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The ‘*talempong batu*’ Lithophone of Talang Anau (West Sumatra) and its Astonishing Tuning System

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Abstract

In 1995 I was asked to acoustically analyse recordings of a nearly unknown lithophone from a small village in West-Sumatra. The *talempong batu* consists of six large stones of unknown grey to beige material, which look quite rough and natural and are approximately 100 to 150 cm long, 30 to 40 cm wide and 15 to 25 cm thick. All six stones show a complex spectrum with inharmonic overtones that is typical of vibrating 3D objects. The interval matrix between the lowest partials of all six stones was determined. The analysis of the tuning system showed quite unexpected results: the four lowest stones establish a complex system of intervals, which perfectly matches some intervals that are known as perfect major third (5/4, 386.31 cent), ‘Pythagorean’ ditone (81/64, 407.82 cent), and syntonic comma (81/80, 21.51 cent). The deviation between these theoretical intervals and the measured intervals from the instrument is less than the just-noticeable pitch difference (JND) that the human ear can detect. If it is assumed that this system did not simply evolve by chance, its existence allows us to draw some important conclusions on the cultural background and capabilities of its creators.

Keywords

Lithophone – Tuning – Indonesia – Sumatra – Pythagorean intonation – Just intonation – Syntonic comma

1 Background

Back in 1995, when I started my career as research assistant at the Department of Musical Acoustics at Cologne University, my ethnomusical colleague Uwe Pätzold returned from field studies that he had conducted in Indonesia in 1994/95. He told me that he had been made aware by some local acquaintances of an interesting stone instrument called *talempong batu* in a small town in the mountains, which had so far received little attention from the scientific community. Although this

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subject had little to do with his main research interests, he decided to visit the instrument and to make some systematic recordings of the instrument and its local environment.

Back in Cologne some months later, he asked me to conduct some acoustical analyses of these recordings, mainly related to the sound characteristics and the tuning system of the instrument. At first glance, this didn't seem like a big deal – until the analyses revealed some quite astonishing results.

We presented our findings in two separate German conference talks, one from the ethnomusicological and one from the acoustical perspective. Unfortunately, for several reasons the proceedings of this conference were not published until 2003 (Louven 2003; Pätzold 2003) and didn't gain much attention in the scientific community. In retrospect, it would probably have been wiser to publish the results in an English-language international journal as early as 1995.

Even today, the *talempong batu* remains nearly completely unrecognized by the international scientific community. Besides the 2003 publications of Pätzold and myself, Google scholar lists only 12 other papers that mention the *talempong batu* in a musical context (and not as tourist attraction in the region). Nine of them are written in the Indonesian language and therefore not easily accessible to the international community. Nearly all of them mention the instrument only briefly, while mainly discussing the *talempong* instrument family of the Minangkabau culture (Adoma 2018; Ardipal 2013; Ardipal 2015; Barendregt 2002; Darlensis 2006; Fraser 2015; Hidayat et al. 2019; Rustayanti 2014; Sari, Desriyeni 2019; Takari 2008; Wahyudi et al. 2019; Wardizal 2022). Ultimately, these publications seem to assume that the *talempong batu* belongs to the Minangkabau culture, mainly *because* it shares the name talempong with other instruments of the Minangkabau tradition: "Minangkabau society have several types of talempong music ensembles, such as Talempong Pacik, Talempong Unggan, Talempong Batu, Talempong Jao, Talempong Batuang, Talempong Sambilu, and Talempong Kayu, and other talempong types" (Adoma 2018: 110).

However, there is no discussion of whether this name might have been chosen simply because people were used to naming such percussion instruments *talempong* – without claiming or even knowing anything about the actual origin of the instrument.

None of these papers gives any further description, explanation, or analysis of the *talempong batu* itself. Therefore, since our findings themselves remain valid and have been confirmed several times by other colleagues, it seems appropriate to revisit the state of musicological research on this astonishing instrument.

2 Description of the instrument

The *talempong batu* lithophone is located in a cabin in the small village Talang Anau in the mountain region of West Sumatra (see Figure 1). The location of the instrument, the village and the surrounding area are described in detail by Pätzold (2003: 277–8).

