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K'ayom amal, the Singing Anuran: a New Organological Variant of Classic Maya Period Double Aerophone

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Abstract

This paper aims to present and acoustically analyze a Late Classic Maya Period double flute with a previously unreported organological configuration. This aerophone features a complex airduct assembly, spheroidal chambers, and exit tubes inserted into the tripod figurine of a standing toad. Computational analyses of the acoustic signal recorded throughout the experimental playing of the flute reveal that the instrument maker purposely designed the sonic artifact to emulate the iterative croak of the depicted anuran. Furthermore, the symbolic impact of the interpreter's gesture is emically studied and correlated with anuran-related Maya iconographic, epigraphic, lexicographic, archaeological, and ethnographic data.

Key words: *Maya, aerophone, organology, musical acoustics, toad (Bufonidae), beats/roughness.*

Resumen

K'ayom amal, el anuro cantante: una nueva variante organológica del aerófono doble del período Clásico maya

Este artículo tiene como objetivo central presentar y analizar acústicamente una flauta doble maya del período Clásico tardío que se caracteriza por una configuración organológica no reportada previamente. Dicho aerófono

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está equipado con un aeroducto que presenta un ensamblaje complejo, cámaras esferoidales y tubos de salida insertados en la figura trípode de un sapo antropomorfo en bipedestación. Los análisis computacionales de la señal grabada durante la ejecución experimental de la flauta revelan que el alfarero diseñó el artefacto sonoro para emular el croar iterativo del anuro. Además, se estudia émicamente el impacto simbólico del gesto performativo del intérprete, el cual se correlaciona con datos iconográficos, epigráficos, lexicográficos, arqueológicos y etnográficos.

Palabras clave: maya, aerófono, organología, acústica musical, sapo (Bufonidae), batimientos/rugosidad.

Résumé

K'ayom amal, l'anoure chanteur: une nouvelle variante organologique d'aérophone double maya de la période Classique

L'objectif du présent article est de faire connaître et d'analyser acoustiquement une flûte double maya datée du Classique Récent, laquelle présente une configuration organologique inédite. Ledit aérophone est équipé d'une embouchure à assemblage complexe, de résonateurs sphéroïdaux et de tubes insérés dans une figurine tripode ornée d'un crapaud anthropomorphisé en position debout. Les analyses computationnelles du signal enregistré lors de l'exécution expérimentale de l'instrument démontrent que le facteur potier conceptualisa sciemment cet artéfact sonore afin d'émuler le coassement itératif de l'anoure. En outre, une étude émique de l'impact symbolique du geste performatif de l'interprète est proposée, laquelle est corrélée avec des données de type iconographique, épigraphique, lexicographique, archéologique et ethnographique.

Mots-clés: *Maya, aérophone, organologie, acoustique musicale, crapaud (Bufonidae), battements/rugosité.*

Resumo

K'ayom amal, o anuro cantor: uma nova variante organológica do aerofone duplo do periodo Clássico maia

Este artigo tem como objetivo apresentar e analisar acusticamente uma flauta dupla do Período Clássico Tardio Maia, que apresenta uma configuração organológica inédita. Este aerofone está equipado com uma embocadura de montagem complexa, ressonadores esferoidais e tubos inseridos na estatueta de tripé adornada com um sapo antropomorfizado em pé. Análises computacionais do sinal acústico, gravado durante a execução experimental

da flauta, revelam que o oleiro concebeu propositadamente o artefacto sonoro para emular o coaxar iterativo do anuro representado. É proposto também um estudo êmico do impacto simbólico do gesto performativo do intérprete, o qual é correlacionado com os dados iconográficos, epigráficos, lexicográficos, arqueológicos e etnográficos.

Palavras-chave: *Maia, aerofone, organologia, acústica musical, sapo (Bufonidae), batidas/rugosidade*.

1. Introduction

Animal-shaped sonic artifacts constitute tangible evidence of extensive ethnobiological knowledge developed by ancient and modern-day cultures. They embody strategies human beings employ to establish relationships with their local ecologies (Fernández and Lepofsky, 2019). Occasionally, artisans design those sound-producing devices to mimic faunal sound patterns and textures (Golemović, 2005; Lewy, 2012, pp. 53, 65; Petrović and Ljubinković, 2011, pp. 102, 115). Such an emulative process implies a meticulous observation of the neighboring biophony, a technical savoir-faire in building instruments, and sufficient knowledge of musical acoustics (Both, 2006, p. 319). Overall, the fundamental reasons underlying this sonic simulative strategy appear to be very diverse. By way of example, many populations have used the biophonical signals artificially generated by decoy flutes and whistles to lure animals in cynegetic practices and pest management since the Upper Paleolithic and Mesolithic (Lawergren, 1988, pp. 34-37; Mannermaa and Rainio, 2020, p. 41; Muller *et al*., 2020). In other cases, these instruments were considered powerful communication tools with spiritual beings, faunal and non-human creatures in ritual context (Brabec de Mori, 2013; Brohée and Stöckli, 2019; Chaumeil, 2011; Hill, 2013; Olivier, 2018 [1997], pp. 400-402). Even though animal-shaped clay aerophones are among the most frequently excavated instruments in Mesoamerica, the correspondence between the call of the featured creatures and the acoustic signal generated by those sonic artifacts is sometimes far from evident and tricky to prove since the original playing techniques generally vanished (Both, 2006, pp. 324-325; Brohée, in press). However, the elaborated organological configuration of some such wind instruments may sometimes evidence the intentionality of the emulative process.

The purpose of the present study is to shed light on an unprovenienced Classic Maya Period double flute held in the Musical Instrument Museum's collections (MIM, Brussels). The wind instrument registered under accession number 1970.001 features a toad in a standing position (Figure 1). Although

its external morphology reminds the numerous Maya tripod vessel flutes or effigy whistles unearthed in the lowlands, highlands, and Pacific coastal Maya areas (Brohée, 2017 [v.1], pp. 139-146, 2017 [v.2], pp. 75-98, 107-113; Flores y Flores, 1981; Gallegos, 2011; Goldstein, 1980; Halperin, 2007, Figs. 13, 17, 18, 23, 26, 28, 42, 2014; Hickmann, 2007, pp. 126-132; Horcajada, 2015; Katz, 2018, pp. 267-270; Michelet, 2014, pp. 198-201, 328-329; Miller, 1975, pp. 16-18; Moya, 2006; Rigatii, 2019), the large orifice in the anuran's pelvic region and the double ducted mouthpiece set it apart from the aerophone types mentioned above. In this particular case, the outer shell of the figurine does not serve as a resonator wall but rather encloses a sophisticated sound-producing system. The radiographic image indeed shows that a complex airduct assembly, two spheroidal resonators (or counter-pressure chamber), and their exit tubes are interconnected in there (Figure 1e). Allowed by its excellent condition, the experimental playing has evidenced that the ceramicist purposely designed 1970.001 to emulate the croaking sound of the featured toad. This research presents an organological characterization, and an acoustic study of 1970.001 to draw attention to the construction techniques and phenomena (beat/roughness) used to achieve this imitative process. Furthermore, we demonstrate that the insertion of the interpreter's hand into the pelvic aperture of the animal was indispensable to trigger the pulsing effect mimicking the iterations of the bufonid call. We suspect that this gestural action had a strong symbolic impact in the context of theatrical sonic performances. To delve into this subject matter, we use the interpretive and sensorial gestural interfaces concepts developed by Kosyk (2019).

Given that 1970.001's archaeological contextual information has been irremediably lost (Brohée 2017 [v.1], p. 149), we briefly examine the role of the batrachians in the Maya worldviews in the hope of puzzling out or somehow clarifying their connection to the sonic, musical, and ritual domains. In the following, we investigate several cases studies encountered in the iconographic record (codex-style ceramics, tripod vessel flutes, carved stele, engraved shell, stuccoed façades, folding manuscript and cave paintings), which emphasize the symbolic association between toads, telluric fertility, abundance, uterine gestation, liminal topographies like caves and Sacred Mountains, the rebirth of venerated ancestors, petition for rain, and the *wahyis* of the Underworld. These themes are further discussed and clarified through the lens of archaeological finds, epigraphic and lexicographic information, or ethnographic accounts. From the strands of data mentioned above, one can assume that anurans were thought to be both malicious and benevolent, which is consistent with their dwelling place since the Underworld is a (re)generation and death location.[1] Furthermore, the toad appeared to be a

[1] Although many substantives exist in the Mayan languages (*i.e. turerk'ajk' in Ch'orti'* [Ramos, 2013, p. 124], *tenb'il q'aq' in Mam* [Ikeda and Pérez Morales, 2001, p. 30], *metnal/mitnal* in Na-

messenger of the otherworld, either of the rain god Chaahk or the Underworld lords. The Maya subsequently interpreted its vocalization as rain-summoning or harmful. Important details concerning the interrelation between the iterative mating call of the anurans and their hypogastric cavity in ritualized contexts will be drawn from the above elements and correlated with 1970.001.

Figure 1. 1970.001, various views (a-d, f), and radiographic image (e).

huatl-influenced colonial-era Yucatec [Barrera Vásquez, 1980, p. 522], *tojmulil* in Ch'ol [Auliet and Auliet, 2009, p. 155], *pa q'aaq' in Tz'utujil* [Pérez Mendoza and Hernández Mendoza, 2001, p. 288], *Xibalba* in colonial-era K'iche' [Christenson, 2003]), the general term "Underworld" will be preferred since 1970.001 is unprovenienced and cannot be linked to a specific Maya group.

2. U nak' le muucho'obo': the belly of the toads

This section briefly examines the role played by batrachians in the regional Maya worldviews to attempt to unravel what might have been their connection with sound, instrumental and ritual practices. To this end, we undertake an iconographic, epigraphic, ethnographic, lexicographic, and archaeological data review.

