

Rock Art Acoustics in the Past, Present and Future

The relationship of sound and rock art is reviewed. Ancient legends of supernatural explanations for echoes are summarized. The hypothesis that unusual acoustics such as sound reflection influenced the selection of rock art sites and subject matter is examined. Techniques that have been used for studying the relationship between acoustics and rock art are described. Results to date are reviewed, including the following new results: 1) a systematic quantitative study of Hieroglyphic Canyon, Arizona, showing the main rock art panels occur at the location possessing the greatest intensity of sound reflection, and 2) quantitative measurement of a ringing rock at Painted Rocks State Park near Gila Bend, Arizona, to characterize the resonant frequency and resonance time. Anticipated future methodological approaches are discussed. Conservation of the natural acoustics at rock art sites is urged.

El conexión del arte del sonido y de la roca se repasa. Las leyendas antiguas de las explicaciones supernatural para las generaciones de eco se resumen. Se examina la hipótesis que la acústica inusual tal como reflexión sonido influenció la selección de los sitios del arte de la roca y del tema. Se describen las técnicas que se han utilizado para estudiar el lazo entre la acústica y el arte de la roca. Los resultados hasta la fecha se repasan, incluyendo los nuevos resultados siguientes: 1) un estudio cuantitativo sistemático de la Hieroglyphic Canyon, Arizona, mostrando los paneles principales del arte de la roca ocurre en la localización que posee la intensidad más grande de la reflexión sonido, y 2) la medida cuantitativa de una roca de sonido en el Painted Rocks State Park cerca de la Gila Bend, Arizona, para caracterizar el tiempo de la frecuencia resonante y de la resonancia. Se discuten los acercamientos metodológicos futuros anticipados. La conservación de la acústica natural en los sitios del arte de la roca se impulsa.

Accumulating evidence suggests that acoustics may have been a motivating influence for the production of a substantial proportion of the rock art found around the world. Sound — in the form of echoing, reverberation, resonance (Bjork 1997; Hedges 1993; Dauvois 1996; Dauvois and Boutillon 1990; Ouzman 1997, 2001; Reznikoff 1995; Reznikoff and Dauvois 1988; Steinbring 1992; Waller 1993a, 1993b, 2000a, in press) and ringing rocks (see below) — appears to have been a determinate for the selection of location and/or subject matter in a large number of cases.

It is a fact known through numerous ethnographically documented legends that most ancient cultures held the belief that certain natural phenomena were caused by supernatural beings. This type of belief is categorized as “animism”, a form of personification.

One complex natural phenomenon that was personified by ancient cultures is echoing, which has been explained only in modern times by invisible sound wave reflections. Legends documented from around the world show that echoes were perceived as emanating from spirits or were considered spiritually important. Examples include the following:

- 1) Europe: The Greek nymph Echo was thought to be responsible for repeated words (Bonney 1992).
- 2) South Pacific: “Echo as the bodiless voice, is the earliest of all existence” (Jobes 1961).
- 3) North America:
 - 3A) A Paiute legend describes witches (tso-a-vwits) living in the belly of mountain sheep and in snakeskins hidden among rocks, from which they take great delight

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in repeating in mockery the words of passersby. (Gill and Sullivan 1992:79).

- 3B) The Acoma migration story describes Masewa (son of the sun) leading the people out of the place of emergence, heading for a place called Aako. As they travel they come upon different places they suspect might be Aako. To test each one, Masewa calls out in a loud voice, 'Aaaakooooo!'. If the echo resounds, the people stay to test the place further. If the echo is not good, they simply pass it by. At a place just east of Acoma, the echo is perfect, and Masewa announces that this is Acoma." (Gill and Sullivan 1992:4,5). (Interestingly, Petroglyph National Park is located at the eastern border of the Acoma aboriginal land claims, and was found by the author to produce excellent echoes.)
- 3C) A site called "Wikwip" in California contains rock art for which there exists ethnographic information that the paintings were made by men preparing for ceremonial dances. The site name means Echo Rock, and is derived from the sound-focusing acoustical characteristics of the cave (Hedges 1993).
- 3D) The Navajo Night Chant (Yeibichai) includes offering of prayers to the divinity Echoing Stone on the first day of purification (Highwater 1984).
- 3E) The Twin Palongawhoya (Echo) features prominently in Hopi creation myths (Williamson 1984).
- 3F) Diverse Native American traditions describe Talking Rocks or hold that the "rocks will speak". (Perhaps this phrase should be taken literally, since at many rock art sites one can experience words bouncing off the rock surface where the art occurs, and it does indeed give the impression that the rock is speaking.)
- 4) Central America: The Aztec earth and cave god called Tepeyollotl was thought to cause echoes. ("Tepeyollotl" Encyclopedia Mythica)
- 5) South America: In Chile, rock art is found in locations associated with a mythological being known as "sereno", who lives where the water sounds; also in Chile there is a rock art painting called Diablo at a site that makes a noise that frightens the villagers when the wind of a dust devil strikes the rock (Claudio Mercado, personal communication 1998).
- 6) Asia: Echoes have religious significance to members of an indigenous tribe of India called the Korku. This

