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Igor Reznikoff

ABSTRACT Caves have natural properties of resonance: some areas sound very good acoustically, the sound lasts for several seconds or produces multiple echoes, whereas other areas have a dull resonance or no resonance at all. In a painted cave, it is extremely interesting to compare the map of the most resonant locations with the map of the locations of the paintings: are there correlations between resonance and paintings? Many Palaeolithic caves in France and in the Ural mountains have been studied, and for most of them the answer was remarkably positive: in short, the more resonant the location, the more paintings or signs are situated in this location. With regard to open spaces, we have studied the problem of the relationship between pictures and echoes at prehistoric painted rocks in Finland, France, and Norway, and we have obtained positive results, particularly in France. Successful research results have been achieved recently in Spain (Diaz-Andreu & Garcia 2012) and in Finland (Rainio *et al.* 2014), while some field experiments have been carried out in the US (Waller 2006).

KEYWORDS

rock-art, painted caves, sound, echo, echolocation, shamanic ritual, Kapova cave, Solsemhula

Introduction

As evidence of the activity of prehistoric tribes, sound is certainly the most intangible. We have, of course, no recordings of such sounds, raising the following question: what evidence do we have of musical performance or, more simply, of the use of sounds by prehistoric people? The comparative study of similar societies, such as hunter and gatherer societies, as taught by ethnomusicology, is certainly convincing, since there are no such societies without chant, music, and dance (see Reznikoff 2002), but a comparative study is not proof in itself. We have, however, the evidence of musical tools and instruments – bone whistles, flutes, rhombuses (bull-roarers), and lithophones – but this provides no information about music itself, little about performance, and no information at all concerning voice, which is, as ethnomusicology also teaches us, the main instrument of human beings, particularly in rituals. However, there are also other remarkable musical instruments:

the painted caves and the landscapes surrounding painted rocks. Most of them are giant resonators, to be understood, in the case of closed spaces, as sonorous pipes, where the sound is not produced by the wind of breath but directly by the voice, which can be remarkably amplified by the resonance of the location. In the case of open spaces, the sound produced by the voice is transformed by echoes. Once we have verified that the shape and geological/acoustical qualities of the studied caves or open spaces remain essentially the same as when the caves were painted, what evidence of the use of these giant instruments do we have?

For about 30 years, we have studied many caves and painted rock sites acoustically, from Norway to Southern France and from Finland to the Ural mountains, and often found remarkable results that answer the question mentioned above positively, with no doubt at all, for painted caves and partially for painted

rocks, where further studies are needed. Here we briefly discuss the method, discoveries, results, and some examples; for more detailed studies, see (Reznikoff 2002). Finally, we discuss the meaning of Palaeolithic Art as suggested by our results (for a full discussion, see Reznikoff 2012b).

In Nordic countries, only painted rocks or small caves have been discovered until now, so the study on painted caves presented here is focused mostly on what may be useful for studies in open spaces.

Painted Caves

Most of the caves are highly resonant, remarkable as acoustic vaulted pipes, and can produce quite astonishing echo effects. If the people using these caves chanted or used sound, it would therefore seem likely that they would have chosen for their rites accessible locations with the best acoustics. This acoustical aspect of the caves had never been considered before our study in 1983 at Le Portel (Ariège, France), which luckily happened to be a very resonant cave. The result appeared clearly: there is a link between the locations of the paintings (engravings or signs) and the quality of resonance at these locations in the cave (Reznikoff 1987a; Reznikoff 1987b; Reznikoff & Dauvois 1988). To state the result simply: the more resonant the location, the more paintings or signs are found at this location.

