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The organological system of Pre-Hispanic flutes

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Abstract

Our understanding of pre-Hispanic music is closely linked to our understanding of its organology. Based on extensive research into sound tools in South America, certain considerations will offer a new perspective on the topic as a whole. These considerations add a new layer of complexity to our understanding of pre-Hispanic sound design, which is reflected in the systematic organisation of musical instruments on the continent. I will use the 'antara' type of flute as an example to illustrate some of these developments. 'Antara' is one of the organological categories of Andean panpipes. I will describe three systems used to modify the sound of the antara: the double flute, the complex tube, the *palq'a* tube and the collective flute, which is designed to drastically increase its complexity.

Keywords

South America – Organology – Pre-Hispanic – Flute sound-design - Complexity

1 Introduction

This article presents new perspectives on the organology of pre-Hispanic and inherited sound tools from South America. The research is based on a database that has been collected over almost 50 years, mainly from museums and collections on the continent and abroad. The focus of the study is sound design, meaning the modifications made to an object or its chosen properties involved in sound production. Focusing on the sound design of these objects, the organology methodology is employed and expanded to include some collective playing methods. A key tool in the organology methodology is the musical instrument classification system developed by Sachs and Hornbostel (1914 - referred to as SH), which allows us to observe the design choices that influence sound production in an instrument. It also enables the relationship between these design decisions to be observed and a time-space cartography of them to be generated. In South America, however, this is obscured by the historical fact that European organology became widely known throughout the American continent after the Spanish invasion, while local organology remains largely ignored in

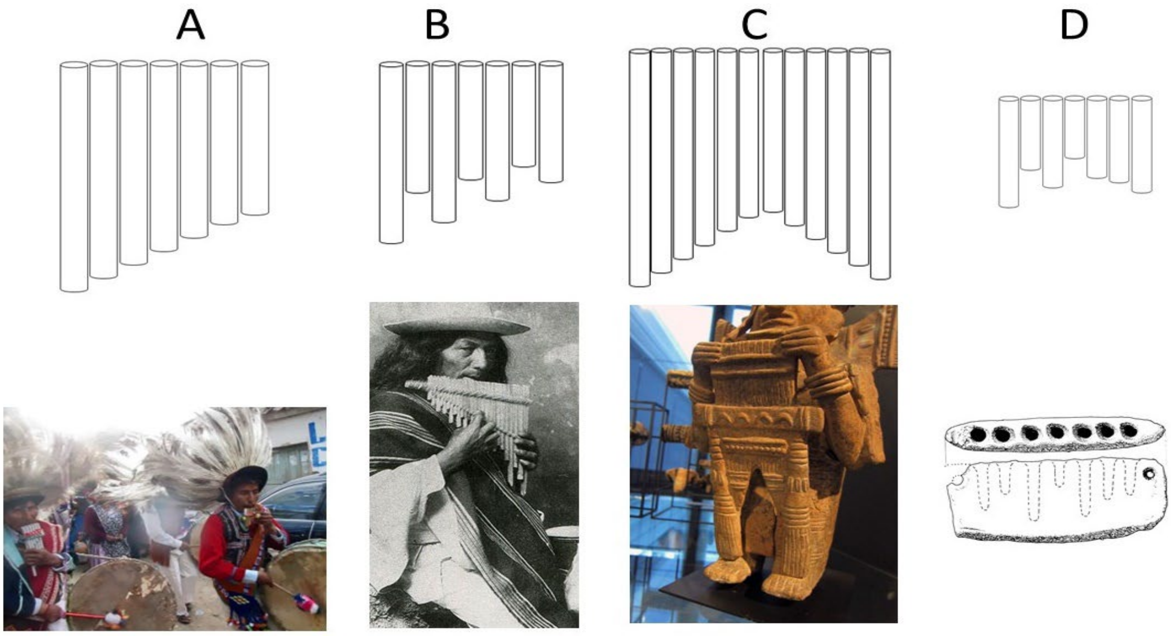

Figure 1: South American panpipe sub-typologies. A) 'antara', photo of Milculpaya feast, Bolivia. Photo: J. Perez de Arce. B) *rondador*. Photo of 'indio' near Quito, Ecuador, ca. 1900. Source: Chiriboga y Caparrini 1994: 99. C) double ladder panpipe Jamacoaque ceramic figure, 44.0 cm, 500 BCE–500 CE, San Isidro, Ecuador. Museo Chileno de Arte Precolombino. D) *piloilo*. stone panpipe with seven tubes, pre-Hispanic, from lago Lanalhue, Chile. 12.8 cm length. Museo Mapuche de Cañete, Ruka kimvn Taiñ Volil-Juan Cayupil Huechicura. Photos: J. Perez de Arce.

historiography. This makes it difficult to clearly and distinctly identify archaeological, ethnographic, or ethnohistoric evidence. I will use these sources of evidence in combination to try to fill the gaps in our knowledge. In the Andes, we adopt the European paradigm of 'music' to categorise musical instruments. This means that, in Andean countries, a local flute, for example, may be regarded by an urban citizen as poor, primitive and uninteresting, whereas for a native it represents the most sophisticated cultural expression. This misunderstanding stems from different perspectives: one focuses on the complexity of the object, while the other recognises the complexity of the sound produced. To understand this, we will review how the sound of a flute can be modified by various mechanisms, some of which are applied to the instrument itself and others to a consort of flutes. I will discuss this using the 'antara' flute as an example. 'Antara', used here as an organological type, is one of the South American panpipe types (SH 421.112.2),[1] with a ladder organization of the tubes in one row, and designed to be used by one person. It differs from the 'siku', another panpipe that is divided into two parts, and played by two persons. [2] Other panpipes types (all subdivisions are a part of only one SH category) are the Equatorian *rondador,* that have an alternating ladder of two different lengths, the double ladder from some Ecuadorian pre-Hispanic panpipes, and the irregular tube organization of the pre-Hispanic mapuche *piloilo*, generally made of stone.

