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Different Blowing Techniques for Palaeolithic Aerophones: Animal Calls, Clarinets, and Flutes

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Abstract

This article examines how individual approaches in experimental music archaeology may produce different results in reconstructing Upper Palaeolithic aerophones. The paper reveals how sound tools have been used by both prehistoric and modern hunters to imitate animal calls or to chase their prey in a specific direction. The best examples of such practices are the phalangeal whistles and a possible scraper, which have been found along with the remains of Neanderthals in Europe. A possible scraper was recently discovered in the Middle Stone Age African Border cave. Early percussion instruments like drums or different kinds of idiophones might have had multiple functions for the nomadic hunters.

From the 1990s to 2009 a number of new finds of possible Palaeolithic aerophones initiated various experimental studies. Unfortunately, many important questions could not be resolved. I intend to revive the discussions on playing techniques on one hand, and to contribute to the arguments for the non-human origin of some finds on the other.

After discussing sound production techniques of simulated animal calls and summarising the possible use of sound-producers as hunting tools, this article briefly presents two possible reconstructions with reeds and two different techniques of blowing a flute without any mouthpiece.

Keywords

Palaeolithic aerophones – Perforated mammal bones – Wing bone flutes

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1 Introduction

The conclusions of my occasional experimental music performances with HF1 aerophone reconstructions in the last 11 years strengthen the hypothesis of Jean-Loup Ringot,[1] who first reconstructed this unique find as a clarinet. Since 2010, I have played with the ensemble "SteinzeitSession" and in the duo "Schtoa". We play replicas of archaeological finds of musical instruments in group performance or in a duo. The songs mostly relate to hunting scenarios or specific animals. The range of experimentation goes from Barbeque at the beach with ten to fifteen musicians and friends to duo or solo meditation music. With the clarinets and flutes, my intention was to discover which possible melodies or melodic motifs are most easily playable. It is clear that the potential to evoke very different moods, as well as a great variety of other applications resides in these sophisticated clarinets and flutes.

Individual approaches influence the reconstruction of different playing techniques for Palaeolithic aerophones. The doyen of experimental music archaeology in Germany, Friedrich Seeberger († 2011), successfully played replicas of Upper Palaeolithic aerophones found at the Swabian Alb in southwestern Germany as oblique or vertical rim-blown flutes.[2] However, his replicas are reconstructed only to the length of the fourth fingerhole. They are remarkably shorter than the Hohle-Fels find. The relation of length and diameter control optimal playability as a flute. Friederike Potengowski[3] and Simon Wyatt[4] repeatedly argue in favour of interpreting these finds as flutes. Their experiments imply that – for professional modern flautists – it is possible to play the tiny aerophones from the radius wing bones of swan or vulture as flutes. However, in my opinion, there are doubts about the accuracy of the replicas played by Friederike Potengowski, which seem to have wider internal diameters than the original find.

In 2012, two articles in *Studien zur Musikarchäologie* 8 by Jean-Loup Ringot[5] and Simon Wyatt[6] introduced me to the importance of reed instruments in Upper Palaeolithic European soundscapes. Ringot presented his interpretation of the Hohle-Fels aerophone HF1 as a clarinet with a birch bark single reed. Wyatt emphasises the convincing sound of the best preserved Isturitz aerophone played with a single reed mouthpiece ("Ersatz clarinet"[7]), which was also tested by Francesco d'Errico and Graeme Lawson,[8] and once more by Carlos García-Benito.[9] In these types of clarinet mouthpieces, the 'tongue' is cut from the wall of a tube with one closed end. The tongues can be cut from the main aerophone tube (like the Saami *Fadno* clarinet[10]), or the mouthpiece may be

1 Ringot 2012.
2 Seeberger 1998; Münzel, Seeberger and Hein 2002; Conard et al. 2004.
3 Conard et al. 2015; Münzel et al. 2016.
4 Wyatt 2012; Wyatt 2016.
5 Ringot 2012.
6 Wyatt 2012.
7 Wyatt 2012: 394, Fig. 4.
8 D'Errico and Lawson 2002.
9 García-Benito 2018.
10 Emsheimer 1964.

separate, consisting of a smaller tube inserted into the main aerophone tube (like on *Launeddas* and bagpipes). Numerous clarinet-like instruments around the globe are sounded with such mouthpieces. An attachable mouthpiece, like I use for Isturitz (Figure 6), allows the playing of the same tube with or without a mouthpiece – one instrument body serves as clarinet or flute, depending on what the situation requires. However, I am so far unaware of any ethnographical parallel for such a double use. Wyatt conducted experiments with clarinet mouthpieces with a tongue split off from the tube in reconstructing the Isturitz aerophone.[11] My results further differ from Simon Wyatt's experiments regarding Isturitz and Hohle Fels: the Isturitz aerophone appears to be a multifunctional musical instrument to me. I can play a clear-sounding flute version – vertically oriented, as Barnaby Brown plays so impressively[12] – including a major third. Alternatively, I achieve a more 'windy' flute version with the oblique rim blowing technique, yielding a minor third instead of the major third. If I insert the attachable mouthpiece, a strong clarinet sound can be produced (five pitches in a range of a fifth; Table 2; Table 3; Table 4).

In 2016, Simon Wyatt tried clarinet and flute playing, and concluded that the HF1 aerophone can also be played like a flute, very beautifully, too.[13] I have not been successful in playing HF1 like a flute. I think this is due to the small diameter in relation to the length. According to Gabriele Dalferth (this volume), a relation between seventeen and twenty-four to one centimetres in length and diameter provides the optimal proportions for Irish six hole whistles. A radius wing bone of a swan or a vulture does not fall within this optimal ratio. The Hohle-Fels aerophone presumably was about twenty-six centimetres long, with 0.8 cm in maximum external diameter and around 0.4 cm in minimal internal diameter (reconstructed to former full size of a radius bone). This is relevant when comparing the differences in aerophone diameters to the differences in sound production. With the clarinet replica in a comparable size of the HF1 aerophone, I am able to play seven pitches in the range of one octave, using all fingerholes (and enhanced air-pressure for the highest pitch, Table 1).

2 Animal calls and perforated bones

Phalangeal whistles have been interpreted as hunting whistles in earlier studies.[14] In 2013, their remarkable impact on reindeer behaviour was described for two distant ethnographic contexts:[15] the animals attribute the shrill sound to alarm calls, carnivore calls, or something similar. The prey reacts by holding still when recognising such a call, standing motionless or even lying down on the ground.

[11] Wyatt 2012: 394, Fig. 4.
[12] See the documentary "Blasts from the Past" (https://youtu.be/mF2LpQA_jtQ).
[13] Wyatt 2012; Wyatt 2016.
[14] D'Errico and Villa 1997; Holdermann 2001; Dauvois 2005; Caldwell 2009.
[15] Neal 2013; Morley 2013; see Praxmarer 2019: 77–78.

Another sound tool that may serve for hunting purposes is the so-called scraper, which imitates a warning call of red deer,[16] or bird sounds like ratchets.[17] Recently, I discovered two new possible scrapers from early archaeological contexts:[18] a raven ulna fragment with intentional notches from the Zaskalnaya VI (Kolosovskaya) site in Crimea, which archaeologists discovered in a Neanderthal context,[19] and a notched baboon fibula from Border cave that belongs to the Middle Stone Age in Africa (Homo sapiens), dated from 44 000 to 42 000 ya.[20]

To assess the possible blowing techniques for Palaeolithic aerophones, potential parallels from modern hunting whistles and animal calls have to be considered. Looking at possible hunting aerophones from Neolithic Scandinavia,[21] it becomes clear how simple tubes or hollowed out objects, with or without perforations, can fulfil helpful functions for hunters. Some of the depicted possible aerophones are reminiscent of perforated mammal bones, mostly bear bones that appear in archaeological contexts of the Aurignacian cultures of the eastern Central European region (Austria, Germany, Croatia, Slovenia). In one case – the Slovenian Divje Babe cave – such a perforated bear bone was found in a Neanderthal context, dated to around 55 000 ya.[22] The possible aerophones from bear bones and comparable mammal bones[23] show perforations that humans could have punched into the bones to craft a bone aerophone.[24] Curt Sachs was one of the first music-archaeologist researchers who postulated that the bear bone flutes represent the earliest aerophones (next to phalangeal whistles).[25] The Slovenian researchers who excavated the prominent find,[26] as well as scholars like Bob Fink,[27] and others who argue for developed cognitive abilities of Neanderthals,[28] argue for the Divje Babe find as a "Neanderthal flute".

