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Conservation of Rock Art Acoustics: "Unexpected" Echoes at Petroglyph National Monument

Abstract: The previously unrecognized need for conserving the acoustical properties of rock art sites is discussed. Petroglyph National Monument (PNM) was chosen as a challenging test case for the acoustical theory of rock art motivation. In numerous other sites around the world, acoustic phenomena such as echoes have been found in association with rock art, suggesting the art was motivated by acoustics. Although the morphology of PNM is not the type that would normally be considered likely to produce sound reflection, acoustic testing revealed that very strong echoes could be heard at each of the representative decorated locations tested. At two non-decorated locations tested within PNM, no noticeable echoing occurred. These results, documented by objective audio recording and analysis, are consistent with the rock art of PNM being motivated by acoustics. The relevance of the spiritual importance attributed to echoes in various ethnographically recorded oral histories of the Pueblo peoples is discussed. Conservation of the natural acoustic environment is urged for PNM, including the recommendation to minimize urban traffic noise.

Introduction

This paper elaborates on the theory and practical considerations of the need for conservation of acoustics at rock art sites in general, and presents research results to substantiate the need for conservation of the natural acoustics at Petroglyph National Monument (PNM) in particular.

Accumulating evidence suggests that sound—in the form of echoing, reverberation, resonance, and other unusual acoustical properties—is a prominent feature of hundreds of rock art sites around the world (Bjork 1997; Hedges 1990, 1993; Dauvois 1989, 1996; Dauvois and Boutillon 1990; Ouzman 1997, 2001; Reznikoff 1995; Reznikoff and Dauvois 1988; Steinbring 1992, Waller 2002a). These documented examples support the theory of a motivational connection between rock art and acoustics (Waller 1993a, 1993b, 2000; reviewed in Waller 2002b). There are many legends from around the world that explain echoes as originating from supernatural spirits, a form of animism (Bonnefoy 1992 [Greek]; Jobes 1961:490 [South Pacific]; Gill and Sullivan 1992:79 [Paiute]; Encyclopedia Mythica 2001 [Aztec]). Since echoes appear to originate from rock surfaces such as those found in canyons and caves, the spirits that were perceived as making these sounds were thus probably thought to dwell within those rocks. It is hypothesized that the rock art subject matter represents the images of the spirits that the artists envisioned to be causing the mysterious echoed sounds. For example, anthropomorphic figures may have been inspired by echoes of voices, and zoomorphic figures by percussive echoes perceived as hoof beats. Thus, acoustics may explain not only the perplexing locations of rock art, but its unusual subject matter as well (Waller 1993a).

A practical implication of these theoretical advances and experimental research results has been the recognition that conservation efforts should be expanded to preserve not just the images themselves, but also the natural acoustical properties of the rock art sites. The question as to whether these acoustical considerations are applicable to PNM is highly relevant, in view of both the abundance of rock art there, and the threat of urban encroachment including proposed construction of a major highway though the monument.

Methods

Test Site Selection: Challenging

Although the author has found sound reflection at nearly every rock art site he has visited that has not had significant modifications, some scholars

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Figure 1. Photographs taken in Rinconada Canyon of a typical location within PNM, showing the general morphology of the escarpment and including a boulder decorated with ancient rock art (courtesy M. Berrier).

have doubted the relevance of acoustics to certain rock art sites because of their opinion that those sites would not be expected to echo. When the author asked one authority for an example of a rock art site that would not be expected to echo in his opinion, and would thus be a challenge to the acoustical theory of rock art motivation, PNM was suggested. Perhaps this opinion was based on the lack of towering cliff faces; instead the escarpments of PNM consist of gentle slopes of boulders (see Figure 1). Thus, echoes at PNM were "unexpected" by that individual based on his previous experience with such morphology (and his opinion was shared by several others). However, echoes at PNM were actually expected by this author based on the predictive value of the acoustical theory of rock art motivation, and his experience at sites with similar morphology (e.g., Deer Valley, Arizona). The PNM challenge was accepted since the location has not suffered modern modification to such a degree that would alter the natural acoustics. Due to limited resources and the large area covered by the petroglyphs, a completely thorough systematic study was not possible at the time. Instead, for this initial survey acoustic testing locations within the monument were chosen to be representative of the various major sections of the monument (see Figure 2): Piedras Marcadas, Boca Negra, and Rinconada Canyon.