[1] The name 'panpipe', derived from a greek flute, is used to define all the flutes made with a row of edge-blowing pipes. I choose the 'antara', 'siku', 'rondador', 'piloilo' and 'double ladder' names to design the different main panpipe types in America, based on different Andean names; see Pérez de Arce 2021–2025: 548–55, 755–61, 835, 881, 1365–67, 1385–87, 1413–18, 1462.

[2] 'Siku' flute is separated in two parts, 'ira' and 'arka', each with half the notes of the scale. To play, both musicians must 'weave' their sounds to produce the melody.

'Antara' and 'siku' are the two main typologies of panpipes in south America. Both represent one of the most developed types of instruments in the continent, with hundreds of variants, and their description is very complex. 'Antara' typology shows a great variety of instruments with different numbers of tubes, scales, external forms and materials, that has been developed during the last 3,000 years. Due to the simplicity of the basic design, they all share the same ladder structure. However, this simple design can be modified in many ways to produce more complex sounds using sound modifiers. Four such modifiers are used in 'antaras': the 'double flute' system, the 'complex tube' system, the 'palq'a' tube system, and the 'collective flute' system.

2 The double flute

The first type of sound modifier is a combination of two flutes. I will use Nasca ceramic 'antaras' as an example. The Nasca culture, which flourished on the southern Peruvian coast between 100 BCE and 600 CE, produced the most refined 'antaras' on the continent. Many investigators have studied them, including Andrés Sas in 1938, Arturo Rossell, Cesar Bolaños and Carlos Mansilla, and Carlos Sanchez, among others. However, only Anna Gruszczyńska-Ziółkowska realised that some of the finest 'antaras' were constructed in pairs to produce a battement sound. Battement is the vibration of sound produced by microtonal differences between two sounds. The vibration depends on the pitch difference between the two sounds. The battement technique was widely used in the double ocarina of ancient Ecuadorian cultures, such as the Chorrera (1300–300 BCE), La Tolita, Jamacoaque, Bahia, Guangala (500 BCE–500 CE), and Cuasmal and Manta (500–1500 CE). 'Ocarina', used here as an organological category, refers to a globular flute with an air duct (SH 421.222.4). It is easy to produce clear battement sounds using ocarinas because they are easy to play and pitch, and their pure sound blends well with a clear vibrated sound. Ancient Ecuadorian cultures produced hundreds of these double ocarinas[3], influencing other cultures as far away as Faldas del Morro in northern Chile (500 BCE–1500 CE) and Tairona in Colombia (500–1500 CE), and influencing present-day musical practices.[4] When blown, all of them produce a single battement sound. The importance of this sound over 3,800 years was not in its 'musical' properties because it was a single tone, but in the vibratory quality of the sound (Gérard 2015). The importance of this vibrated sound becomes clearer when we analyse the complex tube below. For now, it is sufficient to understand that this vibrated sound is deeply meaningful and involved in the aesthetics of flute playing.

The use of double flutes with a battement sound other than that of ocarinas is rare. Some paired bone vertical flutes with an internal wax deflector as an air duct were found in Arica be-

3 The amount of these double ocarinas with battement sound is greater than those single ocarinas in coastal Ecuador from Chorrera to Bahia periods (Pérez de Arce 2021–2025: 1270–80, 1304–29).

4 Stobart (2016) debated largely on the pulsating 'dissonance' in American instruments, comparing to other world examples, and with different systems of production (double flutes, complex tubes, mirlitons, etc.), in order to call attention not to overemphasizing them. With this paper, my aim is to define the different 'pulsating dissonances' of Andean sound aesthetics, past and present.

Figure 2: Some examples of double 'ocarinas' without fingerholes from the Andes. A) double 'ocarina' whistling jar, ceramic, 34.5 cm, Vicus (500 BCE–500 CE, northern Peru). Drawing showing the two 'ocarinas' inside the heads of the two animals. Museo Chileno de Arte Precolombino. B) double 'ocarina' figure, 20 cm, 500 BCE–500 CE, Jamacoaque Ecuador. It is blown from the upper side, and holds two 'ocarinas' in both arms. Museo de Antropología y Arte Contemporáneo de Guayaquil, Ecuador. C) double 'ocarina', ceramic Faldas del Morro, ceramic and wool, 6.1 cm, 900–200 BCE, Arica, Chile. Museo Chileno de Arte Precolombino. D) double 'ocarina', ceramic, unknown culture, 6 cm, Colombia. Museo del Oro de Colombia. Drawing and photos: J. Perez de Arce.

tween 500 BCE and 200 BCE, and the same instrument is used today by Ishir shamans in Onicha (Chaco, Alto Paraguay). They are made from the bones of a local bird and used to cure certain illnesses (MAI 2515).

Anna Gruszczyńska-Ziółkowska's (2009: 303) discovery of Nasca paired 'antaras', which were used to produce battement sounds, was the first description of the use of this double-flute principle in panpipes.