In contrast, other researchers point to the traces of carnivore gnawing which have been found on all potential bear bone aerophones (and other perforated mammal bones).[29]

The Slovenian researchers explain the traces of biting on the possible aerophone with the theory that the "flute" was gnawed both before and after the use as a human musical instrument. I would like to use this opportunity to assess the Slovenian researchers' arguments for human influence on the find. Firstly, they claim to have found remains of the blowing edge.[30] This is a flat edge of 2 or 3 mm, which could easily stem from carnivore influence as well. They also claim to have

16 Holdermann 2001: 90.
17 Cajsa Lund in the documentary "Blasts from the Past" (above, n. 12).
18 Praxmarer 2023.
19 D'Errico et al. 2017.
20 D'Errico et al. 2017b.
21 Lund 1988.
22 Turk 1997.
23 Albrecht et al. 1998.
24 Turk et al. 2020.
25 Sachs 1934.
26 Turk 1997; Turk and Kunej 2000; Turk et al. 2005; Turk and Dimkaroski 2011; Turk et al. 2018; Turk et al. 2020.
27 Fink 2002.
28 E.g. Bedarnik 2015.
29 Zagiba 1976; Holdermann and Serangeli 1998; Albrecht et al. 1998; D'Errico and Villa 1997; D'Errico et al. 2003.
30 Turk and Dimkaroski 2011.

found microscopic scratches,[31] which could easily be explained by the pushing and shoving of the bone in the soil. Furthermore, the experimental attempt to punch holes into the flute does not convince me at all. There is no proof that Neanderthals ever used a multi-compositional set of a silex tool, a bone intermediate piece, and a wooden hammer[32] to perforate a bone.

I will now summarise briefly the differences in creative expressions before and after the Mousterian-Aurignacian transition in Europe. The Divje Babe find has been correlated with a Neanderthal fireplace. The material remains of these Neanderthals belong to the Mousterian culture. The Aurignacian culture is attributed to the time when modern humans first reached the central European region. Symbolic or modern behaviour like multi-component weapons, pigment and adhesive use, burial of dead and care of wounded people, proto-geometric and geometric incisions, was part of the Neanderthals' Mousterian cultures in Europe and the Near East, as well as in Homo sapiens cultures of Middle Stone Age Africa.[33]

The Aurignacian cultures that initiated the Upper Palaeolithic period in Europe in contrast have highly developed traditions of visual arts and musical instruments that surpass many other human hunter-gatherer cultural remains.[34] Aurignacian visual arts included carved statuettes and cave paintings that were rich in naturalistic and precise details, as well as advanced in their figurative composition. The wealth of different types of instruments and sound tools, the possible high-tech sound-production techniques, and intended octave intervals[35] characterise the sophisticated and elaborate musical remains of the prehistoric arts of this era. In my forthcoming doctoral thesis I postulate that the meeting of humans with very different lines of ancestry is responsible for the development of this rich culture of arts in Europe. From Africa to the Near and Far East, modern humans were contemporary and probably in contact with Neanderthals and late-erectus humans like Denisovians. That the Upper Palaeolithic diversification of cultural expression is related to cultural diversity is posited by the Melting Pot Theory (MPT). I suggest that the Upper Palaeolithic cave art would have been impossible without the multicultural setup of the societies of Late Ice Age Europe – cultural diversity leads to cultural variety.[36]

From its position directly at the interface of the two Palaeolithic cultural horizons of the Mousterian and Aurignacian, the Divje Babe possible bear bone aerophone would appear to be the missing link of music archaeology. But ultimately we do not have any evidence for intentional melodic musical aerophones of Neanderthals.

However, a replica of the bear bone with an attached membrane, which works like a modern

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31 Turk et al. 2005.
32 Turk et al. 2018.
33 D'Errico et al. 2003; D'Errico and Henshilwood 2011; Wynn and Coolidge 2015; Wynn and Coolidge 2016; Půta and Soukup 2015; Praxmarer 2023.
34 Clottes and Lewis-Williams 1997; Floss 2006; Conard et al. 2009; Blench 2007; Morley 2013; Půta and Soukup 2015; Praxmarer 2023.
35 Praxmarer 2019; Praxmarer 2023.
36 Praxmarer 2023.

kazoo – a voice disguiser (Figure 1.2) – demonstrates the possible function of such ecofacts as hunting tools. B.M. Blackwood and H. Balfour show the diverse use of vibrating membranes in many musical cultures in an ethnomusicological article from 1938.[37] I own a small collection of modern animal calls made for modern hunters. A small duct flute can imitate mice calls (Figure 2.1), while the technology of reed-constructions enables calling deer (Figure 2.2), ducks (Figure 2.3) or wild boars. Membranes are used to imitate the death-cry of carnivores' preferred game (Figure 2.4), thus convincing the carnivore that mortally wounded game can be found at the location of the death cry.

Another kind of sound tool with vibrating membrane ('mirliton' or 'Ansingtrommel') is a bird imitation rim-membrane construction (Figure 2.5), which is played between tongue and top of the mouth. It enables the hunter to easily play fast bird-call-like sequences by moving the tongue while blowing.

Figure 1: 1. Replica of the perforated bear bone and possible aerophone from Divje Babe (Slovenia) bought in the Ljubljana National Museum. The membrane from bowel skin enables its use as voice disguiser.
2. Modern Kazoo, Voice disguiser for musical purpose

I am able to play the Divje Babe replica in Figure 1.1 like a signal hunting whistle with three pitches (blown from the notch with the lower end closed). If I turn the aerophone around I can use the attached membrane as a voice disguiser. For Palaeolithic hunters, voice disguisers enabled the imitation of animal calls. In my experiments I mostly imitate bison or deer calls. Carlos García Benito et al. (2018) used a similar membrane construction for a bird bone find from the Le Placard cave in France, where a great number of Upper Palaeolithic aerophone remains were found. Jean-Loup Ringot even uses such a mirliton to add distortion to a clarinet.[38] When the fingerhole, which is covered by a membrane, is opened, the membrane vibrates and adds a distortion effect. It is difficult to prove that hunting whistles and animal calls preceded musical aerophones. Still, finds like the early possible scrapers and the phalangeal whistles have long been interpreted in this direction. At any rate, the perforated mammal bones might equally have served as animal calls, signal whistles, or musical tools, depending on what the situation required.

[37] Blackwood and Balfour 1938.
[38] Ringot 2012.