Techniques

The methodology used to quantitatively measure (Blake and Mitchell 1972) the relative intensity of sound reflection was similar to the technique used for previous such studies (Waller 2000). Sound reflectance experimentation at each location consisted of producing a single loud percussion noise via a spring-loaded device designed to reproducibly deliver a percussive impulse (duration < 0.1 sec) with a loudness comparable to natural clapping or stone tool making (mean = 53 dB, standard deviation = 9 dB). Each experiment at each location was conducted in at least duplicate to assess reproducibility of the impulse, intensity of the reflected

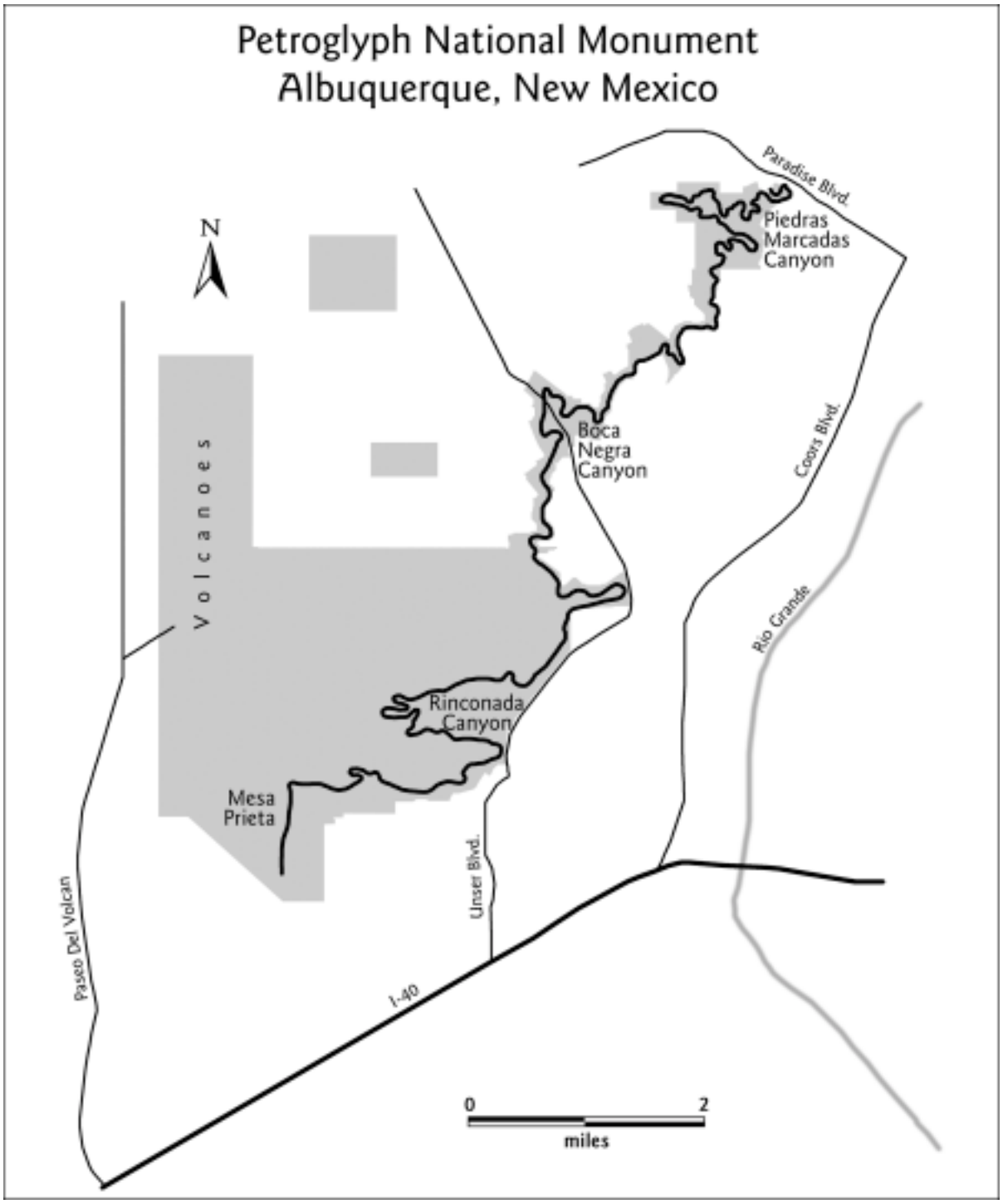

Figure 2. Map showing the major sections of PNM, with the escarpment indicated as a bold line (base map courtesy D. Saville).

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 analog cassette recorder using an 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 kH 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 of the replicate with the least

noise at each location 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 kH, then plotted as a function of time.

Results

Echoes noted at several decorated locations throughout PNM

Strong echoes were experienced and recorded at various decorated locations throughout PNM: Piedras Marcadas Canyon (four separate locations), Boca Negra (upper Canyon Trail and Mesa Point), Rinconada Canyon, and a location off Staghorn Drive in the northern part of PNM. Example plots of sound intensity as a function of time at some of these decorated locations are shown in Figures 3a, b, and c. In these plots, echoes are evidenced after the impulse has diminished, by peaks of sound intensity (up to 31 dB) that occur beyond 0.1 seconds.

Absence of echoes noted at rare locations within PNM that are non-decorated

It was rather difficult to find locations in PNM that do not echo; however, when two non-echoing lo-

