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Psychoacoustic influences of the echoing environments of prehistoric art

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Cave paintings and ancient petroglyphs around the world are typically found in echo rich locations such as caves, canyons, and rocky cliff faces. Analysis of field data shows that echo decibel levels at a large number of prehistoric art sites are higher than those at non-decorated locations. The selection of these echoing environments by the artists appears not to be a mere coincidence. This paper considers the perception of an echoed sound as a psychoacoustic event that would have been inexplicable to ancient humans. A variety of ancient legends from cultures on several continents attribute the phenomenon of echoes to supernatural beings. These legends, together with the quantitative data, strongly implicate echoing as relevant to the artists of the past. The notion that the echoes were caused by spirits within the rock would explain not only the unusual locations of prehistoric art, but also the perplexing subject matter. For example, the common theme of hoofed animal imagery could have been inspired by echoes of percussion noises perceived as hoof beats. Further systematic acoustical studies of prehistoric art sites is warranted. Conservation of the natural acoustic properties of rock art environments -- a previously unrecognized need -- is urged.

A new area for acoustic research has arisen from a previously unsuspected relationship between ancient legends of echoes, and prehistoric art. Could echoes have been a motivational influence for the ancient artists? Acoustic studies at archaeological sites may be starting to answer this important question.

To illustrate the universal perception of echoes being attributed to a supernatural phenomenon in the ancient world, some examples of ethnographically-recorded legends are listed below:

- The classical Greeks numbered among their deities a nymph called Echo (Bonnefoy 1992).
- From the South Pacific: “Echo as the bodiless voice, is the earliest of all existence” (Jobes 1961:490).
- A Paiute legend states that "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).
- The Book of the Hopi describes the importance of a mythological being named Echo in the creation story (Williamson 1984).

Based on documented legends that echoes were considered to be caused by spirits, it is theorized (Waller 1993a,b) that sound reflecting locations were perceived as the dwelling places of these echoing spirits. Special echoing places -- such as caves, canyons, rock shelters, cliffs and stony mountainsides -- where spirits dwelt and audibly responded to mortals would undoubtedly have been considered sacred sites. It would not be surprising then to find evidence that ritualistic activities had been conducted at such sacred echoing sites around the world, and had been decorated by the artists of those ancient cultures. Has archaeological evidence of homage been found in these types of echoing locations?

The answer is a resounding “YES!”. There are hundreds of Paleolithic caves in Europe with prehistoric paintings and engravings deep within. In Africa and Australia there are thousands of painted rock shelters. In America the canyons of the Southwest contain thousands upon thousands of ancient petroglyphs and pictographs. See Figure 1 for an example of rock art in the form of mysterious petroglyphs.

Figure 1. Photograph of prehistoric rock art (courtesy R. Kieffer).

The concept of a connection between echoes and prehistoric art occurred to the author upon hearing an echo emanate from the mouth of an Ice Age painted cave in France in 1987. This connection of acoustics and art is important because there has been no satisfactory explanation of the motivation for the production of rock art, its unusual locations, nor the perplexing subject matter the artists chose. A number of theories on the reason for rock art production have been put forth, e.g., Hunting Magic, Shamanism (reviewed by Bahn 1997), none of which have been totally satisfactory, especially in explaining the odd locations. It is generally conceded that the art was part of a religious ceremony. Accumulating acoustic evidence (Reznikoff and Dauvois 1988; Steinbring 1992; Waller 2000) is suggesting that these religious ceremonies at rock art sites involved producing and listening to echoes, which could augment rather than conflict with other theories of motivation. Producing rock art was clearly a major preoccupation for early Homo sapiens sapiens over a span of tens of thousands of years. How much of this ancient rock art around the world might have been made in response to echoes?

The acoustic properties of more than one hundred and fifty art sites around the world have been documented as possessing remarkable sound reflection in the form of echoes, reverberation or resonance. At many of these sites, the echoing is so clear that painted beings can be made to speak back; the echoing voice appears to emanate from solid rock at the exact spot the artists chose to depict the beings. Engraved hoofed animals can be heard to gallop when percussion noises bounce back as hoof beat-like echoes. A single clap in a cavern reverberates with a thunderous sound reminiscent of the stampedes of bison painted therein. Thus the subject matter (as well as the locations) of rock art is in accord with echoing: the artists appear to have drawn images evoked upon hearing echoes of voices and percussion sounds.