2.1 Anuran-related religious beliefs and practices among the Maya

Throughout history and in various cultural regions of the globe, toads have commonly been associated with fertility, fecundity, abundance, rebirth and regeneration (Barrera Rubio, 1985, p. 253; Bassie, 2014, pp. 39-40; Campbell, 1998, p. 13; Fordan, 2020, pp. 4, 46, 53; Frost, 1932; Furst, 1981, p. 150; Halliday, 2016, p. 22; Hidayat, 2021; Karslake, 1987, p. 393; Kennedy, 1982, p. 275; Lee, 2019, pp. 24-26; Pallua, 2019; Steiger, 2010 p. 91; Wickler and Seibt, 1982, pp. 442-443; Yuan, 2016, pp. 276-277). Among the Mayan-speaking communities, anurans have been linked with the Underworld, the night, and the primal aqueous medium since the Preclassic period (Barrois, 2006, p. 256; Kennedy, 1982, p. 275; Romero, 2017, pp. 108, 184). Their symbolic connections with telluric fertility, female gender, uterine gestation, or caves can undoubtedly be traced back to the Middle Preclassic period (700-450 BC) (Clarke, 2013, pp. 16-19; Schlesinger, 2001, p. 230; Seler, 1996, p. 301; Steiger, 2010, pp. 73-102). In various monumental artworks such as Izapa stela 11 (Chiapas) and the Balamkú frieze (Campeche), renascent venerated ancestors are expelled upward from the mouth of the toad (Clarke, 2013, p. 31; García Capistrán, 2019, p. 158; Guernsey, 2000, p. 83; 2006, p. 171; Miller and Taube, 1993, p. 168; Salazar, 2014, pp. 135, 159-163, 2017, pp. 168-178). These examples suggest that the body of the anuran was considered a liminal and regenerative pathway connecting the Underworld, the terrestrial, and celestial domains. On the stuccoed walls of the Structure 1-A Sub of Balamkú, three amphibians seated on *Witz* [mountain] zoomorphic masks exhibit hybrid traits of anuran, chelonian, snake, and iguana that hint at their supernatural essence.[2] Such hybridization does not apply to the toad featured on 1970.001. Nevertheless, the hieratic attitude, the upright bipedal posture, the earspools located in the tympanum region, and the parabolic mantilla-style veil worn by the toad evoke other Maya tripod vessel flutes featuring maiden of high social status presiding over religious ceremonies, presumably members of the nobility (Figure 2) (Gallegos, 2011; Moya, 2006, p. 135). Despite a relative stylistic

[2] These masks symbolize an animated mountain with a prominent upper jaw or lip. Stuart (1997) pointed out that such architectonic decorations correspond to the head variant of the logogram T529 [WITZ] (hill/mountain).

standardization of the tripod sound-producing figurines during the Classic period, this similarity with the iconographic theme of the ritual officiants suggests that 1970.001 features an anthropomorphized anuran, perhaps a theriomorphic entity of the Underworld. On a large number of codex-style ceramics, Classic Maya artists effectively depicted the toad as a *wahyis* residing in the Underworld, that is, as a psychic entity that can be expelled at night and transferred to the body of a sometimes malevolent non-human being (*'uwahy* [nagual]) (Velásquez, 2009, p. 594).

The iconographic, ethnographic, and lexicographic records suggest that this entity, probably sometimes beneficent, personifies or causes illness and diseases (Moreno, 2014; Velásquez, 2009, pp. 575-576, 595; Velásquez, 2020, p. 15). Furthermore, only the most powerful and eccentric public figures such as ritualists, rulers, and individuals with congenital anomalies are said to possess and manifest it (Garza, 1984, p. 114; Helmke and Nielsen, 2009, p. 54; Stratmeyer and Stratmeyer, 1977, p. 152; Velásquez, 2009, pp. 594, 612-615). They are thought to oneirically obtain this psychic force from the Underworld lords (Garza, 1990, p. 200). It is also during deep sleep that the *wahyis* is expelled through breathing and transferred to animals or natural phenomena (e.g., rainbow, lightning, wind, cyclone) to cause indisposition to the enemies (Garza, 1987, pp. 100, 173; 1990, p. 34; Hermitte, 1970, pp. 118, 120; Moreno, 2014; Stratmeyer and Stratmeyer, 1977, p. 136; Velásquez, 2009, pp. 604, 616, 627-630; Villa Rojas, 1990, p. 355).

Some Classic period painted vessels effectively show the logogram T539 [WAY, way/wahy] attached to the theonym of the toad (*tzuk…amal*) (Grube and Nahm, 1994, p. 686; Macri and Looper, 2003, p. 67; Moreno, 2011, p. 128).[3] The anuran is usually shown holding an offering plate containing a severed hand, an enucleated eye, and a long bone, which links him with ritual activities (Grube and Nahm, 1994, p. 701; Taube, 2004, p. 70). According to Helmke and Nielsen (2009, p. 53), these bloody dishes indicate that the dismembered human body was the favorite sustenance of such evil creatures. May it be that these body parts symbolized the soul remains of adversaries oneirically subjected and consumed during macabre banquets? If we consider the intricacies of the direct historical approach somewhat relevant

[3] As pointed out by Nájera (2002, p. 137) and Velásquez (2009, pp. 570-634), several studies dedicated to the WAY logogram decipherment have mixed up the concepts of nagualism and tonalism (see also Garza, 1984, pp. 112-126). For his part, Velasquez doubts that the notion of spirit companion (co-essence) is adequate to define the concept of *wahyis*. The term *wahy* could instead refer to an elite auxiliary soul entity, which differs from the animal alter ego that every human being receives at birth. To summarize roughly, the *wahyis* is either an oligarchical psychic force capable of oneirically leaving its fleshy sheath to temporally placing itself inside the organism of a non-human being (esoteric) or the ritual specialist turned (i.e., disguised) into a powerful non-human entity during a public ritual performance (exoteric) (Velásquez, 2020, pp. 16, 20-21).

(Diserens Morgan and Leventhal, 2020, p. 512-513), this might, for example, be suggested by various ethnographic testimonies gathered in the Highlands of Chiapas (Villa Rojas, 1990, p. 614). For example, the Tzeltal informants interviewed by Hermitte (1970, pp. 60, 73-75) in the early 1960s consider that the nagual of the *ak'chamel* (ritual practitioner [sickness giver]) eats the flesh of his victims and steals their ch'ulel (immortal human soul connected to a wild animal companion [co-essence], soulish breath, life force of divine origin) while carrying diseases. However, the author further notes that such naguals also eat the *ch'ulel* of their victims (Hermitte, 1970, p. 114). Could it be that the apparent indistinction between the terms "eat" and "steal" is regarded as a form of metonymy? Following Manuel Arias Sojom's account, a Tzotzil resident of San Pedro Chenalhó (Chiapas), the *ch'ulel* can intentionally or malevolently leave the human body; but this situation may lead to death since the affected person is consequently weakened and considered "meat for consumption" (Guiteras Holmes, 1965, p. 241).

Figurte 2. Tripod effigy vessel flutes (a-b), and hybrid figurine (whistle-rattle) (c), Late Classic period (AD 600-900): AAM 56.1 (Art & History Museum [AHM], Brussels) (a); 4266 (MIM) (b); AAM 4372 (AHM) (c); photographs by Author (© KMKG-MRAH).

It is also worth mentioning the fieldwork conducted by Wisdom (1961) among the Ch'orti' people of the Chiquimula Department (Guatemala). The author's informants consider that powerful ritual specialists are capable of causing diseases by inserting germs into the body of their victims and drawing on small animals such as toads (Wisdom 1961, p. 353). Guiteras Holmes

(1965, p. 124) and Holland (1963, pp. 140, 142) reported something similar concerning the Tzotzil belief system (Chiapas). According to their informants, malicious animals such as disease-bearing toads and frogs can be inserted into the victim's body and cause various sufferings such as fever, headache, or dyspnea. According to the late 20th-century Tzeltal inhabitants of San Juan Cancuc, not every uttered word is perceived by human hearing. Some can harm others' bodies when ritual specialists pronounce or sing them with evil intents. These utterances are said to "travel" independently by entering the body of small faunal bearers such as toads and frogs (Pitarch, 1996, p. 101). In the early 18th-Century, Dominican bishop Núñez de la Vega (1988; Moreno, 2011, p. 83) already described similar practices, reporting that such sinister utterances and breathings could, for instance, be inserted in a toad's belly. Comparably, Madsen's Nahuatl-speaking informants believe that the "nagual-shaman" can house several animal assistants such as malevolent toads in his stomach and send them into their victim's body (Madsen, 1960, p. 201). In the Ch'orti' language spoken by modern-day Maya communities of Eastern Guatemala, the term *ah mutč* [aj muuch] (anuran) is also sometimes associated with the word nak (stomach/abdomen). For instance, the expression "to expel a frog from the stomach" (*look'-se e mutč tu: nak*) refers to the aforementioned customs of spell casting (Wisdom, 1950, p. 1106). Lucia Soc, a Maya woman, born to a Mam mother and a Kaqchikel father, recounts that ritual specialists concoct herbal potions to expel the malevolent toads inserted in the victim's stomach (Miller, 1996, pp. 106-112). These anurans are said to be "filth in the stomach" (*u p'on u nak*), that is, foreign matter sent into the abdominal region by powerful ritualists (Wisdom, 1950, p. 110). It should also be mentioned that the substantive nak sometimes refers to a woman's womb. For example, the expression "*waar a-sam-p' ah u nak"* (her stomach was swelling) means "she was pregnant" (Wisdom, 1950, p. 1116). Moreover, the Spanish loanword *alma* (soul) also refers to the stomach, highlighting that the abdominal region is a body part where the human soul can be endangered (Wisdom, 1950, p. 1125).

Garza (1984, p. 278) suggested that the founding principles of the aforementioned collective beliefs might date back to pre-Hispanic times. As far as we are concerned, we consider that there must be some truth in Garza's assertion. However, it is essential to handle the chronological and regional variables of the above-mentioned ethnographic sources cautiously. Some scholars have shown the necessity to critically demonstrate, rather than to assume, the differences and similarities between the pre-conquest, conquest-era, and modern-day ceremonies practiced by the Maya societies (Christenson, 2016; Diserens Morgan and Leventhal, 2020, pp. 512-513; Meehan, 2013, pp. 37-39; Vogt and Stuart, 2005). In contrast, other academics have criticized the notion of long-term cultural continuity and the perpetual quest among archaeologists for pre-Hispanic models and analogies in contemporary Maya

ritual practices (see e.g., Hervik, 2008). For their part, Borgstede and Yaeger (2008, p. 93) do not argue for or against historical continuity or disjunctions. They advise archaeologists to avoid adopting a pan-Maya perspective when using analogy as an interpretative tool. They should rather «(...) prioritize groups that can be documented to be historically descend from the group under study (...)» and take into account «(...) historical changes that have affected a [this] particular group (...)» and their practices (Borgstede and Yaeger, 2008, pp. 104-105). Regrettably, the loss of archaeological, provenience, and provenance information regarding 1970.001 does not allow for such an approach.

2.2 « I am a messenger; my word is contained in my belly »

During pre-Columbian and early colonial periods, toads were symbolically associated with death due to their nocturnal habits and to the fact that they inhabit the watery surface of the earth, that is, the threshold of the Underworld (Romero, 2017, p. 184). For example, the conquest-era *Popol Wuj* portrays the toad as an emissary of the *Xibalba* lords (*Jun Keme and Wuqub Keme*) (Christenson, 2003, pp. 155-156, 158). The sacred book of the K'ichee'-speaking communities relates that a louse was requested to deliver a message to the hero twins on behalf of the lords of the *Xibalba;* the toad Tamazul offered to swallow the louse in order to speed up the process (Christenson, 2003, pp. 154-159; Romero, 2017, pp. 107-108). So did the serpent Saqiq'as soon afterward by swallowing Tamazul and, later on, the falcon Wak by ingesting the snake. It should be emphasized that the louse, the toad, and the falcon stated that they carried the message in their belly, which reminds us of the abdominal orifice of 1970.001. Given that the Underworld is often regarded as the stomach of the earth (Garza, 1995, p. 13; Sotelo, 2002, p. 107), that is, «(...) a fertile and humid place, like the womb of a woman» (Romero, 2017, p. 218) and that the louse had not swallowed any animal, we suggest that the expression " a message in my belly" (Christenson, 2003, pp. 155-158) metaphorically means that the communication proceeds from the Netherworld. Interestingly, similar scenes have been reported on a carved shell and painted vessels of the Classic period (Figure 3) (Kerr, 2004, Figure 6).