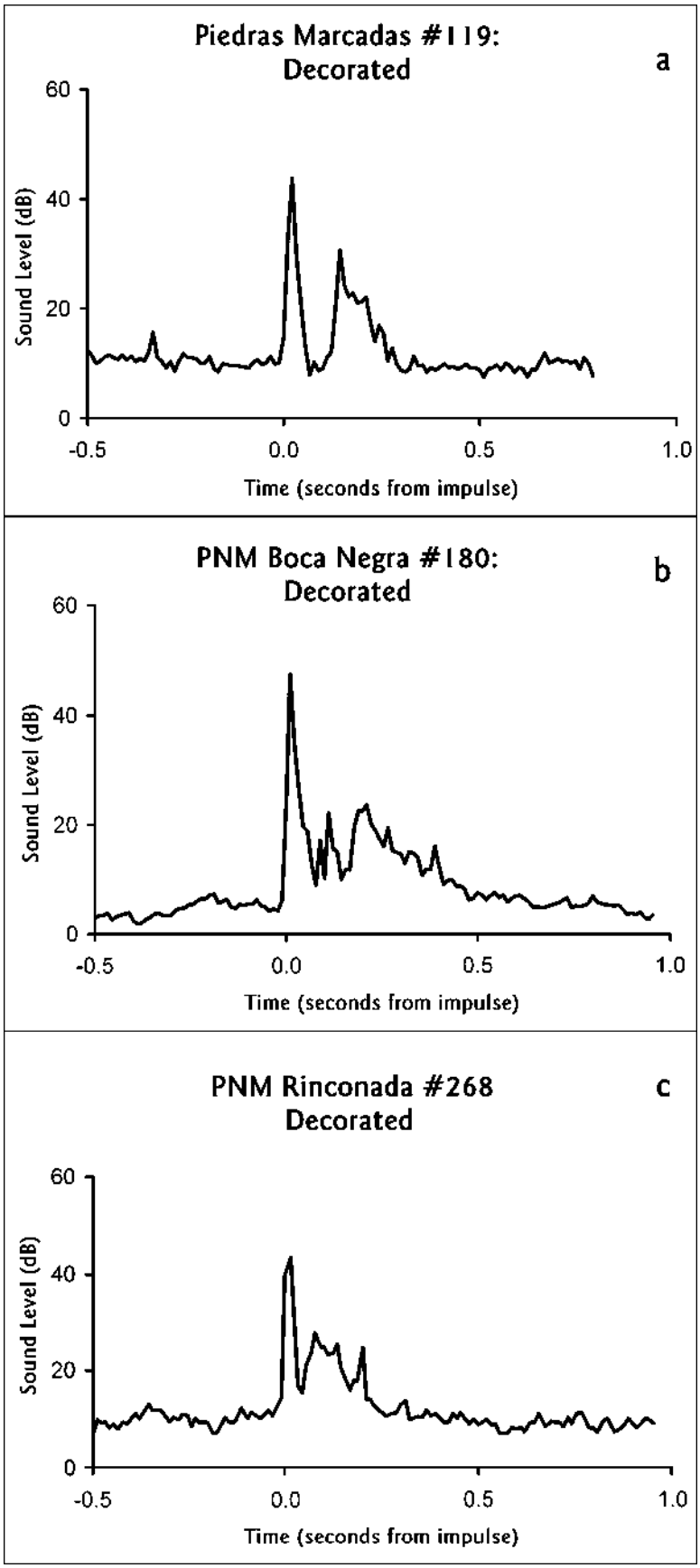

Figure 3. Echoes documented in PNM at various decorated locations (the code # is the tape recorder counter number showing when the recording was analyzed). Sound intensity is plotted as a function of time when an impulse—beginning at time 0 and diminishing within 0.1 seconds—was produced at: a) Piedras Marcadas Canyon; b) Boca Negra; and c) the Rinconada Canyon location illustrated in Figure 1. Note the presence of reflected sounds evidenced by sound intensity well above background occurring beyond 0.1 seconds.

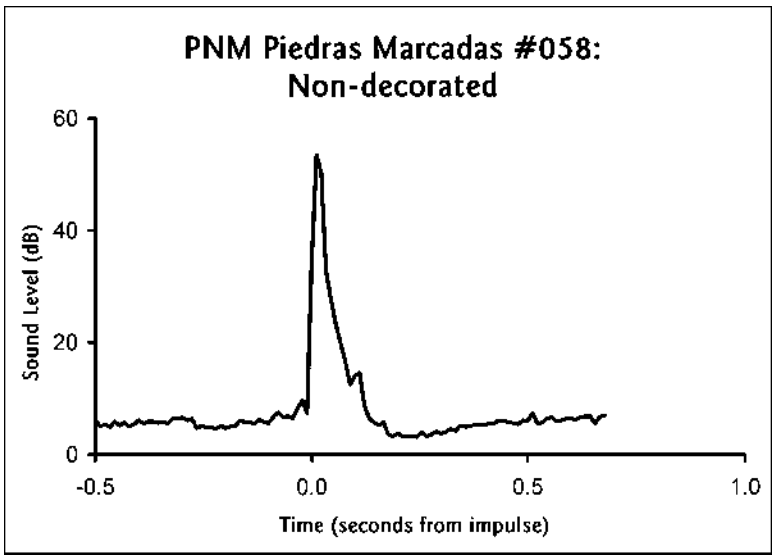

Figure 4. Absence of echoes at a rare non-decorated location in PNM. Sound intensity is plotted as a function of time when an impulse—beginning at time 0 and diminishing within 0.1 seconds—was produced at a non-decorated portion of Piedras Marcadas Canyon. Note the lack of sound beyond 0.1 seconds.

cations were found in Piedras Marcadas Canyon, they were both noted to occur in locations at which there was a conspicuous lack of rock art (even though there appeared to be no noticeable distinguishing visual traits that would explain why the rocks here should not have been drawn upon). An example plot of sound intensity as a function of time at one of these non-decorated locations is shown in Figure 4. In this plot, the absence of echoing is evidenced by the lack of peaks of sound intensity occurring significantly after the impulse has diminished within 0.1 seconds.