Objective sound level measurements have confirmed the echoes heard at a number of these prehistoric rock art sites. These measurements were made using the type of impulse technique typically used for recording sound reflection (e.g., Blake 1972), together with either a sound level meter or a computer program that analyzes sound levels by time and frequency (Waller, Lubman and Kiser 1998). By analyzing recordings made at regular intervals throughout Horseshoe Canyon in Utah, and Hieroglyphic Canyon in Arizona, it was found that the decorated places within these canyons correspond to the places with the loudest echoes (see Figure 2).

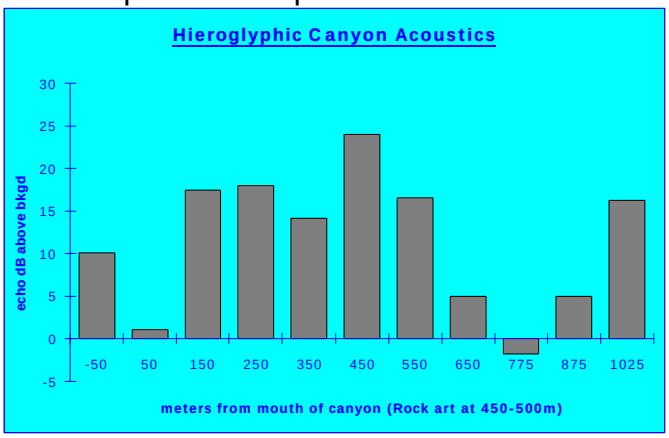

Figure 2. Acoustic survey of Hieroglyphic Canyon.

An example of an echogram recorded at a rock art site is shown in Figure 3. The echo occurring after the impulse shows as a extra signal due to sound reflection, delayed by the amount of time equal to the round-trip travel distance divided by the speed of sound. With a sufficient delay time, this extra signal is perceived as a ***psychoacoustic event*** separate from the impulse.

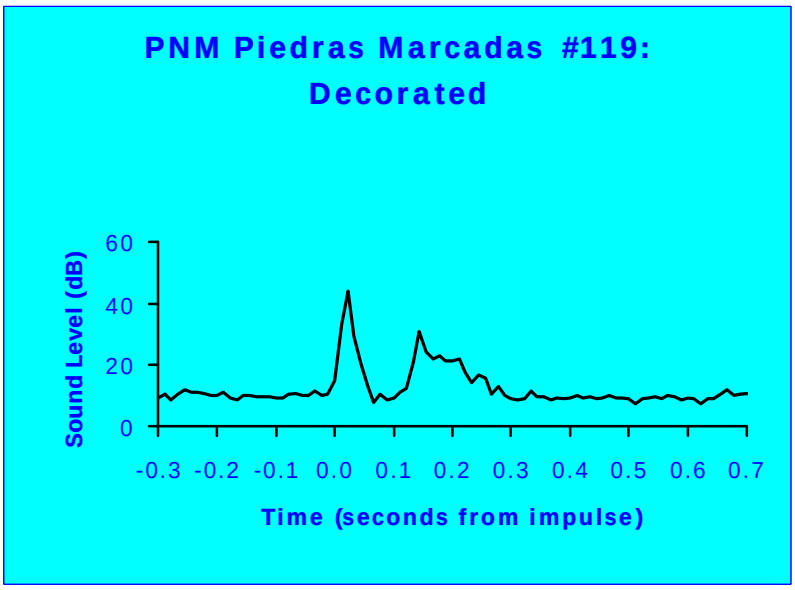

Figure 3. Echogram recorded at Petroglyph National Monument

While modern humans recognize this event as reflected sound waves and term it an “echo”, prehistoric peoples would have had no explanation for this event, other than attributing it to supernatural spirits. The concept of sound wave propagation and reflection is a modern paradigm, and is based on the abstraction of invisible pressure waves being diverted by boundaries between media of different densities. In ancient times, however, the causes for many natural phenomena were explained by personification or animism, including attributing echoes to be the responses of spirits.

Acoustical physics describes the process by which sound waves reflected by the boundary between air and a denser material such as rock can result in an auditory illusion. The echoed sound appears to emerge from within the rock, as if coming through the rock surface that seems to act like a permeable veil (analogous to light images reflected in a mirror appearing to exist on the other side of the glass that seems transparent; see Figure 4). As an example of how real this auditory experience can seem, one researcher said, “I first noticed the acoustics of rock art when I heard a car ‘drive’ out of the Buckhorn panel” (William Biesele, personal communication 1997).