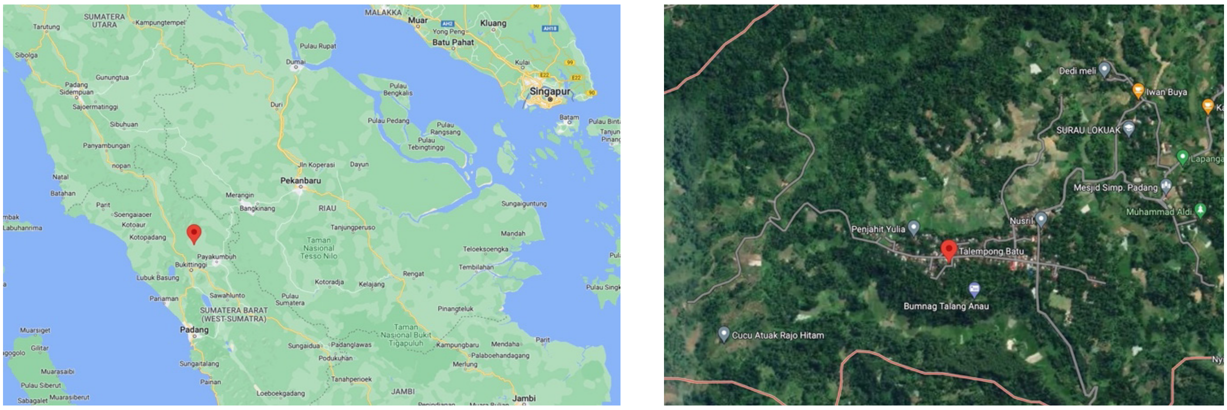

Figure 1: Location of the *talempong batu* in Talang Anau, West Sumatra.

The *talempong batu* consists of six large stones of a grey to beige mineral material. Since Pätzold neither had expertise in mineralogy nor could he take some samples for later analyses, at present one can only speculate on the exact nature of the mineral. The stones are approximately 100 to 150 cm long, 30 to 40 cm wide and 15 to 25 cm thick and rest on two bamboo poles above a resonance pit. As one can see from some recent videos on YouTube, the surrounding cabin and the bamboo poles have been renovated since Pätzold’s visit in 1995 (see the video stills in Figure 2).

The six stones are arranged in a seemingly irregular order that neither follows their sizes nor brings their pitches in a straightforward sequence. However, the analysis will show that this order is to some extent consistent with aspects of the tuning system (see below).

Figure 3 shows a schematic diagram of the instrument. The Roman numbers indicate the order of the stones and are used below to identify the stones.

The stones give a relatively natural or only very roughly worked overall impression. It does not seem as if the creator of the instrument paid special attention to the smoothing of the surface or the shaping of the overall form, for example in the sense of a cuboid or a symmetrically rounded form.

In addition to the actual material of the stones, the age of the instrument is still completely unclear, i.e. when the stones were collected, crafted, and arranged in exactly this order over the

Figure 2: The *talempong batu* lithophone in 1995 (left) and 2015 (right). Video stills.

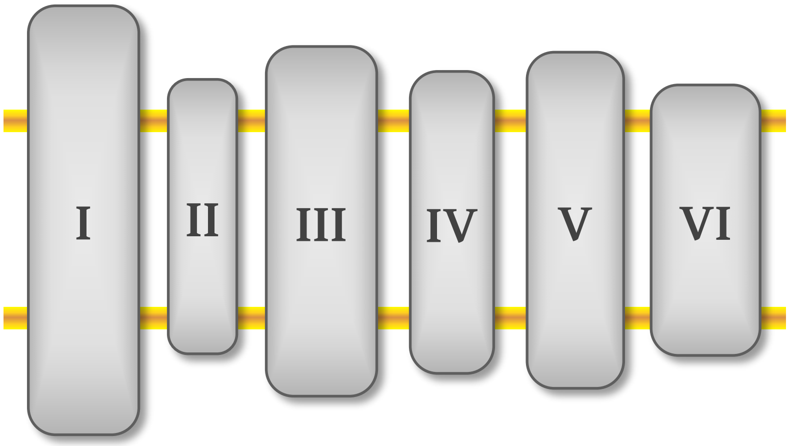

Figure 3: Schematic diagram of the *talempong batu*.

resonating pit. The available information on the instrument is not sufficient to make even an approximate dating. Pätzold (2003: 288) deduces from the statements of his informants on site and his research on oral tradition and local history at least that the instrument must have remained practically unchanged at this location since the beginning of the 19th century: "A relatively recent creation of the lithophone (cannot) be assumed." According to Pätzold's information and considerations, a much older origin of the instrument, possibly going back thousands of years, seems possible. However, there are still no reliable findings on this, so that any attempt at a historical classification must remain speculative and can only be made with caution.