However, producing a tone with battement was relatively easy with double ocarinas; producing it with a panpipe presented significant challenges as it required the construction of multiple double flutes, one for each tube, with precise microtonal pitch differences. This was only possible thanks to the ceramic skills of the Nasca artisans. The double ceramic 'antaras' demonstrate precise microtonal differences across their entire range of tubes. Battement produces a scale ranging from quick vibrations between high notes to low vibrations in bass notes, indicating that Nasca artisans employed a geometric theory to maintain the same proportions throughout the range of tubes. This enabled them to create a new type of vibrated sound that was not confined to one tone, but expanded to a whole scale – meaning it could play vibrated melodies.

However, the paired 'antaras' require two musicians to play them simultaneously, coordinating their playing so that they sound like a single instrument with a vibrating sound. This type of dual playing was also used in the 'siku', which has already been mentioned. At Nasca times, there was probably a sophisticated playing technique whereby two players produced the sound of a single flute playing a melody. In the 'siku' playing technique, both flutists have to 'weave' their sounds, alternating their notes and becoming one player. When applied to double 'antaras', this technique must be adapted for two simultaneous players, both with the same musical intention, so that they sound like a single instrument playing a single melody. In both cases, the 'siku' and 'double antara' are not two flutes, but one single instrument divided into two parts, played by two people.

Figure 3: Two double 'antaras' from Cahuachi. Nasca (100 BCE–600 CE, southern Peru). Museo Antonini. Source: Gruszczyńska-Ziółkowska 2003: 283.

This means that, in order to produce 'antaras' with battement, the Nasca people had to resort to two solutions. One was related to double ocarinas, which allow sound to be produced with battement. The other solution was based on the 'siku' technique of paired playing. By combining the construction of the double flute with the paired playing technique, they were able to produce the unique panpipes with a battement sound that are known in the history of the continent. These panpipes can play melodies with a vibrated sound. This example shows how Nasca artisans combined two sound designs from different organological sources to create a new one. This complex design was not achieved by making the structure of the object itself more complex; it remains relatively simple. Instead, it was achieved by combining two separate design systems. This principle can be observed in the organological development in South America: rather than searching for isolated complex sound objects, the combination of simpler ones permits the achievement of complex sound designs. The main target of this development is the sound design, not complicated or elaborate music or a complex musical system, but rather the promotion of a special vibrated sound to a new dimension: melody-making. Sound production does not occur in the flutes themselves, but in the interference between them, i.e. in the space between them. This is a psychoacoustic phenomenon that changes depending on the listener's position.

3 The complex tube

The so-called 'complex tube' is a composite, closed-end tube consisting of two or more diameters, wider at the open end and narrower at the closed end. When the length-to-diameter proportions are correct and it is blown precisely, it produces a complex, vibrating sound that is acoustically described as a multiphonic sound with a roll (*multifónico con redoble*, Pérez de Arce et al. 2021). Multiphonic sounds are characterised by the perception of a discrete set of sounds (harmonics and/or partials). 'Roll' (*redoble*) refers to the periodic pulsations of the sound. The sound is perceived as a broad spectrum ranging from bass to high notes simultaneously, creating a dissonant, rough and intense sound that vibrates with a heavy pulse.

Arnaud Gérard (2013) analyses the sound of a pre-Hispanic 'antara' from the Bolivian highlands, describing a large number of partials, some of which reach up to 20 kHz. The first two harmonics are clearly audible, as are the seventh and eighth (1281 and 1455 Hz). The sound consists of two pulses: one quick (170 pulses per second) and one slow (19 pulses per second). The same author (Gérard 2004, 2010, 2013 and 2015) compared the sound of different types of flute with complex tubes, such as pre-Hispanic 'antaras' from Bolivia, the 'pifilka' type of flute (SH 421.111 with 'complex tube') from central Chile[5] and Bolivian 'tarkas' (duct flutes), finding that they all produce a multiphonic sound with a roll, but with a different partial and pulsating structure in each instrument. Similar sounds can be found in some 'quena' flutes from the Bolivian and Peruvian highlands, such as *uxusiris* and *jantarkis*.[6] These are used by the Aymara, Quechua and Mapuche peoples, as well as by Central Chilean mestizos, in 'pifilcas', which are notched and plugged flutes. This sound is known by various names, including *sonido rajado, sonido tara, catarreo* and *gorgoreo*.

The pre-Hispanic use of complex tubes is also evident in many examples. The first examples of these tubes appeared in Kotosh, on the eastern side of the Peruvian Andes. This area was home to a culture dating from 1300 to 800 BCE. However, the tubes themselves cannot be dated, so they may have appeared later. Other examples were found in Paracas (700–100 BCE), in southern coastal Peru, where many dated instruments were discovered. Later, they were found in different cultures in Peru (Nasca: 100 BCE–600 CE; Chimu: 1000–1500 CE), Bolivia (Yura: 500–1500 CE) and Chile (San Pedro: 500–1500 CE; Diaguita: 700–1500 CE; Aconcagua: 900–1500 CE; Mapuches: 1300–1800 CE). Some correspond to 'antaras' and some to 'pifilca' flutes.[7] This demonstrates that the production of multiphonic sounds with a roll was a process that took place over 2,700 years in the Andes, from northern Peru to southern Chile.

There is currently no theoretical formula that allows us to describe the precise relationship between the lengths and diameters of a complex tube and the sound produced, due to the complexity of the behaviour of the nonlinear responses of the acoustic system (Gerard et al. 2016). However, there is an equation that enables us to calculate the fundamental frequency resulting from the interaction of two sections of the tube. Many types of a complex tube with slight differences in their internal geometric proportions have been used by different pre-Hispanic cultures and present-day communities. For example, the proportions of highland Bolivian pre-Hispanic flutes are close to 2/3, while those of pre-Hispanic and present-day flutes in Chile are close to 1/2. Paracas and Kotosh flutes have three internal diameters, some with a semiglobular middle section,

[5] 'Pifilka', used here as an organological category, means a one-complex-tube flute.
[6] As organological category, 'quena' means a vertical flute with an open tube.
[7] A description of this diversity of complex tube flutes can be found in Pérez de Arce et al. 2021.