As Milbrath (1999, p. 119) and Velázquez Cabrera (2003) have pointed out, the glyph T740 [SIH?] ("to be born") (Figure 4a) consists of the head of an anuran directed upwards. One can note that what appears to be a sound scroll escapes from its mouth. This logogram illustrates that amphibians personify the concepts of creation, parturition, and regeneration. Furthermore, the sound volute emphasizes the rational connection between their genitive faculties and the deafening collective mating calls they emit. There is little doubt that T740 illustrates their propensity to breed and lay a significant amount of eggs

Figure 3. Unprovenienced engraved shell fragment redrawn by author after Mayer (Hellmuth, 1987, Figure 547).

(up to 35,000 for the *Rhinella marina*) in the rainy season (Clarke, 2013, p. 17; García Magdaleno, 2015, pp. 21, 41). Some scholars argue that the volute flowing out of the amphibian's mouth stylizes aquatic exhalations (Houston *et al*., 2006, pp. 142-144) or drool [U TI'] (Matteo, 2021, personal communication). However, the hypothesis of a graphic representation of their sonorous call seems equally relevant to us. The fact that the body variant of the WINIK glyph (20 days period of the long count) features a toad making a listening gesture, that is, holding the foreleg behind the tympanum while exhaling the aforementioned mouth scroll, might corroborate the hypothesis of its sonic nature (Figure 4d). The archaeological record also attests that the Late Classic Maya linked the breeding powers of amphibians to their vocalizations. For instance, a double-chambered whistle featuring a pair of amphibians engaged in amplexus was unearthed in a fill associated with Yaxchilán's Small Acropolis (Velázquez Cabrera, 2003). The inflated vocal sac suggests that the batrachians were portrayed croaking, while the aerophone was likely designed to mimic their mating or release call.

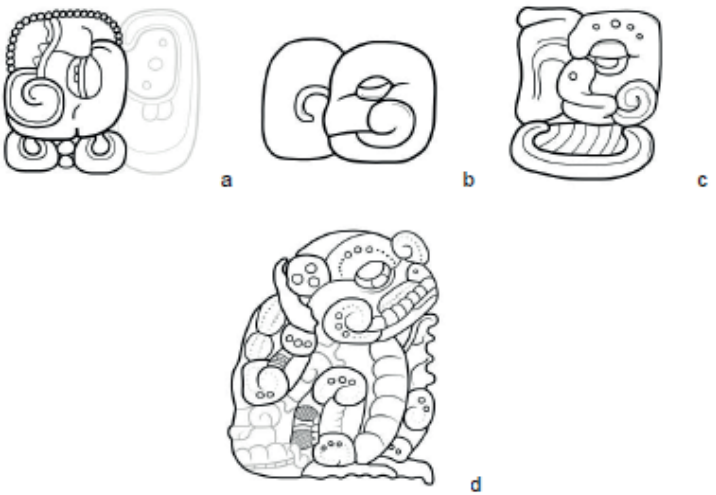


Figure 4. Anuran heads with sound scrolls: (a) T740[:126.181] glyph (SIH?[-ya-ja]), 'to be born [was born]'; (b) T19.741 syllabogram (mu); (c) T19.741v:25 glyph (mu-k[a]), 'burry/hide'; (d) WINIK body variant with three-dotted tympanum (Vector graphics by author after Montgomery [2002]).

2.3 Petition for rain, fertility, and regeneration

Hermitte (1970), Tuz Chi (2009), and García Magdaleno (2015, pp. 73-75) reported various Yucatecan and Chiapan agricultural fertility rites of pre-Columbian origin involving anurans. The informants of these authors consider that amphibians have predictive power since their appearance corresponds to the fall of the first rains (Clarke, 2013, p. 17; García Magdaleno, 2015, pp. 85-86; Hermitte, 1970, p. 63; Tuz Chi, 2009, p. 174). They further believe that it is through their sonorous and iterative call that they can summon this meteorological phenomenon (Bassie, 2014, p. 40; García Magdaleno, 2015, pp. 96, 108-109, 119-120; Garza, 1984, p. 51; Valencia Rivera, 2017, p. 415). Certain anurans are called "sons of Chak" (God B) or "those who grant precipitation" (Valencia Rivera, 2017, p. 414), and they are considered to be the musicians and assistants of the rain god (García Magdaleno, 2015, pp. 110, 113; Garza, 1984, p. 51; Ruiz, 2009, p. 155; Schlesinger, 2001, p. 275; Thompson, 1954, pp. 230, 239; Tuz Chi, 2009, pp. 37-38, 175; Velázquez Cabrera, 2003). For instance, ethnographic accounts gathered in Sisbichen (Chemax *municipio*) relate that amphibians' calls contain a specific message, a prayer that enables them to communicate with non-human entities (García Magdaleno, 2015, pp. 92-93). Similarly, the villagers of Chan Kom believe that toads are the creatures of the rain god and the harbingers of rainfall (Redfield and Villa Rojas, 1962, p. 207). They are said to emerge from the Underworld through land fractures such as cenotes and caves when the *jmen* (ritual specialist) summons them.

Figure 5. Stela 6, Izapa (Chiapas), Late Preclassic (450 BC-AD 250), (Vector graphics by author after Ayax Moreno [Guernsey, 2006, Figure 6.9]).

On the question of agency, that is, the nondeterministic ability of the batrachians to act in the world and affect reality, Izapa Stela 6 (Figure 5) and plate 31 of the Madrid Codex (Figure 6) indicate that they not only had the power to announce or request precipitation but also to expel and outpour the liquid contained in their large belly. Comparing these two works suggests a certain conceptual continuity between the Late Preclassic (450 BC-AD 250) and Postclassic (AD 900-1524) periods. The Izapa bas-relief shows a toad expelling a set of three stacked items. This graphic element has been interpreted as a canoe, a hypothetical reference to the Paddler Gods (Steiger, 2010, p. 77) and mythical passages (Guernsey, 2016, p. 340). However, it seems to us equally probable that this graphic element represented a liquid regurgitated by the anuran. We suggest that this motif was standardized in the Classic period in the form of the HA'AL (rain) glyph consisting of the same U-shaped element and parallel lines of decreasing length that symbolize the spread of fluid (Figure 7). In this regard, it is interesting to note that some modern-day Yucatecan ritual specialists use the word xeej [*xe(e), xeh, xeil* (Barrera Vásquez, 1980, p. 937)], that is, "vomit" to metaphorically designate rain (Guernsey, 2006, p 124; Sosa, 1985, p. 386).

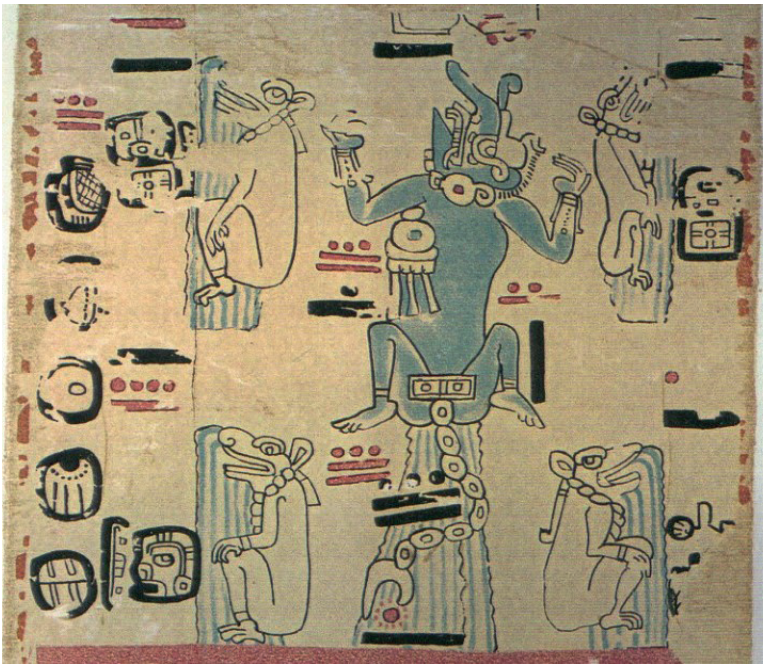


Figure 6. Tro-Cortesianus Codex, plate XXXI (detail), Postclassic period, (Picture: www.famsi.org/mayawriting/codices/madrid.html, © FAMSI).

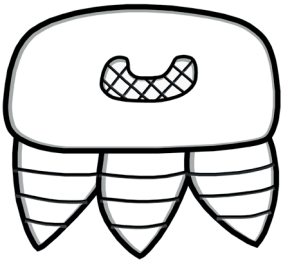


Figure 7. HA'AL (lluvia) glyph (Vector graphics by author after Zender [Stone y Zender, 2011, p. 163]).

From a sonic perspective, Barrera Martin reports that the late 20th-century Maya farmers of the Puuc region commonly believed the sound of toads attracted the rain (cited in Barrera Rubio, 1985, p. 253). In this regard, it should be stressed that the mechanical, periodic, and pulsating iterations of the croak evoke the repetitive and logorrheic prayers of the contemporary ritual specialists (*jmen*), healer and mediator between the cháako'ob (numina of the rain), the *yumtzilo'ob* (general term for "protective numina"), and the

community members (Boot, 1988, p. 38; García Magdaleno, 2015, p. 95; Love, 2011, p. 136; Montemayor and Frischmann, 2021, p. 79; Vail and Hernández, 2013, p. 355). The sanctification prayer of Filiberto Pat Chan (*jmen*) recorded in 2001 in the Yucatecan town of Chanchichimilá (Acevedo *et al*., 2003) and the New Year's prayer recorded in the municipality of Chalchihuitán (Chiapas) by Alderson (1975) are good examples of such performances. As part of his duties, the *jmen* oversees the smooth running of the *cha'a' cháak* (literally "calling out the rain god Chak" and his assistants [Chaks]), a rain petition ceremony of pre-Columbian origin, and the associated *tup k'ak'* ritual ("putting out the fire") (Boot, 1988, p. 30; Love, 1986, p. 10; Meehan, 2013; Ruz, 2002, p. 349; Thompson, 1954, p. 230).[4] In the course of the *cha'a' cháak*, four children tied to each corner of a quadrangular altar that represents the four cardinal points act as anurans and simulate their croaking (Bassie, 2014, p. 40; Boot, 1988, p. 34; García Magdaleno, 2015, pp. 40, 97; Meehan, 2013, p. 38, 40; Ruz, 2002, p. 351; Thompson, 1954, p. 239).[5] According to García Magdaleno (2015, p. 100), those attending or involved in the rite consider that these young people temporarily adopt the essence of said amphibians. Therefore, their call is regarded as a genuine croak. It should be pointed out that the crouched posture of the young boys is reminiscent of the bodily position of the anurans depicted in plate 31 of the Madrid Codex (Figure 6). According to ethnographic accounts, these youngsters vocalize the call of up to seven types of anurans, among which three main species stand out: the léek muuch (*Smilisca baudinii*), the tot muuch (*Rhinella marina*), and the wo much (*Rhinophrynus dorsalis*) (see, e.g. Bassie, 2014, p. 39-40; García Magdaleno, 2015, pp. 78-79). The toad featured on 1970.001 seems to coincide with an amphibian of the buffonid family (Bufonidae), such as the *Rhinella marina* or the *Incilius valliceps* (discussed further down).