3 Sound material and analysis methods

In 1994, Pätzold's recordings were made using an analogue Hi8-Video equipment with external microphones, using both the digital PCM (32 kHz/12 bit) and the analogue HIFI stereo audio tracks. The PCM digital track of the Hi8 system proved to be frequently overmodulated and therefore distorted. Therefore, to get the best material for the analysis, the analogue audio tracks, which were far less distorted, were digitalized with 48 kHz/16 bit in order to be digitally analysed.

During his recording session, Pätzold systematically recorded numerous single strokes with different levels and at different positions of the stones. From each of the three different stroke positions (left end, middle, right end) of each stone, we selected three suitable, not overmodulated strokes. Therefore, all in all, 6 stones × 3 positions × 3 strokes = 54 sounds were used as source material for the acoustic analysis.

4 Sound impression, transient response and spectrum

The stones sound quite homogeneous within the whole instrument and at the different stroke positions. The sound is clear with a distinct pitch perception and appears more reminiscent of a metal instrument like a gong or a bell than of stone.

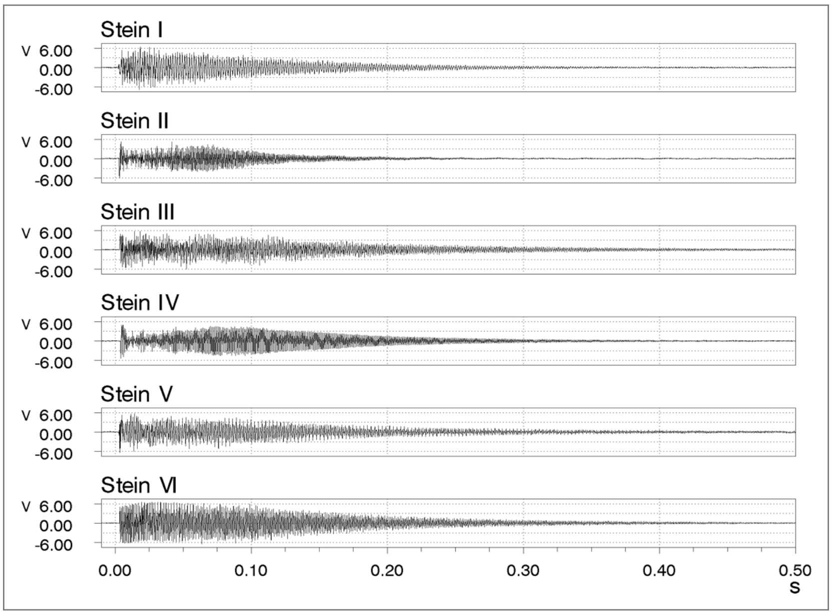

Figure 4: Transient response of all six stones.

Figure 4 shows a typical transient response for each of the six stones. All sounds are quite short (approx. 200 to 400 ms). It is noticeable that there is a slight delay in the transient response of stones II and IV, which reach their maximum only after approx. 60 - 80 ms. The shortness of the sounds would impact the possibilities of tuning such stones to a desired pitch (see below).

To analyse the spectrum and the partials of the stones, high resolution FFTs of all 54 selected sounds were calculated. Signal windows of approx. 1.5 s duration with the stroke in the middle were selected with Hanning signal windowing. Due to the high sampling rate, approx. 70000–80000 sampling values could be considered and thus a high-resolution FFT with 32767 interpolation points and a resolution of Df = 0.7324 Hz could be calculated.

All six stones show a complex spectrum with inharmonic partials, which is typical for any kind of irregularly shaped, vibrating 3D object. Figure 5 shows typical spectra from all three different stroke positions for stone I as an example. The spectra of the other stones overall look quite similar.

