American Indian Rock Art 24:85-94

SPATIAL CORRELATION OF ACOUSTICS AND ROCK ART EXEMPLIFIED IN HORSESHOE CANYON

Steven J. Waller

Steven J. Waller, Ph. D., 5382 Wellesley Street, La Mesa, CA 91942
(member, American Rock Art Research Association)

This report describes the first quantitative study of the acoustics at rock art sites relative to the acoustics of the surrounding undecorated terrain. Digital measurements of sound reflection revealed that the decorated surfaces in Horseshoe Canyon correspond exactly to the regions of the canyon possessing the maximum echo intensities ($R = .84$; $p < .0001$). Reflections of voices can be demonstrated to emanate from the rock surfaces at locations decorated with human-shaped figures. Clapping or making similar percussion noises at these art sites results in echoes that sound like hoof beats of the animals also depicted in the art. Thus the phenomenon of echoing relates to both the location and subject matter of rock art. These results, together with detection of sound reflection at over one hundred other rock art sites around the world, as well as ethnographic evidence, support the theory of an acoustic motivation for rock art. It follows that site management efforts should be expanded to include protection of the acoustical properties of rock art environments.

RELACION QUE EXISTE ENTRE LOS LACALIDADES DE ACUSTICOS DE ARTE RUPESTRE EN EL HORSESHOE CANYON (CANON HERRADURA DE CABALLO).

Este reporte decribe el primer estudio quantitativo entre los acústicos de arte rupestre (en rocas) y la superficie de el no decorado terreno que las rodea. Medidas digitales de la reflexión del sonido revelan que las decoradas superficies en el Horseshoe Canyon (Canón Herradura de Caballo) corresponden exactamente a las regiones del canón que procesan un eco con una intensidad máxima de ($R = .84$; $p < .0001$). Se puede demostrar el reflejo de voces que emanan de la superficie de las rocas que se localizan como figuras con forma humana. Aplausos o sonidos de percusión en éstas areas de arte resultan en ecos similares al sonido de una estampida de animales como los disenados en el arte. Tal es el fenómeno de los ecos que relaciona ambos entre si, localización y sujeto en cuestión en el arte de la roca. Estos resultados en conjunto, y el detectar del reflejo del sonido por sobre cientos de otras localidades con arte rupestre alrededor del mundo, da soporte a la teoría de motivación acústica por el arte rupestre. A esto sigue el que la gerencia de estas localidades se esfueze por incluir una expansión para proteger las propiedades acústicas de el medio ambiente del arte rupestre.

Of the many known behaviors exhibited by ancient humans, the production of images on rock surfaces is one of the least understood. The motivation for the prehistoric cave paintings and rock engravings found throughout the world is a key question in the emerging discipline (Odak 1991) of rock art studies. The extreme amount of effort exerted by the artists over many thousands of years is an indication that the production of rock art held a high degree of significance to ancient peoples. The legacy of rock art produced by diverse cultures on different continents displays unexplained similarities in both the unusual locations selected for decoration and the restricted subject matter of the art. The locations that were selected for artistic decoration are perplexing to modern scientists, as the art was often produced on surfaces quite difficult to reach, such as high on canyon walls or deep within caves, and was usually concentrated in certain spots, while nearby surfaces were ignored. The subject matter of the art is quite narrow, e.g., more than ninety percent of the recognizable figures in Upper Paleolithic cave art consists of hoofed animals (Leroi-Gourhan 1967; Waller 1992). Yet these images have not been found to simply correspond to objects of economic importance (Hadingham 1979:97). There has thus been a lack of understanding of the motivation for the choice of both the content and context of rock art (Bahn and Vertut 1988; Ucko and Rosenfeld 1967).

Upon approaching a Paleolithic cave in France in 1987, the author noticed an uncanny echo of his voice emanating from deep within. He hypothesized that the echoing may have inspired the cave paintings. It is well