Discussion

Despite the morphology-based opinion that echoes at PNM were "unexpected", loud echoes were heard to be plentiful and documented to be very strong at various decorated locations throughout PNM. Ironically, the dB level of the PNM echoes are the highest ever recorded by this author at any rock art site. Furthermore, the rare non-echoing locations that could be identified within PNM were found to be devoid of rock art. These results at PNM showing correlation of rock art and acoustics are similar to the findings at Horseshoe Canyon (Waller 2000), and consistent with the acoustical theory of rock art motivation.

Ethnographic evidence attests to the spiritual importance of echoes to the Pueblo and other peoples of this region, as documented in Native American legends such as the following.

1. **Navajo:** The Navajo Night Chant (Yeibichai) includes offering of prayers to "the divinity Echoing Stone" on the first day of purification (Highwater 1984:40).

2. **Hopi:** The Twin known as Echo (Palongawhoya) features prominently in Hopi creation myths, and echoes are mentioned repeatedly in the "Song of Creation" (Waters 1963:4-7, Williamson 1984:99).

3. Acoma: 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, 'Aaaakooooooo!'. 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). [Note that PNM is located at the eastern edge of the original Acoma territorial claims.]

The recognition that sound characteristics of rock art sites were very important to prehistoric artists leads immediately to the recognition of the need for conserving these acoustical properties (Clottes 1993). To this end, the American Rock Art Research Association is formulating guidelines for the conservation of rock art site acoustics (see Appendix). There are two main components of acoustical properties that are important to conservation: signal and noise. Signal can be thought of as proportional to the pertinent information, in this case the ability of the site to reflect sound the way that it originally did at the time the art was inspired. Noise can be thought of as irrelevant distractions that mask the original information, in this case any extraneous sounds that were not heard by the artists. The ratio of signal to noise is key in maintaining the information content, and an equation can be expressed as follows:

Signal ÷ Noise = Information

By examining this equation, one can readily see

that loss of information can occur from either a decrease in signal or an increase in noise. Thus, rock art acoustic conservation efforts should be directed toward both aspects. Signal should be maintained by preventing loss or distortion of sound-reflecting capabilities. Noise should be minimized by literally minimizing noise, that is, eliminating extraneous artificial sounds and avoiding additional sound reflecting surfaces. Examples are given below of situations leading to deterioration of original acoustical characteristics at rock art sites.

Decrease or distortion of signal:

1. moving art and/or rocks out of context
2. flooding
3. pavilions, enclosures, buildings, platforms
4. walls, fences, signs
5. benches
6. lack of trails that would allow proper positioning to hear reflected sounds
7. erosion or build-up of soil
8. foliage variation
9. earth contouring, widening tunnels, building roadways through the area

Increased noise that would obscure signal:

10. traffic sounds
11. talking, rustling, walking visitors
12. wind, ventilation systems

There have been examples of well-meaning efforts to preserve the art itself, which have altered or destroyed the natural sound characteristics in the environment of rock art. Recognizing the need for conserving the sound-reflecting characteristics at rock art sites, and preventing extraneous noise, can lead to better preservation of the original aural experiences of the artists. Conservation of rock art acoustic efforts can be divided into various categories, in a manner similar to efforts devoted to rock art images:

1. Recording/documentation (see Berrier 2000:718 for acoustic documentation form)
2. Educating/communication
3. Preserving/intervention

Conclusions

These investigational research results and the theoretical foundation behind them call attention to the need for thorough acoustic testing at rock art sites, even—perhaps especially—at those sites that one might not think would reflect sound. The finding of echoes at decorated locations in PNM is highly relevant in view of the spiritual significance attributed to echoes in the past.

From these observations, it can be concluded that it is imperative to preserve the natural acoustical properties of PNM. Urban noise, including sounds from traffic, interferes with the auditory perception of echoes and makes acoustic research very difficult. Such noise ruins the acoustic ecology and should be minimized. Alteration of the acoustical properties themselves should be prevented. Construction of a road through PNM, in addition to destroying irreplaceable art, would also destroy some of the rock art sites' natural sound-reflecting characteristics, which may have been a motivation for the creation of the rock art.

