A POSSIBLE NEW CLASS OF PREHISTORIC MUSICAL INSTRUMENTS FROM NEW ENGLAND: PORTABLE CYLINDRICAL LITHOPHONES

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With one exception, which has been described as a suspended "kiva bell," long stone rods have been interpreted throughout the archaeological literature of North America as whetstones or pestles. Two particularly long rods in a collection of prehistoric artifacts from New England raise questions as to the real use of some of these objects. The prevailing interpretations of the two artifacts may be incorrect, or at least incomplete, because the rods lack the kinds of wear that are found on most whetstones or pestles. They also have different acoustical properties from true pestles, which are usually shorter, and are identical in materials, acoustics, and form to probable prehistoric lithophones from the Old World, which can be played on the lap. The identification of the pair of rods as good candidates for being the first known cylindrical, two-toned prehistoric lithophones from New England introduces a new avenue for the study of fossil sounds and rituals in both the region and continent because it is likely that similar artifacts will be examined for characteristic wear, tested acoustically, and recognized as the objects of prestige and ceremony that they may have been in their role as un-suspended musical instruments.

Con la excepción de un ejemplar, que se ha descrito como "campana de kiva" destinada a usarse suspendida, los grandes artefactos de piedra con sección circular u ovalada siempre han sido interpretados en la literatura arqueológica norteamericana como "afiladores" o "morteros." Dos de esos objetos, particularmente largos, que se hallan en una colección de piezas prehistóricas de Nueva Inglaterra, obligan a interrogarse en cuanto al uso verdadero de algunos de esos objetos. La interpretación común de aquéllos bien podría ser errónea o incompleta, ya que dichos dos cilindros carecen de las características huellas de deterioro presentes sobre afiladores o morteros aseverados ; por otra parte, tienen propiedades acústicas distintas ; finalmente, son aparentados (en cuanto a materiales, sonoridades y morfología) a algunos probables litófonos del Viejo Mundo, que eran tocados puestos sobre los muslos de ejecutantes sentados. Por lo tanto, estos dos objetos bien podrían ser los dos primeros litófonos cilíndricos prehistóricos identificados en el continente americano, ofreciendo alguna posibilidad para iniciar el estudio de sonidos y rituales fósiles en Nueva Inglaterra y el resto del continente. Es probable que otros objetos similares, después de examinadas las huellas de utilización presentes sobre ellos, y después de haber sido probados acusticamente, sean también reconocidos no sólo como instrumentos musicales no-suspendidos, sino además como objetos de prestigio y ceremonia.

With one exception, which has been described as an atypical suspended "kiva bell" (Brown 2005:430–431), long stone rods with round-to-oval cross sections have been interpreted throughout the archaeological literature of North America either as whetstones (Robinson 2006), which were used in mortuary contexts, or as food-processing implements and called "pestles." Two particularly long examples of these reputed whetstones or pestles in a collection of prehistoric artifacts from New England raise questions as to the full significance of some of these objects. The prevailing utilitarian interpretation of the two artifacts may be incorrect or incomplete because the 71- and 72.5-cm-long solid cylinders lack both the ground facets found on whetstones and the grinding or pounding wear found on pestles. Conversely, these cylinders exhibit different acoustical properties and are identical in materials, acoustics, and form to probable prehistoric lithophones from Africa.

After giving examples of prehistoric and historic lithophones that have been found around the world, this article defines the features that have made it possible to identify 34 stone rods from Africa as probable musical instruments. It also explains why the makers of cylindrical lithophones—including, in all probability, the

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makers of those 34 artifacts—were forced by ergonomic considerations and physics to converge on similar designs. It then shows how the two artifacts from New England match the same criteria, making them good candidates for a new prehistoric instrument class in northeastern North America, if not the continent. In doing so, the article offers suggestions as to how researchers who are inexperienced in music and acoustics can nondestructively test other suspected lithophones in the archaeological record.

Types of Lithophones

A number of different types of lithophones have been identified from historic, ethnographic, and prehistoric contexts, including the following examples of *stationary* and *portable* lithophones.

Stationary Lithophones

Stationary lithophones include (1) natural stalagmitic drapery; (2) adulterated ridges and stalactites; (3) natural "rock gongs"; (4) natural, but positioned, stationary stones; and (5) manufactured stationary columns.

Natural stalagmitic drapery. Lithophones made of natural stalagmatic drapery with ridges that produce clear tones (Dams 1984, 1985; Dauvois 1989; Glory 1964, 1965; Glory et al. 1965) were played in prehistoric times in Nerja (Dams 1984), Roucador, Cougnac, Pech-Merle, Escoural (Dams 1985; Morley 2003), Oxocelhaya and other caves in Europe, and in the Lithophone Gallery of Las Ruinas Cave, Oaxaca, Mexico, where about ten speleothems "have percussion wear on one or several sides" (Brown 2005:419; Hapka and Rouvinez 1997:23). Hapka and Rouvinez point out that:

> the acoustics in and between the lithophone room and the altar room are excellent. The resonance creates a phonic space among these different structures: it is thus perfectly imaginable that people near the altar would have received the full effect of beating on these 'stone drums,' a term derived from a Maya glyph translation [1997:23].

Fresh research has tended to confirm such suppositions about potential prehistoric lithophones by finding correlations between places with multiple echoes or greater resonance and the presence of both figurative imagery (Reznikoff and Dauvois 1988; Waller 2006) and abstract signs, which seem to have served as acoustical landmarks in Niaux, for example (Reznikoff 2012a, 2012b). Similar speleothems have also been played in historic times from Tabuhan Cave in eastern Java to the caverns of Luray, Virginia (Gonthier et al. 2010).

Adulterated ridges and stalactites. These consist of rock features that have been shortened to produce a particular tone when struck by a mallet. Such engineered lithophones have been reported in Upper Paleolithic art caves such as Nerja, Rocamadour (Dams 1985; Morley 2003), and Oxocelhaya.

Natural "rock gongs" on stationary rock faces. Rock gongs, "sounding stones," or "ringing rocks" consist of non-figurative pecked zones on fixed rock surfaces, which emit a bell-like sound when struck with a cobble or other hard implement. A great many sites with such non-figurative pecked areas have been found in Africa (Blake and Cross 2008:3), where rock gongs have been linked ethnographically to "use in rites of passage, fertility or rainmaking rituals, as signaling devices or for entertainment" (Kleinitz 2004:14), and around the world (Fagg 1997). Petroglyphs of cattle, which were roughly dated to the period between the mid-fourth and mid-second millennia B.C., are closely associated with rock gongs at the Fourth Cataract in the Sudanese Nile Valley (Kleinitz 2004:15; Kleinitz and Koenitz 2006:39–41).

