greater than at others. The “rate of sound decay” is expressed as the reverberation time at a particular frequency. As one can readily see, the energy at 64 Hz was particularly strong and long lasting.

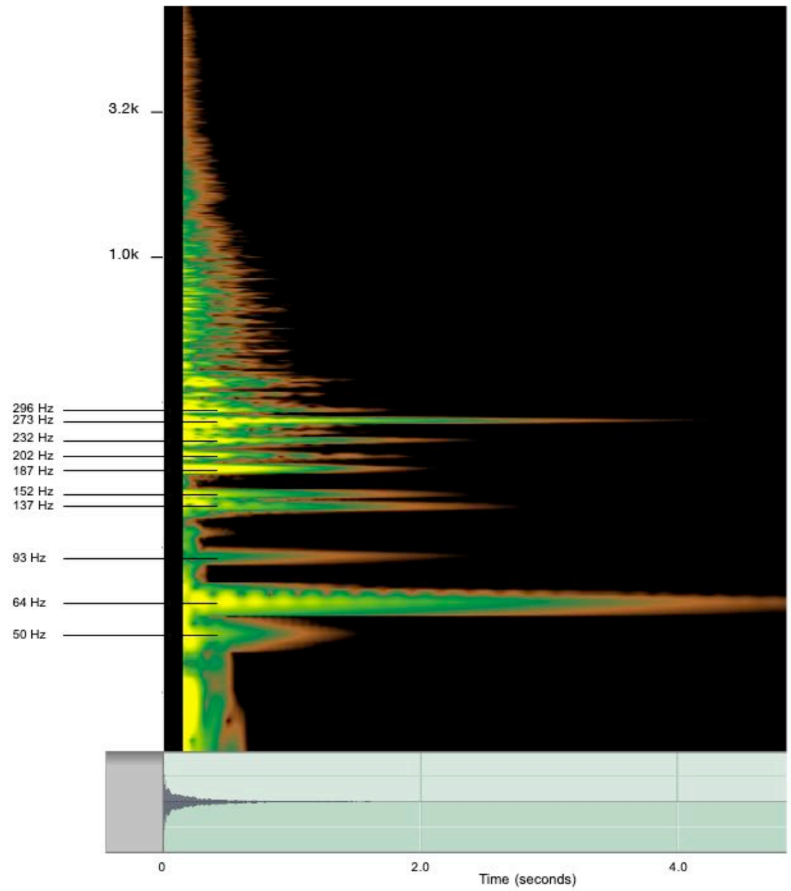

Figure 6. A sonogram of a recording of a balloon burst inside the temazcal and the six seconds thereafter. Note the modulation of the 64 Hz resonance first recognized by Thomason.

As mentioned earlier, one of the characteristics of the preferred frequencies is that their energy is sustained for a relatively long time after the sound source stops, so it is reasonable to infer from the sonogram that at least some of the room modes are revealed by this analysis. However, not all of them are revealed. If the measurement microphone was at a node of a standing wave it would record very little decay and produce no trace in the sonogram. Likewise, If the balloon burst contained no energy at a particular preferred frequency there would be no decay and no telltale trace.

However, it is in the low frequency range where the room's modes are most prominent and influential, and that is the frequency range where a large balloon burst has the most energy. Indeed, the apparent mode at 64 Hz, while very prominent in the sonogram, may not have any special significance; instead, it might just indicate the balloon burst was especially powerful at that frequency and the initial energy level was particularly strong and so took longer to decay completely.

The lowest frequency identified in the sonogram, 50 Hz, is below what even a *basso profundo* singer can produce. The next higher frequency, 64 Hz is two octaves below middle C and is about a low as a *basso* can sing. 93 Hz is approximately as low as a bass singer goes while all the higher frequencies up to 232 Hz still do not go higher than what we know as middle C. At still higher frequencies, the resonances are far less prominent because they are close together and even start to overlap. Figure 6 presents a graphical representation of these relationships.

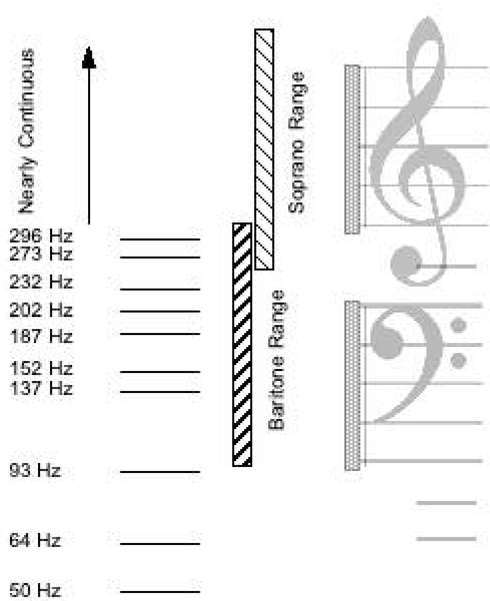

Figure 7. The strong resonances on the left hand side identified in Figure 6 are shown in relation to the approximate range of adult male and female voices and in relation to contemporary musical notation.

