Jacqueline Ortoleva*

Making Sense of Landscape: A New Study of Sound Propagation between Tarquinian Funerary and Habitation Settings

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Abstract: The study of pre-Roman landscape settings has progressed across a long trajectory in its consideration of urban and rural adaptations in Etruria. Such studies, while providing valuable details regarding social organization, have not considered the unique aural nature of the landscape, particularly with respect to funerary settings. Nowhere is this more evident than with painted chambered tombs. Our understanding of Etruscan painted tombs is still largely guided by analytic studies of tomb paintings, epigraphic sources, and typologies. Thus, the bilateral relationship between each tomb's landscape setting and habitation contexts has been explored from a solely visual perspective, rather than from a multisensory perspective, and consequently, ritual performed in and around the tomb space remains unclear. A further understanding of perceptual constructs involving aural information offers a new way forward in confronting these realities. This article utilizes acoustic modeling tools to illustrate the potential range of audibility between the Necropoli dei Monterozzi in Tarquinia and various locations in the landscape. Acoustic and spatial data collected in 2019 inside a series of painted tombs in the Calvario area of the Necropoli dei Monterozzi in Tarquinia provides further information regarding the painted tomb's landscape setting and its environs. The preliminary study suggests that aural information can greatly enhance our understanding of funerary practices in Tarquinia, particularly with respect to how habitation areas in Tarquinia may have engaged with funerary landscapes.

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***Corresponding author: Jacqueline Ortoleva**, Classics, Ancient History, Archaeology, University of Birmingham, Edgbaston, Arts Building, Birmingham, B15 2TT, UK, E-mail: JXO644@bham.ac.uk. https://orcid.org/0000-0002-1414-8191

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1 Introduction

The study of pre-Roman landscape contexts has progressed in recent years to consider urban and rural trajectories in Etruria.[1] Such studies, while providing valuable details with respect to Etruscan society, have rarely considered the aural nature of landscape settings. Nowhere is this more evident than with painted chambered tombs. Our understanding of Etruscan painted tombs is still largely guided by analytic studies of tomb paintings, epigraphic sources, and typologies. As such, the bilateral relationship between each tomb's landscape setting and habitation contexts has been explored from a solely visual perspective, rather than from a multisensory perspective. Consequently, ritual performed in and around the tomb space remains extremely unclear. A further understanding of perceptual constructs involving aural information offers a new way forward in confronting these realities. While multiple scholars have considered figurative depictions of musical performance and particularly musical instruments in Etruria, the behavior of sound has only recently emerged as a viable avenue of study in the pre-Roman record.[2]

When reflecting on sound it is important to note that audition does not simply facilitate what one hears, but also *how* one hears. Many things dictate this process including language (speech, not literacy), biology, and cultural experiences.[3]

1 Landscape studies and surveys include Barker and Rasmussen 1998; Bonghi Jovino and Chiaramonte Treré 1997; Mandolesi 1999; Potter and Stoddart 2001; Moretti Sgubini, Arancio, and Belardinetti Insam 2001; di Gennaro 2000; di Gennaro et al. 2002; Perego 2005; Cascino et al. 2012; Stoddart 2007, 2016, 2020.

2 The study of musical performance in Etruria has predominantly drawn on figurative iconography and the archaeological record. See Jannot 1974, 1979; Lawergren 1984, 1993, 2007; Colonna 1993; Warden and Thomas 1999; Carrese, Li Castro, and Martinelli 2010; Martinelli and Melini 2010; Maras 2016, 2018. The first publications involving an acoustic analysis of the Etruscan record can be found in Ortoleva 2021; Ortoleva and Barnard 2021; Ortoleva 2022a, 2022b (forthcoming).

3 From the perspective of neuroscience, verbal language (which should not be confused with literacy and written textual sources) influences spatial cognition, sensory perception, and other aspects of human cognition. As such, we must always be mindful of the fact that secondary textual sources such as Roman, Greek, and Early Christian texts cannot and should not be solely relied on to clarify human experience in Etruria. Moreover, our own experiences of different sites in Etruria are not necessarily exchangeable with those of the Etruscan individual. This further emphasizes the importance of considering the landscape setting from an aural perspective and therefore one grounded in physics (acoustic science). However, as will be noted later in this paper when we consider these realities regarding human language and cognition, secondary sources emerge as

In other words, we "hear" auditory stimuli because our brain ascribes meaning to different sounds, even when such stimuli are heard but not seen. For example, studies have shown that sounds associated with certain activities can trigger the physical sense of participating in such activities through auditory processes.[4] Auditory stimuli involving music can also trigger the endogenous reward system in the limbic area of the brain, resulting in the release of endorphins, and this in turn stimulates an emotional connection to the setting where music is experienced.[5] None of these neural responses are conscious, and yet they shape emotional experience while fostering social cohesion.[6] This highlights the importance of looking beyond the visual nature of landscape settings to consider other forms of sensory perception such as sound.

In recent years, multiple fields of inquiry involving auditory cognition and bodily movement have evolved in archeology. Most of the progression in these fields has centered on prehistoric contexts. One such field, that of archaeoacoustics, was developed to interrogate prehistoric rock art.[7] Subsequent analyses include the scientific assessment of funerary spaces and other prehistoric architectural structures.[8] More recently, archaeoacoustic studies have begun to focus more intently on landscape settings, particularly from the standpoint of aural exchange and engagement.[9] Other studies, driven by phenomenological and sensory dictates, have also explored auditory experience in prehistoric settings.[10] Recent studies have explored the sonic nature of religious and secular settings in the Greek and Roman records.[11] The present study springs from the perspective in archaeoacoustic studies that we cannot adequately assess the Etruscan record without some level of understanding regarding aural experience. For the purposes of this article, the area of focus is the San Savino Valley which connects Tarquinia's ancient urban center, the Civita, and its largest necropolis, the Necropoli dei Monterozzi.

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viable resources in terms of further understanding cultural interactions between Etruria and its contemporaries. Herein lies an avenue of research involving secondary texts that has not been fully explored in either pre-Roman or Roman scholarship. See Thierry 2016.

4 Regarding mirror neurons and sound, see: Kohler et al. 2002; Guttman, Gilroy, and Blake 2005.

5 Reybrouck, Eerola, and Podlipniak 2018.

6 Morley 2014, 166.

7 For example, see: Reznikoff and Dauvois 1988; Reznikoff 1995, 2006; Diaz-Andreu et al. 2017; Diaz-Andreu and Garcia Benito 2012, 2013; Fazenda and Drumm 2013.

8 Examples include Watson and Keating (1999); Till (2009, 2014, 2019); and Kolar (2017), all of whom have analyzed acoustics in man-made structures.

9 Arsenault 2004; Boivin 2004; Devereux 2008; Diaz-Andreu et al. 2017.

10 Including Betts 2017; Hamilton et al., 2006; Hamilton and Whitehouse 2020.

11 Bellia 2022.

This article seeks to enhance our understanding of aural engagement between Tarquinian chambered tombs (painted or unpainted) in the Necropoli dei Monterozzi and its surroundings. Acoustic modeling tools highlight the range of audibility between several tomb sites and various locations in the landscape, including Tarquinia's urban center. Supplemental data from a recent acoustic study of painted tombs in Tarquinia provide further information regarding potential engagement between the funerary landscape and its environs. The long history of scholarship involving the seventh–third century B.C.E.[12] Etruscan record in Tarquinia (Figure 1) provides a level of contextual information that is unparalleled in other areas of Central Italy. However, studies involving Tarquinia have largely separated funerary settings from habitation areas.