The method consists in studying, in terms of intensity and duration, the resonance of a produced sound of a given intensity and pitch at different points along the cave walls. In this way, the places with the greatest resonance can be located, or, more generally, the quality of resonance at each place can be documented. A map of resonance in the cave galleries can thus be drawn up. In acoustical terms, the changes correspond to the alternation along the wall of nodes and antinodes for the frequencies that are characteristic of particular parts of the cave. The acoustical study was mostly carried out *vocally* in a register from D_1 to G_3 , reinforced by overtones and whistles up to G_5 (in the classical scale, using a tuning fork for the pitches), and *aurally* by listening to the quality of the resonance. The intensity goes from fairly soft sounds (since in resonant places the sound is immediately amplified in the

appropriate pitch of the resonance) to strong sounds of 90 dB (or up to 100 dB in open spaces) at the source, on the vowel *o*, when the number of echoes is measured (see below).

When we started our studies, the methods enabled by purely acoustic means were too rough for the required approach; nowadays, with computers, much finer measurements can be obtained, particularly for the increased intensity in resonant frequencies. However, the living voice allows a very subtle approach. For instance, the voice was essential for the discovery of effects imitating the sounds of animals, what we call *bison effects*, in narrow recesses (see below). Such effects could not be discovered by clapping or using 'white noise', as is usual in acoustics. It is hopeless to try to understand Palaeolithic life and art without an anthropological approach.

A very useful and easy way of measuring the richness of a resonance is, apart from measuring its duration, also counting the number of echoes returned by the resonance. This technique is simple; as indicated above, we use a strong high voice (actually the author's

Table 1. The relationship between the number of echoes and the concentration of paintings in the caves of Arcy (Burgundy, France) and Kapova (Ural, Russia).

Location	Echoes	Duration	Paintings
Arcy-sur-Cure			
Painted ½ pillar	5	4	+
Before the Defile	2	1	–
Red dots	3	3	+
Chaos Hall	2	1	–
Panel with hands	4	4	+
Rhinoceros and paintings	5	5	++
Red panels	6	6	++
Many pictures (Mezzanine)	6–7	6	+++
Kapova			
Chaos Hall	1–2	2	+
Signs Hall	3–4	3	++
Dome Hall	4–5	3–4	++
Paintings Hall	7–8	6	+++

Duration is expressed in seconds.



Figure 1. Main panel in the Paintings Hall, Kapova cave (Ural). On the ground level under the panel, at the left and right of the engraved horse, we can see two very resonant niches in which ‘bison effects’ are easily obtained.

male voice on, for example, a register between $D_1 - C_3$ around 74 to 250 Hz), for a short duration of about half a second. From 0 to 1 echo, the resonance is insignificant, and for 2, 3–4, 5–6, and 7–8 echoes, the resonance is respectively weak, good, very good, and exceptional. In the caves of Arcy-sur-Cure (Burgundy), Niaux (Ariège), and Kapova (Ural), such exceptional resonances correspond to the most exceptional sets of paintings in the caves. To illustrate the relevance of this graduation, we give two simplified schemas of the relationship between the number of echoes and the concentration of paintings in the caves of Arcy and Kapova (**Table 1**) where the number of paintings is proportional to the number of echoes.

More examples are given in Reznikoff (2002; 2010; for the Kapova cave, see also Waller 2006; Lubman 1998 used echoes in a different manner).

A cave, if not too large, can be studied as a whole, but some parts of it can be studied in themselves. Particularly interesting are small recesses (or niches) and narrow tunnels; their study has resulted in two major discoveries.

Recesses and ‘Bison Effects’

A *recess* (or *niche* or *alcove*) is a hole in a wall; it can be small, medium-sized, or large, meaning that, respectively, only a human head, the upper part of the body, or the whole body (possibly standing up) can fit into it. Often such recesses are very resonant. Some are decorated with paintings or *red dots* (see below) and are next to, under, or just in front of paintings or dots; in such cases, using a deep humming voice (around A_1 , 110 Hz, for $\frac{1}{2}$ second), it is easy, or we could say *one is almost obliged*, to imitate sounds of animals, roaring, growling, lowing, or neighing. It is what we call a *bison effect*. In almost all caves, there are such recesses: Le Portel, Arcy, Oxocelhaya (Pays Basque), Labastide (Pyrénées), and Bernifal (Dordogne). In the Niaux and Kapova caves (see **Fig. 1**), such resonant recesses are situated in already very resonant halls, and the effect is even more impressive and can be heard far away (see Reznikoff 2002; Reznikoff 2012a). This discovery is important for understanding the ritual meaning of painted caves.