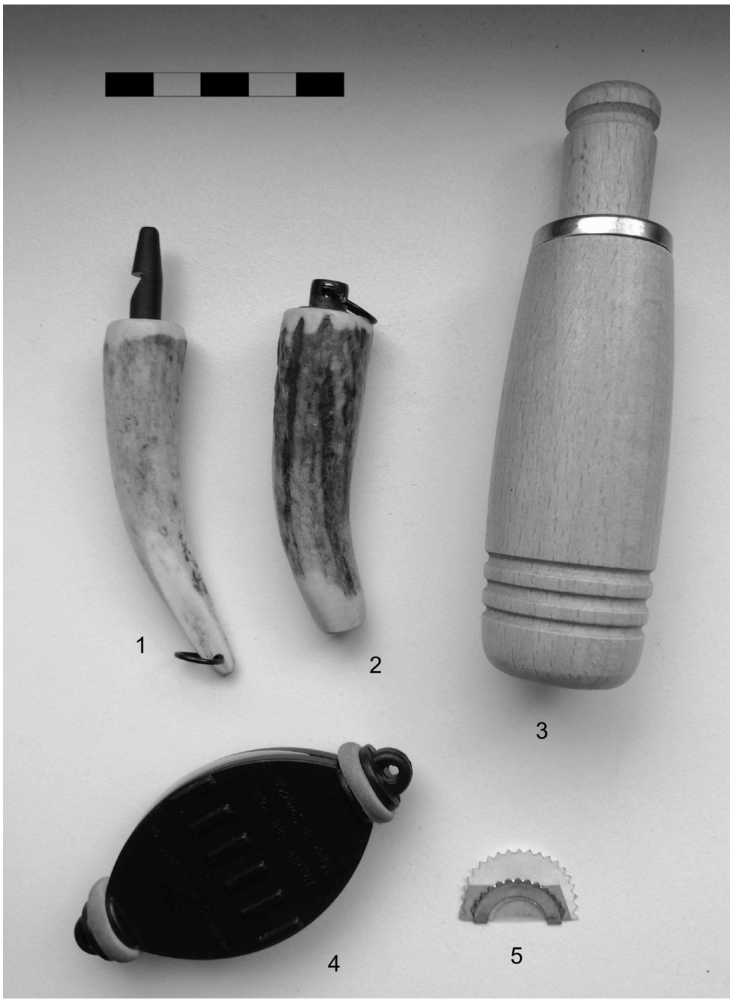


Figure 2: Modern animal calls: 1. Mouse call, duct flute; 2. Red-deer call, reed aerophone; 3. Duck call, reed aerophone; 4. Carnivore call, mirliton membrane; 5. Bird call, mirliton membrane. Scale: 5 cm.

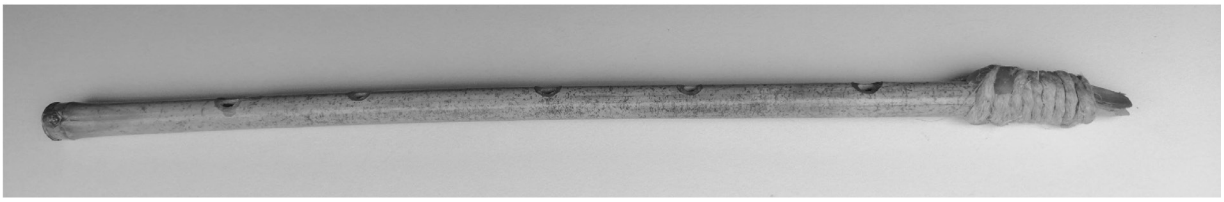


Figure 3: HF1 clarinet reconstruction from bamboo, with a birch bark single reed (clarinet, saxophone) mouthpiece.

The bones gnawed by carnivores from Divje Babe and from the Aurignacien layers in Austria, Germany, Croatia, and Slovenia are the subject of much controversy. Some researchers argue for man-made musical instruments,[39] while others hold that these bones are simply products of carnivore gnawing and are not musical instruments.[40] I suggest, even if these ecofacts have been shaped by animals, they could have been used as aerophones by prehistoric humans, in whose contexts these possible aerophones were found.

[39] Turk 1997; Turk and Kunej 2000; Fink 2002; Turk et al. 2018; Turk et al. 2020; Bedarnik 2015.
[40] Zagiba 1976; D'Errico and Villa 1997; Holdermann and Serangeli 1998; Albrecht et al. 1998; D'Errico et al. 2003.

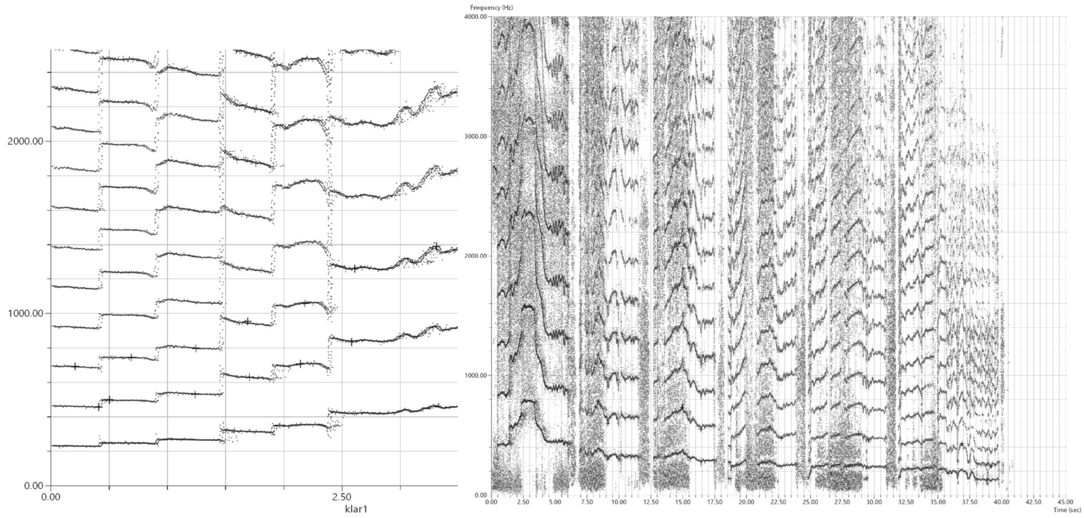
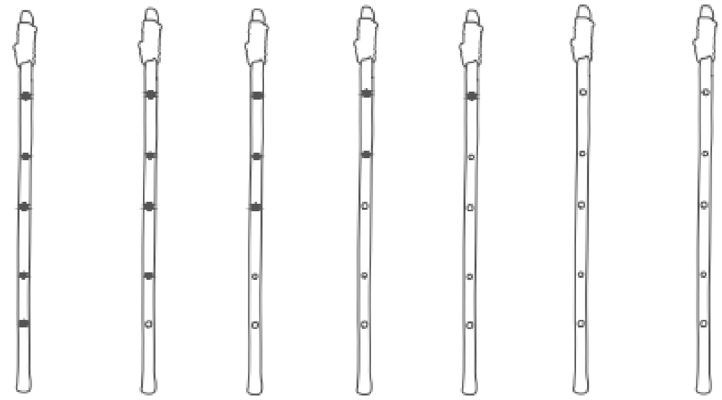


Figure 4: Frequencies played on HF1 as a clarinet: with relative stable air pressure in the left diagram; with lower and higher pressure in the right diagram (x-axis: time in s; y-axis: frequency in Hz).

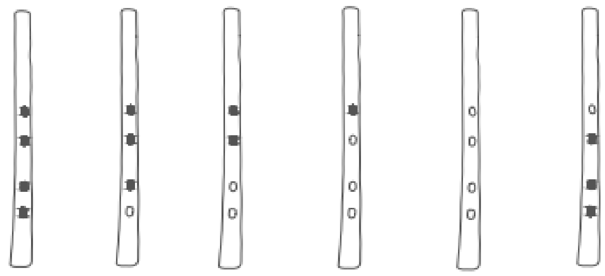


frequency (Hz)	455.94	499.22	529.51	630.49	706.94	833.89	936.31
pitch	$B\flat_4$	B_4	C_5	$E\flat_5$	F_5	$A\flat_5$	$B\flat_5$
Deviation (cent)	-38.38	18.60	20.58	22.76	20.90	6.82	7.38
semitone steps	-	1/2	1/2	3/2	1	3/2	1
minimum pressure	241.59	462.02	474.67	548.75	597.53	832.42	-
maximum pressure	429.53	512.61	572.24	731.23	783.63	1580.43	-
f1 : f2	1.78	1.11	1.20	1.33	1.31	1.90	-

Table 1: Pitches played on HF1 as a clarinet. The sixth finger position is the same as the fifth. The octave is easily achieved by increasing the blowing pressure in this position. This table results from the frequency analyses in Figure 4. The tonal structure might be perceived as the following steps: bass note, minor second, major second, perfect fourth, perfect fifth, minor seventh, octave.