2 Connecting the Dots: Existing Scholarship and the Aurality of Tarquinia

With rare exception, the study of Tarquinia during the seventh through third centuries B.C.E. has been approached in two discrete ways, one centered around the urban center of Tarquinia, inclusive of its temples and religious ritual, and the other on chambered (largely painted) tombs. Such approaches have rarely intersected in a way that could explore how landscapes of the living may have interacted or even engaged with funerary settings. Nevertheless, the long trajectory of Tarquinian scholarship provides crucial contextual information for a sonic study of the Necropoli dei Monterozzi and its environs.[13] The Pian di Civita and Pian della Regina plateaux that made up ancient Tarquinia were first scientifically excavated by Romanelli during the 1930s, and thereafter beginning in 1982 by the Università Statale di Milano. Subsequent formal surveys began during the 1960s, followed by geophysical methods, GIS, and other surveys that are now widespread.[14] With respect to the Necropoli dei Monterozzi, formal surveys of Monterozzi commenced in 1955, when Lerici began to document chambered tombs using resistivity techniques.[15] This body of evidence provides information related to the chronological

12 Subterranean painted tombs emerged in Tarquinia as early as the seventh century B.C.E, however, unpainted tombs emerged earlier during the eighth century B.C.E. See: Naso 1996.

13 See n. 2.

14 The long trajectory of landscape surveys and analysis involving ancient Tarquinia is immense. The following represent a small portion of such scholarship: Bagnasco Gianni and Bonghi Jovino 2012; Bonghi Jovino 1986, 1987, 2001; Bonghi Jovino and Chiaramonte Treré 1997; Harari 1997; Hencken 1968a; 1968b; Iaia et al. 2001; Mandolesi 1999; Marzullo 2013, 2018; Perego 2005.

15 Lerici 1958, 1959, 1960, 1961, 1962, 1965, 1975.

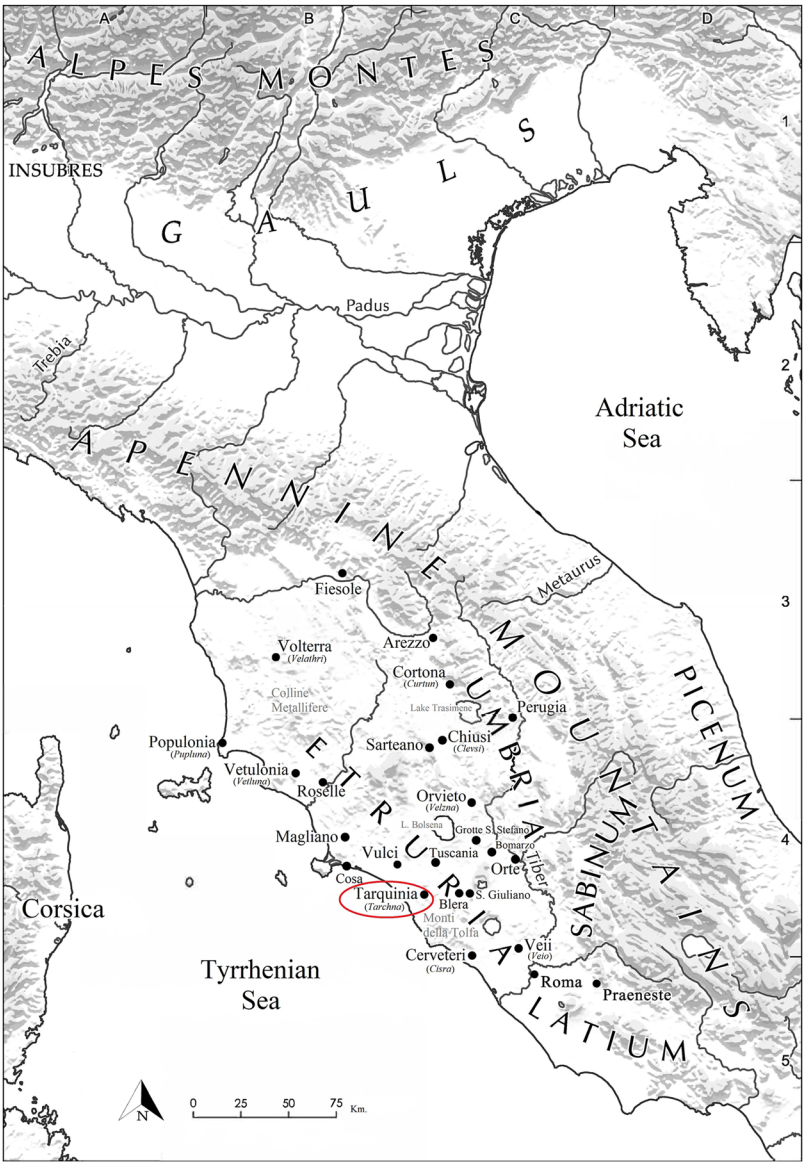

Figure 1: Map of Etruria highlighting the coastal location of Tarquinia. Italy in red (map template from Ancient World Mapping Center, map of Etruria created by C.S. Ortoleva).

development of the surrounding landscape, Tarquinia's urban center, and its cemeteries.[16] The corpus of paintings on tomb walls in Tarquinia has probably generated more scholarship than any other Etruscan medium. This is striking, considering that painted tombs are quite rare in Etruria. In Tarquinia, scholars estimate that of approximately 6100 chambered tombs at Monterozzi, roughly 400 tombs include paintings.[17] Various surveys of tomb paintings provide important details related to the progression of tomb paintings not only in Tarquinia, but across other regions with tomb paintings, such as Chiusi, Orvieto, and Cerveteri.[18] Marzullo's more recent work uses photogrammetry and survey techniques to document Tarquinia's painted tombs.[19] By far, the most common approach to tomb paintings involves social organization, with scholars presenting the paintings as symbolic of gender, status, and the general identity of the deceased.[20] Others have approached the paintings from a more anthropological perspective.[21]

The funerary context of tomb paintings clearly necessitates caution when they are used to assess Etruscan cultural practices. This has been acknowledged by scholars such as Prayon, Warden, and Rouveret, who have redirected the conversation back to the tomb space as a place where funerary ritual was practiced.[22] Although relying more on seventh-century tumuli, Colonna's efforts in exploring the performative nature of the funerary setting deserve mention here because of Colonna's focus on funerary activity. In recent years, scholars have further contextualized tomb paintings along with burial goods, the surrounding landscape, or the overall spatial placement of tomb paintings.[23] Torelli and Roncalli in particular have suggested that the painted tomb space was spatially divided into specific areas for the living, with others intended for the dead.[24] Understanding the funerary experience from the perspective of sound builds on Torelli's and Roncalli's assessments without relying entirely on iconographic, typological, and textual sources. As a first step in clarifying aural experience and engagement

16 Linington 1977, 1980; Brancaleoni, Castellani, and D'Asdia 1989; Mandolesi 1999; Iaia et al. 2001; Perego 2005; Stoddart 2020.

17 Cavagnaro Vanoni 1997; Marzullo 2017, 2018.

18 Steingräber 1981, 1986, 2006, 2014; Naso 1990, 1996, 2005.

19 Marzullo 2017, 2018.

20 For example, Weber-Lehman 1985, 1986, 1995, 1997; Cristofani 1967, 1975, 1987a, 1987b; Colonna and Colonna di Paolo 1997; Rathje 2013; Naso 1996, 2005; Minetti 2006; Bonfante 1971, 1981, 1994; Roth 2012.