Natural, but positioned, stationary lithophones. Examples include a series of engraved doleritic stones, discovered in the Kupgal Hills in Karnataka (Boivin 2004), and assemblages of ringing stones with concussed edges from the Canary Islands, which seem to have been used from before contact with the Spanish until the nineteenth century (Álvarez and Siemens 1988).

Manufactured stationary columnar lithophones. Examples include 56 small columns made of sonorous granite in the Vitthala temple of Karnataka, India, and a tall Lutetian limestone column in Laon Cathedral in France (Gonthier 2012).

Portable Lithophones

Among the variations of portable lithophones found worldwide are examples of (1) natural rocks that were suspended; (2) manufactured suspended lithophones; (3) long bifaces and stone slabs; and (4) stone cylinders.

Natural rocks that have been suspended. Sonorous rocks hanging from a branch at Debré Tsion monastery in Ethiopia are struck like gongs (Gonthier 2012).

Manufactured suspended lithophones. Examples of such lithophones, which are generally sculpted and polished, include suspended stone chimes from Vietnam (*biên khánk*), China (*Pi, bianqing* and *quig*), and Korea (*pyeongyeong*) (Falkenhausen 1994; Yoo and Rossing 2006). Most of the suspended manufactured lithophones that have been identified in the United States are so-called "kiva bells," which come almost exclusively from the Rio Grande Valley (Brown 1967, 1971), although at least two candidates have been identified from outlying areas: one from a Mimbres site in Luna County, New Mexico, and the other from northeastern Arizona (Brown 2005:430–431).

Another example was reported by James Mooney (2006:397 [1900]) from "the old town of Keowee [where] they had a drum of stone, cut in the shape of a turtle, which was hung up inside the townhouse and used at all the town dances. The other towns of the Lower Cherokee used to borrow it, too, for their own dances."

Finally, the Maya suspended schist or greenstone celts from their belts with oliva shells:

> all of which produced rhythmic sounds when worn...by dancers, noblemen and royalty. The fact that many such celts refer to ancestors evokes the 'voice' of the conch, each clang of the celts perhaps calibrated carefully for pitch or tone, as in Chinese jade chimes, summoning forth the voices of ancients [Houston et al. 2006:267].

Long bifaces and stone slabs. Lithophones of this type have been found laid sequentially from shorter to longer blades, forming stone xylophones. Several hundred of these arrays have been found in Vietnam, where the first one to be discovered contained 11 bifacially worked slabs, which were 5,000 to 6,000 years old (Condominas 1952a, 1952b, 1974; Schaeffner 1951). Such musical instruments continued to be used from the Neolithic Bacsonian culture into historic times, when they were still considered to be family treasures by the Tay Nguyen ethnic group, which used them when worshipping deities and to protect their crops.

Another type of lithophonic xylophone, called a *pichanchalassi*, consists of five blades, which are played by Kabré boys, using two hammerstones, during their initiations in the northern mountains of Togo (Verdier 1962).

Stone cylinders. Portable, pecked and polished, solid stone cylinders produce clear tones when struck along the dorsal and lateral faces in the middle of their terminal and central zones when laid flat. The only object from the Americas of which I am aware that fits this description and has been described as anything other than a probable whetstone or pestle is the most "extensively culturally modified" and atypical example in Emily Brown's sample of 69 "kiva bells." This cylinder is unusual both in its degree of shaping and in its isolation from the rest of her specimens, since the 58 cm smooth shaft with pointed and flat ends comes from northeastern Arizona, rather than the Rio Grande Valley, where all but one other specimen were found (Brown 2005:430–431). Brown (2005:430–431) wrote that "in spite of its unusual location and degree of modification, I feel the identification of its function as musical is a good one." This article supports her conclusion, while suggesting that the unusually resonant two-toned artifact, which is not notched, like some true kiva bells, to hold a suspension cord (Brown 2005:424), may be another type of instrument designed to be played *without being suspended*.

Questioning the Presumed Utilitarian Function of Stone Cylinders

The first researcher to question whether long stone rods were in fact food-processing implements was Marceau Gast (1965, 2003), who was working with specimens from the Sahara (Figure 1). The first clue that the prehistoric objects should be treated as a class by themselves was that travelers, explorers, and archaeologists had found fewer than 25, even though they had conducted excavations and extensive surface searches over an area extending from the Atlantic Ocean to Chad (Gonthier 2005). This suggested that the objects were as exceptional as the equally rare

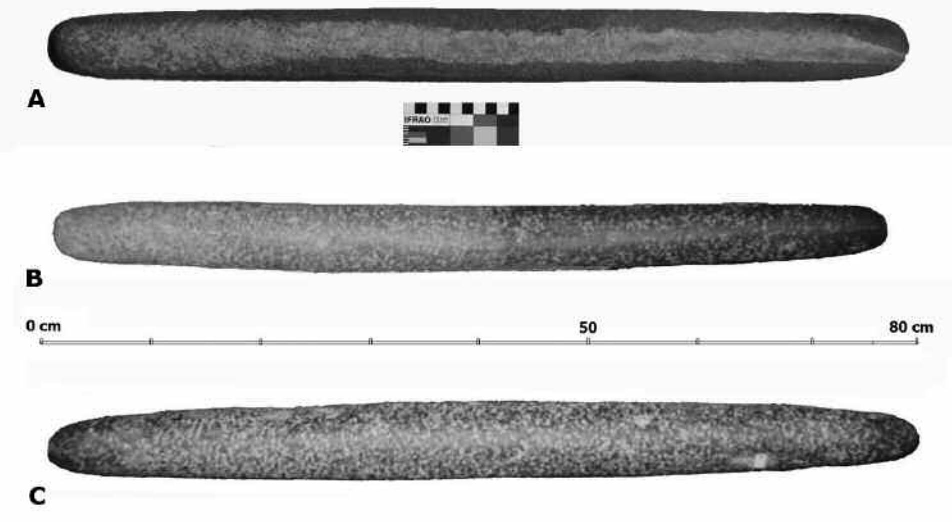

Figure 1. Three probable lithophones from the western Sahara: (a) this specimen, which is 72 cm long, 6 cm thick in the middle, and 6.5 cm wide at the same point, is one of two known to the author with a line of paint running around the entire instrument precisely where the horizontal isophonic plane meets the surface. The paint survived because the artifact remained almost entirely buried until it was found. The only point where it was exposed was an oblique section at top right, which exhibits a dark patina caused by exposure to wind and light; (b) this 76 cm long specimen was found projecting from the ground in the western Sahara, which explains why the left half, which was buried and protected from the wind, is lighter in color than the right half, which shows wind gloss; (c) this specimen, which is 80 cm long, is the second longest cylindrical "lithophone" from the Sahara known by the author.

zoomorphic and anthropomorphic sculptures from the same area, indicating that they were also prestigious or ceremonial objects.