known that ancient peoples attributed echoes to supernatural beings (Bonnefoy 1992; Guirand 1935). Locations that produce echoes might thus have been considered sacred dwelling places of those spirits, and thought worthy of special attention such as ritual decorating. Experimentation with a variety of sounds at echoing locations revealed that echoes of clapping and other simple percussion sounds could mimic the characteristic noise of hoof beats. The phenomena of voices and hoof beats emanating from solid rock can thus relate sound reflection to the narrow subject matter of rock art as well as to its unusual locations in caves and canyons. Initial results of quantitative acoustical testing at rock art sites in France, including Lascaux and Font de Gaume, documented the presence of sound reflection thereby supporting the hypothesis of an acoustic motivation for rock art (Waller 1992, 1993a, 1993b). Acoustic studies have substantiated the existence of sound reflection at virtually all of the rock art sites tested by the author to date in Europe, North America and Australia (Waller 1994a, 1997a, 1997b). In addition, sound reflection at rock art sites, including some in Africa and Asia, have been noted by others (Chakraverty, personal communication 1996; Dauvois 1989; Dauvois and Boutillon 1990; Mazonowicz 1974:1,47,117; Reznikoff and Dauvois 1988; Steinbring 1992, 1993), for a total of over one hundred rock art sites around the world with known sound reflection (see Appendix A for a listing of locations).

Acoustic approaches to rock art are beginning to be cited alongside other major rock art theories (Bahn 1997:27). Ringing rocks (Hedges 1990; Knight 1979) and lithophones (Dams 1985) represent yet another aspect of the relationship of rock art and sound. It is interesting to note that an acoustic motivation for the placement and subject matter of rock art could complement

rather than conflict with other theories of motivation. For example: the theory of shamanism involves production of art from images experienced in a trance; repetitive percussion noises are a known method of inducing a trance (Eliade 1964); echoes of percussion noises may have helped induced trance states and/or evoked the images of hoofed animals in the shaman's mind. As another example, the theory that the art was produced as a form of hunting magic or fertility ritual to increase game fits in nicely with echoing since all one need do is clap in an echoing environment in order to conjure up hoof beats.

The study described herein was designed to gather quantitative acoustic data in a systematic fashion to further test the validity of the theory of acoustic motivation for rock art.

Experimental Study

Selection of Study Location. For the purpose of studying in detail the acoustics of rock art sites relative to their surrounding territory, an important factor is that the entire area be in an unmodified condition. Horseshoe Canyon (formerly known as Barrier Canyon), located in Utah's Canyonlands National Park, meets this requirement. It is considered one of the premier rock art sites in the world, and is the type site of the Barrier Canyon style, a major category of rock art estimated to be thousands of years old (Schaafsma 1980). These images painted in reddish brown are characterized by enigmatic, ghostly looking, anthropomorphic (human-shaped) and zoomorphic (animal-shaped) figures (see examples in Figure 1). In Horseshoe Canyon the rock art occurs in locations distributed unevenly along the canyon, concentrated in four panels: the High, Shelter [SR-12-5], Alcove [SR-12-3] and Great [SR-12-4] galleries (Schaafsma 1971). Visually, there appears to be no obvious reason these sites would have been selected for decoration, as there are plenty of similar rock surfaces suitable for painting all along the canyon.

Results: *1. Perceptions.* The sense of hearing revealed that the rock art in Horseshoe Canyon occurs at places with exceptionally clear echoes, in striking contrast to the undecorated portions of the canyon. For example, at the High Gallery the voice of a tour guide could be heard to bounce from high off the wall exactly where the art occurs, as if the painted beings themselves were

speaking. (Similar echo effects had previously been noted at a variety of other rock art sites, including "Cleopatra" at North Wash [42Ga443] (Schaasfma 1971), which is also classified as Barrier Canyon style.) Little or no echoes could be heard at the portions of Horseshoe Canyon lacking art, even though consisting of the same types of rock surfaces as the art sites; perhaps the geometric angles of those rock surfaces were not conducive to reflecting sound back to the listener.

Results: *2. Quantification of Sound Reflection.* To more specifically and objectively test the hypothesis of an acoustic motivation for rock art production, these subjective aural impressions were verified by digital analysis of echo intensities recorded at regular intervals along the length of the canyon (refer to the Appendix B for technical details of the methodology used). The results of these quantitative measurements, depicted in Figure 2, show that all four rock art groupings occur at places corresponding exactly to locations with a maximum of sound reflection. Furthermore, when an additional location with good echoing was noticed near a bend in the canyon about half-way between the Alcove and Great Gallery (designated as test location #63 in Figure 2), inquiry was made to the Canyonlands National Park Archeologist as to whether traces of art had been found anywhere else in the canyon besides the four major groups. Indeed, the reply was that there is “a single small anthropomorphic figure painted near a bend about midway between the Alcove and the Great Gallery” (Nancy Coulam, personal communication 1996). This dramatic example of anticipating the presence of art at a location with strong echoing relative to its surroundings (together with the many examples of anticipating echoes at art locations)

demonstrates that the theory of acoustic motivation for rock art has predictive ability, one of the hallmarks of veracity.