21 Brandt relies on Greek and Roman textual sources to consider iconography depicting rites of passage. See: 2015, 2020.

22 Rouveret 1974; Warden 2010; Prayon 2010.

23 Leighton 2004; Roncalli 1997; Torelli 1997, 2000; Warden and Thomas 1999; Warden 2009; Ortoleva 2022a.

24 Torelli 1997; Roncalli 1997.

during the funerary event, we must address what makes Tarquinia geologically unique among other regions in southern Etruria.

3 Aural Properties of the Tarquinian Landscape

When the acoustic nature of Tarquinia is considered, several clues are of particular importance. Sound propagation in valley settings is guided by geological and environmental factors such as ground topography, the slope of the valley, and meteorological factors (temperature, humidity, and wind). Tarquinia is geologically distinct from other Etruscan "cities," such as Orvieto and Cerveteri. Although surrounded by volcanic activity. Tarquinia's bedrock is composed of less porous biocalcarenite limestone from the Upper Pliocene interbedded with a weaker fossiliferous biocalcarenite (Figure 2).[25] The lengthy tradition of painted tombs in Tarquinia was likely driven in part by its more stable bedrock, which essentially provided a highly workable surface for the application of an underlay and paint, with a level of stability from the native macco. Because Tarquinia's bedrock is generally denser than that found in surrounding regions, this would have contributed to sound reflecting off the rock walls of each plateau. Acoustic

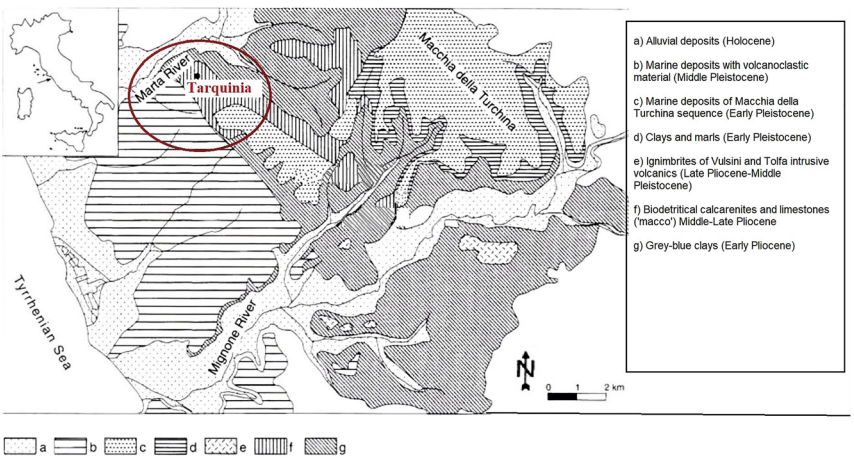

Figure 2: Geological map of Tarquinia (after Mazzini et al. 2000, 247, figure 1, with modifications by J.K. Ortoleva).

25 D'Agostino et al. 2010; Caneva et al. 2020.

absorption qualities of the bedrock and structural choices inside the tomb space enhance, or limit, sonic effects such as echoes and reverberation. Indeed, these factors contributed to the extraordinary acoustics recently documented inside painted tombs, for example the Tomba dell' Orco.[26] The landscape itself offers further information regarding Tarquinia's general audibility and sound projection outside of the tomb.

The San Savino Valley separates the Necropoli dei Monterozzi from ancient Tarquinia's urban center (the Pian di Civita and Pian della Regina), which originally stood atop two plateaux bordered by rock cliffs on three of its four sides (Figure 3).[27] The Necropoli dei Monterozzi is immense, spanning 5 km in length, and diagonally frames a substantial portion of the southern half of the ancient city. Delegated entirely to burials as early as the seventh century B.C.E., the elevation of the necropolis on its northeastern side seems abrupt; however, it is less steep than its surroundings.[28] While the valley terrain has adapted because of agriculture and other building practices, several things are still quite noticeable. The slope of the

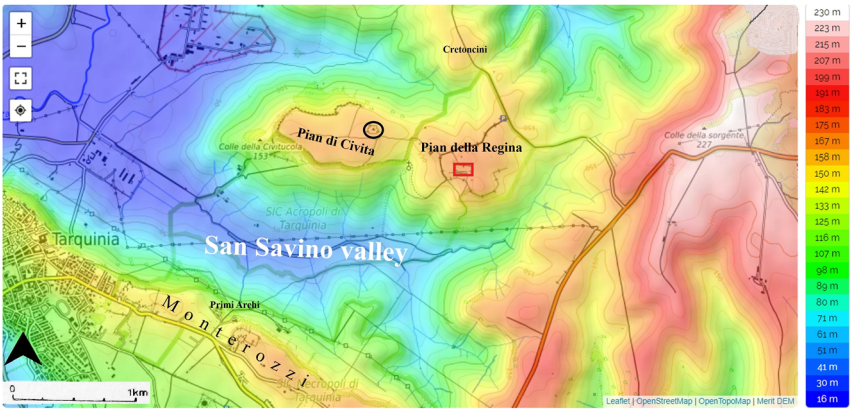

Figure 3: Map of Tarquinia showing the Necropoli dei Monterozzi and the Civita with elevations. Monumental complex identified with black on the Civita and the Ara della Regina noted in red on the Pian della Regina (map after Yamazaki et al. 2017, *Geophysical Research Letters* 44:5844–53 with alterations by J.K. Ortoleva).

26 Ortoleva 2021.

27 Hencken 1968a; Bonghi Jovino 1986; Marzullo 2018.

28 Burial evidence on Monterozzi dates to the Copper Age. However, the site was utilized for habitation and cultural activities as well as burials until the seventh century when the necropolis was entirely devoted to burials and, interestingly, the painted tomb tradition emerged in Tarquinia. See Linington 1980, 1982.

plateaux that the Civita spanned is steep on three sides (south-, east-, and north-facing sides). Only the western portion of the Pian di Civita is less steep. Monterozzi has drops on its northernmost side, and yet its elevation undercuts the Civita, and this would have potentially exaggerated different sounds traveling across the valley. In concave valleys, such as the present one, sound tends to amplify particularly when generated at an elevated slope above the valley floor.[29] The nonhomogeneous topography of the valley is also extremely important, as this would have also attenuated sound and in certain areas of the necropolis and other human-made constructs would have accentuated these effects. For example, a road was built to connect the eastern side of the urban center with the necropolis, while another road horizontally sliced through the latter. The Etruscans tended to build roads that followed the land itself.[30] Building rock-lined roads would have contributed to the exaggeration of sound into and across the valley. Water bodies, such as rivers and lakes, are also of note because they tend to reflect sound in a manner that emulates glass. Even though tributaries connected to the Marta River were interspersed throughout the valley setting, we cannot disregard how they may have contributed to sound propagation on the valley's floor. Such information pertaining to Tarquinia's potential audibility leads to a logical question that deserves further introspection. Who would have been the listeners?

4 Audibility between Landscapes of the Living and the Dead

Interplay between Tarquinia's necropolis and habitation areas was surely not a silent exchange. Tarquinia nevertheless exists today as a visually documented, and yet altogether silent place. Several logical questions involving sound are pertinent here. How far did sound(s) travel during the funerary event? Were sounds emerging from the burial event contained inside the necropolis, in certain sectors of the necropolis, or were surrounding roads or even communities privy to specific funerary sounds? How was sound experienced in the San Savino Valley itself versus each plateau's elevated position? Monterozzi was originally used as early as the Iron Age for habitation and was subsequently allocated as a funerary site. What changes resulted from this change? Did sound serve a role in the construction of walls around certain areas of the Civita?[31] The placement of habitation areas in and

29 Van Renterghem, Salomons, and Botteldooren 2006.

30 Mandolesi 1999.

31 Marzullo's (2018) discussion of walls erected at Tarquinia provides a clear assessment of former scholarship and current theories regarding the placement of walls.

around Tarquinia's urban center offers some clarity regarding Monterozzi's potential soundscape.