Gast's realization that such long Saharan artifacts, which range from 2.5 to 10 kilos in weight and from 35 to 80 cm in length, were exceptional led him to test them as food processing implements and to look for the kind of wear that pounding or grinding should have left at one or both ends. In his summary, he noted both that many of them were far too heavy to have been used as pestles for long because of muscle strain and that a lack of wear proved that they could not have been used for perpendicular pounding. These findings led him (Gast 1965:311) to conclude "that they could not have been conceived for grinding any material by shock. This explains the need to find another name [than pestle] for such objects, whose use and purpose is far from being elucidated."

The first person to suggest that such African artifacts might be lithophones was Erik Gonthier (2005, 2009), who found only 34 candidates after scouring the huge prehistoric and ethnographic collections of the Musée de l'Homme, Institut de Paléontologie Humaine, and Muséum National d'Histoire Naturelle in Paris. Despite the vast geographic area from which these specimens hail, including the Ivory Coast, Cameroon, and Togo, the total number is still surprisingly low.

Another notable feature is that they all seem to have been made from foreign stone (Gonthier 2005). Most were made of chlorito-schists and schist-actinolites, with dolomitic limestone, amphibolites, quartzites, and smectites also represented. Some of the possible African lithophones, such as one made of chlorito-schist (MH, MNHN, 1913.5.220; Ténéré, Niger), which was found in a karstic area, were deposited around 1,000 km from the nearest known metamorphic rocks (Gonthier 2009, Gonthier and Hai 2011), suggesting that their acquisition required great premeditation, while increasing the likelihood that they were rare objects associated with prestige or rituals.

Physical and Acoustical Properties of Portable Cylindrical Lithophones

Gonthier, working alone (2009) and with Tran Quang Hai (Gonthier and Hai 2011), demonstrated that portable stone cylinders shared common acoustic properties when laid on a pair of foam cushions situated about a quarter of the way from

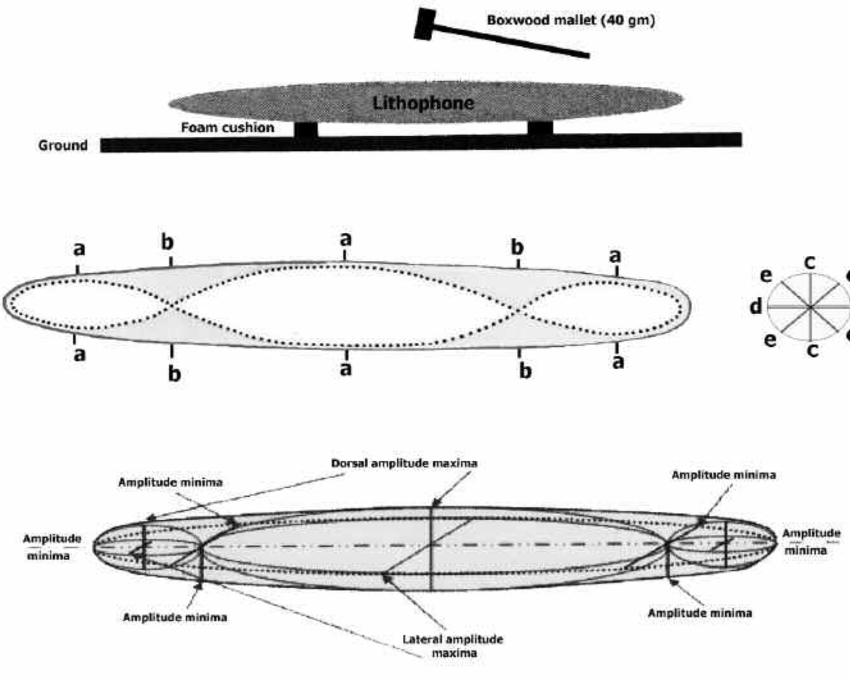

Figure 2. Illustration of acoustic tests, performed by striking each of the Saharan artifacts with a wooden mallet as it lay on foam cushions (top), which were placed under its acoustical dead zones to prevent contact with the ground. Sound waves (center) travel through cylindrical lithophones in sinusoidal curves that form two small lobes bracketing a larger central lobe. The surface of the instrument around the points where each sound wave crosses itself, which form pinch-points, is acoustically dull (b) by comparison to points where the lobes crest on the dorsal and lateral surfaces of the medial and terminal zones (a). Consequently, an elongated lithophone produces its clearest note when struck along the dorsal (or ventral) line in the middle of each of its three lobes (a) while it sounds dull in between (b). An elongated lithophone's acoustical minima and maxima (bottom; after Gonthier 2009).

each end and struck with a 40 gm boxwood mallet in their central and terminal zones (Figure 2).[1] When true pestles from the Sahara, which are smaller and bear traces left by food processing, were struck in the same places, they proved to be acoustically dull. But when the 34-long cylinders between 4 and 8 cm in diameter were struck, they produced clear fundamental tones ranging from *fa4 + 3* at around 700 Hz (Gonthier 2009) through *la*, at around 6,500 Hz, with resonances that varied between 1 and 2.5 seconds (Gonthier 2005). The majority of sounds also turned out to be about a quartertone different on the lateral faces from the dorsal faces, making most of the stone rods two-toned instruments (Gonthier 2005) (Figure 3).

Gonthier (2009) and Hai (Gonthier and Hai 2011) also noted that the apparent lithophones were made of homogeneous rocks whose consistency was especially coherent since discontinuities interrupt the propagation of sound waves through the artifact. The waves spread from a point of impact as the shock deforms the material and triggers a chain reaction at a constant speed, which differs from substance to substance, by provoking both longitudinal and transverse waves. The longitudinal or compression waves are propagated by deviations in the pressure from the material's equilibrium pressure, which causes a moving front of increased density, followed by suddenly decreased density as the wave moves onwards. Transverse waves occur at a 90-degree angle to the direction of propagation as waves of alternating shear stress. As the two kinds of waves move around the lithophone, they periodically displace its matter, causing molecules to oscillate, while the energy in the wave keeps getting converted back and forth between the kinetic energy of the rock's vibrations, on the one hand, and the potential energy of the ex-

