Steven J. Waller, Ph. D.
109 Saint Regis Drive
Newark, Delaware 19711 U. S. A.

3000 words December 13, 1994

Telephone: 1-302-738-5929 (home)
1-302-451-3659 (work)
Fax: 1-302-451-3487

Submission of paper for: From Rock Art to Tribal Art: A Global Perspective

KEYWORDS: Acoustics - North America - France - Australia - Conservation - Rock art research

(TITLE)

Acoustical Studies of Rock Art Sites on Three Continents

(AUTHOR)

Steven J. Waller, Ph. D.

(ABSTRACT)

Echoes may help solve a mystery left many thousands of years ago by our prehistoric ancestors. Beautiful but perplexing paintings and engravings on rock have survived from the Ice Age. These images, found throughout the world, are commonly hoofed animals, but do not simply represent food. The baffling locations the artists chose to decorate were often difficult to reach, such as deep within caves or high up on canyon walls. Quantitative measurements support the observation that a large number of rock art sites have good sound reflecting acoustics. Echoing is known to have been regarded by ancient societies as a supernatural phenomenon, and the artists who produced rock art may have chosen such strange places to decorate because they reflect sound, giving them a mysterious aura. Furthermore, echoes of percussion noises can sound like hoof beats, and the hoof beat-like echoes could explain why hoofed animals were so often depicted. This paper is a summary of the results of acoustical rock art studies to date in France, the United States, and Australia, portions of which have been presented at the 1992 Second AURA Congress in Cairns, and the 1994 International Rock Art Congress in Flagstaff, Arizona. These findings point out the need for conservation of the sounds, as well as the art, at rock art sites.

INTRODUCTION

Rock art in Europe and throughout the world has eluded satisfactory explanation (reviewed by Ucko and Rosenfeld 1967; Bahn and Vertut 1988). The animal subjects have been proposed to be related to hunting magic, although there is poor agreement with species hunted and eaten (Hadingham 1979:97). Also, the hunting magic theory is incomplete in that it does not explain the art's unusual locations or the patterns of decoration (Leroi-Gourhan 1967). Art for art's sake as a theory (Halverson 1987) explains neither the restricted subject matter nor the unusual locations. Theories of totemism (Ucko and Rosenfeld 1967) are based on very tenuous ethnological analogies.

Recently, the locations of deep cave art have been suggested to correspond to places where particular musical notes resonate (Reznikoff and Dauvois 1988). While not explaining open air sites nor the art's content, that report continues a chain of observations in the literature about acoustics and rock art. In 1957 Giedion mentioned the notion of 'acoustic space' in caverns. There have been a number of reports of 'ringing rocks' decorated with petroglyphs (Knight 1979; Hedges 1990), and lithophones (Glory 1968; Dams 1985). Certain rock art sites have been described as having echoing as a 'phenomenal attribute' (Steinbring 1992). Although those reports suggest a possible relationship between acoustics and location, there was no theory plausibly relating acoustics to the art subject matter, leaving the motivation for the art unknown.

The author independently became aware in 1987 of echoes at the mouth of a Paleolithic decorated cave in France, that could be perceived as sounds 'mysteriously' emanating from the cave in answer to sounds made outside. Based on this observation it was postulated that: prior to humanity's discovery of an acoustical theory of sound reflection, echoes and reverberation phenomena could have given the illusion of being spontaneously generated noises produced by certain surfaces. This would have lent a magical aura to such locations as caves and canyons that reflect sound. This postulate is supported by the fact that there have been supernatural explanations of sound reflection, such as the ancient Greeks attributing echoes to a spirit, whom they named Echo (Guirand 1935)from whence our word echo is derived.

Experimentation with different types of noises was performed in a variety of acoustic environments. This led to the discovery that when rocks are struck together in the manner of making stone tools, the echoes sound remarkably like the hoof beats of galloping horses. This was realized to be particularly relevant since statistical studies (Leroi-Gourhan 1967) of Upper Paleolithic art can be reinterpreted as showing that greater than ninety percent of parietal European figurative art is comprised of hoofed animals (i.e., > 90% ungulates). Hoofed animals such as sheep and deer are also very numerous in the rock art of the American Southwest. The observation that sound reflecting places such as caves and canyons can give rise to hoof beat-like echoes that mimic the ungulates depicted there by prehistoric artists, provided a testable theoretical connection between the context and content of rock art.