Not surprisingly, the details of the spectra slightly differ with the stroke position. However, the frequencies of the partial peaks seem to be quite stable and largely independent of position.

For each of the calculated spectra per stone, the frequency and level of the individual partial peaks were determined. With nine measurements per stone, this made it possible to minimise the error of the resulting arithmetic mean, since a Gaussian distribution of the measurement error of the individual measurements can already be assumed here. Calculated from the spectra of all nine strokes per stone, Table 1 shows the mean frequency and the standard error of the mean frequency for all partial peaks above approximately −20 dB for all six stones.

The partials marked + for Stones III and V in Table 1 resonate with a clearly perceptible delay compared to the fundamental, which results in the impression of a slightly lingering seventh in Stone III and a slightly lingering fifth in Stone V. Stone III shows a slight change in the fundamental

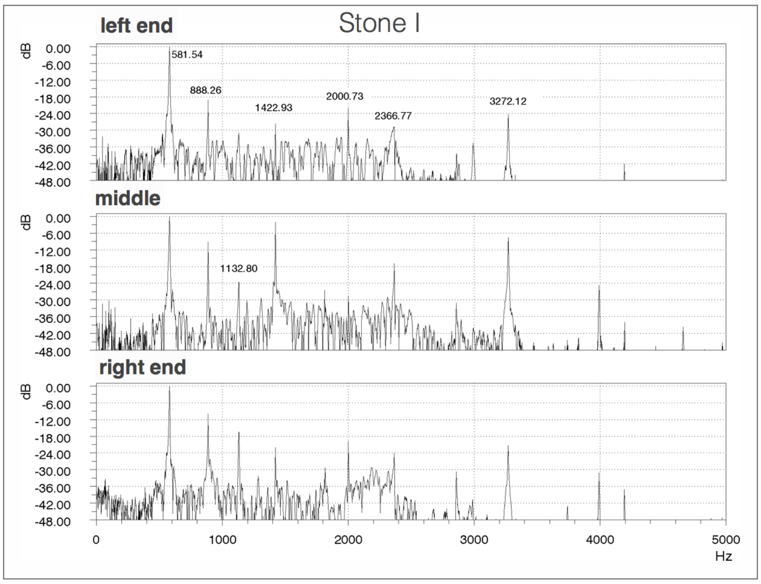

Figure 5: Spectrum of stone I at different stroke positions.

frequency with a change in the point of impact, which does not occur with the other stones, and which leads to a large standard error of the mean value. If the stroke positions of Stone III are considered individually, the fundamental frequency is absolutely stable within each position.

Stone	# (f_0)	f[Hz]	SE(f)
I	1	581.54	0.00
		888.26	0.11
		1132.80	0.12
		1422.93	0.11
		2000.73	0.12
		2366.77	0.18
		3272.12	0.13
II	6	1256.10	0.00
		1524.65	0.17
		2105.05	0.31
III	2	726.80	0.32
		1179.19	0.00
		+1333.24	0.12
		1475.09	0.00
		1943.84	0.00
		2409.74	0.08
		2693.84	0.00

Stone	# (f_0)	f[Hz]	SE(f)
IV	5	1111.65	0.11
		1658.99	0.47
		1814.20	0.17
V	3	736.08	0.17
		+1109.77	0.11
		1826.24	0.13
		2582.02	0.12
		3057.36	0.12
VI	4	918.53	0.08
		1422.60	0.25
		1602.77	0.12
		2841.05	0.00

Table 1: Number of the stone, ordinal number of the fundamental frequency, and mean frequencies with standard errors for each partial above –20 dB.

stone	cent	I	III	V	VI	IV	II
		581.54 ± 0.00	726.80 ±0.32	736.08 ±0.17	918.53 ±0.08	1111.65 ±0.11	1256.10 ±0.00
II	1256.10 ±0.00	1333.20 ±0.00	947.19 ±0.76	925.22 ±0.40	541.86 ±0.15	211.50 ±0.17	0
IV	1111.65 ±0.11	1121.70 ±0.17	735.69 ±0.78	713.72 ±0.43	330.36 ±0.23	0	
VI	918.53 ±0.08	791.34 ±0.15	405.32 ±0.78	383.36 ±0.43	0		
V	736.08 ±0.17	407.98 ±0.40	21.96 ±0.86	0			
III	726.80 ±0.32	386.02 ±0.78	0				
I	581.54 ±0.00	0					

Table 2: Intervals between the fundamental frequencies of the six stones (cent ±MSE).

