Musical Scales in Central Africa and Java: Modeling by Synthesis

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ABSTRACT

The author's research on the tuning and scale systems of the Central African xylophone and Javanese *gamelan* has departed from previous Western ethnomusicological studies in these areas. Rather than relying on acoustical measurement as a primary source of data, his team has adopted an interactive approach involving the participation of Central African and Javanese musicians, who work with researchers to demonstrate their tuning processes using synthesizers and MIDI systems. The author presents results of this experimentation and explains the inconsistencies of previous research in terms of differing cultural concepts of scale.

The study of musical scales in Africa and Indonesia by Western ethnomusicologists began more than a century ago, when technical devices such as tuning forks and monochords came into use; later, electronic devices and computers were developed to further facilitate precise measurements of traditional musical instruments. Ellis [1,2] was the first Western researcher to suggest that many African and Indonesian scales cannot be explained by Western theories of scale construction such as the Pythagorean tuning system and just intonation—and particularly not by physiological theories such as Helmholtz's theory of frequency "fusion" [3]. Ellis and Hipkins theorized an "equipentatonic" scale in their accounts of mainland Southeast Asian and Indonesian instruments [4]; Wachsmann also described such a scale in his studies of Central African music [5]. The equipentatonic scale is considered by most ethnomusicologists to represent a division of the octave (1200 cents) into five equal intervals of 240 cents [6]. The supposed existence of this scale provoked various theoretical discussions about its origins. In 1901, Stumpf [7], a well-known musicologist and psychophysicist, asked how one could tune an equipentatonic interval when its frequency ratio is an irrational number ($F_{n+1}=F_n \cdot \sqrt[5]{2}$). By asking this question he was pointing out that acoustical measurements are not sufficient for a good understanding of the cultural foundations of scales. In modern ethnomusicological terms, we think of scales not as a construction on which to compose music, but as a set of pitch areas that are observed to be used consistently in the musical expression of a given cultural group.

In the 1930s, Hornbostel and Kunst attempted to explain the origin of the *slendro* system according to an ancient Chinese treatise that presents the "blown fifth theory" [8], which is based on a cycle of 23 blown fifths (each measuring 678 cents). This theory questioned the equidistant structure of the *slendro* pentatonic scale. Later, in the 1960s, new observations and measurements showed that the hypothesis of equidistant scales in Java did not hold true [9].

Finally, the situation in Africa was described in the same terms by other researchers. According to Kubik, "whether the basic idea is an even division of the octave into five equal parts, however, remains to be proved" [10]. Furthermore, despite a widely comparative work on the measurements of numerous African xylophones and Javanese gamelans by Jones [11], the existence of equipentatonic tuning was not proven.

Paradoxically, the hypothesis of an Indonesian origin of African xylophone tunings was supported [12]. More and more exceptions to this hypothesis appeared in Central African studies. The measurements of xylophone tunings seemed to present a field of variance in intervallic values that was too large to permit an unambiguous analysis of the scale: it revealed nothing but undefined pentatonic scales. Strangely enough, however, when ethnomusicologist Klaus Wachsmann watched a Ugandan musician retuning his own xylophone—which Wachsmann had asked the musician to do so that he could analyze his tuning process—he observed the musician tuning the instrument to an equipentatonic scale [13]. Was equipentatonic tuning kept hidden by traditional musicians?

Interactive Experimentation Using Synthesizers

Since 1989, our team at LACITO-CNRS [14] has undertaken successive missions in Central Africa and Central Java to study the musical scales of several communities there, using an experimental methodology in which the musicians have participated actively. We began in Central Africa, then applied this methodology in 1993 to the study of the Central Javanese scales of the gamelan in Surakarta, Java, with a view toward developing this methodology within a different culture and verifying the hypothesis of the existence of equidistant scales in both Central Africa and Java. Our aim has been to determine and model musical scales by submitting different hypotheses to indigenous musicians and xylophone or gamelan makers. Our methodology has not only consisted of taking the tuning measurements of traditional instruments; it has also comprised an attempt to simulate instruments with the help of new musical technology in order to allow the modeling of musical scales according to the musicians' evaluations of the simulated tunings. Through the implementation of these methods, we hope to make technology into an area of encounter between the traditional musician and the Western researcher, a place where more implicit and nonverbalized knowledge can emerge. It remains for researchers to prepare this "area of encounter" by putting the technology they use at the service of the cultures they study.