METHODS

Sound reflectance experimentation consisted of producing a single loud percussion noise via a spring-loaded device designed to reproducibly deliver a percussive sound with an intensity at a level comparable to natural clapping. After the generation of each single sound, the direction was noted from which the resulting reflected sound was heard. For quantitation at the European sites, experiments were recorded on high bias chromium dioxide tape using a PMD420 Maranz cassette recorder having Dolby noise reduction and equipped with a Dynamic LOZ Shure SM57 omni-directional microphone, which was placed 1 m from the original sound source. The recordings were measured for reflected sound using a Brüel and Kjær model 2232 precision sound level meter (settings: SLOW, 34-94 dB, AUTO) calibrated with a Brüel and Kjær model 4230 sound level calibrator to 93.8 decibels (A) at 1000 Hz. Playback of the recordings was through an auditorium sound system on a Technics model RS-M6 with Dolby noise reduction and a pause feature that was used to stop the tape immediately after the primary percussive burst. When the sound level meter had quieted, tape play was resumed to measure reflected sound in decibels, which was compared to the dB of the recorded background ambient noise of the art site. The dB values reported are relative in that the measured intensity of echoing heard at a given location is a function of the loudness of the primary sound made, the efficiency of the recording apparatus, the playback volume, and geometry of the sound level meter in relation to the speakers.

For later studies in North American and Australia, sounds were recorded on Type II tape with a Realistic Stereo-Mate SCP-29 Model 14-1068A portable cassette recorder using either an omnidirectional Realistic stereo Electret microphone model 33-1065, or a Radio Shack model 33-3007 Electret unidirectional condenser microphone. These recordings were then digitized and quantitatively analyzed for sound intensity at various frequencies using version 1.0 of SoundEdit Pro on a Macintosh PC, and graphed using KaleidaGraph.

RESULTS

Experiments to detect sound reflection at rock art sites gave results as briefly described below. Example graphs of the acoustics at rock art sites on each of three continents is presented in the figures. More detailed analyses have been or will be presented elsewhere.

1. EUROPE: France

The hypothesis that Upper Paleolithic art is situated in locations of significant sound reflection was first tested by acoustical studies of a non-random sampling of sites in the Dordogne, Lot and Vienne regions of France. These areas were selected as including representations of a wide variety of categories: open-air, shallow and deep cave art; paintings, engravings and relief sculpture; early, middle and late Upper Paleolithic periods. The following locations were all found to exhibit noticeable sound reflection in the form of either distinct echoes sounding like individual hoof beats, or thunderous reverberation sounding like a stampede of hoofed animals. Detailed descriptions of each site along with supporting quantitative data have been published (Waller 1993a, 1993b).

Abri du Roc aux Sorciers, Angles-sur-L'Anglin -- echo from (modified) shelter in cliff.
Abri Poisson -- echo from (modified) shelter and similar natural shelter nearby.
Bara-Bahau -- (modified) reverberation from engraved chamber of cave.
Bernifal -- reverberation in cave chambers.
les Combarelles -- (modified) reverberation in decorated portions better than non-decorated.
les Combarelles II -- reverberation in decorated chamber better than non-decorated.
Cougnac -- profound reverberation in final decorated cavern.
Font-de-Gaume -- (modified) reverberation best at ungulate art, poor at fissure with feline.
Largerie Basse -- (modified) reverberation and echoes.
Largerie Haute -- (modified) reverberation and echoes.
Lascaux -- (modified) reverberation best at ungulate art, poor in chamber of felines.
la Madeleine -- echoes from the distance audible.
la Mouthe -- reverberation amplified by concavities along corridor.
Oreille d'Enfer -- echo from shelter in cliff and from foot of the valley.
Pech-Merle -- reverberations throughout the cavern.
le Roc Sainte Christopher -- echo from cliff and in the distance.
Rouffignac -- (modified) flutter echoes; symmetrical reverberation.
la Vallée de la Grande Beune, with Cap Blanc, Commarque and Laussel -- echoes.
Vallon des Roches of Castelmerle (Sergeac) including the Riverdit shelter -- echoes.
(The sites of Tayjat, Abri Pataud and Sainte Cirq were excluded when the results showed obvious excessive interference from modern structures.)