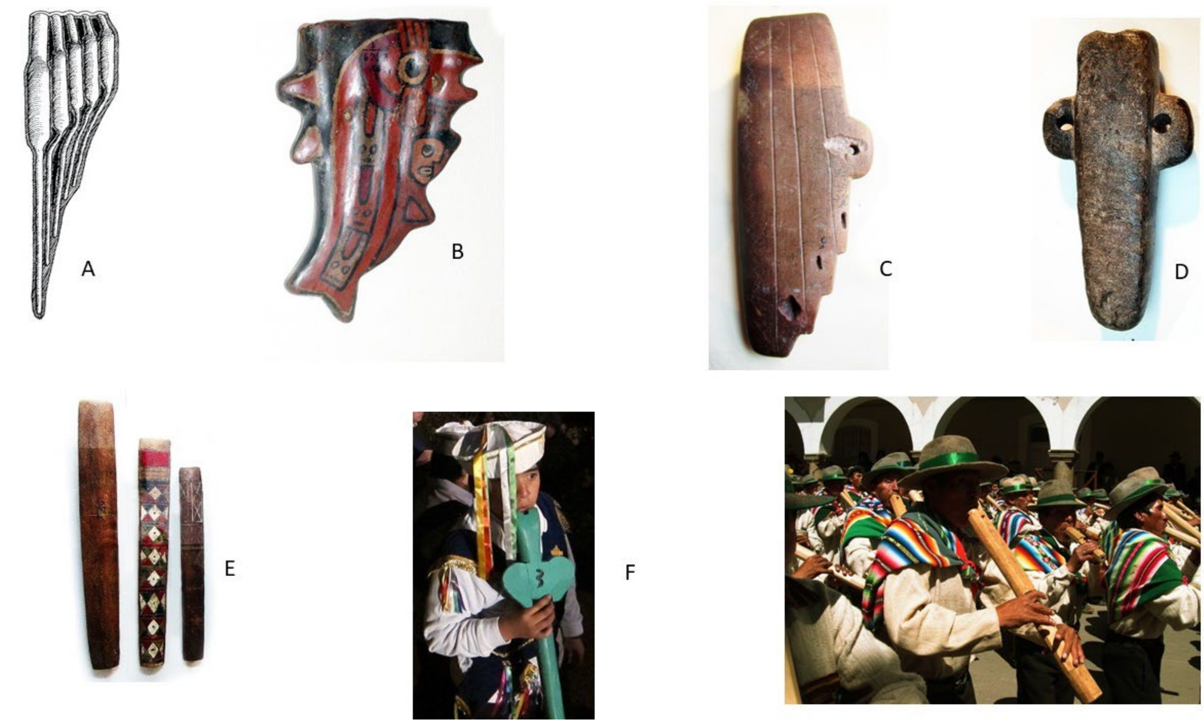

Figure 4: Diverse flutes with complex tubes from the Andes. A) drawing of a ceramic 'antara' with 5 complex tubes. Nasca, 100 BCE–600 CE, southern Peru. Drawing: J. Perez de Arce. B) another 'antara' with 5 complex tubes, 120 mm, Nasca. Museo Nacional de Antropología, Arqueología e Historia del Perú, Lima. Photo: J. Perez de Arce. C) stone 'antara' with 4 complex tubes from La Serena, Chile, 22.5 cm, Diaguita, 1200–1470 CE. The tubes were perforated to 'kill' the sound before putting it into the grave. Museo Arqueológico de La Serena. Photo: Francisca Gili. D) stone 'pifilka' with one complex tube from Antiquina, southern Chile, 11.2 cm. Museo Andino, Buin, Chile. E) three *serére,* wooden flutes with one open complex tube, Bolivia. Museo de Instrumentos Musicales, La Paz. F) boy of the *chino* ritual dance-music in Los Chacayes festivity, holding a wooden 'pifilka' with one complex tube, Chile 2014. G) consort of *tarkas*, wooden plug flutes with 6 fingerholes with a complex tube. Probably from Santiago de Huayllamarca, Nor Carangas, Bolivia, 2008. Photos: J. Perez de Arce.

whereas Bolivian and Chilean flutes have two cylindrical parts. Therefore, the term 'complex tube' does not refer to a single design, but rather to a composite structure consisting of two or three parts with different geometric relationships. What links all these variations is the search for a multiphonic sound with a rolling quality.