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(a)

(b)

(c)

Fig. 1. Musicians tuning synthesizers adapted to simulate the Central African xylophone and the Javanese *gender* and *saron:* (a) a Gbaya xylophonist, (b) Pa Tentrem and (c) Pa Supoyo at work.

The research was conducted with fixed-pitched instruments that present, according to the musicians, a reference tuning structure. In Central Africa, the instruments used were xylophones with multiple-gourd resonators; in Java, bronze lamellophones and the *gender* and *saron* of the gamelan [15].

Because it is inappropriate to present a succession of tones and intervals out of their cultural context, we decided to allow the musicians themselves to verify the simulated tunings, as they usually do with their own instruments. For this purpose, we affixed several 1-in–wide wooden strips to the synthesizer's keys with auto-gripping adhesives. This allowed us to more naturally simulate different kinds of instruments with various numbers of bars: 5 to 12 wooden strips were used to represent the corresponding number of bars in the Central African xylophones; from 6 to 14 were used to simulate the Javanese *gender* and *saron* (Fig. 1). For ensembles of more than one instrument, we used one or two synthesizers to study the scalar relations of both the instruments in pairs and the entire orchestral range [16].

As soon as the musicians could play the experimental instrument, they were able to make their own judgments of each tuning submitted to them. When necessary, the musicians adjusted each tone of the synthesized tuning using a data-entry cursor until they achieved what they considered the "right" or "good" pitch for that note. The analysis of such corrections allowed evaluation of the distance between the projected Western scalar prospects and the indigenous concept of the scale intervals and pitch classes. This evaluation produced many details about the cultural factors involved in determining the criteria that define an interval. The computer allowed for programming on location, as well as storage and analysis of the data; we were also able to record the performances of the African and Javanese musicians on the simulated instruments and save them as MIDI files.

An example of some of our results is shown in Fig. 2, which represents a Javanese musician's process of tuning two adjacent descending bars in a simulated *gender* (the tuning was done by tuner Pa Supoyo in Surakarta in December of 1993). This process was recorded on a sequencer using a MIDI file standard while the musician tuned a slendro *gender* on the synthesizer with the help of its data-entry cursor. Beginning with a given interval of 322 cents, the tuner ad-