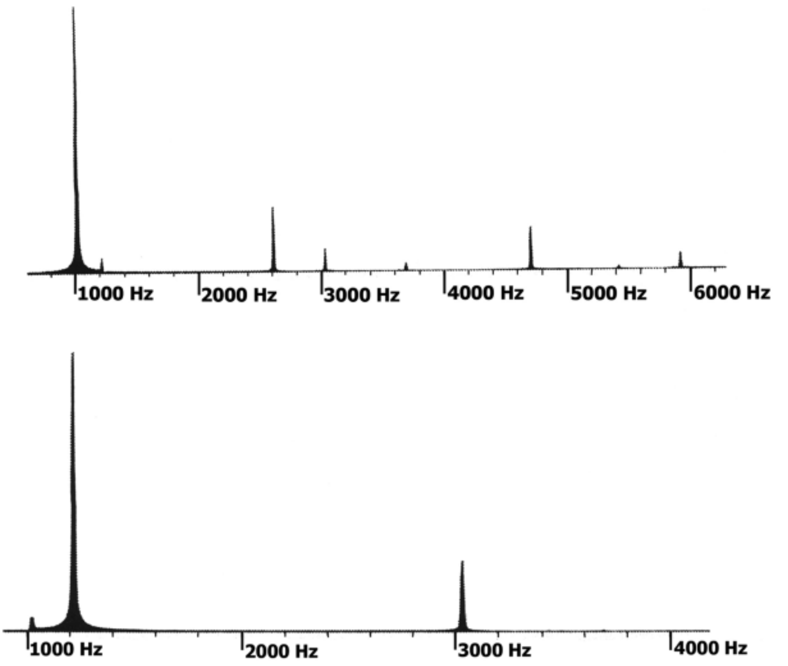

Figure 3. Spectrograms of acoustical analyses performed by Erik Gonthier and Francois Bernard Mâche of the same columnar Saharan lithophone (MH, MNHN, 1913.5.220; Corner Coll., Tafassasset, Valley, Tenere Desert, Niger. 64.4 cm L, 7.52 cm diameter) when struck in the center of the dorsal line (top) and the center of the lateral line (bottom). In Gonthier's (2009) words, "the harmonic waves manifest themselves with particular clarity since they correspond to pure sounds whose height is perfectly defined. We observe that the harmonics are perfect multiples of the fundamental note."

tra compression (in the case of longitudinal waves) and lateral displacement strain (in the case of transverse waves) of the matter, on the other.

Using replicas of Aurignacian flint blades, Cross et al. (2002:3–4) showed that a complex variable[2] derived from the equation for determining the frequency of the first mode of vibration of a chime bar,[3] provided a highly significant predictor "of the frequencies of the sounds produced, [confirming] that the chime-bar model is operational in respect of these lithic resonators." Their conclusion that a "player" would have "a heuristic indication of the sound-producing capacity of [a] specimen" made of appropriate material merely by estimating "its length and (secondarily) its thickness" (Cross et al. 2002:4) is equally valid for cylindrical stone lithophones, although the exact mathematical description of their acoustical phenomena varies depending on their shapes and Poisson ratios (Wang et al. 2012:111–121).

Gonthier (2009) and Hai (Gonthier and Hai 2011) were able to establish that longitudinal and transverse waves travel through the more-or-less cylindrical forms in sinusoidal curves that form three lobes: a large one between smaller ones at each end (Figure 2). The points where each sound wave crosses itself, which form the pinch-points between the lobes, are acoustically dull by comparison to the points where the lobes crest on the dorsal and lateral surfaces of the medial and terminal zones (Figure 2). The dull zones are the only places along a cylindrical lithophone's length where it can come into contact with another medium, such as the ground, without breaking the integrity of its waves and making it worthless as a musical instrument.

These dull zones correspond perfectly to the two spots that lie on an adult player's thighs when one or more lithophones are placed on the lap with the ends hanging over the outside of the legs and the center of each instrument exposed between the knees. The musician could also choose to play the lithophone by laying its dull zones on his or her ankles, which works even better acoustically (Erik Gonthier, personal communication, 2011).

Another way of holding a lithophone without weakening its harmonics, which Gonthier discovered through experimentation, is to hold the instrument off the ground by gripping it at the higher of its two dull zones—something that may be illustrated in a Neolithic fresco from Adjefou in the Tassili n'Ajjer in Algeria (Gonthier 2009), where a harp player faces a figure with a possible lithophone and a small crescent resembling the curved hammers still used to beat drums in the Sahel.

Columnar lithophones also turned out to be most sonorous when their ends were conical or ogival, rather than flat or slightly bulbous, like the majority of pestles, although such ends were hardly diagnostic for columnar lithophones because the range of longitudinal cross sections was quite varied (Gonthier 2009; Gonthier and Hai 2011).

Another feature that added to the quality of such lithophones was having an oval latitudinal cross section (across the instrument's trunk) rather than a circular one, because instruments with even diameters have less variation between the frequencies produced at the apex of the nodes along their dorsal and lateral lines (Figure 2) than lithophones whose horizontal diameter, when they are laid on a flat surface, is greater than their vertical diameter. An almost perfectly round lithophonic candidate from the Tilemsi Valley in the Sahara, for example, produced frequencies corresponding to *sol* whether it was struck on its dorsal surface (818 Hz = *sol#4 - 26*), lateral surface (802 Hz = *sol#4 + 39*), or even 45 degrees between those surfaces (807 Hz = *sol#4 - 50*), where the two sound waves that propagate along the vertical and horizontal planes meet (Figures 2). This contrasts with a probable Neolithic instrument with an oval cross section from the Tafassasset Valley in Niger, which produced frequencies ranging from 1819 Hz (*la#5 - 43*) on its dorsal (or ventral) line to 2115 Hz (*do#6 + 18*) on its lateral lines, and both of the above frequencies 45 degrees between those lines (Gonthier 2009).

Other factors that played a part in differentiating lithophones were the density of the material and changes in length, rather than width, which had almost no effect on fundamental tones. For example, when two lithophones of the same material (schist-actinolite) but different lengths were played, the longer one had a deeper tone. Portable columnar lithophones also have to be at least 4.5 times longer than their width in order to have any resonance, which forces makers to make an 8-cm-wide instrument, for example, at least 36 cm long and, preferably, much longer (Gonthier 2009).

The fact that any irregularities in such lithophones muffle or destroy the instrument's harmonics by impeding the propagation of sound waves also appears to be a partial explanation for why Africans eliminated asperities and made the surfaces of their apparent lithophones as even as possible. But the fact that the diameters of the 34 African candidates, which all seem to have been acoustically optimized by such streamlining, always fall within a narrow range from 4 to 8 cm, suggests that their girth was determined by the need for a comfortable grip. Similarly, the length and smoothness of these columnar artifacts was probably determined by the desire to obtain pure fundamental notes while making the implements as ergonomic as possible. This would have made them easier to transport, play, and even store—because columnar rods tend to keep their equilibrium when planted in the ground, which is exactly the way at least one of the apparent lithophones was found (Figure 1b) near Erfoud, Morocco, half-buried in a vertical position making it visible to anyone searching from afar.

This study of a visually and acoustically distinctive class of rare African artifacts, which were probably used as manually held and played lithophones, provides a set of criteria for recognizing similar instruments from elsewhere. These criteria include (1) diameters between 4 and 8 cm; (2) lengths between 35 and 80 cm; (3) dimensions 4.5 times longer than they are wide; (4) few, if any, signs of being used for vertical grinding or pounding; and (5) the use of such acoustically active stones as chlorito-schists and schist-actinolites.