2. NORTH AMERICA

- UTAH:
Dry Fork Creek at Vernal, including the Three Kings panel [1] -- echoes from cliffs.
Fremont Indian State Park [1] -- echoes from cliffs.
Willow Springs [2] -- echoes from large boulders.
Butler Wash: Wolf man/Yucca and Procession panels [2] -- echo from each cliff face.
Sand Island [2] -- echo from cliff.
River House ruins [2] -- echo from shelter in cliff.
San Juan River: Kachina panels [2] -- echo from cliff.
Hog Springs [2] -- echo and reverberation in large cave.
Capitol Reef [2] -- echo from cliff.
Wire Pass [2] -- echo from cliff.
Horseshoe Canyon [2] sites:
High Gallery -- echoes from high up on cliff where figures drawn.
Horseshoe Shelter -- echoes from canyon wall, and reverberration in shelter.
Alcove -- echo and reverberation in large cave.
Great Gallery -- multipe echoes from decorated shelter and opposite canyon walls.

- ARIZONA:
Lomaki in Wupaki National Monument [1] -- echo from basalt outcrop and crack in earth.
Honanki [1] -- echo from cliff.

Red Canyon near Sedona [1] -- echo from cliff.
Hedgepeth Hills [2] -- echo from large pile of boulders.
Estler Peak [2] -- echoes from surrounding bluffs.
Red Tank Draw sites [2] -- echoes from canyon walls, and from decorated boulder.
Picture Canyon [2] -- echoes from rock walls.
Petrified Forest -- echoes from rock walls.

- WYOMING:
Site #48WE33 [1] -- even normal conversation produces echoes from canyon walls.

- MISSOURI
Lost Creek [2] -- echoes from shelters and cliff face
Ceremonial Cave [2] -- reverberation and amplification of creek sounds.
Wallen Creek [2] -- echoes from surrounding terrain

- ILLINOIS
Gorham [2]; site #11-Jn-41 -- echo from arch-shaped cliff wall.
Fountain Bluff [2]; site # 11-Jn-17 -- echo from shelter.

- PENNSYLVANIA:
Big Indian and Circle Rocks on Susquehanna river [1] -- echoes from steep river bank.

3. AUSTRALIA

The following sites near Laura in Queensland, Australia were tested in August 1992. Good sound reflection was found at all these sites, most of which were shallow rock shelters (Waller , manuscript in preparation; see also Dayton 1992:14).

Mushroom Rock -- echoes from shelters.
Bachelor's Camp -- echoes from across; possible lithophone.
Yam Camp -- echoes from facing cliff across canyon.
Death Adder: East and South shelters -- echo from shelters and from facing cliff.
Flying Fox Site -- echoes from cliff above.
Red Lady Site -- echoes from facing cliff across canyon.
Garfish Site-- echoes from facing cliff across canyon.
Honeymoon Site -- echo from shelter.
Boy's Place -- reverberation in enclosed hollow.
Amphitheater -- echoes from multiple surfaces.
Tunnel Place overlooking Brady Creek Valley -- echo from canyon amplified by tunnel.
Emu Dreaming -- echo from rock face.
Giant Wallaroo -- even normal conversation produces echoes from rock walls.
Giant Horse Gallery -- echo from shelter, reverberation in corridor; dead where no art.
(For the sake of completeness, an unnamed single small petroglyph site near a wooded creek was also visited, and no echo was detected; however there was not enough time available to thoroughly study the site from various distances and at different angles.)

Note that there were no hoofed animals in pre-contact Australia, so percussive echoes would of course not have been interpreted as hoof beats. Instead, echoes may have been attributed to other sources such as kangaroos, which are colloquially known as "thumpers", and which appear as a common theme in Australian rock art.

4. OTHER INHABITED CONTINENTS

Although I have not personally tested rock art sites on the other three continents inhabited in prehistoric times, it is likely that an association of rock art and acoustics will be found there, too. Good acoustics have been heard in at least seven rock art shelters in India, where echoes still have religious significance to indigenous people (Chakraverty, personal communication). I have been told of great echoes at Tassili in Africa (personal communications), where the rock art is legendary. On the basis of the geometry of rock surfaces visible in various photographs of rock art sites in South Africa, South America, and China, I predict that echoing should occur there as well.

CONCLUSIONS

The hypothesis that rock art tends to be associated with locations having good sound reflection is not rejected based on my experience showing that noticeable sound reflection occurs at virtually every rock art site tested out of more than 60 sites spread over three continents.