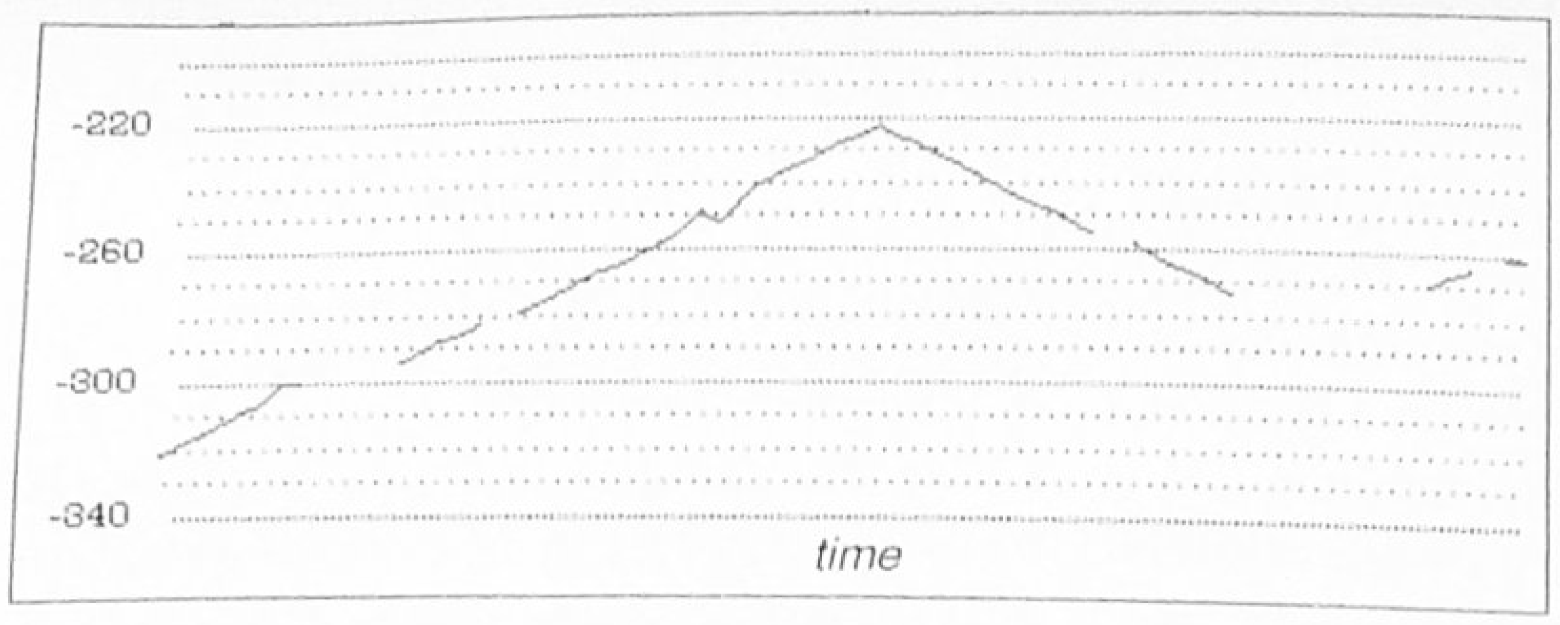

Fig. 2. A graphic representation of tuner Pa Supoyo's process of tuning two adjacent descending bars of a simulated *slendro gender*.

justed the cursor until he produced an interval of 262 cents, which satisfied him. One can observe from this graph that Pa Supoyo hesitated at 250 cents, progressed as far as 223 cents (the peak of the curve), then returned to 262 cents.

The sounds presented to the musicians for these experiments were synthesized from spectral analysis (FFT) of the instruments' original sounds. The different synthesized sounds were always verified by the musicians themselves in comparison to their own original sounds, which were reproduced on a sampler. Furthermore, the synthesized sounds could often be modified—i.e. resynthesized—according to the musicians' suggestions: for example, a timbre with a duration of 350 msec, a quasi-harmonic spectrum and high harmonic components throughout the resonance was preferred by the Central African musicians. Such a high-frequency spectrum corresponds to the timbre of the mirlitons traditionally fixed to the gourds. For the simulated *gender* and *saron,* a timbre with a 4-sec duration, a strong fundamental frequency and higher transient harmonics (reproducing the brightness of bronze lamellophones) satisfied Central Javanese musicians and produced a resonance that was long enough to allow the beats to be heard [17].

The Musicians' Opinions

Our research was conducted in various regions of the Central African Republic with several musicians from different communities, each of which has its own language, rituals, musical repertories and xylophone ensembles. In general, each experiment was conducted simultaneously in two distant villages and, when possible, was reconducted on a different day (Table 1). The musicians, all xylophone makers, included the

- Manza group, with tuners Bawassan and Moussa (the group used one five-bar xylophone)
- Gbaya group, with tuners Wazunam, Zuïbona and Feyumna (one 10- to 12-bar xylophone)
- Ngbaka-Manza group, with tuners Sérendopé, Boua and Kasamba (an ensemble of three xylophones with nine, seven and four bars)
- Ali group, with tuners Wakon and Yangé (an ensemble of three xylophones identical to that of the Ngbaka-Manza group)
- Banda Gbambiya group, with tuner Boroboda (an ensemble of four xylophones with eight, seven, seven and five bars)
- Banda-Linda group, with tuners Patchelepu, Balekenji, and Bambari (two xylophones—one with 10, one with 5 bars—that were not played at the same time)
- Banda-Ndokpa group, with tuner Kangebanda (same xylophones as the Banda Linda group)
- Banda Mbiyi group, with tuner Mandaba (same xylophone as the Manza group)
- Azande group, with xylophonist Tibere (one large log xylophone of 14 bars) and the

Table 1. Results of two experimental sessions concerning the combinational modes of the three constituent intervals of a Manza xylophone. The table lists the musician Moussa's responses to synthesized 5-bar xylophone tunings on two different dates in December 1990. "A" indicates the musician's acceptance, "R" his rejection of a given tuning; his spontaneous comment "very good" is noted as "vg." The self-contradiction of the musician is less than 7%.