For her part, Mary Clarke (2013, pp. 62-67; Clarke *et al*., 2020) reported an archaeological context in which anurans played a fundamental role. The author investigated an Early Classic period sweatbath (Structure 12-F5) unearthed at the site of Xultún (Petén) and referred to as Los Sapos (The Toads). Interestingly, the north façade of this building was decorated with the low sculptural relief of a toad with iguana features (Figure 8). The fact that the doorway of the pib-na (sweatbath) was intentionally located in the pelvic region of the anuran suggests that, by walking into the building, one

[4] The *tup k'ak'* is described in the conquest-era Relación de las cosas de Yucatán (Landa, 1959, pp. 78-79). Meehan (2013, pp. 38-39) diligently pointed out the differences and similarities between the sixteenth-century ceremony and the modern-day version that she witnessed in Yaxcaba in 2011.

[5] Unsurprisingly, rain and fertility petition ceremonies involving children impersonating toads and mimicking their call have been reported outside of the American continent (see, i.e., Hiddayat, 2021).

could symbolically penetrate the batrachian's belly. In all likelihood, the toad personified the sweatbath, an architectural construction that the Mayas cognitively linked to purification, healing, fertility, pregnancy, postpartum activities and sacred landscape elements such as caves and hills (Bill, 2006, pp. 159-162; Clarke *et al*., 2020, p. 67; Moyes, 2005, pp. 187, 205-206; Vogt & Stuart, 2005, p. 168). Given that mountains were considered to be life-sustaining reservoirs filled with water and vital resources (Arnauld, 2016, p. 51; García Capistrán, 2019, pp. 140, 156; López Austin and López Luján, 2009, p. 50), we propose that the abdominal orifice of 1970.001 may have symbolized the threshold of a cave, access point to the rainfall-giving hill and to the Underworld (see further below). Clarke (Clarke *et al*., 2020, p. 83) pointed out that faunal remains consisting mainly of anuran and iguanid skeletons was part of a ritual deposit associated with the pib na (temascal). Since the sweatbath was a place where women used to give birth, the author interpreted the presence of these faunal remains as a symbolic expression of childbirth and pointed out that the crouching position of the amphibian featured on the north facade of Los Sapos was consistent with said hypothesis (Clarke *et al*., 2020, pp. 74, 89).

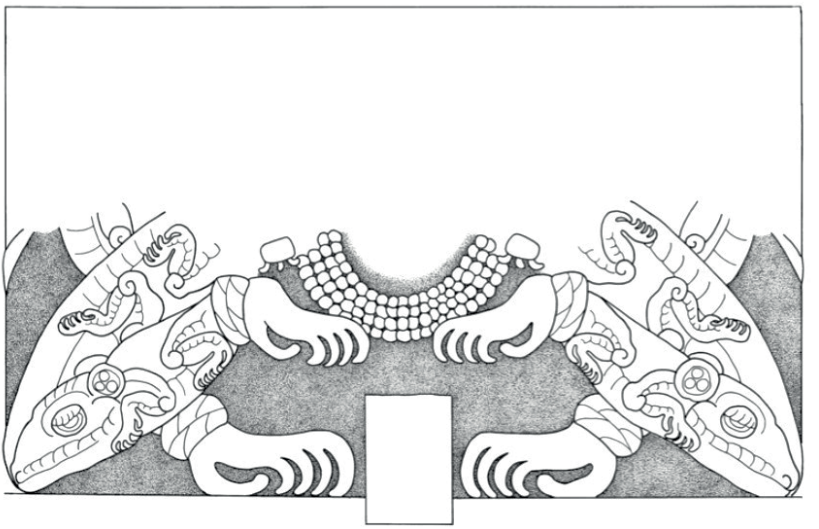


Figure 8. North façade of Structure 12-F5 (Los Sapos), Xultún (Guatemala) (Drawing by Clarke [2013, Fig. 7], Proyecto Arqueológico Regional San Bartolo-Xultún).

Mayan lexicographic data confirms that the toad was symbolically linked to the female genital tract, telluric fertility and caves (Balutet, 2011; Kennedy, 1982, pp. 275-276). By way of example, the Yucatecan term *mu[u]ch* refers to

both the anurans and the female external genitalia (Barrera Vásquez, 1980, p. 532). Although incompletely deciphered, the aforementioned hieroglyphic name of the toads designated as *wahyis* on Classic period vessels consists of two words, tzuk and amal. If amal [ajmal?] refers directly to the toad (Lacadena *et al*., 2010, p. 59), tzuk [tsuk] is of particular interest since it carries several meanings, among which are: hill, belly / abdomen / paunch / animal stomach and "what is inside" (Barrera Vásquez, 1980, pp. 555, 865), "the clouds raised high and denoting, as they say, a storm of water", piling up of various things (e.g., corn silk, trees, horsehair), portion / partition / division, licentious / lustful / lubricious / lascivious, amorality, dirt, fornication, ugly and dishonest (Barrera Vásquez, 1980, pp. 865-867, 949). These examples confirm that, according to the post-conquest Yucatec Maya worldview, the figure of the anuran symbolized the notions of fertility, unrestrained mating, birthing, copiousness, and amorality. Moreover, the animal was linked to abundant precipitation and mountains.

2.4 Sacred Mountain-caves

During the Classic period, caves were believed to be liminal points in the sacred landscape, passageways through which skilled ritualists could communicate with deceased ancestors and entities of the Underworld (Clarke, 2013, p. 30; Salazar, 2014, p. 156, n. 81). It has also been suggested that the mouth of the Classic period zoomorphic Witz (mountain) masks symbolized the threshold of a cave. It is assumed that this cavity interconnected the Underworld and the firmament through the bowels of the Sacred/Flower Mountain (see García Capistrán, 2019, p. 145; Salazar, 2014; Taube, 2004, p. 80). In a mythical landscape, said Sacred Mountain was a place of rebirth of the venerated ancestors.[6] Regurgitated by the toad, these royal personages were depicted emerging from the watery Underworld and ascending to the firmament after their physical death (see e.g., the Balamkú frieze discussed above) (Clarke, 2013, p. 31; García Capistrán, 2019, p. 158; Salazar, 2014, pp. 199-200; Taube, 2004, p. 81). Interestingly, Schlesinger (2001) noted the presence of anuran remains in several Late Classic and Postclassic period funerary contexts: bufonids (unidentified) in Seibal, cane toads (*Rhinella marina*) in Dzibilchaltun, and Gulf Coast toads (*Incilius valliceps*) in Mayapán (Postclassic). If not intrusive, the presence of these anurans might corroborate

[6] Villa Rojas (1969, p. 215) and Hermitte (1970, p. 48) report that the modern-day Tzeltal inhabitants of Oxchuc still interred the most eminent members of a lineage in sacred caves, probably until the first quarter of the 20th century. Unless no longer buried there, grottoes are still places of ritual communication with the ancestors of the clan who are said to dwell there. Predictably, their *ch'ulel* is believed to be located in those entryways of the sacred mountains (Hermitte, 1970, p. 49; Pitarch Ramón, 1996, pp. 49, 79).

Kennedy's (1982, p. 275) assertion that the toad was thought to be a psychopomp. Stuccoed toad reliefs on the plastered walls of various *chultuns* (human-made subterranean chambers) should also be mentioned (Barrera Rubio, 1985; Rissolo 2020, p. 1100). Whether regarded as cisterns (Barrera Rubio, 1985; Rissolo 2020) or artificial caves (Brady and Layco, 2018), these underground spaces dug into the sacred landscape are closely related to water supply, fertility, life-sustenance, and regeneration themes.

On the one hand, archaeological investigations evidence that Classic period music-related ritual activities were undertaken in or around caves. For example, Ishihara (2009) reports that a large number of sound-producing instruments made of fired clay (tubular and vascular flutes, and, to a lesser extent, bone scrappers and small-sized drums) were unearthed in and around the land crevices (caves and rock shelters) of Aguateca's Main Chasm. Given that mist regularly forms in this zone and that ethnographic accounts relate that clouds are believed to emerge from caves (Vogt and Stuart, 2005, pp. 164-165), the author suggests that rain petition ceremonies possibly occurred there. On the other hand, the Naj Tunich paintings provide a remarkable iconographic example of Late Classic period ceremonial events carried out in caves during which groups of musicians and solo dancers performed (Stone, 1995, pp. 140-141, 146, 201, 208-209). Nevertheless, these frescoes appear to show male figures playing only sound artifacts of the idiophone and membranophone types. There is, however, one notable exception in the person of the famous finely depicted goatee wearer individual sitting next to an impressive conch shell (Stone 1995, pp. 198-199). In all likeliness, the marine mollusk exoskeleton's pointy end was sawed off, which means it is a shell horn (lip-reed aerophone). It should be pointed out that this sound-producing artifact probably has the highest sound power level of all Mesoamerican instruments. If played in grottos, the widely regarded "private nature" of Maya cave rituals could have featured loud sound generations (Stone, 1995, p. 181).