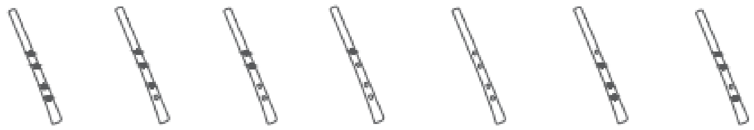
3 Further arguments for Ringot's Hohle-Fels Aerophone (HF1) blowing technique

To show the intentionality behind the measuring of the fingerholes for the replicated aerophones HF1 (Hohle-Fels Cave, southwestern Germany) and the mostly complete Isturitz aerophone (Ist1:



frequency (Hz)	785.49	889.08	966.76	1182.56	1467.41	1536.46
pitch	G_5	A_5	B_5	D_6	$F\sharp_6$	G_6
Deviation (cent)	3.30	17.77	-37.21	11.60	-14.76	-35.15
semitone steps	-	1	1	3/2	2	1/2
minimum pressure	763.88	885.61	970.30	1203.20	1451.97	1526.07
maximum pressure	785.05	917.37	1012.65	1229.66	1483.72	1541.95
f1 : f2	1.03	1.04	1.04	1.02	1.02	1.01

Table 2: Pitches of Ist1 played as a rim-blown flute held vertically. The fifth position is overblown with the uppermost finger hole opened, and all others closed. The tonal structure might be perceived as the following steps: bass note, major second, major third, perfect fifth, major seventh, octave.



frequency (Hz)	708.35	829.36	901.97	1071.39	1240.82	1458.65	1724.88
pitch	F_5–$F\sharp_5$	$G\sharp_5$	A_5	C_6–$C\sharp_6$	$D\sharp_6$	F_6–$F\sharp_6$	A_6
Deviation (cent)	24.35	-2.60	42.69	40.69	-5.13	-25.12	-34.89
semitone steps	-	1	1/2	3/2	1	1/2	3/2
minimum pressure	651.36	760.89	837.56	1018.29	1166.15	1363.31	1648.09
maximum pressure	766.36	875.90	947.09	1111.39	1308.55	1434.51	1774.06
f1 : f2	1.18	1.15	1.13	1.09	1.12	1.05	1.08

Table 3: Pitches played on Ist1 as a rim-blown flute in oblique orientation. The second position from the right side is overblown with uppermost hole opened, and the other fingerholes closed. The last position on the right is overblown with the third finger hole – counted from the upper side – opened, and the other fingerholes closed. The tonal structure might be perceived as the following steps: bass note, major second, minor third, perfect fifth, major sixth, octave and tenth.

southwestern France, 83888(a)/75252-A3 [DB 2][41]), I undertook frequency analyses from short recordings. I played two lines for each blowing technique – one while opening finger holes one after the other and at the same time blowing a continuous breath with a relative stable air pressure; – in the second recording I blew with minimal and maximal pressure in each finger hole position and measured the maximal and minimal frequencies (to have the approximate full range at one position). I have not yet managed to produce sounds from all fingerholes on HF1 reconstructed as a flute (Figure 5). I present the frequency analyses for HF1 as a clarinet (Figure 3 and Figure 4) in Table 1.

41 D’Errico et al. 2003: 39–42.

Figure 5: Hohle-Fels vulture radius Aerophone HF1 reconstruction in bamboo: Notched Flute (or signal whistle?), attachable ideoglot reed mouthpiece (like Sardinian *Launeddas*). This reconstruction of Hohle Fels only works at the first two to three fingerholes when I try to play it like a flute.

With the Isturitz replica from a real vulture ulna-bone (Figure 6), which Jean-Loup Ringot gave to me as a favour, I am able to play in two different ways, vertically as well as obliquely. The sound and intervals between the pitches vary depending on whether the flute is played vertically straight down or softly sidewise over the rim, with the tube turned to an angle of about 22.5° (Table 2; Table 3).

When I put an attachable single-reed mouthpiece into the opening of the same bone aerophone corpus, the instrument becomes a loud clarinet instrument. I find the Ist1 aerophone instrument convincing in all three possible blowing techniques, while HF1 – a very tiny instrument from a radius wing-bone of a vulture – plays convincingly like a clarinet. I was able to procure the radius of a swan, which was used for a replica of the Geißenklösterle swan radius aerophone. The diameters of such radii are so small that the air column activated by flute rim-blowing techniques appears too weak to me to reach the end. When I saw the original find of HF1 in an exhibition in the Blaubeuren Museum during an excursion with a group of musicology students from Innsbruck, I was surprised by how tiny this instrument was. A swan radius in my collection (Figure 11) has a straight cut end, which shows a minimum internal diameter of 0.4 cm. To me, Ringot's proposition absolutely makes sense for that diameter. Flute-like blowing technique might be possible as well. While I do not want to negate all the flute experiments that have been successful in former studies, I am unable to ignore the impression that the flute replicas of aerophones from the Swabian Jura played by F. Potengowski (Geißenklösterle, Vogelherd, Hohle Fels) have bigger diameters than the original finds. This makes it easier to play them like flutes. The reconstructions of the southwest German finds shown by F. Seeberger,[42] consisting of radius bird wing bones, are shorter than the circa 20 to 30 cm that would be the length of a radius aerophone from a complete bird wing bone.

The differential in air pressure between vertical and oblique flutes results in the different sounds they produce. Using the oblique technique, the pitches can easily be bent using the mouth cavity. The vertical technique has a very narrow bandwidth in comparison. The most important differences are that the Ist1 flute plays a minor versus a major third and a major sixth versus a

[42] Seeberger 2002.

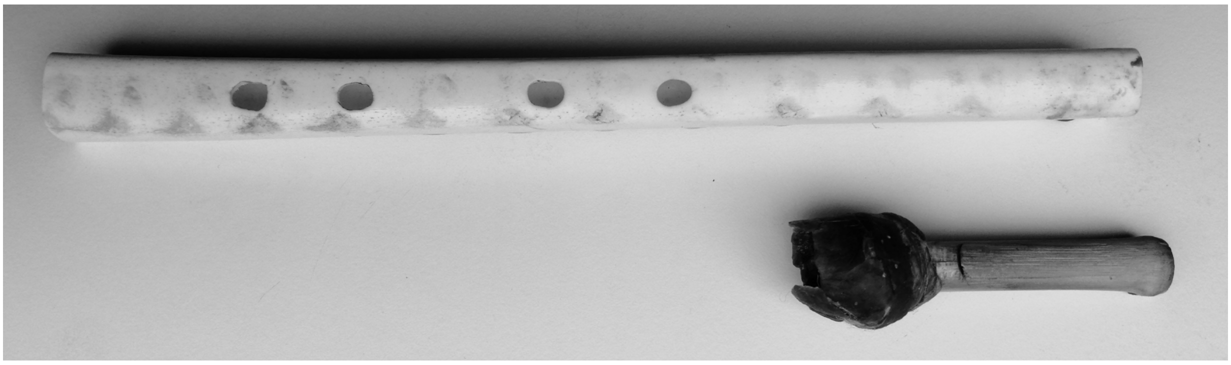


Figure 6: Vulture ulna replica of Ist1: Rim-blown flute and attachable single-reed.