Tunnels and Red Dots

Among the clearly non-figurative signs often found in prehistoric painted caves are red dots or marks made of ochre or sometimes of haematite. These dots have a more or less round shape, about 2 to 3 cm in diameter. Because of their small size, they can be found in various locations, including those where pictures could not be painted. The question arises as to why they might have been painted where they are. For example, in a long narrow tunnel where one has to crawl, one may find an isolated red dot appearing suddenly on the roof or side wall of the tunnel, whereas no dots were found either before or after that point and no other paintings appear to be present at all. What rationale can be given to explain such a situation? As a general rule, *the red dots or marks are related closely to the resonance of the tunnel or part of the cave where they are located.*

This result has received clear verification in some narrow recesses or tunnels. In three tunnels at Oxocelhaya, two of which are approximately 6 and 10 metres long, respectively, and one tunnel of some 10 metres at Le Portel, a red dot appears at the very location of maximum resonance. Such dots can be found by blind trial in which the investigator, progressing through the tunnel in darkness and making humming (see above) sounds, puts on the light when maximum resonance is reached and inspects the walls: the red dot is there.

Since there is apparently no other reason for painting the dot where it is and the correspondence with the point of maximum resonance is precise, the conclusion, astonishing though it may seem, is straightforward: the red dots have a sound-resonant meaning. The probability that all these three red dots correspond to peak resonance simply by chance is close to 10^5 to 1. There are also red dots in other parts of the caves that still correspond to maxima of resonance, although not in such a spectacular way as in the tunnels mentioned above. Considering several locations together, the odds of all these correspondences having come about purely by chance would be reduced to something of the order close to 10^6 to 1. These are very long odds. When we consider them together with the complete absence of any other explanation, the

acoustic meaning of such signs begins to appear very convincing indeed (see Reznikoff 2006).

Of course, prehistoric people were not studying the acoustics of their tunnels as such. Our explanation is that since they advanced in darkness, they had to make sounds, or in a narrow tunnel, just hum with a closed mouth (a sound like *mm* or *hm*), using the sound as a kind of sonar: the response of the cave or of the tunnel to this signal might tell whether there is space ahead and where to advance. Reaching the location of maximum resonance (the acoustical main antinode) is very impressive: the whole tunnel resonates to a simple *hm* and the sound can be heard outside the tunnel, in the main cave (there are often pictures around or in front of the entrance of the tunnel). Progressing further inside the tunnel, one naturally finds oneself pausing at this remarkable sound location. And the dot shows precisely where this living sound point lies, possibly identifying it for use later on. This demonstrates the use of resonance in a *functional* way.

Towards a Meaning: Two Aspects of the Use of Sounds

The explanation above introduces the functional aspect of some paintings and of the red dots; we interpret them as landmarks, and interpret also in the same way the sparse red or black dots that appear in locations where the relationship to resonance is not as obvious as in the tunnels.

Since all people currently studying painted caves use modern means and, of course, electric light, they miss something obvious: in complete darkness, with the help of only small oil lamps that light up the immediate neighbourhood or torches that cannot be used in narrow tunnels, making sounds is a necessity. As indicated above, the sound is used as a sonar; the answer of the resonance, the echoes, their number, and their direction indicate where to go or not to go: if the sound suddenly returns from below, it means there is a hole in the ground. Prehistoric men's fine sensibility to sound enabled them to proceed further to the deepest parts of caves, sometimes a few kilometres deep. For example, in Rouffignac (Dordogne), proceeding in the direction of the best answer to the resonance, one is naturally led to locations of paintings. In many caves,

the prehistoric men exploring them marked the way with painted dots, presumably as in narrow tunnels, in order to know or show that they passed there; the dots are used in a functional way as landmarks. We use the word men, because rather low voices are more appropriate for resonance in some parts of the caves, since they are potentially stronger, and moreover, exploring a cave might be dangerous.