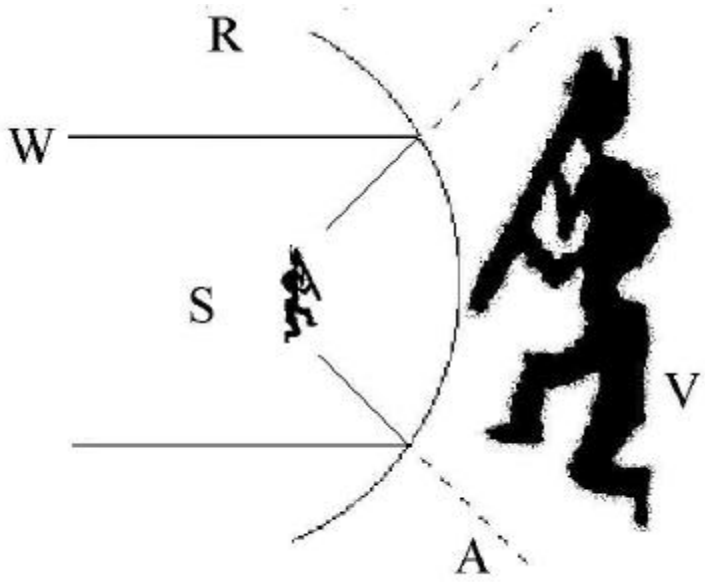

Figure 4. Diagram of light or sound wave reflection resulting in a virtual image apparently behind the reflecting plane. Due to bending, the source waves of this visual or acoustic image are perceived to be coming through the reflecting plane, giving the illusion of permeability and depth. R, reflecting surface (concave in this example); W, waves of light or sound; S, source; V, virtual image (magnified / amplified in this example); A, apparent waves of light or sound.

These sound effects at rock art sites are consistent with -- may indeed have been the foundation of -- the belief that behind the rock surface there is a spirit world resonant with sound. The belief in the spirit world within the rock has been described as very important and relevant to rock art images decorating the rock surface veil (Lewis-Williams and Dowson 1990). The illusion of depth due to sound reflection, together with the phenomenon that echoes can be experienced as voices calling out from within the rock, could have been a likely inspiration for the widespread belief in a spirit world within the rock. Based on what is known globally of cultures that explained natural phenomena in terms of animism, this belief in a spirit world behind the veil of the rock surface would be a quite understandable common response to sound reflection.

A number of ethnographically recorded beliefs lend credence to this hypothesis:
- A collection of San folklore includes the quotation: "O beast of prey! Thou art the one who hearest the place behind, it is resonant with sound." (Bleek and Lloyd 1911:245-247). Painted San rock shelters have been found to produce echoes, e.g., Rose Cottage Cave (Ouzman 1997).
- In North America, legends of the Ojibway and Matagaming around the Great Lakes have been recorded that are remarkably similar to the San case described above. Parallels include: belief in a spirit world within the rock; the magical rock wall appearing

like a transparent window when viewed from within as if the rock paintings hung in the air; sounds of voices heard around these paintings; and spirit beings inside the rock producing many sounds such as heartbeat drumming and songs echoing across the lake (Conway 1993:149-157).
- A site in California called “Wikwip” contains rock art for which there exists ethnographic information: paintings were made by men preparing for ceremonial dances; the name of this site means Echo Rock, and is derived from the sound-focusing acoustical characteristics of the cave (Hedges 1992).
- There is also evidence for a direct connection between sacred beliefs regarding echoes, and the production of rock art: an indigenous tribe of central India called the Korku revere echoes and still produce cave paintings today, using echoes as a selection criteria for which caves to decorate (personal communication, Chakraverty 1996).

While it would be impossible to prove exactly what each ancient artist was thinking, the hypothesis that rock art occurs preferentially at sound reflecting locations is experimentally testable. It is anticipated that such detailed acoustical analyses will yield further insights into the cultures that produced the art. A “Rock Art Acoustics” web page is being maintained at URL **http://www.geocities.com/CapeCanaveral/9461** that includes an on-going list of rock art sites with unusual acoustic properties on five continents. This web page also contains clickable audio files of echoes recorded at some of the sites, photographs of prehistoric art, a description of the acoustic theory of rock art motivation, a list of publications, and links to other web pages pertaining to rock art or acoustics.

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. Documentation of acoustical properties of rock art sites, including ringing rocks, is 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. 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.

It is hoped that more acoustics experts will join with rock art researchers in this new investigational area of rock art acoustics. The reader is urged to please consider this paper as a cry for help echoing through the caves and canyons decorated by our ancestors – there is much work to be done to understand what their works of art are saying.

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