tribe continues to produce rock art today, using echoes as a selection criteria for choosing which caves to paint (Somnath Chakraverty, personal communication 1996).

It should not be considered an affront to a culture's intelligence that echoing was personified. It is important to distinguish "intellectual capabilities" vs. the use of different paradigms or world views. To attribute phenomena of nature to supernatural spirits was a quite common paradigm in ancient times, even for intellectually-advanced cultures. The reflection of sound waves is quite a complex phenomenon. For instance, if a person makes a loud enough noise while standing more than about 15 meters away from a flat or concave rock wall, that person might (if the surface is sufficiently smooth, dense and properly oriented) hear a delayed repeat of the sound coming from the wall. Yet simultaneously, a second person standing closer than 15 meters from that wall would hear only the first person's original sound, and not the echoed repeat. The second person would swear that no sound came from the wall (because of insufficient time delay at that position to distinguish the two closely-spaced sounds), while the first person would swear that there was indeed sound coming from the wall. When the two people switch positions and try it again, they confirm the paradoxical (hence "magical") observation of sound coming from the wall that can only be heard from a distance. That this experience of a paradoxical phenomenon could lead to thoughts and feelings of the supernatural is evident in various synonyms used to express the numinous: miraculous, mysterious, arcane, impenetrable, inscrutable, mystical, unaccountable, unguessed, unknowable, obscure, enigmatic, baffling, perplexing, puzzling, occult, beyond understanding (Merriam-Webster, 2001).

Given the propensity of ancient cultures for attributing echoes to spirits, it follows that the actual rock surfaces that produce echoes would have been considered dwelling places for those spirits. It is reasonable to theorize that locations with such echoing surfaces would have therefore been considered sacred. Typical sound-reflecting locations include caves, canyons, cliff faces, outcroppings and large boulders – precisely the characteristic locations where rock art is found. One question that has baffled rock art researchers is: why are some rock surfaces selected in preference over other nearby surfaces for the depiction of petroglyph and/or

pictographs? The author has found that rock art often occurs at the exact location of the source of sound reflection and/or at a good spot in which to stand for hearing an echo come from elsewhere. If acoustics were indeed an influence for the production of some subset of rock art as theorized, then those locations decorated with rock art should be expected to possess unusually good acoustical properties relative to non-decorated locations.

The possibility that the surfaces of these sites were decorated with images evoked upon hearing the echoes is suggested by the author's experimental observations. For example, echoes of percussion noises such as clapping can mimic the sound of hoof beats, and hooved animals are a frequent rock art theme. Voices appear to emanate from rock surfaces on which anthropomorphic beings are depicted. Thus the artists may have been attempting to depict the spirits who they felt inhabited the rocks and who were responsible for the sounds. Thus, motivation for both the context (location) and the content (subject matter) of rock art can be directly derived from the phenomenon of sound reflection via the ethnographically-documented animism of echoing.

This acoustic theory does not necessarily conflict with other theories (reviewed by Bahn 1997) attempting to explain the motivation for rock art, since sound can be an integral part of activities such as hunting magic, shamanistic rituals involving trance, etc. (see also Lever 1998). While it would be impossible to prove exactly what the ancient artists were thinking, the hypothesis that rock art occurs preferentially at sound reflecting locations is experimentally testable.