Survey evidence suggests that settlements on the Civita and other areas, such as Cavone, located to the east of Monterozzi, and Cretoncini, located north of the Civita, were established during the Bronze Age. Other settlements and cemeteries were scattered around the urban center and Monterozzi, essentially establishing an early spatial and visual interconnectivity between habitation and funerary spaces (Figure 4). Ultimately, the Civita expanded to over 150 ha, connected via a series of roadways, with several connecting to and bordering Monterozzi. According to Mandolesi, some areas indicate a higher level of fluidity. For example, during the eighth century B.C.E., Cretoncini was allocated entirely to burials but was subsequently repopulated during the late seventh century when Monterozzi was designated as Tarquinia's principal necropolis. These changes are often considered in tandem with the rapid growth of Tarquinia's urban center, which is often presented as connecting outlying communities to different civic activities. The identification of multiple religious and civic structures, metal

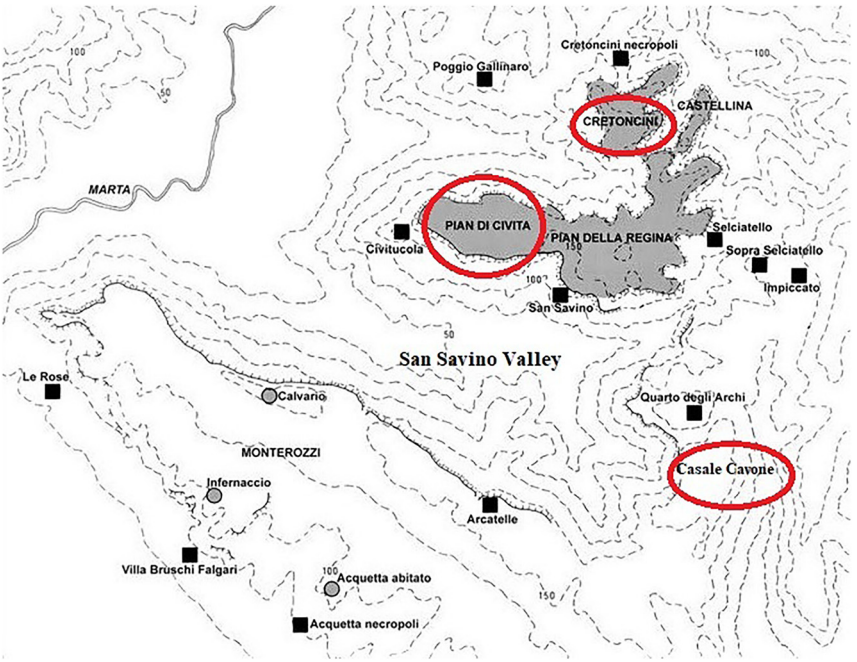

Figure 4: Map showing habitation areas (gray shaded circles) during Iron Age as well as burial areas (black squares). Sixth century B.C.E. habitation areas circled in red. After: Pacciarelli 2017, pg. 574, Figure 33.3.

working, extensive pottery production, stone roads, walls, elaborate hydraulic system, and a developing public forum on its western plateau (Pian della Regina) suggests that both plateaux were immersed in activities connected by a road system that intersected and circled the city. The westernmost plateau, the Pian di Civita, was extended with the Pian della Regina, where renovations ensued to the original temple site (Temple I followed by Temple II, III, and IV), the Ara della Regina, through the sixth–fourth centuries B.C.E.; it ultimately became the largest temple in Etruria. As such, Tarquinia was a demonstrably important region of Etruria, particularly in terms of religious worship. In a manner akin to other religious traditions throughout the world, multiple Etruscan mythical figures physically connected the earth to metaphysical beliefs with representations of the human body and vocalizations.[32] In this, aural experience served a direct role in religious worship.

5 Sound and Aural Experience in Etruria

According to Etruscan iconography and Roman and Greek texts, important divinatory practices allegedly came from the prophetic figure of Tages, who emerged from a plowed field to speak (or sing) important religious rules from the *Etrusca disciplina* to Tarchon in Tarquinia.[33] Figurative iconography, for example on bronze mirrors and engraved gems, is commonly presented as representing Tages and possibly Tarchon.[34] Perhaps one of the most discussed aspects of the Etruscan religion relates to their observation of natural phenomena.[35] The practice of ritualized activities such as *auspicium* are depicted on various media as are images of lightning, some of which, de Grummond suggests, visually symbolize the sound of thunder.[36] Among funerary media in Etruria, including tomb paintings, cinerary urns, and cippi, the illustration of music and dance collectively

32 Separate from obvious monotheistic traditions, there are extensive examples of such traditions in indigenous belief systems. For example, various Northern and Central aboriginal Australian cultures relate rock formations and minerals such as ochre used to create imagery of Dreamtime deities to the sounds of different human vocalizations. See: Goldhahn et al. 2021; Tacon 2021.

33 There is greater focus in scholarship (Pfiffig 1975, 252–55; Jannot 1988) regarding *what* is relayed to Tarchon and/or the appearance of Tages, and less emphasis regarding *how* Tages relays the importance of divination using vocals. The manner in which Tages communicates varies. See Cic. *Div*. 2.50–51.23 for an example of Tages supposedly "speaking" and Censorinus, *DN* IV, 13 for an example of Tages "singing."

34 Pallottino 1979; Torelli 2000, 637; de Grummond 2000, 30.

35 Cic. *Div*. 1.41.92; 2.38.80; Ov., *Fast*. 4.812–18; Livy 1.34.3–10.

36 See de Grummond 2018.

represents sound more than any other imagery. The broad visual tradition depicting musical instruments in Etruria, especially Tarquinia with its dizzying array of tomb paintings has provided a broad visual representation of music without any consequential sound. Such imagery is supplemented with the physical remains of various musical instruments such as litui and cornua, among them the well-known lituus discovered as part of a votive deposit outside of the Beta structure on the Civita.[37] Further evidence of extended cult activity has been uncovered throughout the Civita.[38] Such activities were not conducted without accompanying sounds, tastes, smells, and other sensory experiences. Further clarifying societal and cultural practices in ancient Tarquinia is therefore not fully possible unless we consider how different cultural settings were engaged from different sensory perspectives. Sensory experience, such as olfactory and gustatory experience, tends to be fleeting. However, because aural experience is guided by physics, as dictated by environmental factors, an aural study is possible using techniques developed in acoustic science and the subsequent development of archaeoacoustic methods.

6 Acoustic Modeling of the San Savino Valley, Tarquinia

Acoustic modeling software offers a way to experimentally explore sound on Monterozzi and its surrounding landscape. To accurately model sound propagation, the modeling program ODEON utilizes geometry, and specifically what is known as an "image source method" in tandem with a modified radiance tracing algorithm to model and predict sound propagation characteristics in indoor and outdoor settings.[39] In basic terms, an image source method utilizes a three-dimensional model to assess a space by mathematically calculating the sum

37 See Sarti 2010 for a review of surviving musical instruments from Etruria.

38 Ten interments were uncovered in the Pian di Civita dating between the late ninth and sixth centuries B.C.E. The oldest deposit, an eight-year-old child, was situated sometime during the late ninth century near the foundational walls of an area dubbed "Ara Sacra" by the excavators. The body was deposited with a few objects (a bronze bulla, which indicates he was of a higher social status, a fragment of lead, and a pin). Upon forensic examination, the cranial remains were found to have deformities consistent with a voluminous arteriovenous aneurysm, a large clumping of arteries in the brain that can create a skull deformity. The condition can also cause focal and Jacksonian type seizures and as such the remains have been related back to the story of Tages by multiple scholars. See Fornaciari and Mallegni 1986, 1987; Bonghi Jovino 1986, 1987; Ciafaloni 2006; Colonna 2006; de Grummond 2006.