The playing technique required to produce this multiphonic sound with a roll is precise and is known in present-day traditions. The musician must adjust the blowing pressure so that it sits right between two regimes, forcing the tube to operate in both simultaneously (Gérard 2015: 58). The vibrating quality of the produced sound can be very intense and is sometimes confused with a battement. However, the structures that produce them are completely different and the multiphonic sound adds a complex partial structure that can produce many battements. In Bolivia, the Quechua people play the *tarka*, a type of plug flute with a complex tube and sound holes. By using different finger positions, the *tara* sound (multiphonic with roll) can be produced, and a *q'iwa* sound (a plain, thin sound with few harmonics, simple and not vibrated) can be produced by using other finger positions. Stobart (1996: 67) discovered that the Quechua-speaking community of Ayllu Macha in northern Potosí, Bolivia, conceived of *tara* and *q'iwa* as two reciprocal and opposing categories of sound and timbre. *Tara* is conceived as something mixed (*mezclado*), something double, always paired: two sounds with two mouths and a complex composition. This is explained as either a broad sound rich in harmonics or a hoarse sound like the voice of a llama in extreme distress or heat, the bark of a dog or fox, the bray of a donkey, the croaking of a toad, or the sound of running water. The word 'tara' also means something productive, wide, balanced, discontinuous, stretched, taut, in equilibrium, even, dual, joined in pairs, high-gendered, arrogant, harsh and obstinate. When speaking, the 'r' sound is emphasised. Conversely, *q'iwa* is conceived as a single sound, like the song of a bird, the high-pitched whining or bickering of llamas, or the sound of someone crying (like a crybaby), or something *ch'ulla* (single, alone, without its natural pair). The word 'q'iwa' also means unproductive things, such as a castrated llama or a white potato. It can also describe someone who is lazy, imbalanced, out of equilibrium, lacking in energy, aesthetically unpleasing, continuous, slack, lax, uneven and cowardly. When speaking, the *q'iwa* sound shortens the vowel sound. Although it is opposite to *tara*, *q'iwa* is not a negative concept; rather, it is a necessary Andean opposition to achieve equilibrium. Therefore, both sounds can be understood as expressing one of the dual paradigms of Andean culture, representing the opposing yet complementary principles that permit an understanding of reality. This may explain the great importance given to vibrating sounds, such as battement and multiphonic with roll. Present-day *chino* musicians have no theoretical explanation for the sound and do not use flutes with a simple sound for comparison with their 'pifilkas'.

The complex tube does not come from a theoretical formula or an understanding of the logic implicit in its acoustic aspects, but from the practice of producing them and testing their sound. Present-day artisans in central Chile produce their flutes by trial and error, discarding only those that do not produce the desired sound. Even modern acoustic specialists cannot understand its physical structure. This is why there are so many variants of the complex tube throughout history and in different cultures. All of these variants demonstrate a search for complex sounds with a heavy spectral composition, forcing the flute to produce high and bass notes with a heavy vibrating quality consisting of two or more speeds. The sophistication of this system lies in obtaining the desired sound, which also implies a precise playing technique to accompany each of the artisans' achievements. This construction and playing techniques have been developed and passed down through many cultures in the Central and Southern Andes over 2,700 years, demonstrating the importance of this specific sound production technique that links vibrated sound with a heavy spectral composition.

4 The palq'a tube

The 'palq'a tube' is an additional row of tubes that adds more partials to the harmonic spectra of the main row of tubes in a panpipe. It is known by many other names, including *palq'a, phallqa, pallqa, sanq'a, shallka, chala, q'asa, kaéharisqa, china, compañía, sirinu, serena, sireni, sirena, haylli, ch'usa, orko, iiojo, falso, falsete, carga* and *resonador* (see Gérard 2018). It is widely used in modern-day 'anta-

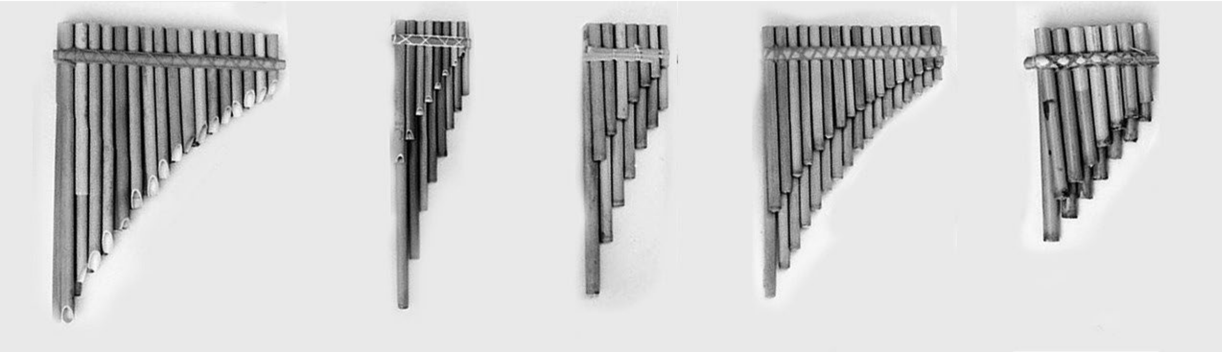

Figure 5: Five examples of *palq'a* tubes; 1/1 open; 1/2 open; 1/2 closed; 3/4 closed, 4/5 closed. Source: Gérard 2018: 13.

ras' and 'sikus' from Peru, Bolivia, Argentina and Chile, as well as in pre-Hispanic panpipes from Peru. This system is unique to panpipes and is not found in vertical or other types of flutes.

Present-day traditions provide a clear idea of its use. The *palq'a* is not blown directly; instead, air escapes from the main tube to produce the sound. This indirect, soft method of playing is known as 'playing with *chusillada*'. When played with this technique, the tube makes a subtle contribution to the sound. Sometimes panpipes are played softly with *chusillada* at the beginning of a tune, for example, and then this contribution is much more intense, slightly blurring the overall sound. This helps the players to find the right notes and adjust their playing until they are all secure and playing in the normal way.