The author has tested over 100 sites in France, Australia and the U.S. for sound reflection, and found echoes and/or reverberations at almost every one of them. A list of these sites, plus a large number described by other researchers as having acoustical properties, is being maintained on the Rock Art Acoustics page of the world wide web at <http://www.geocities.com/CapeCanaveral/9461> (Waller 2001).

Since the author's realization in 1987 of the possible significance of echoes experienced at a paleolithic cave art site, the methodology used for documenting the sounds at rock art sites has evolved. Initial studies involved simply calling out or clapping upon approaching rock art sites and listening for echoes.

This progressed to determining if the echoing sounds better at decorated locations than surrounding terrain. This empirical technique is still useful for preliminary scouting studies of large areas. For objective, quantitative measurements of acoustics, a device for generating reproducible impulse sounds was used in conjunction with portable electronic audio recording equipment, and analysis of the recordings was accomplished by use of sound level meters and specialized computer programs. While sounds were recorded on analog tape for most studies, some of the more recent studies have used digital equipment (Waller, Lubman and Kaiser 1998). The digital results served to confirm both the evidence from analog recordings and the subjective impressions of echoes. Acoustical testing of rock art sites has thus progressed from subjectively listening for the existence of echoes at sites, to performing objective measurements for determining if rock art occurs specifically at locations that echo best relative to the non-decorated surroundings. An analysis of acoustic data systematically collected in a portion of Horseshoe Canyon in Utah showed that the five art sites within the study area correlate exactly with the five locations within the canyon possessing the greatest intensity of echoing (Waller 2000a). The present paper reports consonant results from a similar study conducted in Hieroglyphic Canyon, Arizona.

Also presented is a first attempt at characterizing the sound qualities of a ringing rock associated with rock art. Even today, such ringing rocks often evoke surprise in modern people, since the mechanism of the ringing is not well understood. Ringing rocks, gong rocks, bell rocks, and lithophones, as well as the related but distinct category of sounding stones, have been found by a number of researchers in association with rock art (Bean 1975, Dams 1985, Dauvois and Boutillon 1990, B. Fagg 1956, M.C. Fagg 1997, Heizer 1953, Knight 1979, Nissen and Ritter 1986, Parkman 1992, True and Baumhoff 1981; see also Appendix below for an extensive listing of the results from a search using the term "Bell Rock" in "Rock Art Studies: A Bibliographic Database" compiled by L. Marymor 2001).

METHODS

The site of Hieroglyphic Canyon (in the Superstition Mountains near Phoenix, Arizona) was

selected for detailed acoustical study because it is in an unmodified condition, has relatively low ambient noise (the author had to wait until the departure of a troupe of Boy Scouts who were whooping loudly to play with the echoes!), and contains rock art that is not spread evenly within the canyon so that undecorated as well as decorated locations could be tested for comparison of reflected sound levels. The methodology used to quantitatively measure the relative intensity of sound reflection systematically at multiple locations within Hieroglyphic Canyon is similar to that previously described for Horseshoe Canyon (Waller 2000a).

Briefly, at each location a single loud percussion noise was produced via a spring-loaded device designed to reproducibly deliver a percussive impulse. Each exper-

iment at each location was conducted in replicate to assess reproducibility of the impulse, intensity of the reflected sound, and echo delay time. Ambient sounds before, during and after each impulse were recorded on Type II tape with a Realistic Stereo-Mate SCP-29 Model 14-1068A portable cassette analog recorder using an (uncalibrated) omnidirectional Realistic stereo Electret microphone model 33-1065 placed one meter from the impulse generating device.

These recordings were then digitized at a sampling rate of 22 kHz and quantitatively analyzed for sound intensity as a function of time and frequency using SoundEdit Pro® v1.0 on a Macintosh Quadra Power PC®. The data was exported into Microsoft Excel® v4.0 for mathematical analysis. The average dB for each 6 millisecond interval was calculated over 0.5 to 7.5 kHz, then corrected for background ambient noise. The maximum dB level occurring after the impulse (excluding the first 0.1 sec, which is approximately the threshold for distinguishing an impulse from the repeated sound), was plotted on the Y-axis, vs. the test location as estimated in meters from the mouth of the canyon plotted on the X-axis.