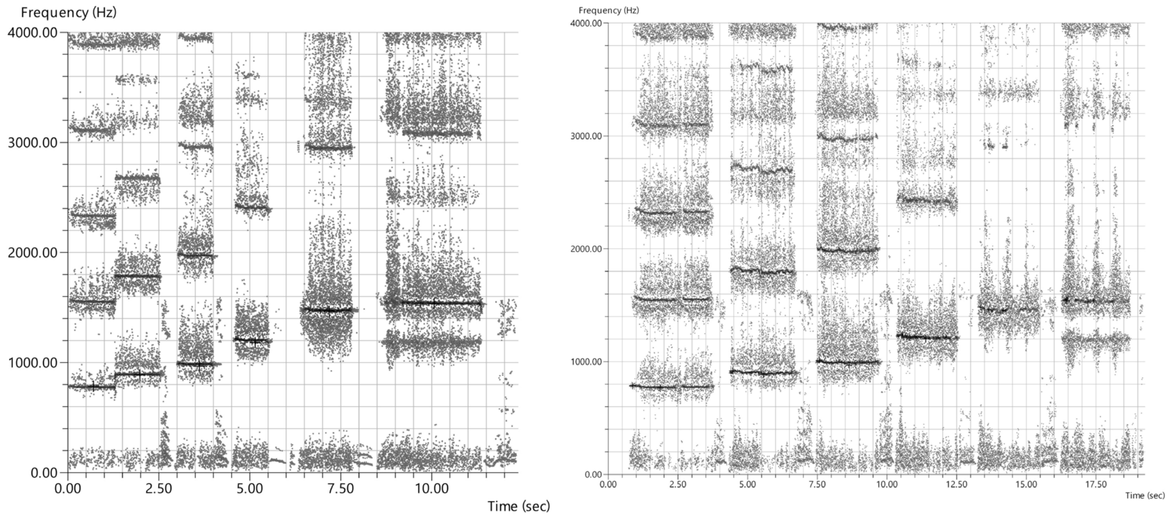


Figure 7: Frequencies played on Ist1 as a rim-blown flute held vertically: with relative stable air pressure in the left diagram; with lower and higher pressure in the right diagram. The vertically oriented version allows very limited variation of the frequencies through air pressure. For this reason, these two diagrams differ only very slightly. The highest frequencies result from overblowing with one finger hole opened (see Table 1).

major seventh, when played in oblique or vertical position, respectively. In summary, the Isturitz vertical flute produces a scale that we might perceive as bass note, major second, major third, perfect fifth, major seventh and octave (Figure 6 and Figure 7; Table 2). When I play the same flute in oblique orientation – with less blowing pressure and a softer timbre – the scale is surprisingly different: bass note, major second, minor third, perfect fifth, major sixth, octave and tenth, including two overblown pitches (Figure 6; Figure 8; Table 3).

If I attach a single-reed (7 mm internal diameter, 6 cm total length inserted by 6 mm) with a cut-out tongue into this flute reconstruction, the sound is rich in overtones and starts an octave lower than when blown as a flute. The sound and melodic character change completely. The scale would fall within the range of bass note minor second, major second, major third, perfect fifth (Figure 6; Figure 9; Table 4).

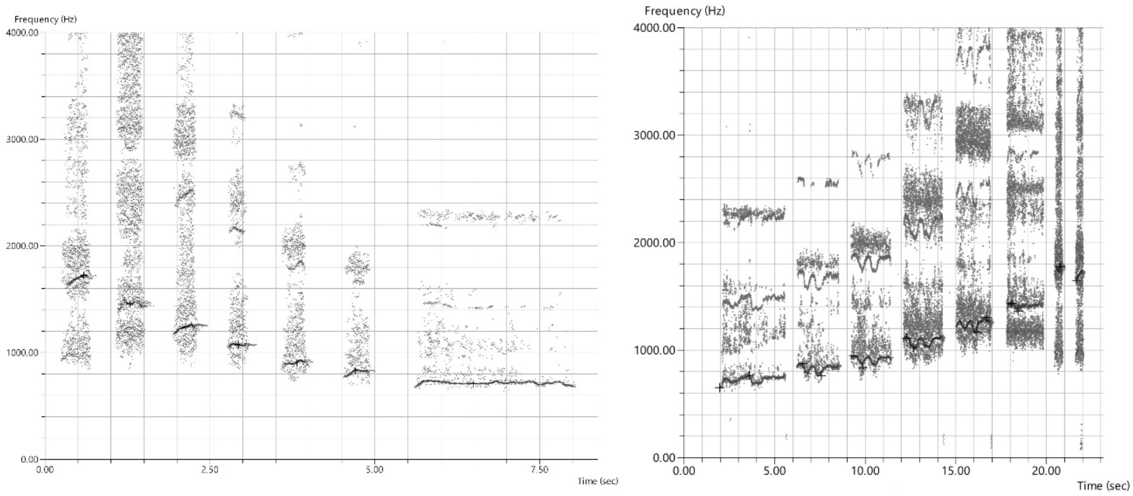


Figure 8: Frequencies of Ist1 played as a rim-blown flute in oblique orientation. Left: relative stable air pressure; right: with lower and higher pressures. The highest frequencies result from overblowing with one finger hole opened (see Table 2).

The HF1 clarinet reconstruction (Figure 3; Figure 4; Table 1) opens up sophisticated possibilities that might be described as bass note, minor second, major second, perfect fourth, perfect fifth, minor seventh, octave. When I play this reconstruction, the sound and melodic properties lead me to play an interpretation of the Pink Panther melody. This might relate to my personal expectations and the sound of the single reed and the number of fingerholes. However, it is a sophisticated instrument, and I find it much more convincing than the flute reconstructions that I have tried. Most importantly, the clarinet achieves exactly an octave range from the lowest to the uppermost finger hole (Figure 3; Figure 4; Table 1). Presumably, the generally wider finger hole distances of HF1 and other radius aerophones make more sense when equipped with a reed, while the fingerholes of the ulna flutes from Isturitz exhibit completely different systems of finger hole positioning. A worldwide comparison between the distances of the first fingerholes to the proximal end should be the subject of future research. The current state of research will be summarised in chapter 3. Finally, Ringot's experimental approach to reconstruct the bevelled (ca. 30°) end with an attached reed – like a clarinet – becomes more plausible with the results of my own experiments. Instead, the remarkably wider ulna bones, which provided the raw material for most of the Isturitz aerophone finds, absolutely make sense as flutes. My experiments therefore show that ulnae might be more suitable for flutes than radii – because of the diameters (Figure 10). Figure 11 shows a swan radius replica in my collection with a maximum external diameter of about 8 mm. The minimum internal diameter at the narrow end reaches about 4 mm (Figure 11.2).

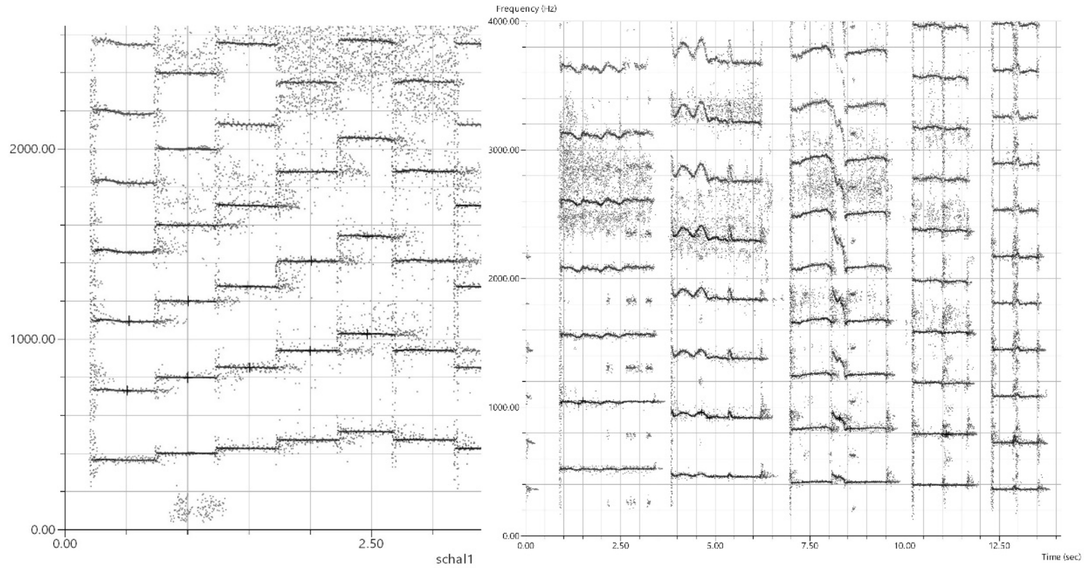
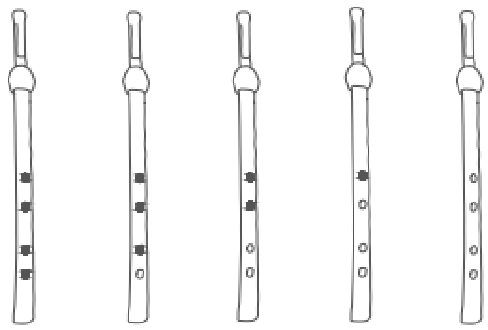