In the early 1990s scholars noted the presence of a ritual artifacts assemblage associated with another network caves of the Petexbatún region known as *La Cueva de los Quetzales* (Escobedo *et al*., 1994, p. 435). Among these objects, archaeologists found a large ensemble of portable ceramic drums and vessel flutes made of fired clay (Brady, 2005, pp. 119-121; Brady and Rodas, 1994, p. 452; Emery, 2004, pp. 203, 209). It should be stressed that the grotto's unique access point originally left open was located in the epicenter of the elite zone of the site of Las Pacayas.[7] It is very likely

7 The artificial recreation of the water/mountain-cave (pyramid/plaza-grotto) sacred complex within Las Pacayas's little acropolis is a widespread pattern in the Maya and Mesoamerican politico-ceremonial centers since the Formative times (Rice, 2021, pp. 17-19). In the 12th century, the Great Pyramid of Cholula was dedicated to 9 *Rain Chiconauquiahuitl* (consort of the rain god) by the Tolteca-Chichimeca newcomers (Rojas, 1927, pp. 162-163). This monumental

that the ceremonial deposit was formed by discarding ritual artifacts in this chimney-shaped aperture that connected the site's two main plazas with the vault of a cave chamber (Brady and Rodas, 1994, pp. 452, 456). Interestingly, cane toads (*Rhinella marina*) have been detected within the faunal remains of a representative sample of this ritual deposit. According to Emery (2004, p. 207), the hypothesis of an intrusive nature of this species is unlikely given the conical configuration and particular location of the deposit. These anuran remains might then be interpreted as having played a symbolic role during music-related ritual performances. Given that the grotto entryway was located right in the middle of the politico-ceremonial center of the site, the public nature of the ceremonies undertaken there seems quite patent.

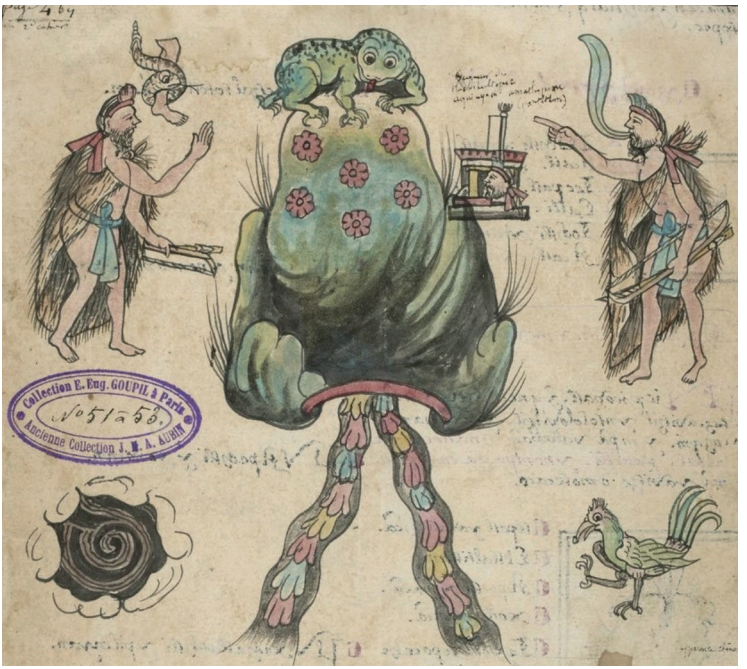


Figure 9. Historia Tolteca-Chichimeca, f. 7v (detail), original manuscript digitized in 2013 by the Bibliothèque Nationale de France, Paris (gallica.bnf.fr).

Colonial-era and Modern-day ethnographic accounts attest that worshipping activities featuring musical performances, dances, and offerings

building was considered an artificial mountain (*tlachihualtepetl*) and rain petition ceremonies were undertaken at its top (McCafferty, 1996, p. 14). *The Historia Tolteca-Chichimeca* (2013, f. 7v) effectively depicts the ceremonial center as a mountain with a cave entryway from which flows out a spring of water (Figure 9). The anuran that sits atop the mountain may possibly be a depiction of the rain goddess *Chiconauquiahuitl*.

undertaken inside or in the direct vicinity of sacred caves are still widespread customs throughout the Maya territory (Josserand y Hopkins, 2007, pp. 106-107; Vogt and Stuart, 2005, pp. 173-175). The request for precipitation and life-sustaining goods to divine ancestors is often the purpose of these rituals (Clendinnen, 1987, p. 50). Moreover, the toad figure appears to be a prominent actor in such a religious context. According to 20th-century Tzotzil Maya accounts gathered in Zinacantán, the *Bankilal Sch'ut* limestone sink is believed to be the stomach of *Yahval Balamil* (Earth Owner) (Vogt, 1969, p. 45; Vogt and Stuart, 2005, pp. 164-166).[8] This presumed modern-day counterpart of a pre-conquest rain god or Underworld lord is called *Anjel* in San Pedro Chenhaló (Guiteras Holmes, 1965, pp. 165-166, 269), or *Yahval Witz* (Mountain Owner) in Chalchihuitán (Kohler, 1995, p. 18). He is said to inhabit the Sacred Mountain bordering the community from which he dispenses life-sustaining goods and precipitation (Bassie-Sweet *et al*., 2015, p. 152). Various Maya groups of Chiapas (Tzotzil, Tzeltal, Ch'ol, and Chontal) and Guatemala (Kaqchikel, Q'ekchi', Mam, K'iche', Chuj, &c.) worship him and visit the porch of his realm (i.e., the cave-mountain). As one may expect, the Classic Maya period rain god Chaahk is also often depicted in stone cave houselike structures (Stone, 1995, p. 35). In the Tzotzil region, ritual specialists perform ceremonies at the threshold of these caves-apertures to communicate with the Earth Owner. For instance, they request rainfall to *Yahval Balamil* at the end of the dry season (Vogt and Stuart, 2005, p. 165). The Earth Owner is also feared because, like the Classic period *wahyis*, he is believed to steal human souls. According to Manuel Arias Sojom's narrative, anyone who wishes to communicate with the rain god *Anjel* should first ask the frog *X'antún* to open his cave portal (Guiteras Holmes, 1965, p. 233; Moreno, 2011, p. 65; Thompson, 1970, p. 268). This anuran-guardian is believed to be the Earth Owner's wife and intermediary (Guiteras Holmes, 1965, p. 166). Her daughter *X'ob* (soul-Mother of maize) can also take the form of batrachian. She spins cotton balls that turn into clouds when struck by *Anjel's* thunderbolt (Bassie-Sweet *et al*., 2015, p. 152).

The Ch'ol Maya people of Chiapas sometimes call the Lord of the Cave *"Chajk"* (rain god), or "Our Grandfather" *Lak Mam* (lightning numen) (Josserand and Hopkins, 2007, p. 103). This personage is believed to reside in a cave on the bank of the Tulijá River with his toad-wife (Hopkins and Josserand, 1990, p. 298). According to Bassie-Sweet (2008, p. xx; Bassie-Sweet *et al*., 2015, p. 153), the modern-day Earth Lord figures parallel the Classic-Period theopolymorph God N/D (*Itzamnaaj*) and his conquest-era counterpart Xpiyacoc as first rainmaker and thunderbolt deity. Probably influenced by modern-day ethnographic accounts such as the *X'antún* myth, she suggests that the

[8] Caves, waterholes, and limestone sinks are all referred to as ch'enetik by the Zinacantecos, that is, "apertures" or passageways to the realm of the Earth Owner (Vogt, 1969, p. 387).

daughter of the Classic-Period Underworld Lord (God L) had a toad form, just like her mother (Bassie-Sweet, 2008, p. 235; Bassie-Sweet *et al*., 2015, p. 203).[9] Since God N/D and God L are assumed to be distinct forms of the "Old Man" theosynthetic entity (Brohée, in press; Martin, 2015), both deities might have hypothetically had a wife and daughter with toad form. If this appears to be purely speculative, God L is still worshiped as an important *mam* (grandfather lord) residing in a cave-mountain. For example, contemporary Poqomchi' and Q'eqchi' consider Xucaneb (God L's modern-day form) the most prominent mountain deity (Bassie-Sweet, 2021, p. 244). He is believed to reside in a cave on the slope of the homonymous Xucaneb mountain (Alta Verapaz). Pilgrims regularly visit him to request rainfall, abundance and fertility (Bassie-Sweet, 2021, p. 245). Ancient cult to rain deities at caves is well exemplified by the life-sized stuccoed masonry sculpture of the god Chaahk at the cave of La Pailita (Petén) (García Barrios, 2007, p. 4; Graham, 1997; Moyes, 2016, p. 178). This now severely damaged carved image in the round has been dated to the Late Preclassic of Early Classic period (Vogt and Stuart, 2005, p. 163).

In view of the above, we suggest that the abdominal orifice of 1970.001 might have referred to the threshold of a cave, access point to the rain-giving hill-womb, and by extension, to the generative substances that it sheltered (López Austin and López Luján, 2009; Stone, 1995, p. 41). The anuran of 1970.001 may have been a sort of visual synthesization of the Sacred Mountain-cave complex and its related religious concepts. Making audible the toad's call as a guardian of the cave entrance and mediator with the human beings might have been a way of requesting an audience to an ancient version of the Earth Lord.

2.5 Contextual conjectures

Although archaeological contextual data loss seriously impedes the interpretation of 1970.001, some preliminary clues can be considered. Given that Maya ritualized sound productions were often a means of communication to invoke gods and non-human beings (Brohée and Stöckli, 2019; Halperin, 2014; Marcus, 2019, pp. 5-7; Sotelo *et al*., 2015, pp. 88, 96-97; Taube, 2004), the toad-flute may have been a ritual communication tool, either with the ancestors and the rain entities that were said to reside inside the Sacred Mountain or with the Underworld numina. In the Popol Wuj, the message of the lords of the Xibalba was carried in the toad's belly. This significant detail undeniably calls to mind the ventral orifice of 1970.001, and the gesture resorted to playing this particular instrument (see § 4.1 and 4.2).

[9] Known as Xbaquiyalo (Lady Bone Water or Lady Egret) in the colonial-period Popol Wuj, she is the first wife of Hun Ixim (Hun Hunahpu) (Christenson, 2003, p. 99).

The presence of a wide circular foramen in the periumbilical region of the anthropomorphized amphibian is also testament to a probable desire to focus the audience's attention on the female reproductive system and, consequently, on the notion of uterine fertility. We have shown that various lexicographic and archaeological information corroborate such hypotheses. Therefore, we suggest that 1970.001 may have been played in propitiatory ritual activities whose purpose was to ensure safe childbearing. By extension, the double flute of the MIM may have been sounded during agricultural fertility and rain petitioning ceremonies, a hypothesis corroborated by pre-Columbian iconographic information and conquest-era ethnohistorical accounts.

However, if we assume that the anuran of 1970.001 was a *wahyis* and considering its sometimes benevolent, sometimes malevolent aspects, the double flute may have enabled either the voice of this numen or the zoomorphic receptacle of this soulish entity (see § 2.1) (Nash, 1975, p. 154; Garza, 1984, p. 118; Velásquez, 2009, p. 630; Villa Rojas, 1963, p. 244). Furthermore, it is interesting to stress that various *wahyis* beings were depicted dancing and playing sonic instruments such as flutes and rattles on Late Classic vessels (see e.g., *k'util hix* [dancing jaguar] in K791) (Moreno, 2016; Sheseña, 2010, pp. 13-15). Finally, given that specific archaeological contexts suggest that anurans were considered psychopomp, 1970.001 could hypothetically have played a sonic role in the course of funeral ceremonies.