39 ODEON 2021.

reflections of a space.[40] Radiance transfer technology differs from an image source method in that it temporally models acoustic energy by dividing each surface or image into elements. Each element is then assessed per the amount of energy that should be reflected from each surface.[41] Because it utilizes two different techniques (rather than one as seen in other acoustic modeling programs), ODEON conceivably provides a more reliable method of acoustic documentation.[42] The use of two different techniques more accurately models a specific space or landscape site, and in the field of acoustic science, higher-end acoustic modeling programs, such as ODEON, are well accepted and often used by acoustical engineers.[43]

Following a method developed by Iannace, Berardi, and Trematerra to study sound propagation at another valley in southern Italy, an experimental model of the San Savino Valley was created to explore sound propagation in the surrounding landscape of the necropolis.[44] The San Savino Valley was initially outlined according to the general shapes of each setting and thereafter scaled per the exact coordinates of different "slices" of the overall site, each one measuring roughly 1900 m in length (including the entire valley and a small portion of the city and necropolis; Figure 5). It is important to note that an acoustic model differs from a photogrammetric model. In fact, an acoustic model can visually seem rather rudimentary, because it relies on accurate scale and acoustic absorption factors of the surroundings to accurately model sound propagation. For the purposes of the present model, the valley was represented by drawing on existing maps of the region and scaling the model to the exact dimensions of the valley setting. The specific area of inquiry is situated on Monterozzi to the east of the Primi Archi, where the Tomba dell' Orco and the Tomba del Vasi Dipinti are located. The model was assigned material values to represent the acoustic absorption rate of the bedrock.[45] As previously intimated, Tarquinia's bedrock is stronger than that of other urban centers such as Cerveteri, which suggests that sound waves are potentially less absorbed in Tarquinia, and this was indeed found as part of a recent acoustic study that will be discussed later in this article (Figure 6). Clearly, when considering the valley setting between the Civita and Monterozzi, we are reviewing how sound propagates outside of the tomb space and specifically the valley "walls" flanking the necropolis and the Civita. The recent aural assessment

40 ODEON 2021.

41 ODEON 2021.

42 Siltanen, Lokki, and Savioja 2009.

43 The author thanks Andrew Barnard, the Director of the Department of Acoustic Science at Pennsylvania State University, for this information.

44 Iannace et al. 2018.

45 Andrew Barnard, personal communication with the author, 2021.

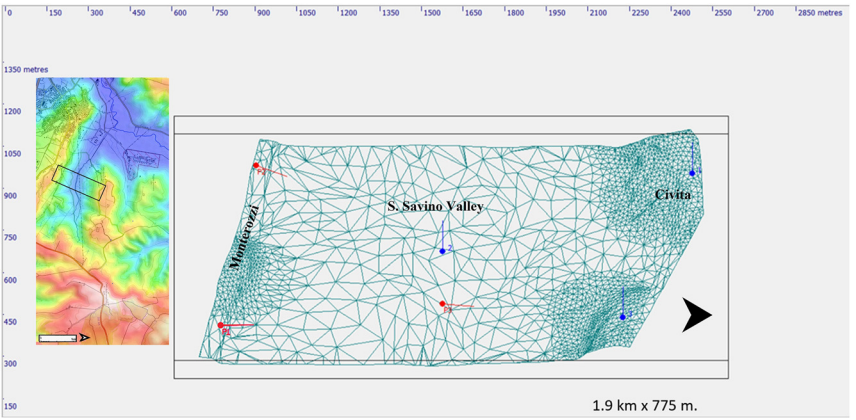

Figure 5: Acoustic model of San Savino Valley in Tarquinia showing the Sound Sources in red and Sound Receivers in blue (acoustic model created in ODEON by J.K. Ortoleva; right map by Yamazaki et al. 2017).

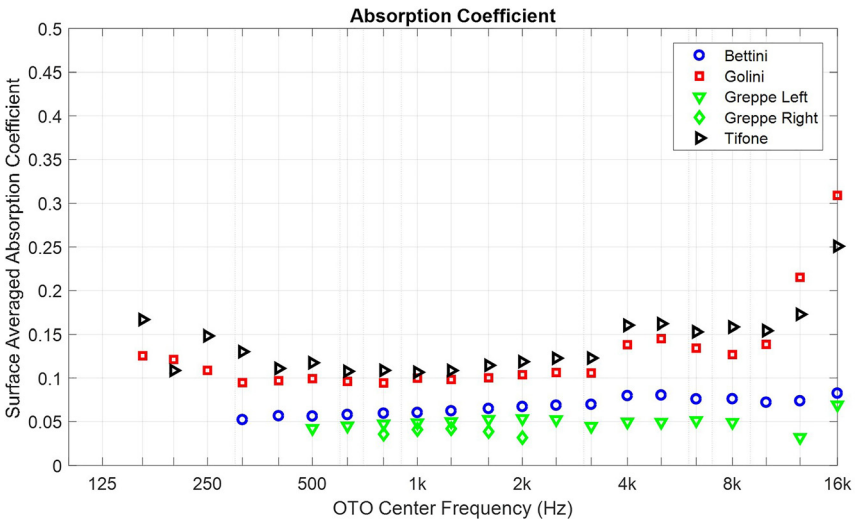

Figure 6: Acoustic absorption values found in several tombs located in Tarquinia, Cerveteri, and Orvieto. Absorption values calculated in MATLAB courtesy of Andrew Barnard, Graduate Program of Acoustics, College of Engineering, Pennsylvania State University.

of multiple chambered tombs in Tarquinia assisted in providing specific acoustic absorption rates for the present model.

The transition order that ODEON uses to consider early sound reflections with respect to the valley walls was adapted to make sure that the sides of each plateau were accurately considered. Once completed, the model was processed with the sound sources (in red) on Monterozzi (placements followed the elevation of a tumulus measuring 2 m) as well as with sound receivers in blue on the Civita. As mentioned, meteorological factors can affect high frequency sounds 2000 Hz and above. Warmer temperatures tend to enhance sounds above 2000 Hz (vocals, whistles) and would have amplified sounds emanating from the city versus the valley, which would presumably have had noticeably weaker sound.[46] Modern Tarquinia is considered part of the Mediterranean macroclimate. During the fieldwork conducted in 2019, temperatures averaged 23.5 °C in May and 20.8 °C in October. Through the sixth century B.C.E., Italy is estimated to have had rainy winters. An average of 670.4 mm of rainfall at Tarquinia was documented between 1951 and 1980 with the rainiest month being November and the driest month July.[47] If wind effects were a part of rainier weather as they are today, this would have affected sound propagation, depending on the direction of the wind.[48]

For the purposes of the study, a "bounding box" was added to the final model to maintain an air temperature of 24 °C and a humidity rate of 65%. The bounding box provides a helpful way to study how different temperatures and humidity would have affected sound across the landscape. Figure 7 illustrates sound propagation generated between Monterozzi and the Civita from a bronze aerophone instrument, such as a lituus. As shown here, depending on surrounding sounds in the city, sounds emerging from the necropolis had the potential to be quite prominent, and during colder months, this effect would have been even more pronounced.[49] Although the valley physically separated the dead from habitation areas, the geological features of the plateaux seem to have simultaneously provided not only a visual connection, but an aural one as well. Although acoustic modeling techniques provide valuable information related to sound propagation in different settings, they are generally followed by fieldwork where a formal

46 A sound field above a valley such as San Savino with uneven terrain, together with a sound source placement at a lower elevation, such as Monterozzi, can result in higher levels of perceived sound versus a sound source and receiver on a level area. Moreover, as previously mentioned, in concave valleys, sound tends to amplify when generated at an elevated slope above the valley floor. The harder bedrock in Tarquinia would have further contributed to sound reflecting off the rock walls of each plateau. These tendencies make it more likely that sound was enhanced at an elevated position above the valley floor. This is demonstrated in the acoustic model depicted in Figures 5 and 6. See: Heutschi 2006 and van Renterghem et al. 2006.