Figure 9: Frequencies of Ist1 played as a shawm. Left: relatively stable air pressure; right: lower and higher pressure.



frequency (Hz)	730.64	797.30	850.63	938.95	1025.61
pitch	F♯$_5$	G$_5$	G♯$_5$	A♯$_5$	C$_6$–C♯$_6$
Deviation (cent)	-22	29.14	41.23	12.25	-34.90
semitone steps	–	1/2	1/2	1	3/2
minimum pressure	724.16	785.61	832.87	915.59	1021.95
maximum pressure	743.07	795.06	915.59	958.13	1052.67
f1 : f2	1.03	1.01	1.10	1.05	1.03

Table 4: Pitches of Ist1 played as a shawm. With a little more air pressure, position 4 yields pitches up to a fifth above the bass note. This table results from the frequency analyses in Figure 9. The tonal structure might be perceived as: bass note, minor second, major second, major third, perfect fifth.

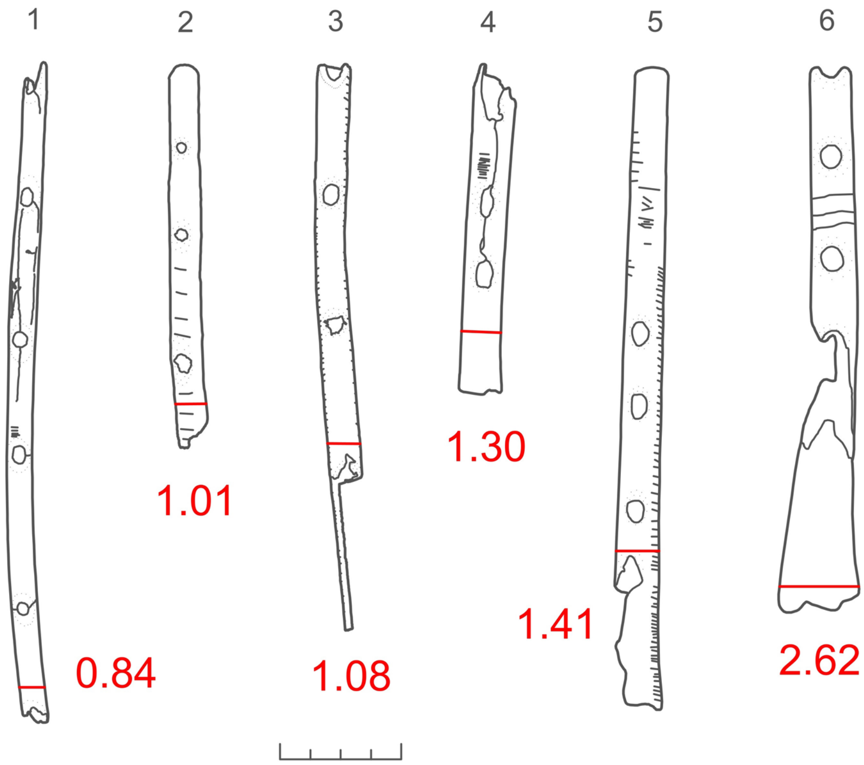


Figure 10: Diameters in cm of the radius (1–2) and ivory (3) aerophones from Germany, and the ulna aerophones from Isturitz (4–6).

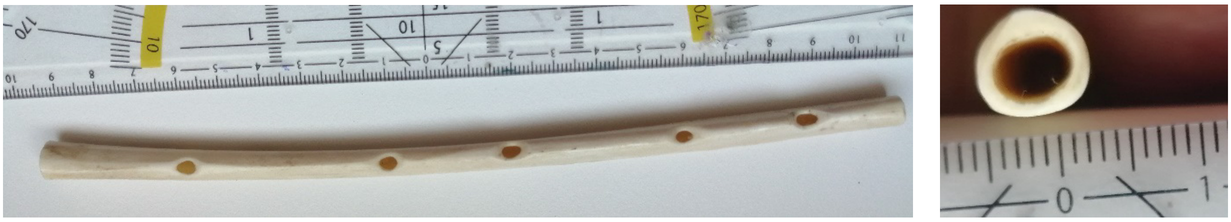


Figure 11: Swan-radius aerophone corpus based on the swan radius find from Geißenklösterle (left). The minimum internal diameter measures about 4 mm (right).

4 The ethnographic record

A look at ethnographic material, even though not fully comprehensive, might contribute to the question whether different aerophone diameters facilitate specific blowing techniques. An argument in favour of a clear mutual influence might be the very restricted distribution of duct flutes and aerophones with fingerholes in the indigenous cultures from Australia and Africa.[43] In contrast, indigenous Americans and Northern Eurasian modern-day hunter-gatherer ethnic groups do make use of duct-flutes[44] and single-reed aerophones[45] with fingerholes. The diameter of the

[43] Blench 2007.
[44] Blench 2007; Omerzel-Terlep 1997: 205.
[45] Emsheimer 1964.

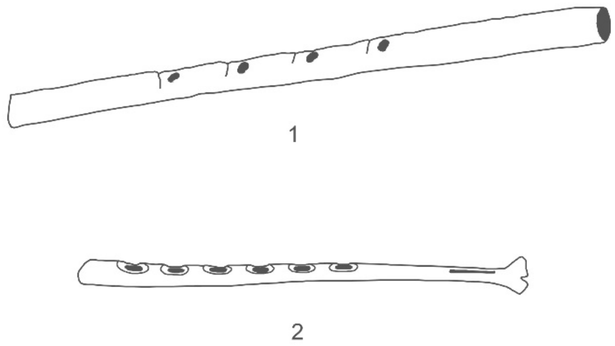


Figure 12: 1: Elder wood flute, Blackfoot Native Americans of the Plains (according to Morley, 2013, Figure 2.1); 2: *Fadno*, Saami, indigenous people from Northern Eurasia (according to Emsheimer, 1964a, Figure 2).

elder-wood rim-blown flute presented by Morley[46] among the musical instruments of the Blackfoot indigenous Americans is comparable to the Isturitz diameters, while the *Fadno*[47] – a Saami (northern Scandinavia) single-reed aerophone – has a remarkably small diameter (4–7 mm), comparable to radius wing bones (Figure 12).

Are the octave ranges measured in the frequency analyses (HF1 clarinet, both Isturitz flute techniques) incidental or intentionally created intervals? Do they depend solely on the individual peculiarities of the reed I made and on my own personal playing methods of these aerophones? Whenever a prehistoric aerophone carver places a fingerhole halfway along an aerophone's effective length, the resulting frequencies will come close to an octave. The 2:1 relation of the frequencies can be clearly seen in Table 1–Table 3. As the pitch relations of flutes and reeds differ, the fingerholes have to be positioned differently. A flute physically represents a tube with two open ends, with wavelengths of $\lambda_n = 2s/n$ (s: length of the tube, n: number of natural oscillation) and therefore natural oscillations following integer relations (1, 2, 3, ...). A cylindrical tube with one closed end, such as a clarinet, in turn produces wavelengths of the form $\lambda_n = 4s/(2n-1)$ so that the natural oscillations follow odd relations (1, 3, 5, ...).[48] I propose that the octave intervals received with the HF1 clarinet replica (with my reed design) and the Ist1 flute versions have been purposely constructed with the intention of locating the uppermost fingerhole at the octave.