Probable New England Lithophones

The factors that apparently led Africans over such a wide area to adopt or converge upon the same design for portable lithophones are based on a combination of ergonomic considerations and physical laws. These universals probably explain why the two artifacts from New England (Figure 4) with the acoustical characteristics of two-toned lithophones are almost identical to the Saharan implements.

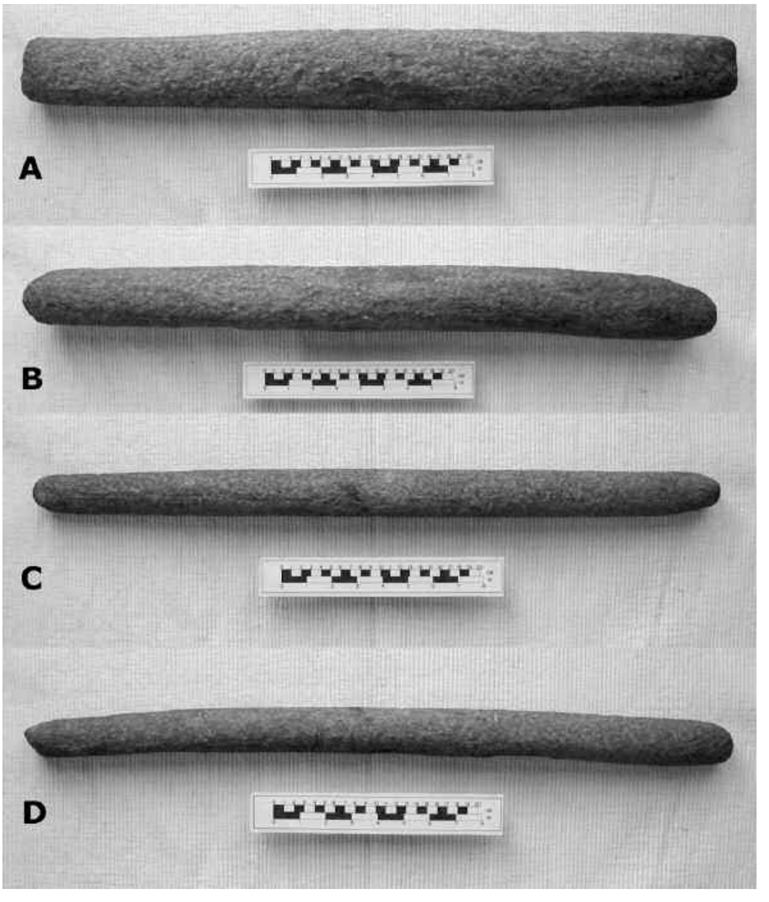

Figure 4. Probable lithophones from New England: (a–b) the longer of the possible cylindrical lithophones from New England is 72.5 cm long and comes from the Connecticut River Valley in Massachusetts; (c–d) the shorter of the two is 71 cm long and was found at Amoskeag Falls, New Hampshire.

The first and larger of the two prehistoric artifacts (Figures 4a, b) is from the Connecticut River Valley in Massachusetts, where it was found in the early 1900s and belonged to a family named Sherman. Like many of the probable African lithophones, which tend to weigh between 5 and 10 kilos, the dense (2.77 g/cm^3) Massachusetts specimen, which is 72.5 cm long and weighs 7.74 kg, is too heavy to be used for long as a pestle, according to Gast (1965, 2003). The artifact also shares two other characteristics with the largest group of Saharan lithophones. It is made of exactly the same class of rocks, chloritoid schists—in this case a chlorotoid-mica-schist with garnet inclusions—and exhibits anisotropy, defined by mica in visible foliation layers. Such schists are known to occur in four places within trading range of the Connecticut River Valley—a zone near Worcester, Massachusetts; Dutchess County, New York; the Narragansett Basin of Rhode Island; and southeastern Canada (Horst Marschall, personal communication 2012).

Unlike the majority of the African instruments, though, both of the possible American lithophones exhibit a noticeable curve when viewed laterally, suggesting that they may have been specifically designed to be played on the lap, where their curve gives them great stability. This camber in the two artifacts also counts against their use as the equivalent of rolling pins, which only work well when they are almost perfectly cylindrical, making them easy to roll, rather than easy to seat and keep steady.

If the artifacts are in fact lithophones that were played on the lap, then they can be said to have a dorsal surface. This feature allows one to speak of

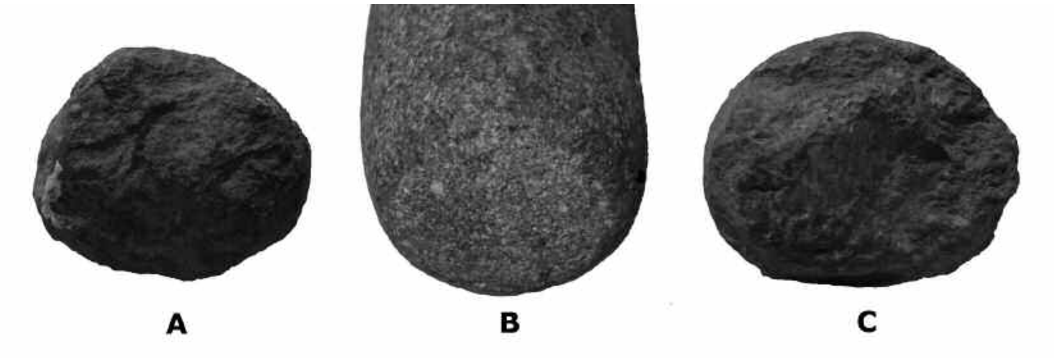

Figure 5. End views of true pestles and lithophones. Neither end of the probable Massachusetts lithophone (a, c) shows signs of ever having been used for pounding or grinding, whereas pestles, like the 24.5 cm specimen from California, whose end is shown at center (b), are often flat, concussed, or ground at one or both ends.

vertical and horizontal diameters, which in the center of the rod are 6.3 cm and 7.6 cm respectively, giving the Massachusetts artifact an oval cross section.

The second of the probable cylindrical lithophones from New England (Figure 4c, d) is from Amoskeag Falls, New Hampshire, where it was found some time between 1890–1910. The name of the falls derives from the Pennacook word "Namoskeag," which roughly means the "good fishing place," and covers a set of rapids created by a 15-meter (50-foot) drop in the Merrimack River. This drop provided one of the best places along the river for intercepting sturgeon, alewife, and salmon with a variety of methods, including nets stretched across the rapids.

Collection data shows that the Amoskeag specimen belonged to Bruce Jarnot before being acquired by Kevin Cordeiro and its present owner, William Moody. This New Hampshire example is 71 cm long and has vertical and horizontal diameters at its center of 4.1 cm and 4.6 cm, again producing an oval cross section (Figure 4c, d). The fact that both of the probable American lithophones have such distinctly oval, rather than round, cross sections, like some of the Saharan specimens, indicates that they may have been conceived as two-toned instruments. Before this can be confirmed as a general characteristic, however, more cylindrical lithophones have to be identified in the region. It is also noteworthy that their median diameters fall precisely within the same range as the African ones (4 to 8 cm).