The association of rock art with unusually good sound reflection, as suggested by this data, leads to some interesting speculative possibilities. Were the artists motivated to produce their art in response to echoing? Although a cause and effect relationship has not been proven, this possibility is supported by the unusual locations chosen for the art: caves (especially selected chambers), canyons, cliffs, shelters, and even large boulders, each of which can reflect sound.

Did the prehistoric people draw images of what they thought they heard? Hoofed animals as common themes of rock art are consistent with percussive echoes sounding like hoof beats. Anthropomorphs could have been inspired by hearing vocal echoes. When a sound echoes from a rock surface, it can appear as if the sound is actually spontaneously emanating from the surface. Could this have been the origin of legends of talking rocks? We modern humans with our knowledge of acoustics simply imagine the sound waves propagating through the air and reflecting back from the surface. Thus explained, we tend to ignore or trivialize echoes. The physics of echoing is complex, however, and without an understanding of these invisible sound waves, the phenomenon must have appeared quite mysterious. The objection that people would have recognized the echoed voice as being their own voice is not valid since even modern persons hearing their tape-recorded voice for the first time commonly exclaim they do not sound like that, due to the sound not being transmitted internally through structures in the head as it usually does.

I am not attempting exact literal interpretations of any particular rock art designs, merely proposing acoustics as a framework by which insights into the general motivation might be gained. For example, the abstracts might have been attempts to represent sound visually, or could have been inspired when sounds invoked phosphene patterns. Echoing locations would have been particularly conducive to entering into altered states of consciousness via rhythmic percussion.

Such speculation could be carried further, but is subject to criticism and debate. What cannot be debated is objective data, and that is why it is important to collect a firm basis of facts. There may be different interpretations of available data, leading to further experimentation to distinguish alternative hypotheses. Might the good sound reflection at the rock art sites tested so far be circumstantial and artifactually appear associated with rock art when there was no such association for the artists? Since rock art by definition occurs on rock, and rock has as one of its properties the ability to reflect sound, the apparent association of rock art and echoes could be a case of two independent variables co-correlating with a third variable. Current efforts are focused on systematically and objectively documenting the author's impressions that the acoustics at the rock art sites are

superior to nearby locations and that the sound reflection appears to emanate from the very location that the artists chose to decorate (Waller, manuscript in preparation).

A very important implication of these observations of echoes at rock art sites is the need for conservation of theses acoustics. Rock art conservation efforts have traditionally focused on preserving the art images themselves. If, as the data suggests, a sizable portion of rock art was motivated by acoustics, then the acoustical properties are an important part of the rock art sites. Since sound reflection is a complex phenomenon, it is worthwhile to explain what I mean by conservation of rock art site acoustics. The environment surrounding the rock art should be maintained as close as possible to its natural state to enable echoing to occur as it did in the past. Buildings, walls, solid fences, and even large signs should not be erected anywhere near rock art where they could either add unnatural echoes or prevent echoes by interfering with sound wave propagation. Widening passageways, leveling terrain, planting sound-absorbing foliage, displacing boulders: all should be avoided since these actions can alter the site's acoustics. Extraneous noises such as humming machinery, traffic, even barking dogs and fluttering flags should be controlled. The sites should be considered as concert halls, which require exact architectural engineering to achieve the desired acoustical properties. To attempt to preserve rock art by building walls or enclosing it in a solid structure would be like destroying the function of a cathedral pipe organ by encasing it in Plexiglas resin. Jean Clottes has agreed that the sound reflecting properties at rock art sites should be conserved: "...[Waller's] argument for preserving acoustics in caves so that further study remains possible is legitimate and should be borne in mind from now on." (Clottes 1993:96).

There are a variety of reasons for preserving the acoustics of rock art sites. The data suggesting the possibility of a connection between acoustics and rock art placement as well as subject matter is only preliminary and much more acoustical data needs to be collected. Unfortunately, the sound reflection at many sites has already been unintentionally altered in well-meaning attempts to protect the art itself, although study of the images alone has not been able to reveal the motivation for its existence. Further acoustical research efforts to gain knowledge about our past could be irreparably hindered if the acoustics are ruined. In addition to scientific reasons, the acoustics should be preserved to enable visitors to fully experience rock art sites: aurally as well as just visually. To hear hoof beats and voices emanating from the rock walls where hoofed animals and anthropomorphs are depicted is perhaps to experience the sites as the prehistoric artists once did, and can be very moving. Finally, if as it seems from the data so far, echoing at rock art sites was indeed sacred to our ancestors, that is reason enough to devote efforts to preserve this phenomenon.