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Appendix

The following document has been adopted by the Conservation and Preservation Committee of the American Rock Art Research Association as part of its forthcoming *Guide for Land Managers*.

Acoustics Conservation at Rock Art Sites

Steven J. Waller

The management, study, and appreciation of rock art is multi-sensorial, involving the sense of hearing as well as sight. Rock art is frequently found in environments that are echo-rich. Land Managers should be acutely aware of the previously unrecognized need for conserving these acoustical properties, as well as for preserving the art itself. Accumulating evidence is suggesting that echoes and other sound characteristics such as ringing rocks and whispering galleries were important influences for the ancient artists, since such sounds were considered to be spiritually animated phenomena by many past cultures. While the sounds of the past may have been fleeting, the acoustical properties of the sites responsible for such sounds remains as part of our heritage today, marked as significant by

the art. World renowned rock art specialist Jean Clottes, Conservateur Général du Patrimonie, Ministère de la Culture of France, in 1993 published the statement that:

> Waller's contention that sound played an important part in rituals, and that echoes and similar phenomena were mysterious enough to lend a magic aura to the places from which they seemed to emanate, is quite plausible. Many ethnological examples could be found to support it. In addition, whatever one thinks of his theories, his argument for preserving the acoustics in caves so that further study remains possible is legitimate and should be borne in mind from now on.

In this perspective, the very definition of the "rock art site" to be managed is broadened to include not just the actual rock surfaces that are decorated, but also the surrounding terrain that may include quite distant sound-reflecting surfaces and/or remote listening points from which to hear echoes returning from the decorated surfaces. It is important to keep this large-scale environment around rock art in its natural state so as to conserve the acoustics that are "within ear-shot" of the rock art.

Acoustics conservation should be kept in mind before any modifications of the land around rock art is considered. Rock art acoustic conservation efforts should be directed toward preventing loss/distortion of sound-reflecting capabilities, and minimizing noise by eliminating extraneous artificial sounds and avoiding additional sound-reflecting surfaces. Examples of situations to avoid since they would lead to deterioration of the original acoustical characteristics at rock art sites include moving art and/or rocks out of context; flooding by dams; pavilions, enclosures, buildings, viewing platforms; "protective" walls and fences; "educational" signs; benches and seats; lack of trails that would allow proper positioning to hear reflected sounds; erosion of rocks and/or build-up of soil; earth contouring, widening tunnels, building roadways through the area leading to traffic sounds; ventilation systems; loudspeakers that blare artificial sounds. (In some cases, it may be necessary to achieve a balance between the necessities of protecting the art itself against vandalism and protecting the acoustics.) To a Manager without acoustic training, some interventions may not seem like they would have an acoustical impact (and the acoustics of some sites may not even be appreciated), so even minor modifications should not be undertaken without consulting with an acoustics expert. There have been many examples of well-meaning efforts to preserve the art itself which have altered or destroyed the natural sound characteristics in the environment of rock art. Recognizing the need for conserving the acoustical properties at rock art sites, including minimizing extraneous noise, can lead to better preservation of the original aural experiences of our ancestral artists.

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References cited

Berrier, Margaret
2000 Proposed Documentation and Storage of Data Related to Acoustical Phenomena at Rock Art Sites. In: Peggy Whitehead, William Whitehead, Lawrence Loendorf, and William Breen Murray, eds., IRAC Proceedings, Volume 1, pp. 7-18. *American Indian Rock Art, Volume 26* [Part 1]. Tucson: American Rock Art Research Association.

Bjork, Carl
1997 Why Here? *Bay Area Rock Art News* 15(2):1,7.

Blake, Michael P., and William S. Mitchell
1972 *Vibration and Acoustic Measurement Handbook*. New York: Spartan Books.

Bonnefoy, Yves, compiler
1992 *Greek and Egyptian Mythologies*. Translated by Wendy Doniger. Chicago: University of Chicago Press.