3. Iterative croak and beats: organological configuration and acoustic mechanism of 1970.001

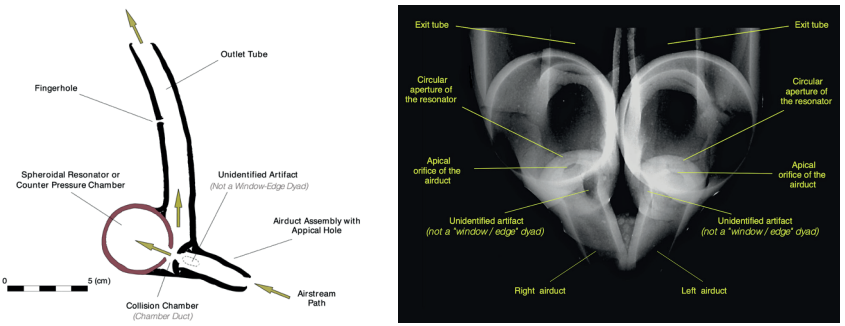
In the following, we examine how the analysis of the organological configuration and the acoustic mechanism of 1970.001 can provide additional information and clarify the concepts presented above. Among the organological characteristics of the aerophone, it stands out that its mouthpiece consists of two insufflation ducts (airducts or windways) connected to two independent tubes open at the distal end (Figure 1e and Figure 10a). Each exit tube is fixed to the rear wall of an independent spheroidal chamber that serves as a resonator or, possibly, as a counter-pressure chamber. A confined area sometimes referred to as "collision chamber" or "chamber duct" (Figure 10a, Figure 11 and Figure 13) (Both, 2008, p. 385; Rawcliffe, 1992, pp. 11-14) interconnects this four-volume system (i.e., airducts, collision chamber, spheroidal chambers, and exit tubes). The length of the tube combined with the volume of the spheroidal chamber determines the fundamental frequency of the sound generated by each flute (Velázquez Cabrera, 2009). At first glance, the radiographic image

reveals the presence of what appears to be a "window/edge" dyad located at the upper edge of the airducts (Figure 1e). However, µCT scans of the mouthpiece performed at the Royal Belgian Institute of Natural Sciences (RBINS) to clarify the exact configuration and morphology of the airducts assemblies disprove this initial assumption (Figure 11).[10] Thus far we did not detect any hole drilled laterally in the airduct or the outlet tube's lower wall that covers it, either using CT scans or a fiber-optic endoscope. Nevertheless, an oval-shaped white coating line is discernible in the corresponding area of the internal wall of the air duct (Fig. 12b). Further research still needs to be carried out to understand better the nature (organological feature, restoration evidence, firing crack, taphonomic alteration, localized merging, density fluctuation, &c.) of this currently unidentified artifact (Fig. 10b). It should be noted that a small external clay wall occludes the bulbous distal end of the airducts (Figure. 10a, Figure 11 and Figure 12b). An apical constricted hole drilled in it is aligned with the narrow aperture of the spheroidal chamber (Figure 10a, Figure 10b and Figure 11). Furthermore, a fiber-optic endoscopic investigation of the mouthpiece showed that both orifices are relatively close (Figure 12c). According to preliminary investigations carried out with instrument maker Osvaldo Padrón Pérez while modeling a single goitered tubular flute replica, it appears that the airstream breaks on the upper edge of the spheroidal chamber orifice and starts to oscillate. The constriction of the airduct outlet not only increases the velocity of the airstream at a constant flow but also enables accurately orientating it. The incoming air jet collides and bounces off the one exiting the spheroidal chamber on the inside of the aforementioned “chamber duct” confined space, thus resulting in complex interactions between turbulent fluid flows and the acoustic field (Coltman, 2006; Dequand, 2001). The care taken in the construction of this junction zone (holes diameters, distance between them, angle, volumes shapes) affects the quality of the timbre, the loudness, the aeroacoustic response, the frequency stability, and the range of the instrument (see e.g., Rawcliffe, 1992, p. 36).

From the aforementioned strands of data, it stands clear that the double flute 1970.001 constitutes a variant of the organological type referred to as “noise generators with tubular air duct” by Velázquez Cabrera (2009), which includes the Classic Maya period goitered chamber duct tubular flutes (Rawcliffe, 1992; Rodens, 2007, p. 133; Rodens, 2011, pp. 927-928, Figure 7-Figure 9; Rodens and Sánchez, 2014, pp. 57-62) and the Aztec noise whistles (Both, 2005a, pp. 34-35; 2005b; 2008, pp. 384-385; Velázquez Cabrera,

[10] Equipment: RX Solutions EasyTOM150 scanner (Chavanod, France). Maximum resolution: 4µm 40-150kV. Vertical sections of a 3-D reconstruction model and experimental fired clay prototypes made by the Mexican ceramist Osvaldo Padrón Pérez (2022) will be presented elsewhere.

2009, 2015). However, it should be noted that the timbre of the Brussels specimen is less noisy, and its harmonic structure is more marked than the "noise generators". This timbral characteristic undoubtedly stems from the mouthpiece assembly features (Figure 10a and Figure 11). Nevertheless, the spheroidal resonators, the enclosing tripod outer shell, the collision chamber, and its connecting features with the outlet tubes strongly impact the timbre of 1970.001 by adding some nasal characteristics, that is, additional energy in the mid-range (500 Hz to 2 kHz) and upper mid-range (2 to 4 kHz) zones of the audio spectrum. The spectrogram indeed shows that partials (*p*) 2, 5, 6, and 9 to 12 are the more marked and that *p1* (fundamental frequency) has less energy than *p2* (Figure 14a). The same is true when the performer plays a single note at a time, that is, when he only blows one blowing duct. Given all the above, we propose the organological designation of "double tubular flute with goiter-shaped resonators and compartmentalized airducts", which has the advantage of not emphasizing the notion of noise perhaps less relevant in the case of 1970.001. In a few words, 1970.001 does not correspond to the categories of the Hornbostel-Sachs (1914) system reconsidered by Montagu (2009) since it is not a vascular flute with an airduct (421.221.4) and with a single fingering hole (421.221.421), or a set of flutes with open tubes (421.222.1) and various finger holes (421.222.12). The aerophone held by the MIM hybridizes both subtypes and presents specific characteristics of the Mesoamerican "noise generators" group. However, its dual configuration and the complexity of its airduct assembly have not been reported elsewhere.



a) b)

Figure 10. 1970.001: section of the left flute [vector graphics by author] (a); radiography of the mouthpiece and spheroidal chambers portion (b).

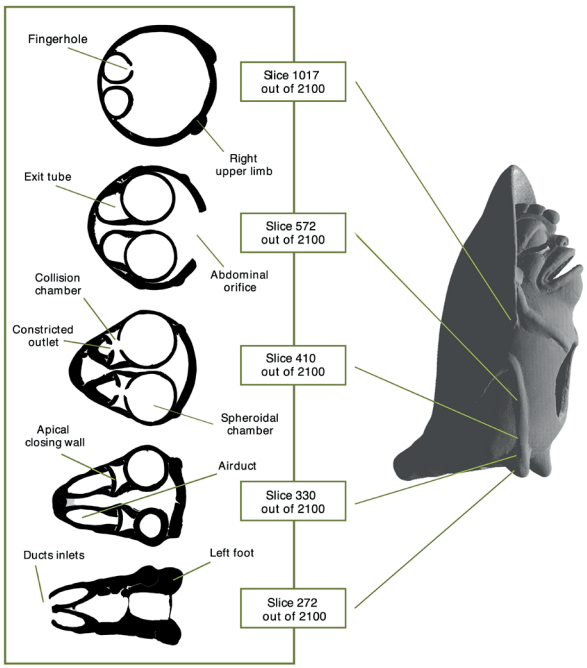


Figure 11. Top-view µCT scans slices (y-axis) and 3-D rendering (right profile) of 1970.001.

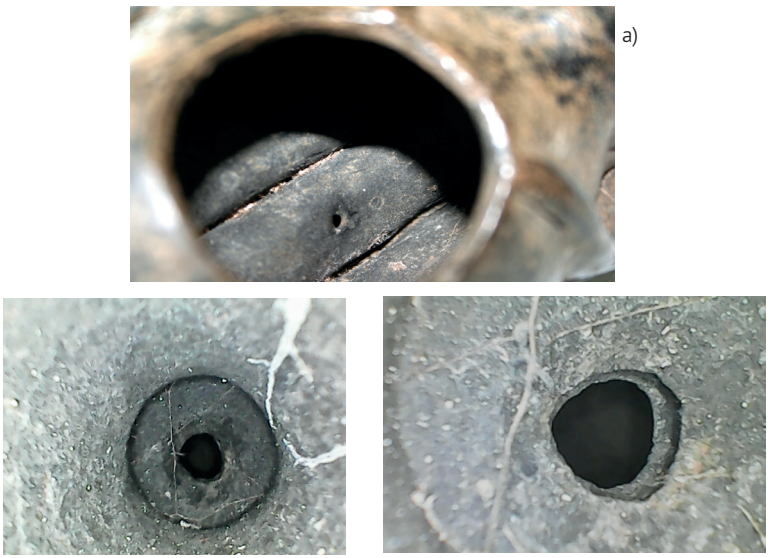


Figure 12. 1970.001 (details): finger hole of the left flute (a); endoscopic images showing the hole drilled in the apical wall of the right airduct (b) and a partial view of the spheroidal resonator aperture (c).

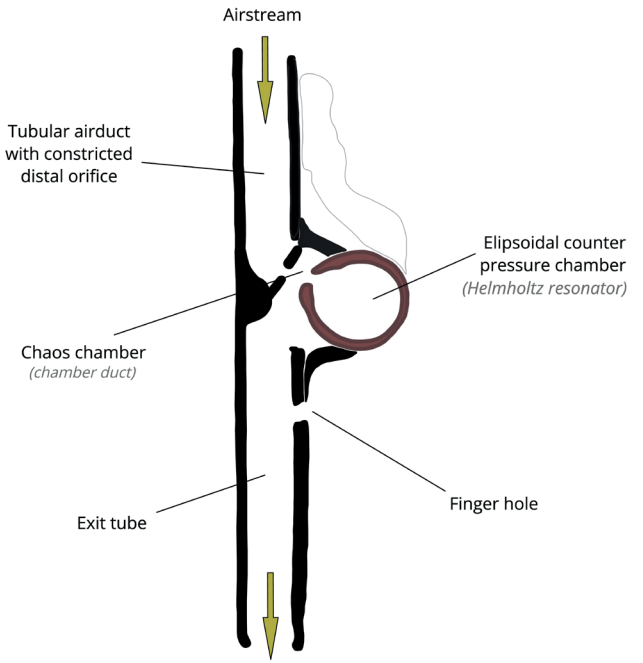


Figure 13. Section of a tubular chamber duct flute (vector graphics by author after Sánchez Santiago [Rodens y Sánchez, 2014, p. 58]).