There are many types of *palq'a* tube, each of which is designed to add different partials to the harmonic spectrum. If the *palq'a* tube is of a similar size and open at one end, it produces an octave higher sound by adding all its partials to the sound of the main tube. A half-size closed tube produces an octave higher sound with only the odd partials, while a half-size open tube produces a sound that is double the octave. There are also less common combinations of lengths, both open and closed. In open *palq'a* tubes, the distal end is cut to shorten it slightly and match the exact pitch. This is known as 'end correction' in acoustic terms (Gérard 1999: 119). Each type of *palq'a* tube adds a specific series of partials to the sound of the main tube, modifying it in a different way.

The *palq'a* is designed to modify sound. There are many types of *palq'a*, each designed for a specific sound modification. In Taquile, it is said to add 'taste' to the sound (Bellenger 2007: 140). Each of the thousand or so types of pan flute in use today has traditionally had a specific kind of 'palq'a tube', or none at all. In Bolivia, for example, most 'sikus' have an open 1/1 palq'a (*siku* 45, *siku* 50, *siku* 55, *siku* 60, *siku* 65, *siku* 70, *siku de Aiquile*, *jach'a siku*, *inca siku*, *lakitas de Aiquile*, *lakitas de Guaqui*, *lakitas de Tiwanaku, chiriwanos de Tambocusi, chiriwano de Ayopaya, qantu, qantus de Niño Corin, Palla Palla and Villa Potosí*. The open 1/2 palq'a is used in Bolivia in the *siku de Italaki* and the *siku de General Bilbao* from Potosí. The closed 1/2 *palq'a* is used in modern urban sikus, Argentinian *siku susques* and Peruvian urban *tablasikus* (Pérez de Arce 2021: 94). We can see that the choice of this modifier is usually not optional, but rather a matter of tradition. When making a specific type of panpipe, the artisan knows which type of *palq'a* tube to use. All tubes in a set of panpipes must have the same type of *palq'a* tube, and all consorts of panpipes share the same type of *palq'a* tube.[8] Therefore, we can conclude that the *palq'a* tube is a precise theoretical technology that modifies the sound of flutes. This knowledge is applied in practice, even though the artisan is not familiar with the acoustic physics behind it. However, they are familiar with its sound behaviour, and it is applied to many styles of panpipe.

5 The collective flute system

The collective flute system does not correspond to an acoustic mechanism designed to modify the sound of an instrument. Rather, it is a system that combines several flutes to create a complex instrument, akin to a 'super flute', capable of producing intricate sounds.

Ancient flute ensembles in the Andes and Amazonia were produced by gathering similar flutes and playing them in unison, so the performance resembled a large flute played by many people. This technique is used with various types of flute, including panpipes, plug flutes, notched flutes and 'pifilkas'. The greatest variety and quantity of these instruments can be found in the Bolivian highlands, but they also extend to the Amazon and Central Chile. We can also trace its origins back to pre-Columbian times (Pérez de Arce 2018). Based on this evidence, we can construct a model of the collective flute system that is based on five fundamental principles. These are: 1) all flutes play the same music in unison, 2) all flutes share the same acoustic structure, 3) all flutes have some micro pitch discrepancy, 4) the sizes of the flutes are almost the same or in simple proportions to each other, and 5) the sound produced is slightly unstable due to micro differences in the sound structure of each note. By examining these rules, we can understand this system in terms of its object and sound structure, as well as its performance.

The first rule is that all the flutes must play in unison as if they were one large flute. Each musician plays the same part simultaneously, but avoids playing in strict time, allowing for small differences in rhythm, intensity and expression. The idea is not to merge all the playing into one expression, but rather to reveal the composition of this expression, which is formed from many different voices. There is a 'participatory discrepancy' (Keil 2001) based on a certain tolerance of mistakes that facilitates the integration of new players and people with little musical ability. This enables the orchestra to achieve unity with a degree of dispersion, making collective playing easier. Highland Bolivian musicians in Potosí say that an urban flute ensemble in which all the flutes sound the same is defective, as it does not allow us to see the multiplicity that makes it up (Gérard 2018, personal communication). Depending on the group, there are many ways to achieve this participatory discrepancy; the easiest occurs when beginners make mistakes, slightly deconstructing the musical discourse. In some styles, such as *jach'a sikuris*, experienced musicians intentionally produce errors to achieve the same effect (Castelblanco 2015: 68). The *tropa* usually has a central group of similar medium-register flutes that are easier to play and integrate beginners, masking

[8] This rule, of course, has many exceptions, as described below.

their errors. The bass and acute flutes are played by the best musicians because of their outstanding sound. Urban groups tend to avoid errors and play in strict unison, and sometimes do not accept those who make mistakes, unlike the usual procedure for rural musical ensembles. In this case, the system lacks one of its most powerful social functions.

The second rule is that all flutes have the same acoustic structure. For example, in an 'antara' group, all instruments have the same number of tubes, the same scale and the same type of 'palq'a tubes'. This implies that the ensemble is a multiplication of one type of antara with the same sound design. Usually, one artisan makes an entire ensemble, so all the flutes will have his personal sound design. When all the flutes sound together, they produce an enhanced timbre that is characteristic of this type of flute. This creates the unique sound of each ensemble, which traditionally represents one village. In practice, however, this rule is not absolute. For example, some consorts have large panpipes without the 'palq'a tubes' of the others to make them easier to play. Sometimes the *luriri* is short of reeds and does not put 'palq'a tubes' in all the sikus. Also, at ritual festivals, friends who arrive with slightly different types of flute are accepted (following the participatory discrepancy principle). However, the intention behind this rule is to produce multiple models of siku sound that are enhanced in all their acoustic and performance characteristics.