5 Intervals and tuning system

Since the perception of the fundamental pitch and the partials may be crucially dependent on subjective phenomena such as residuals or combination tones, which would remain undetected in the applied acoustic analysis method, an auditory analysis of the individual sounds was carried out for comparison. In no case could a residual or a combination tone be detected that differed from the lowest partial, so that the frequency of the lowest partial can be assumed to be the fundamental frequency and primary perceived pitch. Therefore, the analysis of the tuning system was based on the intervals between the lowest partials (fundamentals) of the stones. Table 2 shows the complete cent-matrix of intervals (with Mean Squared Error of the cent value).

The analysis of the tuning system shows some very surprising results. When we take a closer look at the intervals between the four stones with the lowest pitches (framed in Table 2) we find some intervals that are nearly identical to some specific intervals that are of great relevance in documented tuning traditions, not least the Western: the 'Pythagorean' ditone, the perfect major third, and consequently also their difference, the so-called syntonic comma (see Table 3). Matching intervals in Tables 2 and 3 are marked with the same colours.

In the European tradition, the 'Pythagorean' ditone and the perfect major third mark the main difference between two historically important tuning concepts (Barbour 1951):

○ The so-called 'Pythagorean' Intonation derives *all* intervals solely from pure fifths (frequency ratio 3/2) and octaves (2/1). In this system, which dominated Chinese music theory and was also of eminent importance in Ancient Greek and subsequently Arabic and European music thinking, all the notes of the scale are created by staggering pure fifths and balancing octave crossings with pure

'Pythagorean' ditone (81/64)	407.82
Perfect major third (5/4)	386.31
Syntonic comma (s, 81/80)	21.51

Table 3: Theoretical intervals (cent).

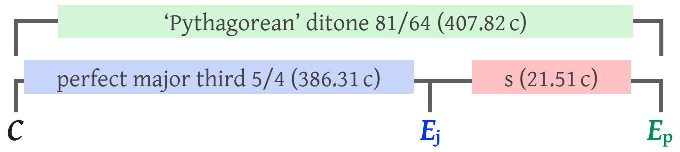

Figure 6: Theoretical relations between intervals.
E_j: *E* in just intonation; E_p: *E* in 'Pythagorean' intonation; s: syntonic comma.

octaves. For example, the frequency ratio of the third above the tonic (scale step 3, '*E*' in a C-major scale) is effectively calculated by staggering four pure 3/2-fifths (C^1–G^1–D^2–A^2–E^3) and subtracting two 2/1-octaves (E^3–E^2–E^1). The resulting 'Pythagorean' major third then has a frequency ratio of $(3/2)^4 / (2/1)^2 = 81/64$ and is called the 'Pythagorean ditone' in European tuning tradition. Measured in cent, 81/64 equals an interval size of 407.82 cent.

- The idea of *Just Intonation* introduces 'pure' or 'perfect' major thirds (frequency ratio 5/4) into the calculation of the scale intervals. This 5/4-third is the same interval that is found in the overtone scale between the fourth and the fifth partial. In Just Intonation, scale step 3 does not have to be calculated in a complicated manner, but is simply tuned as the 5/4 perfect major third ratio, which equals an interval size of 386.31 cent.
- The syntonic comma marks the small difference between these two kinds of thirds. Its frequency ratio is calculated by dividing the ratio of the 'Pythagorean' ditone by that of the perfect major third: $(81/84) / (5/4) = 81/80$, corresponding to 21.51 cent.

Figure 6 shows the relation between the larger 'Pythagorean' ditone, the narrower perfect major third and syntonic comma in between.