Statistical analysis of this quantitative data shows a very good correlation, R = .84, between the presence of art and echo intensity. The difference in echo intensity in the environment of decorated locations vs. non-decorated locations in Horseshoe Canyon is statistically significant at the $p < .0001$ level.

Discussion

Such a high degree of statistical correspondence between art and echoing cannot reasonably be attributed to chance alone. There is also no reason to believe that this correlation arose taphonomically (Bednarik 1994, Waller 1994b) as an artifact of echoing locations being more likely to result in preferential preservation of images, since only the Alcove paintings occur in a protected cave while the rest of the art occurs on vertical walls exposed to weathering. Thus the conclusion drawn from these results is that the artists deliberately chose to produce their art at the specific locations within the canyon that best reflect sound, and were not motivated to decorate any non-echoing locations.

The predominantly human-shaped figures and hoofed animals that the artists produced only at the echoing locations are consistent with the perception of echoes as answering voices and hoof beats emanating from solid rock, a

phenomenon still demonstrable today. Even the dog figures would be consistent with echoes of barking. Thus the subject matter can be tied in with the phenomenon of sound reflection, so that the rock art images themselves, as well as the locations chosen, appear to be directly related to the concept of the sacredness of echoes.

A critical analysis of Figure 2 raises some interesting questions regarding the possible link between acoustics and rock art. Was there a minimum threshold of sound reflection necessary to motivate decoration? Might such a threshold have been influenced by previous exposures of the artist to other places that echo? Would a site with excellent echoes (e.g., the Alcove at location #43) have caused an artist to ignore a nearby location (e.g., #48) that has merely good echoes? Such questions of data interpretation should influence the way data are collected, since they point out the importance of standardization in order to judge the sound intensities at each location relative to other locations.

Ethnographic information suggestive of a possible acoustic motivation for rock art exists from a number of sources. The supernatural interpretation of echoes is well-known not just from Greek mythology (Bonnefoy 1992), but also from ancient myths around the world associating echoes with spiritual deities. For example, in a South Pacific legend, “Echo as the bodiless voice, is the earliest of all existence” (Jobes 1961:490). As recorded by L. White in 1932, the Acoma emergence and migration story, in which Masewa (son of the sun) leads the people out of the place of emergence called Shipap, continues as follows:

"The people decide to go to the South where they hope to raise parrots. They head 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, 'Aaaakoooooo!'. 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).

A Paiute legend recorded by R. H. Lowie in 1924 appears to relate echoes to common rock art themes:

"One day a witch (tso-a-vwits)...steals baby U-ja...and convinces him to hide with her in the belly of a mountain sheep...when the witch comes out to get food, Eagle swoops down and carries U-ja away...Frightened, the witch goes to her grandfather, Rattlesnake (To-go-a) for help...She crawls into Rattlesnake's stomach to hide, making him very ill. Rattlesnake crawls out of his own skin, leaving the witch imprisoned in it...When eagle approaches and calls for the witch, she repeats his words in mockery. Since that time witches have lived in snakeskins and hidden among rocks, from which they take great delight in repeating the words of passersby." (Gill and Sullivan 1992:79).

Thus the appearance of mountain sheep and snakes in rock art could have been symbols representing the echo, which the legend describes as being harbored in these animals. A site called “Wikwip” in California contains rock art for which there exists ethnographic information: 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 1992).

Direct ethnographic evidence for acoustics as a motivation factor for the production of rock art has recently been found in India. Echoes have religious significance to members of an indigenous tribe 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). The findings in many other parts of the world of an association of echoes with rock art (see Appendix A), together with relevant ethnographic information, suggest that a substantial proportion of rock art around the world may have been motivated by echoes. Exactly what proportion remains to be determined by acoustic tests such as described herein. This gives a whole new added meaning to the task of "rock art recording", which would be incomplete if it were not to include audio recording.

A practical implication of this body of research is that rock art conservation efforts should be expanded to preserve not just the images themselves, but also the acoustical properties of the sites. The construction of highways, information centers, rest areas, walls meant to protect the art itself, or even the posting of large signs near rock art, can mar the sites by interfering with the natural acoustics that appear to have been an important influence for at

least some rock art. Based on the evidence presented, the author strongly recommends that the environment around rock art sites be kept in a natural condition. Let us hear, as well as see, rock art sites as our ancestors did.