Clottes, Jean
1993 Sound reflections? *Rock Art Research* 10:96-97.

Dauvois, Michel
1989 Sons et Musique paléolithiques. *Les Dossiers de l'Archéologie* 142:2-11.

1996 Evidence of Sound-Making and the Acoustic Character of the Decorated Caves of the Western Paleolithic World. *International Newsletter on Rock Art* 13:23-25.

Dauvois, Michel, and X. Boutillon
1990 Etudes acoustiques au Réseau Clastres: salle des peintures et lithophones naturels. *Bulletin de la Société Prehistorique Ariege-Pyrénées* 45:175-1.

Encyclopedia Mythica.
2001 Tepeyollotl . In: http://www.pantheon.org/mythica/articles/t/tepeyollotl.html [page accessed on 6/27/01].

Gill, Sam D., and Irene F. Sullivan
1992 *Dictionary of Native American Mythology*. Oxford: Oxford University Press.

Hedges, Ken
1990 Petroglyphs in Menifee Valley. In: Ken Hedges, ed., *Rock Art Papers, Volume 7*, pp. 7:75-83. San Diego Museum Papers 26.

1993 Places to See and Places to Hear: Rock Art and Features of the Sacred Landscape. In: J. Steinbring, Alan Watchman, Paul Faulstich, and Paul Taçon, eds., *Time and Space: Dating and Spatial Considerations in Rock Art Research*, pp. 121-127. Occasional Aura Publication 8. Melbourne: Australian Rock Art Research Association.

Highwater, Jamake
1984 *Ritual of the Wind*. Toronto: Methuen Publications.

Jobes, Gertrude.
1961 *Dictionary of Mythology, Folklore and Symbols*. New York: Scarecrow Press, Inc.

Ouzman, Sven
1997 Hidden in the Common Gaze: Collective and Idiosyncratic Rock Paintings at Rose Cottage Cave, South Africa. *Navorsinge van die Nasionale Museum, Bloemfontein* 13(6):225-256.

2001 Seeing is Deceiving: Rock-art and the Non-visual. *World Archaeology* 33(2):237-256.

Reznikoff, Igor
1995 On the Sound Dimension of Prehistoric Painted Caves and Rocks. In: E. Tarasti, ed., *Musical Signification: Essays on the Semiotic Theory and Analysis of Music*, pp. 541-557. Approaches to Semiotics 121. New York: Mouton de Gruyter.

Reznikoff, Igor, and M. Dauvois
1988 La Dimension Sonore des Grottes Ornées. *Bulletin de la Société Préhistorique Française* 85:238-246.

Steinbring, Jack
1992 Phenomenal Attributes: Site Selection Factors in Rock Art. In: Donald E. Weaver, Jr., ed., *American Indian Rock Art, Volume 17*, pp. 102-113. El Toro: American Rock Art Research Association.

Waller, Steven J.
1993a Sound and Rock Art. *Nature* 363:501.

1993b Sound Reflection as an Explanation for the Content and Context of Rock Art. *Rock Art Research* 10:91-101.

2000 Spatial Correlation of Acoustics and Rock Art Exemplified in Horseshoe Canyon. In: Frank G. Bock, ed., *American Indian Rock Art, Volume 24*, pp. 85-94. Tucson: American Rock Art Research Association.

2002a "Rock Art Acoustics" web page: **http://www.geocities.com/CapeCanaveral/9461**

2002b Rock Art Acoustics in the Past, Present and Future. In: Peggy Whitehead, William Whitehead, Lawrence Loendorf, and William Breen Murray, eds., IRAC Proceedings, Volume 2, pp. 11-20. *American Indian Rock Art, Volume 26* [Part 2]. Tucson: American Rock Art Research Association.

Waters, Frank
1963 *Book of the Hopi*. New York: Viking Press.

Williamson, Raymond A.
1984 *Living Sky: The Cosmos of the American Indian*. Boston: Houghton Mifflin Company.