Despite its superficial resemblance to the Massachusetts specimen in length, the probable Amoskeag lithophone has several particularities. The first is that it is made of porous siltstone, instead of chloritoid schist. A geological team from the Woods Hole Oceanographic Institution's (WHOI) Maclean Laboratory, which identified the material, suspected that its porosity gives the Amoskeag instrument its deeper acoustical tone in comparison to the Massachusetts specimen. Another distinguishing characteristic is that the artifact weighs just 2.55 kg. This is due both to its low density (2.26 g/cm^3) and to its relative thinness.

Its weight is so low, in fact, that it is much more likely to have been used as a pestle than the Massachusetts specimen, according to Gast's (1965, 2003) experimental findings. This suspicion even seems to be confirmed by grinding at one end, but the WHOI team concluded that the grinding zone, which is completely unpatinated, unlike the rest of the artifact, was a modern adulteration. It was supposed that a collector either ground away the distal cone to create a flat base, so that the artifact could be displayed standing on end, or that someone modified the artifact recently to make it comply with his preconceptions of it as a "pestle," perhaps while demonstrating its supposed use.

Although dozens of elongated artifacts in Massachusetts collections were tested during this study, the two artifacts under consideration ended up being the only ones without ancient evidence of having been used for vertical pounding or grinding (Figure 5a, c), and the only two which were acoustically active. This suggests that such artifacts are as rare in the region as the ones Gonthier studied in Africa. If they are as rare in

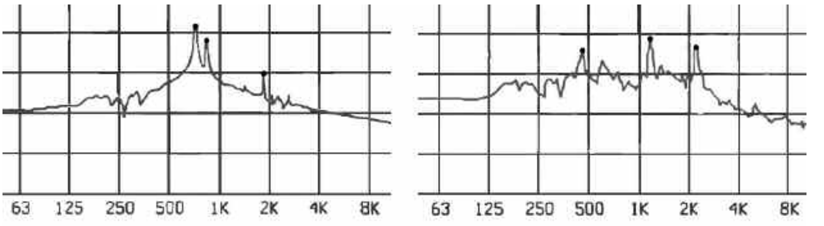

Figure 6. The acoustics for the two probable American lithophones differ, in part, because of their materials. The left graph, whose vertical axis is in 25-decibel units, shows the acoustical signature of the first hit on the Massachusetts artifact (#1, Figure 8), which was on the dorsal surface of its right end. The strikes at the center and left end of the dorsal surface on this candidate produced nearly identical curves and the same fundamental note, *F#5 – 31c* (726.9 Hz). The graph on the right shows the signature of the third hit on the probable New Hampshire lithophone (#2, Figure 9), which was at the dorsal center. The other strikes on the dorsal surface of this candidate, which is lighter, thinner, and more porous than the Massachusetts example, produced equivalent graphs and the same fundamental note of *D6 + 13 / 15c* (app. 1185.5 Hz). The only graphs that differed significantly from these samples for each possible lithophone were the ones produced by striking their lateral surfaces, which produced maximum peaks at *G#5 + 44c* (852.4 Hz), for Lithophone candidate #1, and *A#4 - 13c* (462.8 Hz), for Lithophone candidate #2.

their context as the African ones were in theirs, then it might be an indication that they were associated with such exceptional circumstances as rituals or displays of prestige.

Acoustical Analyses

Unlike the tests on the Saharan artifacts, which were conducted on foam cushions, the acoustical analyses of the New England artifacts were conducted by laying each specimen across a player's lap, with the dull zones—a quarter of the way from the tips—lying on his legs. Each artifact was then struck one time in the center of the dorsal surfaces of its right, left, and central acoustical lobes, and then, again, 90 degrees away on the side of its central lobe with a beaver wood, birch mallet. All eight of these tests (four per specimen) were recorded with iAnalyzer Lite software (Figure 6; Table 1), which generated a graph showing the signature of the sound waves created by each impact, in terms of decibels and hertz, and the musical note associated with the most audible peak.

Both lithophonic candidates proved to be two-toned, with the three successive hits on the dorsal surface of the heavier Massachusetts specimen producing the same note, *F#5* (F sharp 5 = 726.9 Hz), while the three strikes along the dorsal surface of the New Hampshire artifact all produced their own characteristic note, *D6* (1184.2 Hz). Both "instruments" produced another note when struck on the side of their central lobes, *G#5* (852.4 Hz) for the probable Massachusetts lithophone and *A#4* (462.8 Hz) for the Amoskeag, New Hampshire, artifact.

While this testing procedure worked well for artifacts that were identical to ones that were already known to be good sound emitters when played on the lap, the same assumption cannot be made for artifacts that are not rod-like. Therefore, researchers who want to test the acoustical properties of such objects should probably insulate them from the ground, by suspending them or placing them on small foam cushions, before tapping each potential sound-producing zone just once with a wooden percussor. If an artifact turns out to be a good sound emitter, the researcher should stop striking the original object because each impact has the potential of destroying signs of the artifact's use as a prehistoric instrument. Although it might seem onerous, researchers should make replicas of acoustically active objects in the same materials and strike the copies, rather than the originals, during any further testing or demonstrations.

Incidentially, compositional experiments carried out in this research went a long way towards revealing the rich potential of the two-toned New England artifacts for creating complex music, especially in association with such known prehistoric American instruments as flutes, rasps, rattles, tinklers, and drums. Although the sounds were clearly audible to everyone within a large auditorium, they were not nearly as loud or piercing as some drums and whistles, suggesting that the instruments, if that

Table 1. The Most Audible Peaks Graphed for Four Successive Hits on Each of Two Possible Lithophones from New England.

Lithophone candidate 1 (Massachusetts)			
1st hit (Dorsal right end)	104.1 dB	726.9 Hz	F#5 – 31c
2nd hit (Dorsal left end)	105.7 dB	726.9 Hz	F#5 – 31c
3rd hit (Dorsal center)	105.9 dB	726.0 Hz	F#5 – 31c
4th hit (Lateral center)	107.6 dB	852.4 Hz	G#5 + 44c
Lithophone candidate 2 (Amoskeag, NH)			
1st hit (Dorsal right end)	102.5 dB	1184.2 Hz	D6 + 13c
2nd hit (Dorsal left end)	104.6 dB	1183.8 Hz	D6 + 13c
3rd hit (Dorsal center)	98.0 dB	1185.5 Hz	D6 + 15c
4th hit (Lateral center)	92.2 dB	462.8 Hz	A#4 - 13c

is what they are, were used in gatherings rather than for long-distance communication.