If the spheroids have the same internal volume, one can easily observe that the two tubes have a slightly different length and, therefore, generate distinct frequencies (Figure 1e). The interval tends towards a semitone and varies depending on the blowing pressure level (Table 1 and Table 2). These near-unison frequencies played simultaneously interfere with one another and generate beats that result from the periodic phase shift of two waveforms of similar amplitude and harmonic structure (Castellengo, 2015, p. 411; Leipp, 2010, pp. 28, 62, 133). This acoustic phenomenon produces a periodic amplitude modulation of the resulting signal whose rate is the difference of the two fundamental frequencies. If the modulation rate varies depending on the range of each partial, it should be pointed out that the human ear primarily perceives the beat frequency of the fundamental tone since all the amplitude maxima coincide with that of *p1* (lowest partial) (Figure 14a). It is crucial to note that a finger hole has been drilled in the longer tube (Figure 1e, Figure 10a, Figure 11 and Figure 12a). Its occlusion increases the interval ratio between the fundamental frequencies generated by each tube since it is null or minimal when unstopped (Table 2). Therefore, we argue that the

finger hole of the left tube of 1970.001 served as a beat trigger since it seems unlikely that it was designed to generate melodies or tonal modulations in the strict sense of the term (Table 1). Moreover, the presence of the finger hole confirms that the search for the pulsing effect was intentional.

Table 1. Frequencies in Hz generated by 1970.001 with the corresponding tones (musical notes with cents deviation) depending on the blowing pressure level

		Long tube		*Short tube*
Blowing pressure level		*Finger hole stopped (f1)*	*Finger hole unstopped (f2)*	*/ (f3):*
Low	Hz	416,7	433	431,8
	♪/cents	G#4 +6	A4 -28	A4-33
Medium	Hz	423	445	445
	♪/cents	G#4 +32	A4 +20	A4 +20
High	Hz	433,2	467	468
	♪/cents	A4 -27	A#4 +3	A#4 +7

Table 2. Beat frequencies in Hz and interval values between left and right tubes depending on the blowing pressure level

		Finger hole of the long tube stopped		
Blowing pressure level		*Subtraction of signals (f3-f1)*	*Beat frequency (fb)*	*Number of semitones*
Low	Hz	431,8-416,7	15,1	0,616 (<1)
Medium	Hz	445 – 423	22	0,877 (≈1)
High	Hz	468 – 433,2	34,8	1,337 (>1)
		Finger hole of the long tube unstopped		
Blowing pressure level		*Subtraction of signals (f3-f2)*	*Beat frequency (fb):*	*Number of semitones*
Low	Hz	431,8-433	(-) 1,2	0,048 (≈0)
Medium	Hz	445–445	0	0
High	Hz	468–467	1	0,037 (≈0)

Is it possible that the designer of 1970.001 intended to emulate the croaking sound of the anuran by devising a beat-generating organological mechanism? When comparing an audio file recorded during the experimental playing of 1970.001 (Audio File 1) with the mating call of the tot muuch (*Rhinella marina*) (Audio File 2), an amphibian species frequently depicted in the pre-conquest Maya and proto-Mixe-Zoque iconographic record (Clarke,

2013; Clarke *et al.*, 2020; Guernsey, 2006; Kennedy, 1982; Mata and Serech, 2015; Romero, 2017, pp. 186-187; Salazar, 2014, 2017; Steiger, 2010), the imitative process appears to be obvious.[11] However, it should be emphasized that toads do not use the same sonic mechanism to generate the iterations of their croak since the anurans emit a single signal, unlike the double flute of the MIM. The iterative sound of the batrachians is characterized by a periodic interruption of the entire spectrum whose pulse rate is determined by the frequency of vibration of the arytenoid cartilages (or, hypothetically, the vocal folds) when expelling the air through the laryngeal cavity (McAlister 1961: 90-91; Toro et al., 2006, p. 3). As Gas (1973, p. 1186) states, "The vocal cords establish a fundamental frequency upon which the vibration of the arytenoids imposes an amplitude modulation." In other words, all partials are interrupted simultaneously, which stands out in the fishbone-shaped waveform of the cane toad audio recording (Figure 14b). Therefore, the term "synchronous roll" should be used here (Castellengo, 1982, p. 7).

Concerning the average beat frequency of the sound generated by 1970.001, that is, 15 to 35 Hz (Table 2), it should be noted that it corresponds globally to the pulse rate of the vocalization of various species of the Bufonidae family, such as the previously mentioned *Incilius valliceps* (32-40 Hz) and *Rhinella marina* (12-20 Hz) (Campbell, 1998, pp. 69-70; Gas, 1973, p. 1187; Muller *et al.*, 2020, pp. 45-46). However, the iteration velocity can vary significantly depending on the size of each specimen studied and its specific morphology (i.e., vocal sacs, pulmonary, arytenoids, and buccal chamber volumes). Velázquez Cabrera (2003) already hypothesized a possible imitative process concerning a group of double toad-shaped whistles (see § 2.2). Nevertheless, the author does not seem to have correlated the emulative process with the beats generated by these aerophones but rather with the playing technique applied, which is tricky to demonstrate. The Mexican researcher considered that these interfered sounds probably helped achieve an altered state of consciousness.

As regards 1970.001, the beat frequency (or pulse rate) turns out to be too low to generate distinctly audible additional tones such as collaterals. Indeed, spectrographic analyses show that partials located above and below (i.e., collaterals) the two fundamental tones (f1 and f1') progressively stand out when the beat frequency exceeds approximately 35 Hz (Brohée, 2019). These partials are generally the exact summation and difference of f1' and f1 (Castellengo, 2015, pp. 120-123). Depending on the register, the wider the gap between fundamental frequencies is, the more audible the collateral tones are. Although detectable in the spectrographic analysis of the signal generated by 1970.001 (Figure 15), collateral frequencies (cf) are too low

[11] Audio File 1 access link: https://soundcloud.com/user-637598693/inv-1970001-corto. Audio File 2 access link: https://soundcloud.com/user-637598693/rhinella-marina.

in amplitude to be perceived as additional sustained tones by the human ear. The complex auditory effects resulting from medium-speed amplitude modulations (between 23 and 35 Hz) produced by the beats generated by 1970.001 have been termed "roughness" by scholars (Castellengo, 2015, pp. 122-123; Pressnitzer, 1998; Vassilakis, 2005). This substantive aims to describe a textured sound whose buzzing timbral features result from a medium-fast amplitude modulation. The experimental playing and acoustic analyses carried out by the author showed that the roughness characterizing 1970.001's timbre does not explicitly lead to a disorienting impact on the listener's sensory experience.

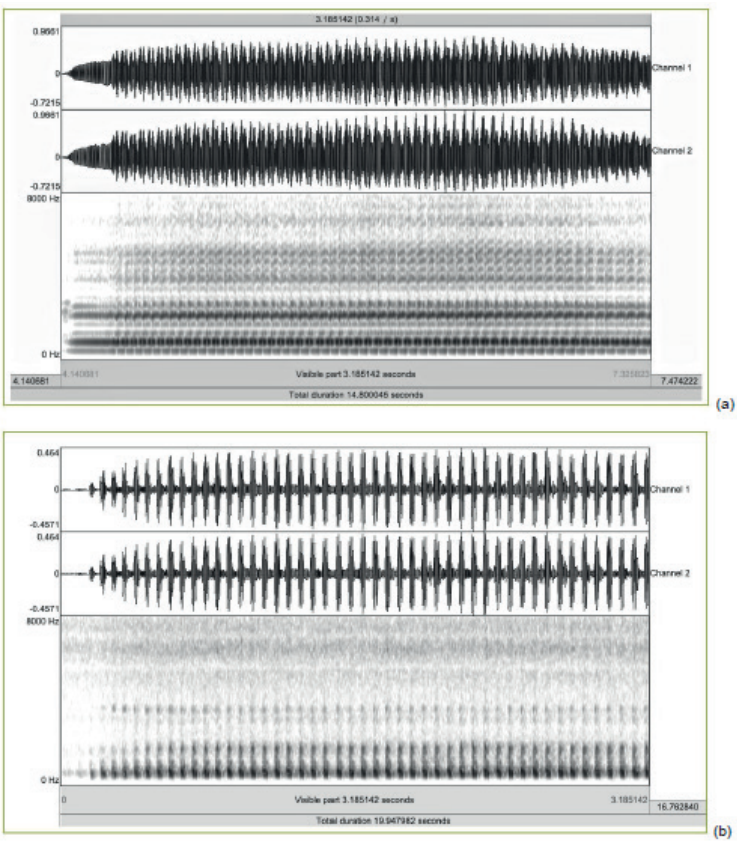


Figure 14. Sepctrograms and waveforms of the acoustic signal generated by: (a) 1970.001, (b) a marine toad (*Rhinella marina*).[12]

[12] The sound of the marine toad was recorded in the Calakmul Biosphere Reserve (Campeche) on June 6, 2018 by the author.

In addition, two sustained loud (at sound pressure from 20 to 65 dB) tones played simultaneously generate a psychoacoustic phenomenon of a third perceived frequency. These so-called combination(al) tones (differential and sometimes summational) are not visible in the spectrographic analyses, possibly because they are generated in the inner ear itself (Helmholtz, 1875, pp. 236-237). Although further research needs to be carried out, scholars hypothesize that this auditory phenomenon might result from a nonlinear response of the basilar membrane within the cochlea or of the auditory cortex (Both, 2005a, p. 96; Brohée, 2019; Giguère *et al.*, 1997; Helmholtz, 1875, pp. 621-623; Rawcliffe, 2008, p. 334). Researchers often consider that beats, roughness, collateral, and combinational tones were sought-after by ancient aerophone makers because they were meant to help reach an altered state of consciousness (ASC) or trance condition (Both, 2005a, p. 306; Hainge, 2004, pp. 8-9; Perkis, 1991, p. 112; Rawcliffe, 2008, p. 296). However, we argue that the differential tones generated by 1970.001 turn out to be too low-pitched (15,1 to 34,8 Hz) and summational frequencies too subtle to have a significant auditory impact on the listener's state of consciousness. For the aforementioned reasons, we state that the beats and roughness generated by 1970.001 primarily had an imitative purpose.