In the Introduction above, speaking of evidence for the use of sounds, we mentioned instruments and, among them, whistles and flutes. But the use of a whistle is mostly functional and suited for open spaces: whistles were certainly used for calling herds (an experiment has been done with reindeer). In a gallery, the high frequencies are quickly deadened and whistles are not suitable for progression in a cave; the same is true for flutes. However, flutes, which have finger holes, are clearly musical instruments and not properly functional tools. Thus we have a second level for the use of sounds: the musical or *ritual* level, including the possible use of bull-roarers, lithophones, and drums.

When the cave has been vocally explored and the best resonant places discovered, then, in such resonant locations, provided there is a panel or panels that are suitable for painting or that can be prepared for painting by scraping, it would be natural, indeed, to paint pictures of animals. A ritual dedicated to the animal is best performed in such a place, since a ritual is always done with chant, sounds, and possibly dances, if the space is large enough. This is why the paintings are mostly located in resonant places. In a large hall, such as the *Salon Noir* in Niaux, the *Hall of Paintings* in the Kapova cave, or the *Main Hall* in the Isturitz cave (Pays Basque), where flutes were found (Buisson 1990), real ceremonies with voices, including female ones, flutes, etc., were probably carried out. Thus, we have a parallel between the two levels of sounds and paintings:

- 1) Functional level: vocal sounds as a sonar, related to red dots
- 2) Ritual level: chant, flutes etc., related to figurative paintings or engravings

Curiously enough, while ethnology and ethnomusicology teach us that there are no ancient civilisations without some notion of an *invisible world* and without rituals related to it, these notions are never mentioned in prehistoric studies, probably because they are not visible or tangible, any more than sounds are. People nowadays don't really believe in such things, but ancient civilisations certainly did, and we miss the point and have no chance of understanding the Palaeolithic caves if we do not take this into account. Singing may be used to act in the physical world, imitating various sounds in order to attract animals and possibly catch them, but is used also to act in the invisible world, to affect the spirit of an animal by incantation.

The representation of an animal may be related to the two levels of meaning discussed above: to the functional level of hunting, which belongs to the visible, physical world, and to the invisible level of the *spirit* (or *soul*) of the animal. In rituals, music and above all chant contribute to both levels, but vocal incantation mostly to the invisible one. Let us stress that imitating the sounds of animals is a major technique for achieving deep levels of consciousness in shamanistic rituals. The recesses studied above are quite appropriate for this. Of course, this does not exclude other uses and meanings of prehistoric paintings (for a longer discussion, see Reznikoff 2012b).

Painted Rocks

After the first studies in the caves, the idea came naturally of studying in a similar way the sound value of the locations of prehistoric paintings on rocks in the open air. For such paintings, for example, around lakes in Northern Europe or in the mountains of Provence, the problem of an explanation for the choice of their location is even more difficult than in the case of painted caves. There is also, of course, a need for a good rock surface for painting, but this doesn't really limit the possibilities, since in the open air there are usually many (apparently) good locations from this point of view. The relationship of the locations to their orientation and, for example, to the rising or setting sun is rather doubtful, since paintings are often oriented

quite differently; however, a possible relationship to the celestial system has to be investigated carefully.

Of course it is still possible that there were no special reasons for most of these choices, or rather no sole reason or any real rationale in these choices, and that they were made arbitrarily. But this is not a very satisfactory explanation, and the idea that the choice of the locations could be related to sounds or, here in the open air, echoes, thus appears quite interesting.

The method was elaborated in the field. The voice was used from D_2 to D_3 (150 to 300 Hz) with a powerful open-air singing technique (about 90-100 dB at the source). In order to obtain a good echo effect at a given point in front of a picture, the best position and direction for the voice have to be found on the spot. It would also be possible to use a horn. The criterion for an acceptable sound location was the existence of *at least* a triple echo: a double echo is not a rare phenomenon, and four echoes would be too restrictive a condition to start with. Of course, this echo property of a location depends on the weather and especially on the wind. The echoes often move in space, and depending on the wind and landscape, the effect can be astonishing and sometimes seems even magical.