In my opinion, the melodic sophistication of these early aerophones seems to surpass many aerophones from ethnographic or archaeological contexts of modern and prehistoric hunter-gatherer societies. Iain Morley and Ian Cross stated that "the sophistication of these instruments exceeds that of many medieval and contemporary examples of such pipes".[49]

The Upper Palaeolithic melodic instruments constitute a key element in the period of deliberate and elaborate artwork that is preserved in the European caves. We might extend Morley's argument for the sophistication of these instruments to the visual arts. The ice age depictions in

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[46] Morley 2013: Figure 2.1:f.
[47] Emsheimer 1964: Figure 2.
[48] Hall 1997: 238–43.
[49] Morley and Cross 2009: 74.

rock arts and mobile arts between 40 000 and 10 000 ya seem to surpass many prehistoric and modern-day hunter-gatherer visual arts in their naturalistic expression and narrative composition. The most convincing interpretations of Upper Palaeolithic cave arts decode the activities as initiation rites.[50] I assume such rituals to have been related to educational matters and the early aerophones to reflect early mathematical and physical concepts. This can be explained by the multicultural environment of these communities, which catalysed the creative behaviours in Upper Palaeolithic Europe.[51]

5 Conclusion

Simple forms of mirlitons, flutes, and reed pipes might have constituted part of the hunting equipment of early humans (perhaps also in Middle Stone Age Africa and in Middle Palaeolithic Europe). The Divje Babe Neanderthal find and the bones perforated by carnivore gnawing do not attest that Neanderthals used melodic musical instruments. All the other perforated bones in the archaeological record of the Palaeolithic are from Aurignacian layers. The non-human origin is in my opinion the most plausible explanation. The aerophones of Upper Palaeolithic Europe (including HF1 and Ist1) stand out for their melodic sophistication when compared to modern-day hunter-gatherer or medieval aerophones.

The reconstructions of Divje Babe (DB1), Isturitz (Ist1), and Hohle Fels (HF1) demonstrate how different approaches to aerophones or wind instruments can lead to different results. When we look closer at the flute reconstructions of the southwestern German aerophone finds, we find that the diameter of HF1 is exceptionally small, with a maximum external measure of 0.84 cm, and a minimum internal diameter of about 0.4 cm. The two other best preserved aerophones from the context of southwestern German cultures have somewhat wider maximum external diameters – a swan radius from Vogelherd with 1.01 cm, and the famous mammoth ivory aerophone from Geißenklösterle with 1.08 cm. The inner diameters could not be assessed with precision. The French aerophones from Isturitz have still wider maximum diameters ranging from 1.30 cm to 2.62 cm (Figure 10).

The smaller diameter of the instrument body and the possible achievement of a scale of six pitches in an overall spectrum of an octave may support the hypothesis that HF1 represents a stone age clarinet. Furthermore, we have to reckon with the possibility that reed whistles might have been part of the human hunting toolkit. Perhaps humans used duck calls or deer calls with reed technology before the concept of melodic aerophones left traces in the archaeological record of Upper Palaeolithic Europe. A survey on the beginnings of music and the musical instruments from Palaeolithic, Mesolithic, and Neolithic periods is forthcoming in cooperation with Adje Both.[52]

50 Lewis-Williams and Clottes 1997; Till 2018; Till 2014.
51 Praxmarer 2023.
52 Both and Praxmarer forthcoming.

Bibliography

Albrecht, G., Holdermann, C.S., Kerig, T., and Serangeli, J. (1998). “Flöten” aus Bärenknochen – Die Frühesten Musikinstrumente? *Archäologisches Korrespondenzblatt* 28, 1–19.

Bedarnik, R. (2015). Hominin Mind and Creativity. In: B. Půta and V. Soukup (eds), *The Genesis of Creativity and the Origin of the Human Mind*, Prague: Karolinum Press, 35–44.

Benito-García, C., Mazo Pérez, C., and Alcolea Gracia, M. (2018). Calling for the Deer. An Eunuch Flute at Le Placard. In: Ch. Delage (ed.), *The Grotte du Placard at 150. New Considerations on an Exceptional Prehistoric Site*, Oxford: Archaeopress, 124–145.

Blackwood, B.M. and Balfour, H. (1938). Ritual and Secular Uses of Vibrating Membranes as Voice-Disguisers. *The Journal of the Royal Anthropological Institute of Great Britain and Ireland* 78.1/2, 45–69.

Blench, R. (2007). *Using ethnography to reconstruct the culture of early modern humans*, unpublished chapter, available at: www.rogerblench.info.

Both, A. and Praxmarer M. (forthcoming). Musik in der Steinzeit – Zu den möglichen Ursprüngen der Musik und ihrer Bedeutung in der menschlichen Entwicklungsgeschichte. In: S. Fontaine et al. (eds), *Interdisziplinarität in der Disziplin. Musikwissenschaft als akademisches Fach*. Berlin.

Caldwell, D. (2009). Palaeolithic Whistles or Figurines? A Preliminary Survey of Pre-historic Phalangeal Figurines. *Rock Art Research: The Journal of the Australian Rock Art Research Association (AURA)* 26.1, 65–82.

Conard, N.J., Malina, M., and Münzel S.C. (2009). New flutes document the earliest musical tradition in southwestern Germany, *Nature* 460.7256, 737–40.

Conard, N.J., Malina, M., Münzel, S.C., and Seeberger, F. (2004). Eine Mammutelfenbeinflöte aus dem Aurignacien des Geißenklösterle: Neue Belege für eine musikalische Tradition im frühen Jungpaläolithikum auf der Schwäbischen Alb. *Archäologisches Korrespondenzblatt* 34.4, 447–62.

Conard, N.J., Münzel, S.C., Hein, W., and Potengovski, A.F. (2015). Flötenklang aus fernen Zeiten. *Archäologie in Deutschland*, Sonderheft 7, 30–37.

Cross, I. and Morley, I. (2009). The evolution of music: Theories, definitions and the nature of the evidence, In: Steven Malloch and Colwyn Trevarthen (eds), *Communicative Musicality: Exploring the Basis of Human Companionship*. Oxford: Oxford University Press, 61–82.

Dauvois, M. (2005). Homo musicus palaeolithicus et Palaeoacustica. *Munibe (Antropologia-Arkeologia)* 57, 225–41.

D’Errico, F. et al. (2017b). From Number Sense to Number Symbols. An Archaeological Perspective. *Philosophical Transactions of the Royal Society B* 373: 20160518, 1–37. https://doi.org/10.1098/rstb.2016.0518.

D’Errico, F. and Henshilwood, Ch. (eds) (2011). *Homo Symbolicus. The Dawn of Language, Imagination and Spirituality*. Amsterdam and Philadelphia: John Benjamins Publishing Company.

D’Errico, F., Henshilwood, Ch. et al. (2003). Archaeological Evidence for the Emergence of Language, Symbolism and Music – an Alternative Multidisciplinary Perspective. *Journal of World Prehistory* 17.1, 1–70.

D’Errico, F. and Lawson, G. (2002). Microscopic, Experimental and Theoretical Re-Assessment of Upper Palaeolithic Bird-Bone Pipes from Isturitz, France: Ergonomics of Design, Systems of Notation and the Origins of Musical Traditions. In: E. Hickmann, A.D. Kilmer, R. Eichmann (eds), *Studien zur Musikarchäologie* 3, 119–42.

D’Errico, F., Majkić, A., Evans, S., Vadim, S., and Tsvelykh, A. (2017a). A decorated raven bone from the Zaskalnaya VI (Kolosovskaya) Neanderthal site, Crimea. *PLoS ONE* 12.3: e0173435, 1–33. https://doi.org/10.1371/journal.pone.0173435.

D’Errico, F. and Villa, P. (1997). Holes and Grooves: The contribution of microscopy and taphonomy to the problem of art origins. *Journal of Human Evolution* 33, 1–31.

Emsheimer, E. (1964). A Lapp Musical Instrument. *Ethnos* 12.1–2, 86–92. https://doi.org/10.1080/00141844.1947.9980661.

Fink, B. (2002). The Neanderthal flute and origin of the scale: fang or flint? A response. In: E. Hickmann, A.D. Kilmer, R. Eichmann (eds), *Studien zur Musikarchäologie* 3, 83–87.