47 De Zuliani 2011, 26.

48 Heutschi 2006; van Renterghem et al. 2006.

49 Bérengier et al. 2003.

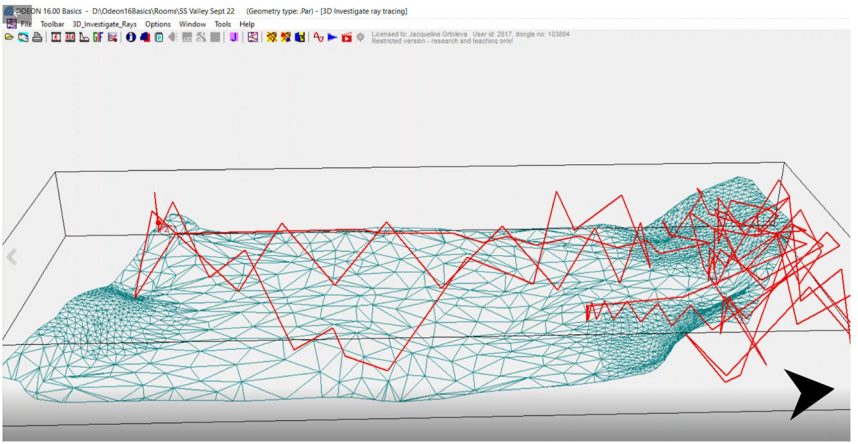

Figure 7: San Savino Valley acoustic model showing sound propagation triggered by a bronze aerophone instrument between the Necropoli dei Monterozzi (east of the Primi Archi) and the Pian di Civita (acoustic model created with ODEON by J.K. Ortoleva).

acoustic protocol is administered to confirm modeled sound propagation. Recent acoustic fieldwork on Monterozzi involving multiple painted tombs provides further insight into the present acoustic model.

Although one may assume that tombs located in the northern sector of the plateau would face the Civita or sanctuary on the Pian della Regina, most do not. Yet the Tomba della Pulcella, Tomba Pallottino and some other tombs on Monterozzi do, and part of the reason may relate more to spatiality, visibility, and sound than to orientation as is often presented.[50] Monterozzi was named after the many tumuli that once blanketed the long plateau, some of which impeded panoramas of the Civita. Late sixth-through early fifth-century B.C.E. Tombs were sometimes arranged in rough formations, which created an open atrium-like area in the center of each arrangement for funerary activities.[51] Such is not the case with the Tomba Pallottino or the Tomba della Pulcella, both of which face the Civita. The Tomba della Pulcella is located in the northernmost sector of Monterozzi (Calvario) and includes a lengthy open dromos that is oriented towards the Civita (Figures 8 and 9). The result of their orientation presented a funerary event that visually and, I argue, aurally connected to the valley and perhaps even to areas of the Civita. The documentation of sound properties in and around della Pulcella's dromos informs the present discussion.

50 Steingräber 1986.
51 Leighton 2004.

Figure 8: The Tomba della Pulcella's dromos facing south towards the burial chamber (photograph by J.K. Ortoleva).

7 2019 Acoustic Survey Method

Three types of measurements are of common focus in acoustic science, namely those involving acoustic reverberation, echoes, and audibility from a distance ISO 3382-1. Although the present discussion focuses on the San Savino Valley, the documentation of echoes directly outside of one of the documented tombs, the Tomba della Pulcella, provides interesting contextual information regarding tombs at the northernmost flank of Monterozzi. In 2019, a formal acoustic survey was conducted in three Etruscan regions, Tarquinia, Orvieto, and Cerveteri.[52] The study analyzed sound propagation with respect to the interior and exterior settings of each painted tomb's burial chamber and dromos using digital and live reconstructions of sound. The sonic examination was performed across three stages: development of acoustic protocol and sound sources; fieldwork (documentation of each tomb using photography, acoustics, and spatial survey); and the analysis of acoustical data using professional software for the measurement of acoustics. Before visiting the tombs, a digitalized sound sample was created based on the musical instruments depicted in the painted tomb record. Multiple surveys

52 Ortoleva 2021; 2022 forthcoming; Ortoleva and Barnard 2021.

Figure 9: Dromos of the Tomba della Pulcella facing north, towards the San Savino Valley (photograph by J.K. Ortoleva).

regarding musical instruments in Etruria were especially helpful here.[53] Ultimately, three instruments were included in the digitized sound source, all of which are depicted in tomb paintings: the double pipe (Figure 10), the lituus, and concert kithara.[54] A female a cappella song (sung in soprano and recorded in an outdoor setting), and handclaps were also incorporated into the final sound source.

Only certain sound sources can be used to document certain acoustic metrics, such as reverberation. These sources require a strong burst of sound that spreads across multiple frequencies, such as a bursting balloon, gun shot, handclaps, and artificial sine waves. Handclaps were chosen for the present study largely due to logistical concerns. The delicate nature of the tomb paintings limited the time spent inside each burial chamber. Half of the tombs also lacked electricity and had steep and lengthy dromoi. Thus, the use of a laptop computer to produce an

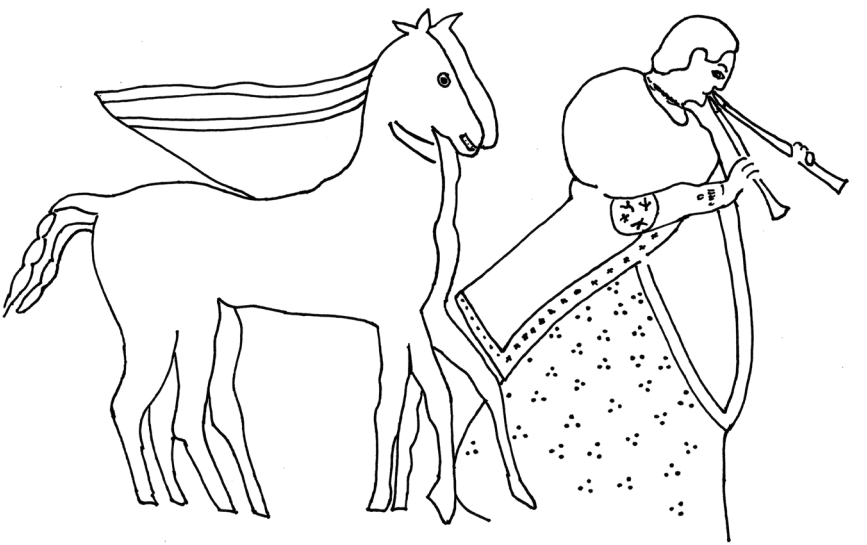

Figure 10: Rear wall of the Tomba Francesca Giustiniani, 500–450 B.C.E., showing a double pipe player (drawing by Joseph Ortoleva).