Expanding the Sample Set and Determining Cultural Affiliations

The next phase of the study will concentrate on identifying more acoustically active artifacts from New England. One particularly promising area for finding new candidates is Amoskeag Falls, the place where the second possible lithophone from New England was found. Indian settlements existed on both sides of the cascade, but especially on the high bluffs overlooking the east bank, where Arthur Schricker found "fragments of at least nine ground stone rods" from "seven to nine cremation deposits within a large red ocher stained pit ... in 1937" (Robinson 2006:348). This feature on a gravel terrace overlooking both the falls, which lie about 30 meters below the cremation deposits (Murphy 1998:75), and the Neville site, has produced four AMS age estimates between 8260 ± 70 and 8690 ± 60 B.P. (Robinson 2006:362). One type of rod in the assembly (Robinson 1992:99–100; 2006:370, Figure 9b) is similar to an expanded-head rod that was found in a feature dated to 8985 ± 210 B.P. at the Weirs Beach site in New Hampshire (Bolian 1980:125; Robinson 2006:352).

Such rods, which are one of the earliest types in a typological sequence that spans 3,500 years, from 8500 B.P to 5000 B.P. (Robinson 2006:352–353), and another type called "Penobscot pendants," which have perforations and occur at the end of the period, seem to have been designed for suspension. But other rods from the beginning to the end of the series, including some from Table Land (Robinson 2006:370, Figure 9a), do not have any suspension features. One cache of three rods from the upper Penobscot River, for instance, lacks any signs of suspension and contains a 71 cm rod (Robinson 2006:371, Figure 10a) that is basically identical to the artifacts that have been proposed here as lithophones.

The other two rods in the cache have the same kind of "pronounced whetstone use facets" (Robinson 2006:371, Figure 10b–c) as many rods, which have been found with full-channeled gouges in the region's Early-to-Middle Archaic mortuary assemblages. This explains why both faceted and unfaceted rods from such contexts have generally been interpreted as whetstones for sharpening the gouges, or at least whetstone equivalents (Robinson 1996:106). According to the first hypothesis, rods without use facets like the 71 cm specimen in the cache have been interpreted as preforms (Robinson 2006:371), although they are generally longer and more finished than rods with facets. This anomaly led Robinson (1996:106) to suggest that such unfaceted rods might be symbolic and exaggerated equivalents of whetstones. This hypothesis could actually be compatible with the suggestion that the artifacts are lithophones, since "ritual and utilitarian factors may influence each other" (Robinson 2006:358) and a variety of gestures could have been used to make the artifacts emit sound, including stroping gouges, which would probably have added to the rods' semiotic significance as musical instruments.

Other examples of such possible "lithophonic" whetstone equivalents are a 27-cm-long rod from cremation burial CB103 from the Morrill Point Mound site, which has been dated by association with an adjacent feature, CB101, at ca. 8457 ± 52

B.P. (Robinson 2006:349, 368, Figure 7a), and a 46-cm-long, 2.3-cm-thick specimen from the Richmond-Castle site (Robinson 2006:353, Figure 9c).

Given the typological similarities between the acoustically active artifacts from Massachusetts and New Hampshire and rods that can be safely ascribed to the Early-to-Middle Archaic, all of the ancient rods from Massachusetts to the Canadian Maritimes (Murphy 1998:75) should probably be tested for their acoustical qualities, whether they show signs of suspension or not. This might reveal that artifacts with perforations or other signs of suspension are as acoustically active as "kiva bells" or the lithophonic celts, which Mayans suspended from their belts (Houston et al. 2006:267), while showing that some of the longer rods have all the ergonomic and physical properties of lithophones that could be played without being suspended.[4]

Future Investigations of Use Wear

Another goal of future study involves the microscopic comparison of use wear on suspected prehistoric lithophones with stigmata left on replicas of acoustically active American artifacts by soft percussors. A particular focus will be placed on wooden ones because their effects, to our knowledge, have not been studied before (Blake and Cross 2008; Cross et al. 2002), although wood was readily available to most prehistoric cultures and makes a highly effective sound producer.

This study will be modeled on the work of researchers who have studied the results of repeated percussion of flint, antler, and bone on stone. The first of these studies, which used only stone percussors, resulted in the consistent appearance of either small, densely clustered conical fractures or multiple small, densely clustered areas of polish on flake surfaces. "The cone-cracking results from direct, head-on percussion, while the polishes and scratches may result from a softer and more 'stroking' impact against the flake surface" (Cross et al. 2002:4).

The second study, which comes closer to ours with wooden percussors, looked for the faint signs left by two other resilient substances—antler and bone (Blake and Cross 2008). It showed that an antler "left dark, smeared markings," which turned out to be calcium/phosphorus deposits from the hydroxyapatite found in all bony materials, and that the deposits overlay "surface deformation in the form of clustered surface depressions" (Blake and Cross 2008:13).

Despite the excellent acoustics of the two artifacts that have already been studied from New England, if they were played with such soft percussors as wood, neither one is likely to have preserved the kind of non-random distribution of wear seen in the first study after a player repeatedly struck a blade (Cross et al. 2002:4), given that the rods have been subjected to geological forces, plowing, and more than a century of handling in successive collections. But there is still a chance that the discovery of the kinds of use wear characteristics of musical performances will be found on rods that are located *in situ*, if they are handled carefully.

Contextualizing the Probable Lithophones

The only part of North America where a wide range of prehistoric musical instruments has survived is the Southwest, where "bone and wood flutes; bone, wood, and reed whistles; copper and clay bells; shell trumpets; shell, stone, hoof, and nut tinklers; gourd, tortoiseshell, hide, clay, and cocoon rattles; bone and wood rasps; stone kiva bells; and wooden bullroarers" (Brown 2009:46) have all been found. We have seen how one of the reputed "kiva bells" in Brown's study was an anomaly that did not resemble any of the other artifacts in the sample, either in the area where it was found or in the way it was made (Brown 2005:430–431). It was not only longer and more highly sculpted and polished than any other specimen, but it was also cylindrical, especially resonant, two-toned, and lacked any visible means of suspension. In other words, it was just like the lithophonic candidates that have been described from New England and Africa, which seem to have been designed for manual prehension and playing and do not need to be suspended like true kiva bells to realize their full acoustical potential. Its distinction from the rest of Brown's artifact class and similarity to the New England examples suggest that the three artifacts may represent a previously unidentified genre of prehistoric musical instruments not only in the northeastern part of the continent, but also in the rest of North America.