Floss, H. (2006). Als der Mensch schuf, schuf er richtig: Europas kreativer Urknall vor 35 000 Jahren. In: G. Uelsberg (ed.), *Roots: Wurzeln der Menschheit*. Mainz: Philipp Von Zabern Verlag Gmbh, 209–26.

García-Benito, C. (2018). Wind from the Sky, Wind from the Earth. The Earliest Bone Pipes and Whistles. In: S. De Angeli et al. (eds), *Music and sounds in ancient Europe: contributions from the European Music Archaeology Project*, Rome: European Music Archaeology Project, 26–29.

Holdermann, C.S. (2001). Musik und Tanz. In: H. Müller Beck, N. Conard and W. Schürle (eds), *Eiszeitkunst im Süddeutsch-Schweizerischen Jura. Anfänge der Kunst*, Stuttgart: Theiss, 88–94.

Holdermann, C.S. and Serangeli J. (1998). Einige Bemerkungen zur Flöte von Divje babe I (Slowenien) und deren Vergleichsfunde aus dem österreichischen Raum und angrenzenden Gebieten. *Archäologie Österreichs* 9.2, 31–38.

Hall, D.E. (1997). *Musikalische Akustik: Ein Handbuch*. Mainz: Schott Music GmbH & Co. KG.

Lund, C.S. (1988). On animal calls in ancient Scandinavia: theory and data. In: E. Hickmann and D.W. Hughes (eds), *The Archaeology of Early Music Cultures*, Third International Meeting of the ICTM Study Group on Music Archaeology, Bonn: Verlag für systematische Musikwissenschaft, 289–303.

Lewis-Williams, D.J. (1992). *Vision, Power and Dance: The Genesis of a Southern African Rock Art Panel.* Amsterdam: Nederlands Museum.

Lewis-Williams, D.J. and Clottes, J. (1997). *Schamanen. Trance und Magie in der Höhlenkunst der Steinzeit* (Thorbecke-Speläothek, Band 2). Stuttgart: Jan Thorbecke Verlag.

Morley, I. (2013). *The Prehistory of Music: Human Evolution: Archaeology and the Origins of Musicality*. Oxford: Oxford University Press.

Münzel, S.C., Conard, N.J., Hein, W., Gill, F., and Potengovski, A.F. (2016). Interpreting three Upper Palaeolithic Wind Instruments from Germany and One from France as flutes. In: R. Eichmann, L.-C. Koch, J. Fang (eds), *Studien zur Musikarchäologie* 10, 225–43.

Münzel, S.C., Seeberger F., and Hein, W. (2002). The Geißenklösterle Flute: Discovery, Experiments, Reconstruction. In: E. Hickmann, A.D. Kilmer, R. Eichmann (eds), *Studien zur Musikarchäologie* 3, 107–18.

Neal, L.C. (2013). *The Earliest Instrument: Ritual Power and Fertility Magic of the Flute in Upper Paleolithic Culture*. New York: Pendragon Press..

Omerzel-Terlep, M. (1997). A typology of bone whistles, pipes and flutes and presumed palaeolithic wind instruments in Slovenia. In: I. Turk (ed.), *A Mousterian Bone Flute and Other Finds from Divje Babe I Cave Site, Slovenia*, Ljubljana: Znanstveno Raziskovalni Sazu, 199–218.

Praxmarer, M. (2019). Blasinstrumente aus dem europäischen Jungpaläolithikum. Fundmaterial, Interpretation und musikwissenschaftliche Aspekte. *Archaeologia Austriaca* 103, 75–97.

Praxmarer, M. (2023). *Music(s) in the European Upper Palaeolithic. The Melting Pot Theory*, PhD Thesis, Leopold Franzens University Innsbruck; forthcoming Berlin: ēkhō.

Půta, B. and Soukup, V. (eds) (2015). *The Genesis of Creativity and the Origin of the Human Mind*. Prague: Karolinum Press.

Ringot, J.-L. (2012). Upper Paleolithic aerophones – flute or pipe? An experimental approach: summary report. In: R. Eichmann, J. Fang, L.-C. Koch (eds), *Studien zur Musikarchäologie* 8, 389–91.

Sachs, C. (1934). *The History of Musical Instruments.* New York: W. W. Norton.

Seeberger, F. (1998). Zur Spielweise paläolithischer Knochenflöten. *Archäologisches Korrespondenzblatt* 28, 31–33.

Seeberger, F. (2002). *Steinzeit selbst erleben! Waffen, Schmuck und Instrumente – nachgebaut und ausprobiert.* Stuttgart: Verlagsbüro Wais & Partner.

Till, R. (2014). Sound Archaeology: Terminology, Palaeolithic Cave Art and the Soundscape. *World Archaeology* 46.3, 292–304.

Till, R. (2018). Sounds and Caves. In: S. De Angeli et al. (eds), *Music and sounds in ancient Europe: contributions from the European Music Archaeology Project*, Rome: European Music Archaeology Project, 22–25.

Turk, I. (ed.) (1997). *A Mousterian Bone Flute and Other Finds from Divje Babe I Cave Site, Slovenia* (Opera Instituti Archaeologici Sloveniae 2). Ljubljana: Znanstvenoraziskovalni center SAZU.

Turk, I. and Kunej, D. (2000). New Perspectives on the Beginnings of Music: Archaeological and Musicological Analysis of a Middle Palaeolithic Bone "Flute". In: N.L. Wallin, B. Merker, S. Brown (eds), *The Origins of Music*, Cambridge, MA/London: MIT Press, 235–68.

Turk, I., Pflaum, M., and Pekarovič, D. (2005). Rezultati računalniške tomografije najstarejše domnevne piščali iz Divjih bab I (Slovenija): prispevek k teoriji luknjanja kosti. Results of Computer Tomography of the Oldest Suspected Flute from Divje Babe I (Slovenia): Contribution to the Theory of Making Holes in Bones (English & Slovenian). *Arheološki vestnik: Acta archaeologica* 56, 9–36.

Turk, I., Turk, M., and Otte, M. (2020). The Neanderthal Musical Instrument from Divje Babe I Cave (Slovenia): A Critical Review of the Discussion. *Applied Sciences* 10.4:1226. https://doi.org/10.3390/app10041226.

Turk, M. et al. (2018). The Mousterian Musical Instrument from the Divje babe I cave (Slovenia): Arguments on the Material Evidence for Neanderthal Musical Behaviour. *L'Anthropologie* 122.4, 679–706. https://doi.org/10.1016/j.anthro.2018.10.001.

Turk, M. and Dimkaroski, L. (2011). Neandertalska piščal iz Divjih bab I: stara in nova spoznanja, Neanderthal Flute from Divje babe I: Old and New Findings (English & Slovenian). *Opera Instituti Archaeologici Sloveniae* 21, 251–65.

Wyatt, S. (2012). Sound production in early aerophones: short report on a work in progress. In: R. Eichmann, L.-C. Koch, J. Fang (eds), *Studien zur Musikarchäologie* 8, 393–98.

Wyatt, S. (2016). Whistle up a Storm: A further report on sound production in early Aerophones. In: R. Eichmann, L.-C. Koch, J. Fang (eds), *Studien zur Musikarchäologie* 10, 201–12.

Wynn, T. and Coolidge, F. L. (2016). An Introduction to Cognitive Archaeology. *Current Directions in Psychological Science* 25.6, 386–92.

Wynn, T., Coolidge, F.L., Hicks, J.M., and Overmann, K.A. (2015). Cognitive Archaeology and the Cognitive Sciences. In: E. Bruner (ed.), *Human Paleoneurology* (Springer Series in Bio-/Neuroinformatics) 3, 177–208.

Zagiba, F. (1976). *Musikgeschichte Mitteleuropas 1: Von den Anfängen bis zum Ende des 10. Jahrhunderts* (Forschungen zur älteren Musikgeschichte, Band 1). Wien: Verband der wissenschaftlichen Gesellschaften Österreichs.