	Intervals following the 5-bar xylophone topology (cents)					December 13th 1990	December 14th 1990
n °	A	B	C	D	E	response	response
1	925	240	200	285	200	-	A
2	885	300	200	200	185	R	R
3	925	200	200	285	240	A	A - vg
4	800	200	200	200	200	R	R
5	925	200	240	285	200	A	A
6	920	240	200	240	240	A	A
7	880	200	200	240	240	R	R
8	885	200	200	200	285	R	R
9	925	240	285	200	200	R	R
10	925	240	200	285	200	A	A
11	965	200	240	285	240	R	R
12	1010	200	240	285	285	R	R
13	925	285	240	200	200	R	R
14	960	240	240	240	240	A	A
15	925	200	285	200	240	A - vg	A - vg
16	840	200	200	240	200	R	R
17	920	240	240	240	200	A	A
18	920	240	240	200	240	A	A
19	965	200	240	285	240	R	R
20	925	200	285	240	200	R	R
21	925	240	200	200	285	R	R
22	840	200	200	200	240	R	R
23	925	200	285	200	240	A	A - vg
24	885	200	200	300	185	R	R
25	925	240	200	285	200	A	A
26	885	200	300	200	185	R	R
27	925	200	200	240	285	A	R
28	925	200	240	200	285	A	R
29	925	285	200	200	240	R	R
30	920	200	240	240	240	A	A - vg
31	925	285	200	240	200	R	R
32	1005	240	240	285	240	-	R

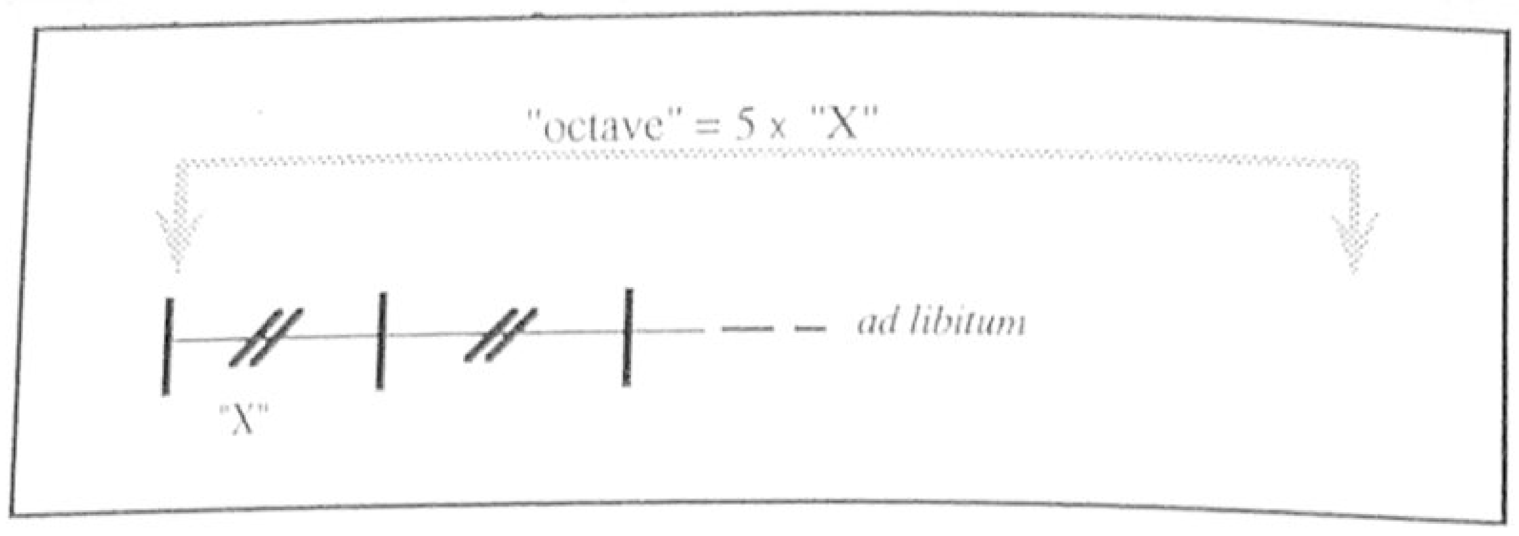

Fig. 4. A schema representing the Central African conception of the equipentatonic scale system.

ertheless appears that the musicians are able to discriminate the adjacent intervals to within +/−20 cents—better than one-tenth of a tone [18]. This degree of precision became better when the musicians themselves tuned the experimental xylophone (+/− less than 10 cents). Thus, we were able to determine three constituent intervals: 200, 240 and 280, each at +/−15 cents [19].