Firstly, we have studied four examples of rock paintings in Finland: at three lakes in the Helsinki area and one in the area of Mikkeli (in 1987). Three of these studies were positive. The paintings have been dated to approximately 3000–2000 BC depending on the specific painting (but these chronological limits are still under debate). Then we studied several areas in the mountains of Provence, in France, at the Massif de la Sainte-Baume (Var) in 1993 and in the Vallée des Merveilles (Alpes Maritimes) in 1999. Finally, in 2011, we studied sites in Norway.

An important study on painted rocks related to sounds in Spain has been recently carried out by Diaz-Andreu and Garcia Benito (2012).

In Front of Lakes in Finland¹

Except for the first example below, the echo method was applied from the shore of the lake, next to the paintings. But one should have tried also *on the lake*,

from a boat not too far from but not too close to the pictures, since on a lake in still weather, it is relatively easy to obtain echo effects. Our best result was on the lake at Valamo, where, under very still conditions, we obtained 11 echoes answering to a single vocal short melody and moving around the shore². On the other hand, in the winter, when the lake is under ice and snow covers the whole landscape, most of the echoes disappear.

Area of Helsinki

1. We started at Nuuksionjärvi, *Swan Lake*, near Espoo, with a painting representing an elk on a rock situated in the south-west part of the lake. The painting is very close (1.5 m) to the water surface, so that a boat is necessary. Under rather rainy conditions, there were three echoes (the third being weak) from the opposite bank, and only two at other locations around the painted rock.
2. It was in the east part of the lake of Vitträsk, “Valkoinen järvi”, that the first rock paintings were discovered in Finland (by Europaeus, in 1917). A reindeer and geometric designs are represented in a recess on a cliff about 15 m above the water surface. Under rather good weather conditions, there were three strong echoes. At locations around, under, or above the paintings on the cliff, the echo was not so clear.
3. Juusjärvi. The pictures represent some human figures, a hand, a fish, and zigzag lines. Here the location of the pictures (5 m above the water) on the eastern shore of the south part of the lake is certainly remarkable for echo effects. It is easy to get three or even four echoes (the last being an echo of an echo) from the nearest opposite bank and also from the little island in the lake. We did not obtain such good effects when trying around.

This last example being satisfactory, we concluded in 1987, on the basis of the study of these three

¹ For more detailed discussion, see Reznikoff 1995.

² As mentioned in *Suomen Kansan Vanhat Runot* (Ancient Finnish Epics), the practice of echo effects was common in ancient Finland, especially on the lakes (see Reznikoff 1987c). The practice of echo was still alive in Finland at the end of the 19th century, as we can read in Aleksis Kivi's *The Seven Brothers* (1934, Chap.3, “Legend told at Sonnimäki”) and hear at the end of Runeberg's Hymn of Finland.

locations, that the idea that painted rocks are related to sound and echo was interesting and had to be investigated further.

The Mikkeli Area

The study of Astuvansalmi on the Yövesi lake, at Ristiina near Mikkeli, where there was slight evidence of echoes in front of the pictures (humans, hands, elks, boats, etc.) raised a very serious problem: the changing water level. For a discussion and bibliography, (see Reznikoff 1995). Recently a study has been initiated in Northern Finland (see Rainio *et al.* 2014).

Provence³

Pin de Simon (Sainte-Baume, Var)

The study at Sainte-Baume was remarkable especially at the cliff called Pin de Simon. Reflected from the opposite cliff, there are indeed quite noticeable echo effects. There are seven cavities in this area of the cliff, but *only the two that are painted produce good echo effects* coming from the opposite cliff. In the first cavity, the best effects (4–5 echoes) are obtained where five of the eight major paintings are concentrated, in particular in front of a picture of a human with open hands and fingers facing the sky and the opposite cliff. At this picture, 5 echoes are produced, the echo effect lasting up to 5 seconds. From the last cavity, up to 8 echoes (at night, in complete silence and no wind) can be obtained during 6 seconds, eventually producing melodies, the last echo appearing after a little while in a very surprising manner (melody).