The recording of the ringing rock at Painted Rocks State Park near Gila Bend, AZ was made and analyzed with the same equipment described above. This site was not pre-selected for testing, rather the

Hieroglyphic Canyon Acoustics

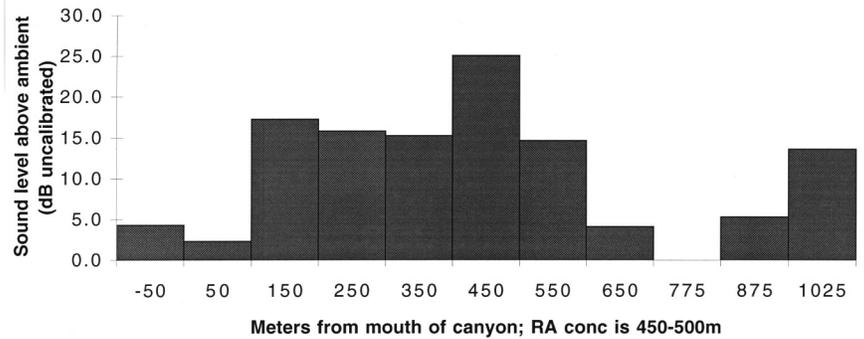


Figure 1: Measurements of sound reflection at locations throughout Hieroglyphic Canyon, AZ.

author fortuitously was present and recording when the sound of the rock was produced by a person (unknown to the author) who struck the ringing rock with a smaller rock.

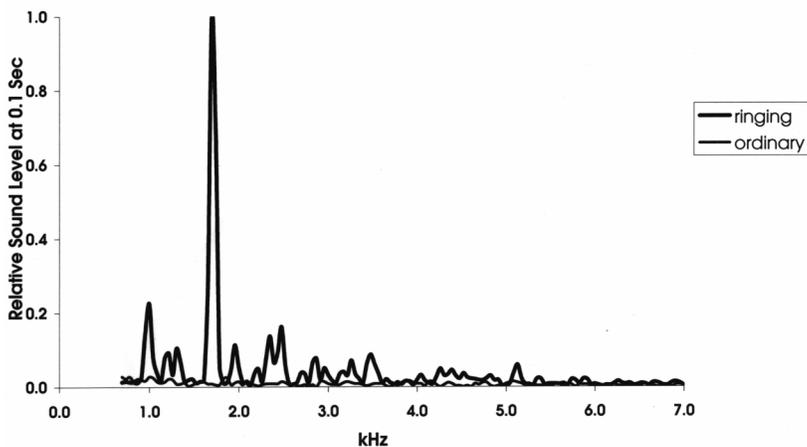
RESULTS

1) Hieroglyphic Canyon, near Phoenix, AZ

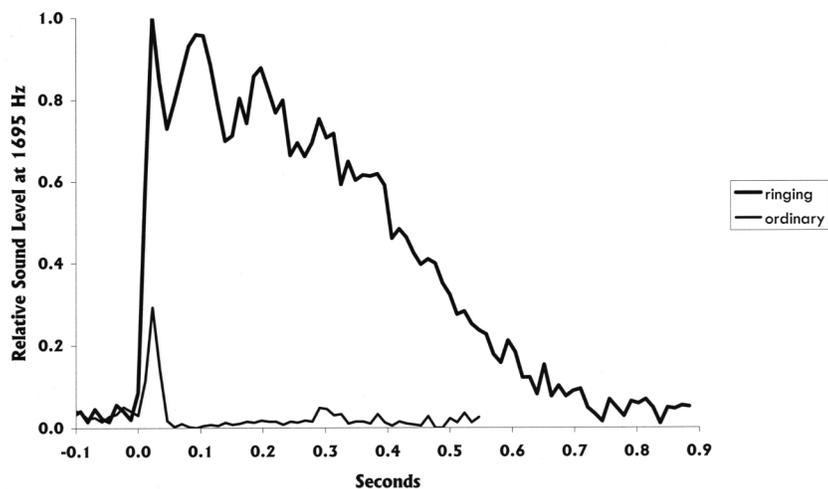
Figure 1 shows the intensity of sound reflection tested at regular intervals through a portion of Hieroglyphic Canyon. These results show that the location of maximum sound reflection intensity at 450 to 500 meters from the mouth of the canyon corresponds exactly to the location of the densely decorated main rock art panels (also at 450 to 500 meters from the mouth of the canyon). The few isolated art figures down canyon (less than 450 m from the mouth of the canyon) are situated at locations with measurable sound reflection, but at a relatively lower dB intensity than the main concentration of figures. The undecorated locations up canyon (further than 500 meters from the mouth of the canyon), even though possessing rock surfaces perfectly suitable for decorating, have the lowest dB level of sound reflection.