But Brown's comparison with "kiva bells" remains deeply significant for two reasons: (1) because all three artifacts could have been suspended despite the absence of diagnostic notches, perforations, or abrasions left by cordage; and (2) because real "kiva bells" are among the few native lithophones from the continent, which both go back into prehistory and have known cultural uses. According to Edgar Hewett (1909:655), they were "suspended from the roof by strings of deer-skin," where they were "tapped with stones of the same kind" when a "priest" wanted to call men to a kiva. Frances Densmore (1938:45–46) reported that "[t]he larger stone is heavy, black in color, and shaped roughly like a crescent with notches cut in the concave edge. One man carries the stone, suspended by a heavy thong, and strikes it with a smaller stone, producing a sound like that of bells." According to Densmore (1938:45–46, 172–173) and Brown (2005:420), the stones were used during ceremonies that were linked with sicknesses, winter solstices, and death. The association with death is particularly striking (so to speak) in light of the fact that lithophones were probably associated with funerary practices in New England, too, even if those practices were both geographically distant and much farther back in time.

The similarity of Mooney's (2006:397 [1900]) and Hewett's (1909) descriptions of lithophones, which were both suspended in buildings—one in a Lower Cherokee town and the other in Taos Pueblo—suggests that such instruments might have been widespread in North America. Nevertheless, an engraving by Theodor de Bry (1528–1598), which shows a Timucuan clubbing a stone on the ground between two rattle players during a display of trophies (Alexander 1976:Pl. XVI; Howell 2012:163–164, 168) has to be taken with circumspection, both because de Bry "apparently borrowed images (and texts) from accounts from one region of the New World to use in his books about another" (Mark Howell, personal communication 2012) and because lithophones tend to lose their sonority when laid directly on the ground. Despite these reservations, the combination of the illustration with the ethnographic reports suggests that several types of lithophones were once played in North America. It is likely that they included the kind of highly sculpted, portable, cylindrical lithophones that seem to have been identified now in both New England and Arizona.

Conclusions

The main goals of this paper have been to propose a new instrument class for the American Northeast, if not the continent, and to offer suggestions as to how people who are inexperienced in music and acoustics can non-destructively test suspected lithophones in the archaeological record. As Emily Brown (2005:424) noted in her dissertation, this is a problem she attempted to circumvent by tapping such potential lithophones with her fingernail. Despite the simplicity of the additional suggestions offered here, which involve the use of free analytical software for cell phones (iAnalyzer Lite) and the minimal use of wooden rather than stone percussors, they can be used to test artifacts quickly, while eliminating any visible effects on their surfaces. This is significant because lithophones, which are sometimes almost completely unmodified rocks, are often much harder to recognize than such musical instruments as flutes or rattles—even by experts.

Combined with the difficulty of recognizing many lithophones, the perceived risk of testing candidates probably helps to explain why so few have been identified outside of the Southwest in North America. The two cylindrical artifacts, which were assumed to be unusually long pestles even though they lacked the ancient wear associated with such tools while displaying all the ergonomic, lithic, and acoustical traits associated with probable portable lithophones in the Old World, not only represent a new class of potential musical instruments in New England, but also serve as a reminder that we must not take previous definitions for granted.

The re-evaluation of artifacts to determine whether they could have been lithophones may have surprising results. One example was brought to our attention by engineer and inventor Robert Trotta (personal communication, 2010), who wondered whether some artifacts currently classified as projectile points could have been suspended like chimes. He considered turkeytail points to be the best candidates for such lithic tintinabulums, as they are almost always made of acoustically rich Indiana hornstone. Furthermore, their tiny stems make them difficult to haft, and, consequently, hard to use as knives or projectile points. He pointed out that their small bases would have been perfect, however, for hanging them, while their unusual thinness may have made them particularly sonorous.

Trotta's suggestion is intriguing, both because there is an excellent precedent in North America in the form of stone tinklers or "ringing stones," which are small suspended blades that were often made of acoustically active petrified wood (Brown 2005:371–376) and because the excellent depositional contexts of many turkeytail caches makes it likely that his conjecture can be tested by looking for the kind of use wear that was found on replicas of Aurignacian flint blades (Blake and Cross 2008; Cross et al. 2002).

In the meantime, the identification of two artifacts whose combination of features seems to fit those of cylindrical, two-toned, portable lithophones, in a region where high humidity and the lack of protective caves have led to the loss of prehistoric musical instruments made of perishable materials, makes their likely identification all the more noteworthy. I hope that this analysis will trigger the recognition of more of these sonorous artifacts and of other possible forms of lithophones, which could vastly expand our knowledge of the fossil sounds and rituals of the New World.

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Notes

1. The prehistoric artifacts referred to in this article were struck only enough times (usually four) to determine their acoustical properties and only with resilient materials, which would not leave apparent concussion marks. Once the acoustical qualities of the prehistoric artifacts were determined, modern replicas were produced, which were used in later demonstrations, and the original artifacts were no longer struck in order to protect their surfaces.

2. The complex variable was obtained by dividing the thickness of each specimen by the square of its length (t/L^2).

3. $f = 1.03(Ym/\delta)^{0.5}t/L^2$; where f = the frequency of the first mode of vibration, Ym = Young's modulus of elasticity, δ = density, t = thickness and L = length.

4. Upon reading an earlier version of this paper, Brian Robinson (personal communication, 2012) wondered whether "they might produce musical notes as well," which would "greatly add to their role as suspended ritual objects." These objects, as he says,

> are well dated ... with multiple forms and cross sections from round (early) to flat (late). Some are clearly used as whetstones, many are not. Bradley [1996] reported on one enigmatic specimen that was well pecked and ground flat only on one side. The specimen is 38 cm long, 8 cm wide at one end and 3.4 cm wide at the other end, thus not symmetrical but also rather odd in terms of whetstone use. It was found cached with gouges diagnostic of the Middle Archaic period. [His paper includes] ... an account of another rod 43 cm in length that was more symmetrical and found with Middle Archaic period gouges at the Portage site [Bradley 2006:48]. I report on a flattened perforated pendant or whetstone that is 71 cm long and I know of a cache of round stone rods (perhaps 2 cm thick) that are 71 cm long. Could any or all of these fall into the category of lithophones? I have never dared strike them.... Importantly, none of these have wear patterns like those of a pestle, so 'reputed whetstones' should be cited as an alternate functional suggestion for such rod-like stones. The smaller rods, often eight inches to a foot or more, are usually less than 2 cm in width and often have curiously ground ends and are often drilled for suspension. David Sanger found a quarry for the manufacture of these rods at the Gilman Falls site in Maine. The site yielded 147 rod fragments, broken in manufacture, made from a foliated quartz-muscovite granofels and/or phyllite (Sanger 1996:14).

Although the acoustical analyses described in this article already demonstrate the acoustical qualities of two of the rods, which can safely be incorporated into the Early-to-Middle Archaic rod sequence studied by Robinson (probably at the beginning, given their oval cross sections), they probably represent only one of the types of lithophones that were played in the region—the kind that was designed to be played on a lap or while being held manually, unlike perforated, notched and large-headed rods, which were probably suspended and played like chimes. The presence of both forms in the same mortuary assemblages suggests that the two were played during funerals.

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