These results seemed to be paradoxical, given the fact that the same musicians tuned the octave, fifth, major third and their inversions within a field of variance close to a semitone, as previously observed by Kubik [20]. This apparent contradiction does not appear to be inherent in the Central African system or in the experimental results, but rather in a Western definition of consonance. This definition is refuted by the practices of these musicians, who tune their xylophones by following adjacent intervals, step by step. Our experimentation verified that "perfect" consonances are not a constituent of a Central African concept of the scale. These musicians do not judge a strict octave (1200 cents) to be better than a large major seventh (1150 cents) or a small minor ninth (1250 cents). On the contrary, the Banda Linda musicians prefer the small "octave" (1150 cents) in any register, probably because of the roughness it creates on the octaves that are always played simultaneously with double sticks in each hand.

Thus, these paradoxical observations could be easily explained once the Western concept of consonance was left behind. The roughness of consonances in the Central African scale results in no way whatsoever from a margin of tolerance. Such roughness constitutes a thickness built into the Central African system itself. In other words, any one of the three constituent intervals—200, 240 and 280 cents—can substitute for another in any place on different xylophones of the orchestra. Unisons and other consonances present a systematic thickness that corresponds to the difference between each constituent interval.

Figure 3 shows two close pitches that differ in the system because they are part of different scalar patterns. At the same time, these two pitches have the same melodic or harmonic function in the music. This is the essence of the ambiguity of the Central African scales: the equivalence that permits the substitution of the constituent intervals gives to the unison different versions of the same tone. Thus, each *degree* of the pentatonic system can be actualized by means of close but distinctive *pitches*. As a Central African musician might say without any contradiction, "it is the same but not the same."

A special case of scalar pattern in the Central African system is equipentatonic tuning, in which the sole constituent interval is 240 cents. The musicians judged this tuning pattern the best of all the combinations, including two or three different constituent intervals. The origin of the equipentatonic system could be explored from a new perspective: how is it that Central African musicians prefer equidistant tuning while also preferring an imperfect—i.e. stretched or compressed—octave? Given this ambiguous octave, how can musicians account for the equipentatonic system that results from the division of the octave into five equal parts?

Here again, the response to this question requires an alteration of the Western definition of an equipentatonic system: we have verified that equipentatonic tuning is considered correct in Central Africa as long as the intervals are equal to each other. In effect, tunings consisting of a succession of five times 230 cents, five times 240 cents or five times 250 cents are judged equally well-tuned, despite the difference between the octaves created by this succession (however, different combinations of these three intervals in the same tuning, creating a deviation of +/−10 cents, are rejected). Furthermore, a succession of 200-cent intervals does not appear to be undesirable to the musicians, despite its hexatonic structure. Exposed to this stranger structure, Central African musicians approved its equidistant wholetone pattern, but only for the first five pitches (i.e. as a pentatonic scale).

As we have seen previously, equipentatonic tunings are never actualized on the xylophones measured; this being the case, how could we have observed it experimentally? The system itself explains this phenomenon: the equipentatonic system in Central Africa cannot be actualized because it has no precise size, but only the notion of equality. It appears to be a conceptual feature that is actualized through a combination of three constituent intervals—200, 240 and 280 cents—whose precise values may be a compromise between concept and reality. That is, this concept of equality holds these three constituent intervals as equivalent, but also different.

It is important to note that the equidistant concept is common to all the cultural groups we visited in Central Africa. However, the actual tunings used in each community differ in their combinations of the three constituent intervals (see Fig. 3).

The Equipentatonic Systems

According to the Central African concept of scale, the equipentatonic system *proceeds by a summation of equal intervals* (see Fig. 4), rather than dividing the octave into five equal intervals, as specified by the Western conception. The "octave" results from a summation of virtual equal intervals (designated "X" in Fig. 4) and has no precise value.

Is this equipentatonic conception peculiar to Central Africa? Our experimental work in progress in Surakarta, as well as the explanations of the gamelan makers there, has indicated that the *slendro* pentatonic system presents many deviations according to the *rasa* or "feeling" of the musician or tuner. It is not within the scope of the study thus far to determine how or if the *rasa* is systematic according to each musician or orchestra. However, our current results demonstrate some interesting points:

1. The strict octave (1200 cents) is recognized as a fixed and standard reference, but sometimes needs to be stretched or compressed by two to three beats—*ombak*—during the sound. In practice, this deviation appears to be *irregular* and depends on the *rasa* rather than the instrumental register.