In early European music history, 'Pythagorean' Intonation was the predominant system for hundreds of years. It works perfectly for all kinds of music with the (open) fifth as characteristic harmonic element, since, due to the construction principle of the scale, all fifths that occur in the music will be perfectly tuned. However, if the notes bounding a 'Pythagorean' ditone are sounded simultaneously, the resulting third is generally perceived as lacking in resonance. Therefore, when multi-part music began to focus more on thirds as a characteristic harmonic element in about the 15th century, 'Pythagorean' Intonation was predominantly replaced by the idea of Just Intonation. However, the syntonic comma was never used as a melodic or harmonic interval as such, but rather as an aid to conceiving different types of tuning for certain kinds of music and instruments.

As one can see from Tables 2 and 3, the intervals in the *talempong batu* nearly perfectly match the values of the theoretical intervals: the mean deviation of the *talempong batu* from the theoretical values is just 1.27 cent, the maximum deviation not more than 2.95 cent (between the 5/4-third and the interval V/VI). As we know from experimental psychoacoustics, this small deviation is far less than the pitch differentiation ability of the human ear: in this frequency range, the pitch differences between two tones must exceed about 5 cents for the ear to perceive the tones as different in a direct comparison (just notable difference JND, cf. Fastl, Weinberger 1981).

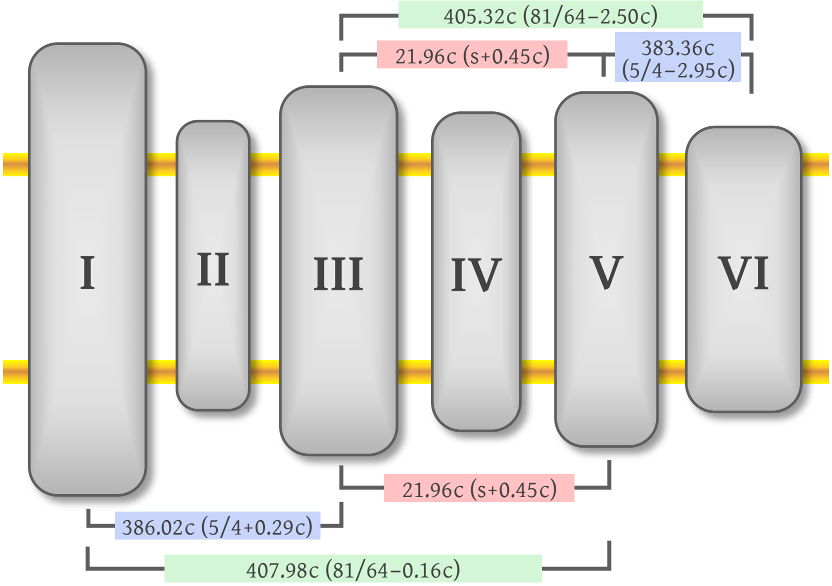

Figure 7: Order of intervals within the *talempong batu* (deviation from theoretical intervals in parentheses).

Figure 7 shows the arrangement of the matching intervals within the actual order of the stones of the *talempong batu*. If we compare this to the theoretical relations of the intervals in Figure 6, it becomes obvious that the intervals between the four lowest stones not only match the size of the theoretical intervals, but that the whole arrangement of the stones, which at first glance seems to be somehow irregular, reflects the theoretical meaning of the intervals *twice* in a perfectly symmetrical way, upwards and downwards with the syntonic comma in the middle.

6 Conclusions and open questions

When we first realized the surprising results of our analysis, we certainly were quite sceptical and wondered whether the results could be caused by some systematic errors, e.g. from the digitalisation of the audio material or the calculation of the FFTs. Therefore, we repeated the coding and analysis several times with slightly different approaches. Moreover, the original material was given to some colleagues with broad experience in sound analysis, musical acoustics and tuning systems, namely Wolfgang Auhagen of Martin-Luther-University Halle/Germany and Christoph Reuter of Vienna University/Austria. However, all these re-analyses confirmed that the frequencies of the stones and the intervals between them had been accurately measured as described above. In addition, I have recently conducted some new analysis based on the sounds of new videos of the instrument that can be easily found on YouTube now. Again, the results on the frequencies and spectra of the stones were almost identical to the results that I first found 27 years ago. There can be no reasonable doubt about the astounding fact that the tuning of this stone-made instrument in the Sumatra mountains indeed accurately matches some intervals that are well known in other tuning traditions and that the overall arrangement of the stones perfectly reflects the theoretical meaning of these intervals as well.