Acknowledgments. The author is very grateful for: the outstanding Colorado Plateau Rock Art field trip provided by Jenny Blue and Rick Moore through the Museum of Northern Arizona; guidance to other sites by Steven Freers, Ken Hedges, Frank Magre and Bill Reich; the information provided by Somnath Chakraverty about the echo-revering tribe in India; the helpfulness of Canyonlands National Park Archaeologist Nancy Coulam in identifying the location of a little-known rock art figure; Spanish translation of the abstract by Dagmar Rivera; and most of all the understanding and loving support of my wife Patrice, son Jason, and daughter Julia.

APPENDIX A

List of over one hundred rock art sites with known sound reflection (tested by the author unless otherwise indicated):

EUROPE: *-FRANCE:* Abri du Roc aux Sorciers in Angles-sur-L'Anglin; Bara-Bahau; Bernifal; les Combarelles; les Combarelles II; Cougnac; Font-de-Gaume; Largerie Basse; Largerie Haute; Lascaux; la Mouthe; Oreille d'Enfer; Pech-Merle; Rouffignac; la Vallée de la Grande Beune containing Commarque and Laussel; Vallon des Roches of Castelmerle (Sergeac) including the Riverdit shelter; Tayjat; Abri Pataud; Sainte Cirq; Grotte du Portel (Reznikoff and Dauvois 1988); Réseau Clastres (Dauvois and Boutillon 1990); *-SPAIN:* Altamira (Mazonowicz 1974:1); La Pena de Candamo (Mazonowicz 1974:47);
NORTH AMERICA: *- UTAH*: Dry Fork Creek at Vernal, including the Three Kings panel; Fremont Indian State Park; Willow Springs; Butler Wash: Wolf man/Yucca and Procession panels; Sand Island; River House ruins; San Juan River Kachina panels; Hog Springs / North Wash; Capitol Reef; Wire Pass; Horseshoe Canyon sites of High, Shelter, Alcove, and Great Galleries and at small anthropomorph (Nancy Coulam, personal communication 1996); *-ARIZONA:* Lomaki in Wupaki National Monument; Honanki; Red Canyon near Sedona; Hedgepeth Hills; Estler Peak; Red Tank Draw's canyon; Red Tank Draw's boulder by road; West Clear Creek; Montezuma Castle; Picture Canyon near Flagstaff; Petrified Forest; Verde Valley; Woo Ranch Canyon; Grand Canyon's Bright Angel Trail (just past first tunnel on south rim); King Canyon; Signal Hill; Holbert Trail in South Mountain Park; Painted Rocks State Park; Sears Point; Gallespie Dam; Waterfall and Goat Camp trails in White Tank

Mountains; Heiroglyphic Canyon; - *WYOMING*: Site #48WE33; - *MISSOURI:* Lost Creek; Ceremonial Cave; Wallen Creek; Washington State Park; - *ILLINOIS*: Gorham site #11-Jn-41; Fountain Bluff site # 11-Jn-17; - *PENNSYLVANIA*: Big Indian Rock, Little Indian Rock, and Circle Rock on the Susquehanna river; - *CALIFORNIA:* CA-RIV-506; CA-RIV-1024 (Dog Rock); CA-RIV-1025 (Fin Rock); CA-RIV-1036; CA-RIV-1037; CA-RIV-333 (thunderhead shaped rock with cupules); CA-RIV-61 (Spring Shelter, Winter Shelter, heavily vandalized boulder, and boulder on opposite side of creek in Mockingbird Canyon); Painted Cave near Santa Barbara; Wikwip (Hedges 1992); *CANADA:* Herschel Petroglyph Site (Steinbring 1993:98);

AUSTRALIA *(Queensland, near Laura):* Mushroom Rock; Bachelor's Camp; Yam Camp; Death Adder East; Death Adder South; Flying Fox Site; Red Lady Site; Garfish Site; Honeymoon Site; Boy's Place; Amphitheater; Tunnel Place overlooking Brady Creek Valley; Emu Dreaming; Giant Wallaroo; Giant Horse Gallery;

AFRICA**:** Tassili (Mazonowicz 1974:117);

ASIA: *INDIA:* Pachmarhi, Behimpetka, and Isco (Somnath Chakraverty, personal communication 1996);

APPENDIX B

The methodology used to quantitatively measure (Blake 1972) the relative intensity of sound reflection at multiple locations is described in this Appendix. 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 triplicate to assess reproducibility of the impulse, intensity of the reflected sound, and echo delay time. Ambient sound before, during and after each impulse were recorded on Type II tape with a Realistic Stereo-Mate SCP-29 Model 14-1068A portable 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 two replicates with the least noise out of the three trials at each location were 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 corrected for background ambient noise. The maximum peak height over the interval of 0.1 to 0.5 seconds after impulse was normalized to constant impulse and to a constant distance as determined by echo delay time. Statistical analysis was performed using JMP v3.1.5.