Because of the remarkable sound value of the place, we were sure that there should be more paintings. Indeed, by looking carefully once more, we discovered a new ochre painting, situated on the rock outside the cave at the left of the entrance, facing the sun, wind, and sometimes rain. In this picture, we see what is, in our opinion, a rowing boat (the Mediterranean Sea can be seen from the Pin de Simon). In this case, it would be the oldest representation of a boat in Europe, since the paintings in this area are dated to the Chalcolithic age, 2500–2000 BC.

Vallée des Merveilles, Mont Bego (Alpes Maritimes)

Finally, in Provence, we made a preliminary study at Mont Bego in the Vallée des Merveilles, whose pictures have been exhaustively presented and studied by H. de Lumley (2001). Our study was quite promising. There are several areas where we discovered a conjunction of rich sound values and pictures. Two areas are really remarkable. First the Lac des Merveilles, next to which there is a very large flat rock (sometimes called the Altar stone) covered with more than a thousand pictures. There, by the lake, the echo answers whole melodies and it is a pleasure to sing or play; one can easily imagine a ‘concert’ or rather a celebration using voice and horns. Another very remarkable site is the upper area with once again very large flat rocks and, facing the sky, many pictures, including a famous one of a human figure (or ‘god’) with zigzag (or ‘lightning’) hands. There, because of the dominant position of the rocks, the echoes come from mountains all around, some at a distance, creating an unreal magical impression. At the Vallée des Merveilles, therefore, we have again the conjunction of (i) large flat rocks covered with many pictures and (ii) very rich resonance expressed through echoes, easily suitable for ritual or celebration using voice and sounds. A more systematic study of this important site remains to be completed.

Norway

The study in Norway was different, because the sites we studied there are not in the open air, but are small caves. However, they are very different from the deep painted Palaeolithic caves and rather similar to the sites of painted rocks by the dating (3000–2000 BC) and style of paintings. We studied the caves of Skaaren-Monsen and Solsemhula on the west coast of Norway, north of Trondheim, in 2011, with the help of Adjun Selfjord (see Selfjord 2011). In the first cave, the study was not conclusive, probably because a thick level of clay dust and sand has covered the ground. In Solsemhula, there is a remarkable link between the main red ochre picture and the resonance: a group of humans walking hand in hand in procession to the narrow bottom of the small cave (bottom) that resonates very strongly if used as a recess (kneeling on the ground with the head inside the recess), eventually suitable

³ For more detailed discussion, see Reznikoff 2002.



Figure 2. Solsemhula cave in Norway. The procession of painted humans on the right wall is walking towards the recess at the bottom of the cave; in this recess, it is easy to obtain 'bison effects'.

for what we call bison or other animal effect (see **Fig. 2**). This conjunction of a large painting pointing to a very resonant recess is unique and very impressive. We plan to study other painted caves on the north coast of Norway.

Conclusion on Painted Rocks

The ideas, method, and positive results (at Pin de Simon and Mont Bego, as well as around Northern lakes) obtained with painted rocks must be related to what we know of lithophones in the open air. While there was nothing known of sounds in the prehistoric caves before our discovery, sounding rocks or rock gongs that were used as lithophones in ancient times have been studied long ago by Fagg and others (Fagg

1956; Conant 1960; Ablova 2003). According to Fagg, some megaliths, mostly in Africa but also in Brittany, seem to be ringing stones. The evidence of a sound dimension to painted rocks is naturally supported by the study made in the painted caves. In the caves, also lithophones have presumably been used (Dams 1985; Dauvois & Boutillon 1994; Reznikoff 2002). The sounding stones, thus, create a link between the open air and the ornamented caves. As far as we know, the painted rocks around the Northern lakes and in Provence – rock walls or big flat rocks – cannot be used as gongs, but we now have knowledge of how rich, for the prehistoric tribes, the relations were between sound, caves, space, lakes, rocks, mountains, visible and invisible worlds, animals, and paintings, and how deep and alive the sound was for them.

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