53 For example, Sarti 2010; Martinelli 2007; Martinelli and Melini 2010.

54 By far, the most common instrument in tomb paintings is the double pipe, which is depicted 69 times in tombs. Chordophone or string instruments are the second most commonly depicted instruments. However, the concert kithara is depicted in only one tomb, the Tomba della Pulcella. The use of the concert kithara in the acoustic study was guided by a sound clip of a concert kithara recorded outdoors without other secondary sounds, which is crucial if one hopes to accurately assess sound.

electronic signal was ruled out. The cognitive-acoustic goals of the study also made human-generated sounds much more suitable than synthetic sources. Following Fletcher, the handclaps spanned across low-high frequencies (26–15.566 Hz) through the use of different hand positions, three of which were flat and two cupped.[55] As part of the digitized protocol, the aural response of each tomb was digitally recorded at six to ten sites inside and outside of each burial chamber (Figure 11). Each sound receiver was placed on a tripod that stood at a height of 1.65 m, which was ascertained from osteological evidence from unpainted Tarquinian tombs.[56] A second acoustic protocol was conducted on subsequent visits to five of the previously documented tombs to consider live musical performance and human speech inside each tomb's burial chamber and dromos. Each visit involved the placement of a musician skilled in playing chordophone (string) instruments to play a chelys lyra in different areas of the tomb in an attempt to understand sound in terms of bodily movement. The second protocol further allowed the documentation of female speech inside each burial chamber and dromos. One acoustic measurement (that of echoes) is especially helpful in terms of Monterozzi's landscape setting.

An echo is generated when a sound travels across 17 m or more and returns back to the listener, giving the impression of a sonic "response." Depending on spatial and topographical attributes of an outdoor setting, an echo can potentially travel long distances, over 200 km, which is striking when one considers that the

Figure 11: Open dromos of the Tomba della Pulcella, c. 450–420 B.C.E. Sound source 1 (SS1) location shown in red and sound receiver placements highlighted in white (ground plan from photogrammetric model by J.K. Ortoleva).

55 Fletcher 2013.

56 Cavagnaro Vanoni 1977, 205–11; Becker 1990, 1993.

Civita is situated a mere 1.5 km across the valley from Monterozzi.[57] Echoes were mathematically calculated in the acoustic program used for the study (EASERA), based on the timing and calculation of sound reflections in response to each separate sound cue (in this case in response to handclaps, female soprano song, female speech, and the musical sounds of a double pipe instrument, lituus, chelys lyra, and concert kithara). With respect to the Tomba della Pulcella, when playing an a cappella song originally performed in an exterior setting by a female soprano, echoes lasting between 2.5 and 7.25 s were documented inside the burial chamber (Figure 12). The sound source was placed 20 m outside of the tomb towards the end of the open dromos and near the northern flank of the plateau (Figure 11). What this suggests is that certain high-pitched sounds, such as female song (sung in soprano, the most common pitch of the female voice) and higher pitched instrumental sounds, such as those generated by a lituus, would have triggered lengthy echoes from the tomb space. How then would such sound effects have sounded in and across the valley, particularly considering the propagation of high frequency sounds as shown in the present acoustic model? As noted, across the valley, the urban center of Tarquinia was composed of two intersecting plateaux that rose above the Necropoli dei Monterozzi. The Pian di Civita stood roughly 155–160 m

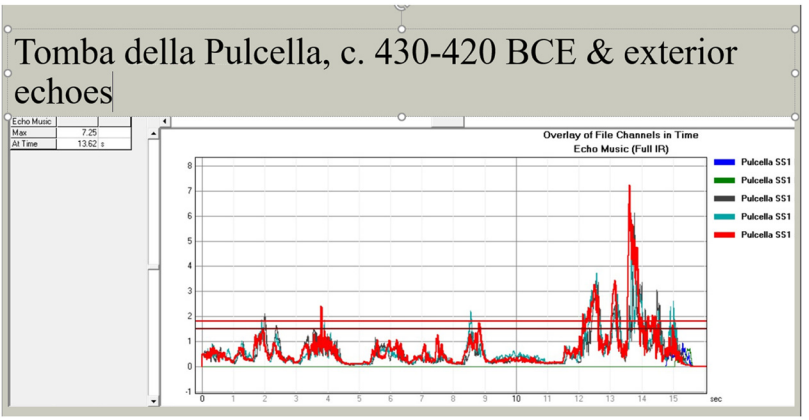

Figure 12: Graph showing the distribution of echoes documented at the Tomba della Pulcella in response to a female soprano a cappella song with the longest echo documented at 7.25 s highlighted in red and the shortest echo documented at 2.5 s (acoustic data assessment by J.K. Ortoleva, using EASERA).

57 See Ross 2001.

above sea level (Figure 2).[58] Moreover, on the connecting plateau, the Pian della Regina, the city's temple, the so-called Ara della Regina, was further elevated atop a large basement.[59] As mentioned, a sound field above a valley, such as San Savino, with uneven terrain together with a sound source placement at a lower elevation, on Monterozzi, can result in higher levels of perceived sound versus a more closely arranged sound source and receiver on level ground.[60] Indeed, the natural slope of limestone plateaux has been found to attenuate sound in other valley settings, particularly with respect to high frequency sounds.[61] The placement of Tarquinia's urban center above Monterozzi suggests that sounds from funerary events likely traveled well outside of the "bounds" of the necropolis to neighboring settlements and areas of the Civita itself.

8 Discussion

When we consider the Etruscan archaeological record, it is striking how prevalent visual representations of sound and music are across different contexts. From media that include musicians and dancers to musical instruments, and multiple Greek and Roman textual sources, sound and aural experience permeate the surviving Etruscan record. It is therefore equally extraordinary that we know so little regarding aural experience in Etruria. Frankly, this lack of acoustic evidence never fully occurred to the present author until personally standing in the middle of the Tomba dell' Orco, c. fourth century B.C.E., or another equally reverberant tomb and witnessing deep cathedral-like sounds emanating from their interior chambers and dromoi.[62] Of course, these experiences are understood through my own cultural experiences, native language(s) and so forth.[63] However, the aural evidence as presented here is not based on subjective experience, but rather an acoustic model supplemented by information from a scientifically sound acoustic protocol.

With this in mind, how can we "make sense" of the aural information involving Tarquinia's landscape setting? The present acoustic model demonstrates that the Civita, and likely other areas of the surrounding landscape (for example, habitation areas such as those located at higher elevations to the east of Monterozzi)

58 Bonghi Jovino 1986, 2001; Bagnasco Gianni and Bonghi Jovino 2012; Marzullo 2018.

59 Bagnasco Gianni and Bonghi Jovino 2012.

60 Heutschi 2006.

61 Heutschi 2006.

62 Ortoleva 2021 details an acoustic survey completed inside the Tomba dell' Orco in 2019. Ortoleva 2022b (forthcoming) details the acoustic nature of some dromoi at Tarquinia.

63 See n. 3.

aurally engaged with its primary necropolis on some level. Even if it was difficult to visualize the burial event from surrounding areas, acoustic modeling of Monterozzi suggests that sound can indeed propagate well outside of the necropolis. Moreover, the landscape setting of Monterozzi together with architectural structures such as dromoi seem to enhance sound effects such as echoes from distances of 20 m. This suggests that funerary observers outside the tomb would have been able to aurally engage with the tomb space even without entering it. Through sound, these different structures seem to extend the spatial bounds of the tomb space and necropolis.