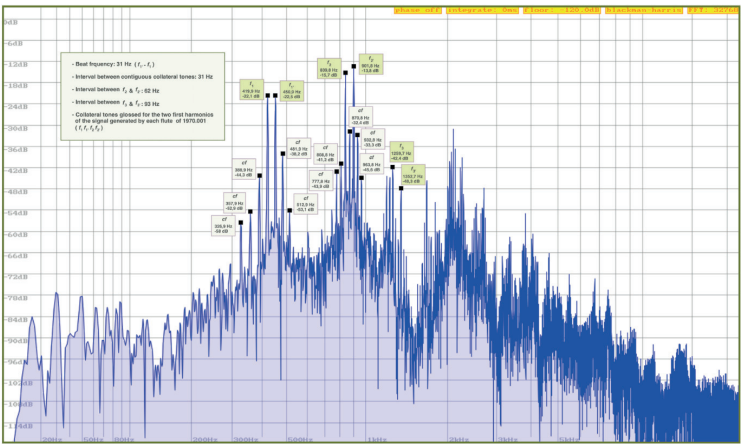


Figure. 15. Spectrographic analysis of the signal generated by 1970.00 (medium-high blowing pressure level; finger hole of the left tube stopped) showing collateral tones.

4. Gestural interface: manipulation strategies of 1970.001

In the following, we explore the hypothetic bodily management of 1970.001 by the Late Classic period performer(s) and its symbolic implications. To this

end, we use the sensorial and interpretive gestural interface concepts exposed by Kosyk (2016, 2019).

4.1 Sensorial gestures

The concept of sensorial gesture (Kosyk, 2019, p. 132) examines how the body movements of the instrumentalist impact the acoustic characteristics of the sound generated. On the one hand, the experimental playing of 1970.001 demonstrated that the toad's abdominal orifice (Figures 1a-c) may serve as a band-stop filter when covered by the palm. Technically, its covering might be partial, integral, or movable and significantly attenuate the mid-range tones around a center frequency of 940 Hz with a bandwidth (fractional octave) of 0.10 and a gain adjustment of up to -42dB (Audio File 3, 1'10"-1'20").[13] However, we do not know whether the Classic-period performers resorted to this playing technique. On the other hand, we had previously stated that the value of the interval between the two fundamental tones generated by the double flute tended toward zero when the finger hole of the left tube was uncovered (Table 2). Therefore, it is evident that the insertion of the hand in the pelvic orifice of 1970.001 (Figure 1a, Figure 1b and Figure 1c) was a sine qua non to stop this finger hole (Figure 10a, Figure 11 and Figure 12a) and trigger the pulsing effect used to emulate the croak of the toad. Nevertheless, we noticed an airstream pressure disparity between the two mouthpiece airducts when the figurine was slightly moved from left to right relative to the insufflation axis. It means that, even when the finger hole of the left tube is left open, the most tenuous body movements of the instrumentalist inevitably caused low frequency (Hz) beats to appear (Table 2; Audio File 3). The experimental playing of the toad-flute also demonstrated that the partial or movable stopping of the finger hole enables to vary the beat frequency considerably. This hypothetical playing technique may also have been used as an additional tool for musical expression (e.g., *rallentandos, accelerandos*, and beat *rubatos*) (Audio File 3). The emic approach leads one to suspect that both the designer and performer of 1970.001 were aware of this organological potential.

4.2 Interpretive gestures

The concept of interpretive gesture tends to determine what may have been the semiotic impact of the body movements of the performer in accordance to the iconographical features, the organological configuration, and the sonorities generated by the instrument in a specific cosmological and cultural context (Kosyk, 2019, pp. 129-131). In general, the interpretive gestural interfaces are closely linked to the sensorial gestures, that is, to the impact of

[13] Audio File 3 access link:https://soundcloud.com/user-637598693/1970-001-improvisacion

bodily actions on the sonic performance's acoustic and musically expressive characteristics. For instance, the fact that the exit of the tubes is positioned to the level of the toad's mouth (Figure 1e) gives a realistic effect, as if the toad was effectively croaking. There is little doubt that the flute maker intentionally designed this organological feature to achieve this gesturally-impacted dramatic sonic effect. As Marcus (2019, pp. 6-7) has pointed out, many scholars have argued that the sounds generated by many Mesoamerican effigy-flutes were possibly attributed to the beings that appeared on them. It is plausible that the insertion of a stream of vital breath in the sonic figurines would have activated the presence of the featured entity (see above) (Velásquez, 2009, pp. 503-504).

Regarding 1970.001, it should be emphasized that the imitative process supports this conjecture since the sound that flows from the toad's mouth has a lot to do with its natural mating call. As we have mentioned several times, this type of acoustic realism requires a bodily action on the performe's part. In the previous sections, we have highlighted that the effigy flute of the MIM was part of a semantic and ritual complex associated with the themes of abundance, fertility, healing, petition for rain, and communication with non-human beings of the Underworld. For example, some Lowlands Maya groups consider that anurans have a belly full of young corn and that touching it grants opulence (García Magdaleno, 2015, p. 74; Thompson 1975, p. 210). They estimate that the toads are in charge of delivering the offerings of *sak ha'* (white water) to the *chaako'ob* (rain entities) and that they carry this concoction in their belly (García Magdaleno, 2015, p. 107; Romero, 2017, p. 80). Exclusively ritual, this beverage was already prepared in pre-Columbian times as offerings to the agrarian entities (Beliaev *et al*., 2010, pp. 263, 266; Houston *et al*., 2006, p. 108; McGee, 1990, p. 48). The fact that the flutist has no other option but to insert his hand in the periumbilical region of the toad to trigger the iterations of its croak seems to link its breeding capacities with its sonorous mating call. This symbolic gesture may have been a way of dramatizing a culturally accepted truism.

Another possible interpretation is that the ventral orifice of 1970.001 referred to the threshold of a cave, that is, an access point to the Sacred Mountain and the Underworld realm. Indeed, various scholars consider that the Netherworld and its cave access are the moist and regenerating belly of the world (Garza, 1995, p. 13; Romero, 2017, p. 218; Sotelo, 2002, p. 107; Stone, 1995, p. 41). Furthermore, we stressed that the herald-animals of the *Popol Wuj,* such as the toad, louse and laughing falcon, carried the message of the lords of the *Xibalba* in their belly. Similar scenes are observable on Late Classic decorated artifacts (Figure 3). Putting the musician's hand into the toad's belly to make him sing would have been a dramatic way of ritually collecting this message. The fact that the figurine concealed the quasi-

integrity of the performer's face may lead to think that he supposedly acquired the essence of the amphibian during the performance . Within this context, a ritual specialist might have been considered capable of bodily turning into a powerful *wahyis* entity through the sound generated by 1970.001 (see exoteric nagualism concept discussed in footnote 3). Since Maya ethnographic accounts and lexicographic data intimate that *wahyis* spirits were located in the stomach (Hermitte, 1970, p. 78; Madsen, 1960, p. 201; Miller, 1996; Moreno, 2011, pp. 31-33; Stratmeyer and Stratmeyer, 1977, p. 131; Velásquez, 2020, p. 20; Wisdom, 1950, p. 1106), the insertion of the performer's hand into the abdominal orifice could have been a way of showing the ritual acquirement of this non-human spirit. As previously discussed, the Maya toad entity has been involved in communication with non-human beings of the Underworld, rain petition rituals, or the cast of spellings.

5. Concluding considerations

This article has endeavored to show that the Maya double effigy-flute registered under accession number 1970.001 at the MIM of Brussels is organologically similar to the said "Mesoamerican noise generators" type (e.g., Aztec noise whistles, Maya tubular noise generators with a counter-pressure chamber). Nevertheless, the complexity of its airduct assembly and dual configuration have not been reported elsewhere. Indeed, no other Mesoamerican double flute of the aforementioned organological type has been brought to the scholars' attention or the general public. Comparing to the noise generators, 1970.001 presents a less noisy timbral feature, that is, a less randomly complex proportion of the acoustic signal. Furthermore, the harmonic series of the generated sound spectrum appears to be more marked. Nevertheless, the spheroidal resonators, the enclosing outer shell of the figurine, and the collision chamber connected to the outlet tubes generate additional energy in the mid-range (500 Hz to 2 kHz) and upper mid-range (2 to 4 kHz) zones of the audio spectrum. Therefore, we propose the following sub-type designation for 1970.001: "double tubular flute with goiter-shaped resonators and compartmentalized airducts".

Since direct archaeological contextual information concerning this instrument irredeemably vanished, we focused mainly on selected excavation reports, iconographic, lexicographic, epigraphic, and ethnographic data in order to examine the role played by batrachians in regional Maya worldviews and to attempt to understand what might have been their connection with sonic and ritualized instrumental performances. On the one hand, it stands out that the sonorous mating call of the anurans resounds at the beginning of the rainy season. For that reason, the Maya symbolically associate them with precipitation, fertility, agrarian opulence, regeneration, Chaahk, and

the sweatbath (*pib na*). Due to the acoustic power of the toad's mating call, its reproductive aptitudes were linked to its vocalizations, a conjecture corroborated by epigraphic data. Moreover, pre-Columbian iconographic data and post-conquest ethnographic accounts showed that the Maya believed that its croak augured precipitation and caused rain to fall. Therefore, we proposed that one of the hypothetical functions for 1970.001 was the petition for rain.

On the other hand, the anuran is often depicted as a malevolent creature (*wahyis*) of the Netherworld in the Classic period iconographic record. He is also an emissary of Jun Keme and Wuqub Keme and establishes a connection between different world layers. We argue that the insertion of the instrumentalist's hand into the pelvic foramen of the toad in order to trigger the pulsating effect that characterizes the croaking sound of the anuran undoubtedly had a strong semiotic impact. Following the interpretive gestural interface concept (Kosyk, 2019, pp. 129-132, 2016), we suggested that the designer of 1970.001 intentionally conceptualized this body action to emphasize the comprehensive link between the toad's croak and its fecund belly. Whether the pelvic hole referred to the notion of fertility or to the threshold of a cave as an access point to the Sacred Mountain and the Underworld remains an open question.

To conclude, a crucial question regarding this aerophone concerns its uniqueness. The apparent absence of other such double-ducted wind instruments is indeed puzzling since 1970.001's probable ritual function(s) seems to have been associated with critical aspects of Late Classic Maya societies (e.g., rain petition ceremonials). One consistent explanation is that the double flute stored at the MIM constituted a technical tour de force and was possibly designed for a special occasion. Highly skilled instrument makers of various workshops might have competed in adapting and re-crafting an out-of-the-ordinary organological variant of a previously known aerophone type (i.e., the aforementioned "noise generators"). It should be pointed out that 1970.001 was probably meant to be played during a private or semi-private ritual involving individuals of relatively high-status. This would be consistent with the organological complexity of this instrument and the exceptional skillfulness of its designer. In contrast, organologically unsophisticated and mass-produced tripod aerophones were extremely widespread during the Early and Late Classic periods (see introduction). It is very likely that the external tripod configuration was globally favored because such vessel flutes and whistles were stored, arranged, and exhibited on altars or in specific places of the sacred landscape like caves (Clendinnen, 1987, pp. 9-10, 73). Be that as it may, the medium acoustic power of the sound generable by 1970.001 does not seem to have been adapted to a rowdy large-scale public ceremony.

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