This may be significant, because it suggests that the peculiarities of the temazcal's acoustics are far more likely to be excited by men's voices than those of adult women or children. Indeed, in such an acoustical environment someone chanting a constant tone at a resonant frequency might be able to pause briefly to take in a new breath without the interruption being heard by others in the space – the appearance of a continuous drone would be maintained.

SUMMARY AND CONCLUSIONS

Of all the earthen architectural buildings of Cerén, the domed temazcal has attracted the most attention by visitors and scholars. It is not the small, family-oriented sweatbath of the Maya today, because it easily seated a dozen people, and probably was used for a wide variety of functions. A 1:1 scale replica was constructed in the public area of the archaeological park so visitors could inspect it and enter it. Upon entering, many people noted how fundamentally it changed their voices. To investigate the acoustics, two recordings were made. One, with a good recorder, was of a speaking voice outside, then inside, then back outside the structure. The second recorded the results of a balloon burst with a professional acoustic instrument. The remarkable changes became clear with both recordings, as "room resonances" were strikingly amplified, while other frequencies were suppressed. The non-favored frequencies, at high tones, faded out quite quickly. The low tones persist and were amplified as standing waves.

Cerénians' experiences of sounds within the temazcal would have been so utterly different from their experiences of sounds in the outdoors, or in earthen architecture buildings with absorptive thatch roofs.

The sonogram divulges the primary standing wave at 64 Hertz from a spoken voice. That is so low that a basso singer can barely achieve it. The acoustic landscape within the temazcal fundamentally enhances mature male voices. It does not enhance mature female voices or those of children. One's speculative imagination is triggered by this realization. The effect of a shaman/diviner upon a client could have been much more powerful. Likewise an elder in an educational or disciplinary mode could have been more effective. A rite of passage could have been enhanced. A curing ceremony could have invoked the supernatural more compellingly.

RESUMEN Y CONCLUSIONES

De todos los edificios arquitectónicos en Joya de Cerén, el temascal con domo genera la mayor atracción a visitantes y estudiosos. No representa el sauna contemporáneo Maya, pequeño y orientado a la familia, porque este puede sentar fácilmente a doce personas y probablemente fue usado para una variedad de funciones. Una réplica a escala 1:1 fue construida en el área pública del parque arqueológico para que los visitantes puedan verlo y entrar. Cuando entran, mucha gente nota cómo cambian sus voces. Se realizaron dos grabaciones para estudiar la acústica. La primera, con una buena grabadora, era una voz afuera, luego adentro y después afuera de la estructura nuevamente. La segunda grabación se hizo con un instrumento acústico profesional, de una vejiga explotando. Los cambios fueron claros en ambas grabaciones y fueron amplificados grandemente, como en un “cuarto de resonancia”, mientras otras frecuencias fueron suprimidas. Las frecuencias no favorables, en tonos altos, desparecen rápidamente. Los tonos bajos persisten y fueron amplificados fuertemente en ondas altas.

La experiencia de los sonidos dentro del temascal, por los habitantes de Joya de Cerén, habría sido muy diferentes de su experiencia con los sonidos en el exterior o en las estructuras de tierra con techo de zacate.

El fonograma revela las primeras ondas de una voz a 64 Hertz. Esto es tan bajo que un tenor de opera apenas lo logra. El ambiente acústico del temascal fundamentalmente aumenta las voces de los hombres adultos. No aumenta las voces de las mujeres adultas o de los niños. La imaginación se motiva por estos hechos. El efecto chaman/adivinador sobre un paciente puede ser más poderoso. Así mismo, un adulto en un modo disciplinario o educacional pudo haber sido más efectivo y un rito de pasaje pudo haber sido magnificado. Una ceremonia de curación pudo haber invocado lo sobrenatural de una forma más convincente.

Acknowledgements

We heartily thank Michael Thomason for his insightful analysis of the first recording, and for his continued support for this further analysis. His suggestions for further research on the acoustics of this temazcal replica point the way into the future. We thank Roberto Gallardo for translating the abstract, and the summary and conclusions sections.

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List of Figures

1. Map of the Cerén site. Structure 9 is the temazcal. The replica was built at the northern end of this map, where visitors could enter it and experience the acoustic effects on their voices.
2. The Temazcal at Cerén. The earthen architecture with the dome was protected by a thatch roof. Two lava bombs penetrated the roof and dome, damaging them, but allowing tephra to support other portions of the dome.

3. . The Temazcal replica. It is located in the public access area of the archaeological park, so people can enter it and experience the acoustic phenomena.
4. Room modes of a parallelepiped: planar, dihedral and trihedral
5. Ray tracing study illustrating effects of concave underside of the dome.
6. Above, a sonogram and below the impulse response for a six-second window of a recording of a balloon burst inside the temazcal.
7. The strong resonances on the left hand side identified in Figure 6 are shown in relation to the approximate range of adult male and female voices and in relation to contemporary musical notation.