2) Ringing rock at Painted Rocks State Park, Gila Bend, AZ

2A: Gila Bend Ringing Rock: Frequency



2B: Gila Bend Ringing Rock: Resonance Time



Figures 2a & 2b: Characterization of ringing rock at Painted Rocks near Gila Bend, AZ.

Figure 2A is a plot of sound intensity in decibels (measured at a given time of 0.1 seconds after striking) on the Y-axis, vs. frequency in Hertz on the X-axis; this shows that the main resonating frequency of the ringing rock near Gila Bend is approximately 1695 Hz. The time decay curve of this resonance frequency at 1695 Hz is shown in Figure 2B, in which sound intensity in decibels on the Y-axis is plotted vs. time in seconds on the X-axis; this yields a resonance time of approximately 0.7 seconds. (By contrast, the duration of sound from an ordinary non-ringing rock is much less than 0.1 sec, yielding a percussive clicking sound rather than a ringing effect.)

DISCUSSION

The Hieroglyphic Canyon results corroborate the earlier results from Horseshoe Canyon, since both studies show that the art occurs specifically at the locations that correspond to the highest levels of sound reflection. These data support the hypothesis that rock art occurs preferentially at echoing locations. There were no obvious differential erosive factors that might have preferentially destroyed any presumed art in non-echoing locations (see discussions of taphonomic considerations in Bednarik 1994 and Waller 1994). Thus these results suggest that the artists in diverse cultures and regions intentionally chose to decorate surfaces having unusual acoustic properties.

The analysis of the ringing rock near Gila Bend represents a step forward in characterizing the acoustical properties of a ringing rock associated with rock art. Characteristics measured include the main resonating frequency (1695 Hz) and an estimation of resonance time (approximately 0.7 sec). Much work remains in terms of standardization of technique.

The findings in many parts of the world of an association of acoustics with rock art, together with relevant ethnographic information, suggest that a substantial proportion of rock art around the world may have been motivated by sound.

The magnitude of this proportion remains to be determined by acoustic tests such as those described herein.

Digital video recording with its CD quality sound is expected to provide an important means for documenting sounds together with the sights of rock art locations (Schaleben 1999; Waller 2000b). Future methodology improvements planned for acoustic testing include use of a binaural dummy and Polar Energy-Time Curve analysis that would enable localization of the apparent source of the reflected sound (auralisation of the "acoustic image"), as well as less

labor-intensive characterization of the acoustic environment. An exciting new invention that can visualize sounds and has demonstrated the ability to localize the exact source of sounds, including reflected sounds, is the Acoustic Camera (Heintz 2001); plans are underway to apply this new equipment to study rock art locations. It is anticipated that such detailed acoustical analyses will yield further insights into the cultures that produced the art.

Documentation of acoustical properties of rock art sites, including ringing rocks, is also important for reasons related to conservation. This gives a broader meaning to the task of "rock art recording", which would be incomplete if it were not to include audio recording and detailed descriptions of sound characteristics (see Berrier 2000 for a formalized documentation form for acoustical phenomena at rock art sites). Unless more attention is brought to the relevance of acoustics, inadvertent damage to the sound characteristics of rock art sites will continue, such as damage to sound-reflecting surfaces and construction of structures that interfere with sound waves (Waller 2000c). Acoustical data can be used as a baseline for determining at a given site the effects over time of weather, erosion, noise pollution, site intervention and vandalism on the acoustical properties that may have been a major motivation for the art in those locations. A direct implication of this body of rock art acoustic discoveries is that the environment around rock art sites should be left in a natural condition so that the acoustical properties are preserved.

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APPENDIX

**"Bell Rock" search results from Rock Art Studies: A Bibliographic Database
compiled by Leigh Marymor, conducted 8Sep01**

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