This of course does *not* imply that we suggest that the tuning of the instrument in any kind was directly influenced by any of these traditions. Quite possibly the underlying principles may have been realized independently in the Sumatra region.

Although very little is known about the age of the instrument (see above), our findings may help to learn something about the culture that created it. This assumes, of course, that the tuning system was actually intended by its creators to be exactly this way. However, it seems hard to believe that a complex system with this level of theoretical matching and perfect conceptual symmetry might simply arise by chance. If the *talempong batu*'s tuning system was indeed intentional, its existence may say a lot about the theoretical and practical resources and skills of the maker(s) and their cultural context.

- As explained above, the perfect major third can be found in the overtone scale. As such, it is not too complicated to discover and reproduce with quite simple means like an overblown pipe or a vibrating string. However, this is neither the case for the 'Pythagorean' ditone, not for the Syntonic Comma. 81/64 and 81/80 are relatively complicated ratios that cannot simply be found in nature. To find these ratios, the creators of the *talempong batu* had to have some competency to think in proportions and to calculate with fractions, may it be practically or theoretically.
- The conceptualization *and* realization of the 'Pythagorean' thirds in particular, would have depended on a tool to reliably reproduce reference intervals and pitches during the actual tuning process. The most reliable and easy to use tool to achieve this is a reference instrument based on vibrating strings (as has been the monochord in European tradition). An alternative might be a blown pipe, such as a flute with distinct finger holes. However, this seems less likely because, in contrast to vibrating strings, the frequency of wind instruments depends also on parameters that are difficult to control (e.g. air pressure and humidity) and hence makes it difficult to reliably produce defined reference pitches for tuning. Therefore, it seems more plausible that the culture of the creators of the *talempong batu* did know stringed instruments.

These considerations are of course somewhat speculative, but they nevertheless seem at least plausible. However, some essential aspects of the cultural background and the making process of the *talempong batu* remain totally unclear so far:

- Even with a fixed reference frequency from a stringed instrument, the actual process of tuning the stones remains mysterious. On the one hand, the accuracy exceeds the just-noticeable difference (JND) for pitch of the human ear. Therefore, the simple comparison of the desired reference pitch (whether it is produced by a pipe or a string) with the pitch of the stone that is to be tuned would never have achieved such accuracy. Of course, there indeed exists a tuning technique that could lead to such level of accuracy and that piano tuners still use every day: the technique of counting interference beats between the reference and target pitches. If the interference beats disappear while tuning the target pitch, both frequencies are perfectly equal. But this can only work if both sounds last long enough, so that the tuner has enough time to listen to the slow interference beats in the combined sound. But as shown above, the sounds from the *talempong batu* will last for only about 200 to 400 ms. This appears to be much too short to apply the interference technique for the tuning of these stones. So far, it remains unclear how the surprising precision of the tuning could be practically achieved.

- The actual tuning of a 3-dimensional body of hard, brittle, mineral material to a desired pitch naturally requires a very accurate and precise craftsmanship. But moreover, it requires precise knowledge and experience of where to work on the stone to obtain the desired result without taking the risk of ruining the work or even completely destroying it. As Pätzold (2003) stated, the *talampong batu* is a *unique* instrument. Even if the maker did not produce any further instruments, it remains unclear what might have happened to the preliminary works that went into acquiring this special expertise. So, one may wonder why no other similar lithophones have been discovered.
- The consistent tuning system that was described above includes only the four lowest stones of the instrument. So, what about the two highest stones (II and IV) that do not seem to fit the consistency of the system? Is there any plausible, consistent explanation for their pitches? This question will be hard to answer without further investigation of the instrument itself. It would be essential for example to look for some evidence that the pitches of the stones somehow might have changed due to damage or erosion.
- Last but not least, there is no plausible explanation so far as to how this complex tuning that was realized at least hundreds, maybe thousands of years ago, could remain unchanged with the described level of precision until today.

Considering all these open questions, the *talempong batu* is a quite fascinating, but also mysterious, object. To answer these questions, further interdisciplinary research with experts from the fields of musicology, archaeology, cultural history, and mineralogy seems absolutely necessary. Indeed, the answers to these questions could be an important testimony to the cultural history of the region.

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