The third rule is that, among similarly sized tubes, there must be some micro-differences in length to create a 'dense unison', 'dense sound quality' or 'wide unison' (Turino 1988, 1993; Gérard 1999). This unison contains many dissonances and battement. These micro differences in the panpipe consort arise as a consequence of cutting the hundreds of canes needed to build a consort. The same result is obtained in *pinkillos* (vertical cane flutes with six finger holes, SH 421.221.1) using different methods, such as perforating the finger holes slightly out of alignment with each other. This clarifies the intention behind the 'dense unison' sound design. When playing, Andean people tend to intensify this effect by blowing strongly to force the partials and sometimes forcing the octave to change from one note to another. In northern Potosí, *pinkillos* are blown extremely strongly to produce a stammering quality, a battement caused by strong differences in beats (Stobart 1993). Consequently, the music lacks perfect unison and pitch intervals. It is a kind of thick melodic line that we can sing in tune, but which we cannot transcribe due to its complex and unstable microstructure. These micro-pitch differences, which we perceive as being out of tune, are not avoided; quite the contrary. If Bolivians come across a flute orchestra made by urban artisans with perfectly tuned flutes, they reject it, saying that the sound lacks flavour (Gérard 1999: 159; 2010b: 132). In fact, urban troupes tend to tune all their flutes perfectly, following the 'pitch paradigm' that pervades their musical thinking. This causes the *tropa* to lack horizontal social structure, instead becoming vertically ruled.

The fourth rule is that the sizes of the flutes are almost identical or in simple proportions to each other. As can be seen above, flutes of the same size produce a 'dense unison' with a little dispersion. Flutes in simple proportions produce intervals between them with slight dispersion of sound, in accordance with the third rule. Double-sized and half-sized flutes expand the sound to a bass octave and a higher octave respectively. Other sizes (1/4, 1/8, 4/1 and 8/1) expand the sound further. Adding a two-thirds size expands the sound to an upper fifth, and the same process is repeated with upper or lower octaves. There are many other sizes, such as 3/2, which refers to a fifth below the main siku and is repeated at different octaves. There are also rare cases where other sizes are used. The entire system of sizes is very complex, with many names in various combinations (González Bravo 1949; Ponce 2007; Sánchez 1996, 2007; Apaza 2007; Baumann 2004). The rule is that medium-sized flutes are the most common and define the central tone; the different sizes expand the sound by one or more bass or high octaves, fifths, or other intervals. The result is that the consort sounds like an enhanced 'antara' with a greater range.

The fifth rule is that the produced sound is slightly unstable due to micro-differences in the sound structure of each note. This arises from the construction of the consort, in which the micro-pitch differences are distributed randomly among all the flutes. This means that the structure of micro-pitch relations changes randomly from one note to another in the melody. This is perceived as an unstable sound that changes subtly and unexpectedly. This can be understood as an expansion of the participatory discrepancy described in the first rule, providing an incentive for beginners to join. In urban panpipe ensembles, this is usually avoided to generate a more stable, plain sound. These five rules act as an expansion of the characteristics of the flute; they expand its spectral structure by multiplying the number of flutes and expand its sound to include many large and small intervals by multiplying the sizes. The consort operates as a complex system with many layers of complexity, ranging from the acoustic properties of a single flute to the music produced by all the flutes together. The final melody, with its thick, dense unison, complex sound structure and unstable development, emerges from the whole system; it does not exist at the level of the individual flute, but in the relationships between them. This emergence maintains the sound characteristics of the individual flute (its sound design and mode of playing), but transforms them into a complex system of flutes. Thanks to the dispersion of tone, intervals and playing techniques, the result is not only an expansion, but also something more complex and slightly diffused.[9]

On the one hand, the sound is very complex because of the dispersion across many layers (unison, intervals, sequences of sounds and playing techniques), but on the other hand, it is also very unified because of the shared timbre and playing techniques. While dispersion shows the internal composition of the sound and its social diversity, the unified structure is important for participating in the complex scenario of great festivals, where the ensemble must circulate through dense crowds in very noisy contexts. Without training, the collective flute can easily lose its musicality, descending into chaos. When playing alongside other ensembles, a 'sound battle' ensues, testing the unity and cohesion of the ensemble. These 'battle sounds' have been documented among different flute ensembles in Peru (Bellenger 2007: 175–77, 283), Bolivia (where it is known as *batalla sonora*, *choque*, or *atipanakuy*; Baumann 1985: 26; Ajata and Zanga 2013: 44), and Chile (where it is known as *contrapunteo* or *contrapunto*; Mardones and Riffo 2011: 10; Ávila 2012). These

[9] I am referring only to sound production practices between players. Flute ensembles also moves through different resonating spaces, and change it sound trough dances and other type of movements, not mentioned here; see Pérez de Arce 1996, 2018.

sound battles result in the combination of two similar melodies played by similar flute ensembles, producing a 'multi-orchestral polyphony' (Pérez de Arce 1996) – a highly complex sound structure that moves through space (e.g. roads, hills, valleys, streets and squares), enabling each listener to have a unique experience. This musical structure does not correspond to an orchestra, but rather to the convergence of two or more, producing a new layer of complexity in the structure.