ACKNOWLEDGMENTS

I thank all those graciously allowing access to the art sites, guiding tours and engaging in helpful discussions: M. Archambeau, Paul Bahn, Jenny Blue, Frank and AJ Bock, J-P. Chadelle, Somnath Chakraverty, Jean Clottes, Mme Daubisse and sister, L.

Duggan, Mme Duret, R. Paul Firnhaber, P. Foucher, Jach Francis, M. Geneste, A. Graham IV, Mary Gordon, Ken Hedges, Mr. Hexon, W. Hoeney, Michel Lorblanchet, Frank Magre, Rick Moore, Paul A. Nevin, J-C. Papinot, Y. Pemandrant, J. Plassard and father, J-Ph. Rigaud, Jack Steinbring, James Swauger, Stephen Trezise and Alice Tratebis. I also gratefully acknowledge my wife Patrice and son Jason for their continual support throughout these studies.

Footnotes:

[1] (Waller 1994)

[2] (Waller, manuscripts in preparation)

REFERENCES

BAHN, P. G. and VERTUT, J. 1988. *Images of the Ice Age*. Facts on File, New York.

CLOTTES, J. 1993. Sound reflections? *Rock Art Research* 10:96-97.

DAMS, L. 1985. Paleolithic lithophones: descriptions and comparisons. *Oxford Journal of Archaeology* 4:31-46.

DAUVOIS, M. 1989. Sons et musique paléolithiques. *Les Dossiers de l'Archéologie* 142: 2-11.

DAYTON, L. 1992. Rock art evokes beastly echoes of the past. *New Scientist* 136:14.

GIEDION, S. 1957. *The Eternal Present: The Beginnings of Art*. Pantheon, New York, p. 526.

GLORY, A. 1968. L'enigma de l'art quaternaire peut-elle etre resolue par la theorie du culte des ongones? In Simposio de Arte Rupestre, Barcelona 1966 (pp 25-60).

GUIRAND, F. 1935. *Greek Mythology*. Translated by Delano Ames. Paul Hamlyn Limited, London (pp 122, 127).

HADINGHAM, E. 1979. *Secrets of the Ice Age*. Walker and Co., New York (p 97).

HALVERSON, J. 1987. Art for art's sake in the Paleolithic. *Current Anthropology* 28:63-89.

HEDGES, K. 1990. Petroglyphs in Menifee county. *Rock Art Papers* 7:75-83.

JOBES, G. 1961. Dictionary of Mythology, Foklore and Symbols. Scarecrow Press, Inc., New York (pp 490, 785).

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*.. Translated by N. Guterman. Abrams, New York.

REZNIKOFF, I. and M. DAUVOIS 1988. La dimension sonore des grottes ornées. *Bulletin de la Société Préhistorique Française* 85: 238-246.

STEINBRING, J. 1992. Phenomenal attributes: site selection factors in in rock art. *American Indian Rock Art* 17:102-113.

UCKO, P. J. and A. ROSENFELD 1967. *Paleolithic Cave Art*. McGraw-Hill, New York.

WALLER, S.

1993 (a). Sound and rock art. *Nature* 363:501.

1993 (b). Sound reflection as an explanation for the content and context of rock art. *Rock Art Research* 10:91-101.

1994. Acoustical characteristics of North American rock art sites. *American Indian Rock Art* (in press).

FIGURE 1. Acoustics in Lascaux, France (Europe). Long reverberation time in the Hall of Bulls is shown by the persistence of sound until approximately 1.0 seconds after the experimentally produced percussion sound (graph A), in contrast to the almost imperceptible sound reflection in the Chamber of Felines where the sound pressure returns to baseline in about 0.15 seconds (graph B). (See Methods section for details.)

FIGURE 2. Acoustics at the Great Gallery in Horseshoe Canyon, Utah (North America). Echoes can be seen at approximately 0.35 and 0.7 seconds after the experimentally produced percussion sound. (See Methods section for details.)

FIGURE 3. Acoustics at the Amphitheatre site in Queensland (Australia). Echoes can be seen at approximately 0.15 seconds after the experimentally produced percussion sound, which is extended by reverberation. (See Methods section for details.)