Although we cannot ascertain how such sound effects personally affected those present, the illustration of deity figures in Etruria (such as Cacu, who is depicted receiving prophetic messages from his *lyra*) or imagery showing disembodied heads (some presumably representing Tages) emerging from the earth to sing or speak are pertinent.[64] The identity of the heads is not of particular importance for the present study, but rather the *representation* of sound and aural experience. Such iconography embodies the importance of acknowledging vocal and musical messages from beyond.[65] Ultimately, whether reciting chants, singing, or playing an instrument to receive prophetic messages, sound would have propagated across the necropolis and its environs, potentially connecting the dead with those who chose to honor them.

There are multiple ways in which sound can enhance future studies involving the Etruscan record. These assessments must involve not only the Necropoli dei Monterozzi and its surrounding landscape, but other funerary contexts, chronologies, and regions of Etruria.[66] While acoustic absorption rates ascertained from Tarquinian chambered tombs informed this study, archaeobotanical evidence can assist in further understanding how vegetation growth adapted across different chronologies contributed to changes in sound propagation.[67] The chronological implications of the present study deserve mention as well. For example, a series of large elliptical Iron Age structures on Monterozzi's Calvario sectors are often mentioned, because of their longhouse-like dimensions. What about potential aural engagement between activities conducted in and around the structures and surrounding habitation settings? Moreover, did sound play a role in where

64 Disembodied heads in Etruscan iconography on engraved gems and mirrors are identified as Tages. Other depictions on mirrors and vases amay represent Urphe (Orpheus), Silenus, and Medusa, while others are more difficult to identify. Overall, all of the heads symbolize prophecy, often via speech or song. See Torelli 2000, 529; de Grummond 2000, 30; 2006, 33–4; De Puma 2001.
65 de Grummond 2006; see: Watson and Keating 1999.
66 Ortoleva 2021, 2022a, 2022b.
67 An acoustic study of the funerary landscape is currently under development by the present author as part of a postdoctoral project.

ritualized activities were practiced in and around the Civita? The potential of accruing new aural information, particularly involving different landscape settings, is extensive.

9 Concluding Thoughts

According to Stoddart, the Central Italian landscape provides an inimitable context for a further understanding of human lives and cultural practices.[68] The funerary landscape of the Necropoli dei Monterozzi exemplifies Stoddart's argument across various points of reference. The present data demonstrate that the Tarquinian landscape shaped potential exchange between habitation areas and Monterozzi. However, the wide range of existing scholarship dedicated to clarifying Tarquinia's urban center and its environs have often separated these contexts without any attempt to connect settlement patterns, roadways, and even urban trajectories to the landscapes of the dead. Although we use terms such as "homes of the dead" to describe chambered tombs across Etruria, rarely do we explore *how* such contexts were engaged and what such processes actually involved.[69]

Perhaps one of the most crucial outcomes of the present study involves the "interactive" nature of pressure waves that we call sound. Sound, by its very nature, is generated between different points, thus connecting yet also *extending across* physical and visual boundaries. This is demonstrated with the lengthy echoes documented at the Tomba della Pulcella; it is further illustrated with the present acoustic model and is especially pertinent to our understanding of boundaries in the Etruscan record. To a society as aurally focused as Etruria, it is difficult to accept that "boundaries" were entirely understood from visual perspectives. Sound likely served a primary role in the designation of what was visually perceived as each tomb's boundaries and thresholds. Interestingly, emerging data from the present study strongly suggest that sound phenomena related to the tomb space can be manipulated with different sonic cues. For example, the echoes documented at the Tomba della Pulcella were only triggered with higher-pitched sounds such as female soprano song. Lower-pitched

68 Stoddart 2020, 207.

69 Colin Renfrew has emphasized the importance of looking beyond what the scholar may see in the archaeological record and instead considering how different settings, objects, and even inscriptions were actually used. See: Renfrew 1994; Renfrew et al. 2009. Fernández-Götz, Maschek, and Roymans (2020) provide another interesting take on object-centered agency in Roman archaeology.

instruments, such as the double pipe, did not trigger similarly long echoes. The present aural data therefore have the potential to clarify and perhaps even adapt our understanding of boundaries in the Etruscan record. As illustrated throughout this article, the present aural approach would not be possible without the long history of scholarship involving Etruscan landscapes and music, along with more recent phenomenological studies dedicated to clarifying the funerary record of Etruria.

Whether the surrounding landscape survives intact, partially intact, or not intact at all, the benefit of studying sound propagation and auditory experience in the Etruscan record lies in the importance of the Central Italian land itself. Indeed, landscape studies are crucial to the implementation and assessment of an acoustic study, particularly in the exploration of different topographical and geophysical contexts.[70] A properly administered acoustic study results in objective data that do not rely on the scholar's own senses, but rather on the behavior of sound as guided by spatial and environmental conditions. Resulting data can therefore enrich approaches involving bodily and sensorily guided movement.[71] As seen with the present discussion of boundaries in the Etruscan record, the same may be said regarding spatial analyses inside painted tombs.[72] Scholarship involving musical instruments and iconography in the Etruscan record is also enriched with the addition of acoustic information.

When Tarquinian iconography illustrating dancers and musicians on tomb walls are considered, together with surviving archaeological evidence of musical instruments in funerary contexts and the recent acoustic assessment of multiple painted tombs, such as the Tomba dell' Orco, the Etruscan record suggests that aural phenomena were not underestimated in ancient Tarquinia.[73] To consider different Etruscan settings without any awareness of sound negates this extensive history. The present study is novel (at least with respect to the Etruscan record, as clearly this is the first time that sound has been scientifically assessed in any

70 Carrese, Li Castro, and Martinelli (2010) offer an excellent culmination of scholarship involving musical instruments in the pre-Roman and Roman archaeological record. See also Jannot 1974, 1979, 1988; Martinelli 2007; Martinelli and Melini 2010; Sarti 2010.

71 Phenomenological and sensory perspectives involving prehistoric landscape settings consider bodily movement as well as sensory experience. See for example Hamilton et al. 2006; Hamilton and Whitehouse 2020; Skeates 2010. With respect to the Etruscan archaeological record, P. Gregory Warden has emphasized the importance of looking beyond typologies to consider bodily movement and navigation through space. For example, see Warden and Thomas 1999; Warden 2010, 2013, 2016. Taylor (2020) provides an interesting review of a Chiusine funerary base from the perspective of proxemics.

72 See n. 23.

73 See n. 2.

Etruscan setting), and as such, more questions are perhaps introduced here than are answered. However, not asking such questions results in a fragmented perspective of the Necropoli dei Monterozzi, the Civita, and, I argue, the underlying landscape setting of Tarquinia. While it is perhaps easy to disregard what we cannot aurally experience ourselves when navigating the Necropoli dei Monterozzi today, particularly because it now lacks most of the original tumuli that once blanketed the landscape, it is a mistake to assess the necropolis and indeed its magnificent tomb paintings without considering sound and aural experience as part of the underlying funerary setting. When approached in a scientific manner that draws on the physical and applied sciences, the unique soundscape of the valley connecting Tarquinia's urban center and the Necropoli dei Monterozzi might be allowed to "speak" once again.[74]

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74 See: Renfrew 1994; Stoddart 1995; Warden and Thomas 1999; Warden 2016; Serra Ridgway 2004.

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