In summary, the 'antara' can be seen as a musical instrument, as is normally defined, but much of its description remains in the shadows. Many good scholars have offered this description, including Izikowitz (1935), Vega (1946), d'Harcourt (1959) and Tekiner (1977). They described it as lacking musical knowledge and sensibility, showing an inability to tune instruments, and as a form of primitivism involving monophony and a lack of inventiveness in organising ensembles with different instruments. However, with our knowledge of advanced technologies for searching for vibrated sounds, complex partial structures and unstable and diffused sounds, we can define it as a specific sound theory. The social interactions produced within the collective flute can be described as a cohesive, interactive and reciprocal system. We can also describe the ontological changes produced by the dissolution of the self within the group and the altered states of consciousness brought about by long hyperventilating playing sessions as part of this same system. All these aspects form part of 'antara' playing. Some can be described as the refined sound achievements of local cultures, some as the most refined social mechanism to promote socialisation and some as the most accessible way to achieve personal spiritual change in terms of collective integration and immersion in different states of consciousness. Some of these issues can be found in many types of orchestra around the world, but normally to produce different kinds of polyphony. Here, the aim is to produce complex sounds.

6 Conclusion

We have seen how the Andean people use simple sound objects, such as *antara* panpipes, and sound modifiers, such as *palq'a* tubes and double flutes, to build complex sounds. By applying these same sound modifiers to different types of sound objects, they created a variety of shared sound structures, each with its own musical possibilities. We demonstrate how the antara changed when different sound modifiers were used. Its simple yet versatile original sound structure can be modified in various ways to create battement sounds, multiphonic sounds with rolls, enhanced spectral structures and complex, multi-orchestral polyphonies. These achievements of ancient local cultures are still evident today in many different types of flute, including 'antaras' (Sánchez 1996; Baumann 2004). This exercise reveals some methodological issues to consider when analysing pre-Hispanic 'music'. Firstly, the 'musical' paradigm used in South America excludes much of the cultural significance of Andean pre-Hispanic sound objects. Instead, the 'sound' paradigm is useful for observing that sound structures were important in their own right, independent of the musical context and not restricted to an organological typology. The four examples of 'antara' (paired flutes, palq'a tubes, complex tubes and collective flutes) can be observed in other types of flute if we consider sound production. The differences between these sound production systems lie in the timbre, the spectral composition of the sound and the presence of vibration and sound texture.

Many pre-Hispanic Andean flutes produce only one tone. They have a limited 'musical' role. However, if we consider the 'sound' paradigm, we can observe a dense and varied spectrum of textures. This aligns with the idea of the primacy of sound in Amerindian ontologies, as proposed by the 'sonorism' concept (Schoer, Brabec de Mori and Lewy 2014: 16), and the primacy of hearing as a means of knowing and existing in the world, as proposed by the 'acoustemology' concept (Feld 2013). When we apply these concepts to pre-Hispanic sound cultures, we recognise that the process of hearing is cultural (Polti 2015: 141). Given the importance of entheogenic substances in relation to music, it is clear that 'hearing' must have many implications. All the dimensions of the analysed sound qualities were imbued with meaning, much of which was related to trans-species communication, including with spiritual entities (ancestors, natural forces, etc.). Sound aesthetics then become a kind of language in their own right, operating to relate different layers of reality. These complex sounds can also be studied in terms of their psychoacoustic properties and cultural significance. Some are composed of two elements (two flutes, two parts of the tube, two types of tube), while others are produced not by the objects themselves, but in the space between them (battement and collective systems). These aspects must have been of great importance in the past. Another methodological consequence is that we can use the SH organological system as a layer of complexity – that of single-instrument sound design – and combine it with other systems, such as sound modifiers or the collective flute system. This creates a more complex overall picture, in which the SH system only explains part of it. Other parts can be explained by the relationship between the sound design of the object and the structures that modify its sound, or by playing techniques that are specific to other instruments or the combination of many similar sound design objects to create a collective one. This creates many layers of complexity. If we observe one 'antara', for example, it can be described as a very simple instrument. If we observe the music of the 'collective antara', it can be described as simple monophonic unison playing. However, when we observe the collective instrument, a complex instrument emerges, with many sound structures and relations between flutes and players. Within this, we can describe the simple instrument and music as part of the organological system. This was most probably achieved in several parts of the world many times over, but the combination of simple objects and practices to produce complex systems was a constant feature of pre-Hispanic cultures. For example, the interweaving of two layers of threads produces a complex textile. The logic behind these examples is that combining separate conceptual systems produces a new, complex outcome. If a sound modifier such as a complex tube is applied to multiple sound objects like 'panpipes', 'pifilkas' and 'duct flutes', they will all share a similar sound structure, but their musical capabilities will differ. They can all be considered an organological category outside the SH system, related to a type of sound and the acoustic structure that produces it. The vibrated sound can also be considered an organological category, linked with two sound modifier structures and many SH typologies. By doing so, we can observe one of the most significant and widespread categories of sound in pre-Hispanic South American music, which has endured to this day.

The application of complex systems theory and complex thought, as formulated by Morin (2011), Nicolescu (1996), and Earls (2013), is a valuable approach for exploring these intricate structures within South American pre-Hispanic musical cultures (Pérez de Arce 2022). This allows us to understand the relationship between different interacting systems, how simple structures combine to form complex ones, and the multiple systems that can be observed using different approaches. One of the most clarifying aspects of this theory is the emergence of new properties when combining simple objects and performances, and it adapts well to the way in which pre-Hispanic and present-day indigenous cultures create cultural values. The relationship between musical instruments and sound modifiers is a relevant topic in the archaeological record of music. The Andean perception of 'sound' may be much more sophisticated than we realise. What we usually study is only the acoustic signal produced by certain pre-Hispanic flutes, analysed in a laboratory and described as a physical property of the instrument. However, the way in which pre-Hispanic people perceived this wave was determined by their culture (Polti 2014: 140), and the considerations that open up the complex systems theory, which integrates separate fields into coherent objects of study, can help us to understand these perceptions to some extent.

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