REFERENCES CITED

Bednarik, R.G.

1994 Epistemology and Palaeolithic Rock Art. *Rock Art Research* 11:118-120.

Bahn, P.,G. and J. Vertut

1988 *Images of the Ice Age*. Facts on File, New York.

Bahn, P.G.

1997 The First Artists (Special Report / Archaeology). In *Science Year, The World Book Annual Science Supplement*.

Blake, M.P.

1972 *Vibration and Acoustic Measurement Handbook*. Spartan Books, New York.

Bonnefoy, Y.

1992 Greek and Egyptian Mythologies. Translated by W. Doniger, University of Chicago Press, Chicago.

Dams, L.

1985 Paleolithic Lithophones: Descriptions and Comparisons. *Oxford Journal of Archaeology* 4:31-46.

Dauvois

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

Dauvois and Boutillon

1990 Etudes acoustiques au Réseau Clastres: salle des peintures et lithophones naturels. *Bulletin de la Société Préhistorique Ariege-Pyrénées* 45:175-186.

Eliade, M.

1964 *Shamanism, Archaic Techniques of Ecstacy*. Princeton University Press, Princeton

Gill, S. D., and I. F. Sullivan

1992 Dictionary of Native American Mythology. Oxford University Press, Oxford.

Guirand, F.

1935 *Greek Mythology*. Translated by D. Ames. P. Hamlyn Limited, London.

Hadingham, E.

1979 *Secrets of the Ice Age*. Walker and Co., New York.

Hedges, K.

1990 Petroglyphs in Menifee County. *Rock Art Papers* 7:75-83.

1992 Places to See and Places to Hear. Paper presented at the Second AURA Congress, Cairns, Australia; *Occasional AURA Publication* No. 7:17.

Jobes G.

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

Knight, L.

1979 Bell Rock and Indian Maze Rock of Orange County. *Pacific Coast Archaeological Society Quarterly* 15:25-32.

Leroi-Gourhan, A.

1967 Treasures of Prehistoric Art. Abrams, New York.

Mazonowicz, D.

1974 *Voices from the Stone Age*. Thomas Y. Crowell Co., New York.

Odak, O.

1991 A New Name for a New Discipline. *Rock Art Research* 8:3-12.

Reznikoff, I and M. Dauvois

1988 La dimension sonore des grottes ornées. *Bulletin de la Société Préhistorique Française* 85: 238-246.

Schaafsma, P.

1971 *The Rock Art of Utah*. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge.

1980 *Indian Rock Art of the Southwest*. University of New Mexico Press, Albuquerque.

Steinbring, J.

1992 Phenomenal Attributes: Site Selection Factors in Rock Art. *American Indian Rock Art* 17:102-113.

1993 Thunder from the Ancient Past: the Acoustics of Palaeoart. *Rock Art Research* 10:97-98.

Ucko, P.J., and A. Rosenfeld

1967 *Paleolithic Cave Art*. McGraw-Hill, New York.

Waller, S. J.

1992 Sound Reflection as an Explanation for the Content and Context of Rock Art (abstract). Paper presented at the Second AURA Congress, Cairns, Australia; *Occasional AURA Publication* No. 7:35.

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.

1994a Acoustical Characteristics of North American Rock Art Sites (abstract). Paper presented at the International Rock Art Congress 1994, Flagstaff, Arizona.

1994b Taphonomic Considerations of Rock Art Acoustics. *Rock Art Research* 11:120-121.

1997a Acoustical Characteristics of North American Rock Art Sites. *American Indian Rock Art*, in press. Ms. 1994.

1997b Acoustical Studies of Rock Art Sites on Three Continents. In *From Rock Art to Tribal Art: A Global Perspective*, edited by Chakraverty, India, in press. Ms. 1994.

FIGURE CAPTIONS

Figure 1. Examples of Barrier Canyon style rock art in Horseshoe Canyon.
(A) Anthropomorphs: “The Holy Ghost and His Attendants” panel located in the Great Gallery.
(B) Hoofed zoomorphs: mountain sheep in the Great Gallery

Figure 2. Measurements of sound reflection at locations throughout Horseshoe Canyon, compared with locations decorated with rock art. Abreviations for rock art sites: H = High Gallery; S = Shelter; A = Alcove; * = approximate location of anthropomorph; G= Great Gallery.