2. We have found no consensus among musicians about tuning preferences.

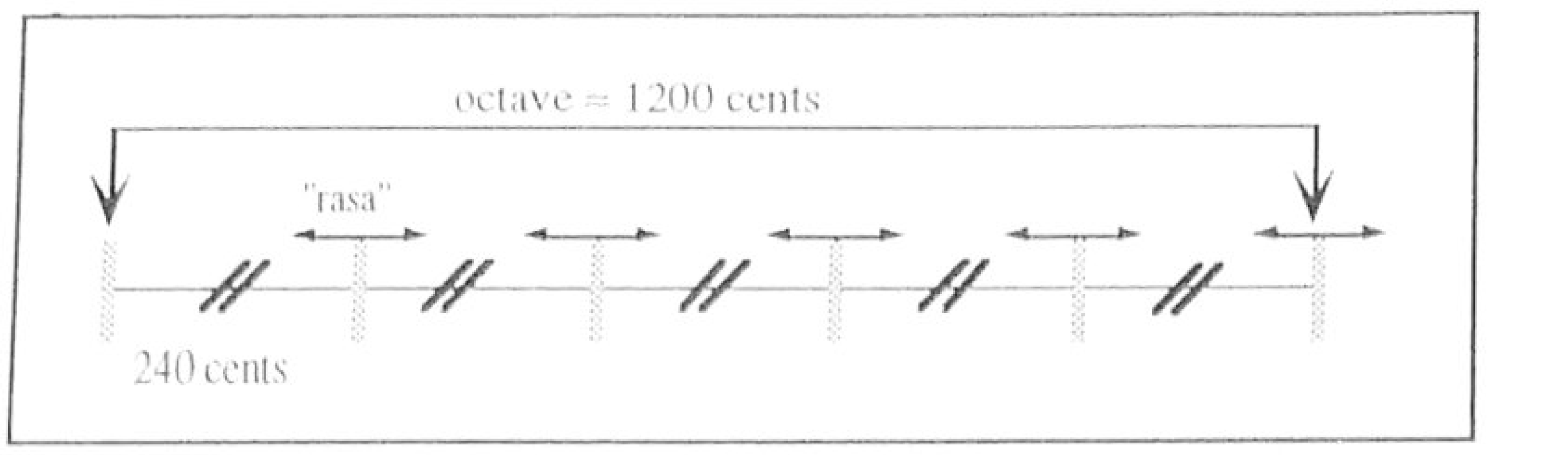

Fig. 5. Schema illustrating the Central Javanese conception of the equipentatonic scale system.

3. According to the participant musicians' explanations, the equipentatonic system constitutes a kind of reference that needs to deviate according to the *rasa* (see Fig. 5); thus, in Central Java, the equipentatonic system seems to be a model that comes from a developing conceptualization rather than an inherent concept.

CONCLUSION

We have seen here that the same apparent structure—i.e. equipentatonic—proceeds from two very different concepts: (1) a division of the octave into equal intervals and/or (2) a construction of a scale from successive intervals of the same size, regardless of the size of the sounded octave. The results of this research demonstrate that the study of scalar systems cannot be based solely on acoustical measurement, as tuning research has been until now, but must also consider the conceptual dimensions of scale in the various cultures studied. As expressed by a Wolof proverb: "wisdom is not far, but it is hidden."

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14. The several collective field studies in the Central African Republic and in Central Java (Surakarta) have been undertaken over a period of years by myself, Simha Arom and Gilles Léothaud from the Department of Ethnomusicology in the Laboratory of Languages and Civilizations of Oral Tradition at LACITO-CNRS in Paris.

15. Both sets of instruments are classified as idiophones, i.e. "self-sounding" instruments.

16. The technology we used in the field consisted of two 8-bit digital MIDI synthesizers (Yamaha DX 7-II) and an 16-bit sampler (Akaï S1000), capable of programming musical scales with a precision of 1.17 cents and 1 cent, respectively. We also used an 8-channel MIDI merger (Audio-Architecture) and a Macintosh SE30 computer with 8 Mg of RAM (random-access memory).

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