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Sounds from a Base Camp. Different Ways of Reconstructing and Playing the 'Grubgraben' Wind Instrument

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Abstract

Since the discovery of a fragmented Ice Age wind instrument was made in 1994 at a base camp of Palaeolithic reindeer hunters in Grubgraben/Kammern in Lower Austria, several attempts to reconstruct the instrument have been made. Due to the fact that both ends of the bone are broken pre-depositionally, varying options for reconstruction have been discussed since 1997. The most prominent research questions remain: How was the instrument likely played, how did it sound, and how can the sonic results of reconstruction experiments be displayed and interpreted? This paper will build a bridge from the first detailed research, carried out in the late nineties, to today's more wide-spread field of scientific research on Palaeolithic aerophones, in order to shift attention to possibilities for reconstructing the Grubgraben artefact beyond those first attempts. It will also contextualize the instrument within recent music archaeological research and data. Throughout this paper, the main focus will be on studies of the instrument as an end-blown flute and the resulting tonal properties and pitch ranges, as they were presented and discussed at the 11th Symposium of the International Study Group on Music Archaeology in Berlin in November 2021 by Maria Hackl and Veronika Kaudela.

Keywords

Palaeolithic wind instrument – Bone flute – Epigravettian – Kammern/Grubgraben – Experimental archaeology

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Figure 1: The perforated bone artefact from Grubgraben, Lower Austria.
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1 Introduction : More than twenty years of research on an Epigravettian artefact

In 1994, excavations at the Upper Palaeolithic site 'Grubgraben' near Kammern in Lower Austria produced a well-preserved fragment of a 165.3 mm long bone with three perforations. The right tibia of, presumably, a reindeer,[1] was punctured with three holes of nearly the same diameter, transforming the bone into a wind instrument. Unfortunately, this unique specimen is broken at both ends. This means that it remains unclear whether there was a specific mouthpiece, and if so, where it was placed.

A few years after the artefact was found, archaeozoological attempts were made to identify to which animal species the bone fragment belonged. Additionally, the stratigraphical context of the object was researched, and microscopic and other analysis on how the perforations were produced were undertaken. In 1997, Bernadette Käfer and Thomas Einwögerer conducted several reconstruction experiments with both reindeer and red deer bones, which resulted in the satisfactory reconstruction of different end-blown flutes, played from the distal end of the bone. The sound of one of those instruments can be heard on two CDs.[2] A master's thesis on Palaeolithic wind instruments in the Eastern Alpine region[3] by Bernadette Käfer, which includes these reconstruction attempts, remains, until now, the most detailed work on the Grubgraben instrument within the context of other wind instrument finds.

[1] In 1998, Florian Fladerer proposed that the bone belonged to a young reindeer; Einwögerer et al. 1998: 21–25; Käfer and Einwögerer 2002: 93.
[2] Käfer 2001; Käfer, Scherner 2004.
[3] Käfer 1998.

In the following years, the Grubgraben artefact was listed in different databases on Palaeolithic wind instruments[4] and a few reconstructions of the Grubgraben instrument as flutes were made.

Since 2015, research on the Grubgraben wind instrument has intensified again, with Maria Hackl not only experimentally reconstructing the object in a series of experiments assuming different methods of play[5], but also researching the morphology of the bone and the site context. For the first time, different plausible types of instrument (other than end-blown flutes) were taken into account, and playing reconstructions from the proximal end of the bone was also explored by experiment. Furthermore, Ljubomir Nikolić, a composer and researcher on the Academy of Arts Novi Sad, used recordings of the newer reconstructions for the music and soundscape of an interactive exhibit installed in four museums along the Danube, and is currently exploring experimental playing techniques and the tonal possibilities of the instruments in his research and compositions.[6] In 2021, Veronika Kaudela, a researcher for the Austrian Archaeological Institute (ÖAI) of the Austrian Academy of Sciences (ÖAW) at the Grubgraben site, where excavations and research are still conducted today, supported the ongoing research on the instrument with new data regarding the artefact and the site.

This paper will cover the tonal output of reconstruction experiments conducted in Austria since the discovery of the find. Finally, it will conclude by summing up questions and widespread future plans for research on this fascinating piece of Ice-age art and craftsmanship.

Since the first reconstruction experiments were conducted more than 20 years ago, the scientific approach to reconstructing archaeological instruments has evolved, and the dating of the Grubgraben site and artefacts have changed. These new insights and the difference between the older and the more recent reconstruction experiments, including additional forms of play, will be highlighted in this paper. Therefore, in the following chapter the find and site history, as well as the new data will be presented. After that, the research approach, assumptions, and reconstructions of the Grubgraben instrument during the nineties will be described by Bernadette Käfer who conducted the first research. In chapter 4, the research which was conducted since 2015 and the reconstructions and tonal results which were produced in this period will be explained. Chapter 5 provides a summary and future research attempts concerning the Grubgraben instrument.

2 The site and the circumstances of the discovery of the Grubgraben wind instrument

(Veronika Kaudela)

The archaeological site Grubgraben, where the object of research was found, is located near the village of Kammern, in the North of Austria. It lies in the Southeast extension of the Moravian-

[4] Morley 2013, Appendix Table 1; Neal 2013: 74–97; Praxmarer 2019, 89–92.

[5] More than 15 bone instruments have so far been constructed by Maria Hackl as possible reconstructions for the Grubgraben wind instrument. Two of the reconstructions were constructed together with Sarah Defant.

[6] Nikolić 2019.

Figure 2: The site during the excavation, 1993. Photo by Gerhard Trnka

Bohemian highland, near the Danube. The site is situated in a trough-shaped valley, opening southwards to the Danube plain, and flanked by two hills which today are called Heiligenstein and Geißberg. In recent centuries this area was formed into a narrow terrace, surrounded by more terraces on the hills, to benefit the cultivation of grapes for wine-making.[7]

The site was first mentioned in 1885, when objects appeared in the profile of a modern ravine-like narrow pass which cuts into a Palaeolithic occupation layer. Different kinds of investigations followed, and the first authorised excavations were conducted by Friedrich Brandtner and Anta Montet-White between 1985[8] and 1990, and F. Brandtner and Bohuslav Klima between 1991 and 1994. Unfortunately, the documentation of the stratigraphy and finds was inconsistent and imprecise, compared to today's standard, and challenges the archaeologists in retracing their work until today.[9]

The artefact of interest was found in 1994 when a reindeer antler shovel[10] was recovered in a block[11] and taken apart by Brandtner himself.[12] The block contained the antler shovel, fragmented bones and a long bone with three perforations.[13] The block was assigned to the "Kulturschicht" or

[7] Händel et al. 2021: 138.
[8] Brandtner 1990.
[9] Einwögerer 2019: 8.
[10] For further remarks on the reindeer shovel see p.18 below.
[11] Einwögerer et al. 1998: 21.
[12] Neugebauer-Maresch et al. 2016: 228.
[13] Einwögerer et al. 1998: 21.

archaeological layer III,[14] which is the main archaeological layer with the highest density of finds. It is called archaeological horizon 2 in the recent framework.[15] A bone of this layer was sampled for radiocarbon dating[16] and produced a result of 18,920 ± 90 uncalBP. In 2016 Paul Haesaerts, who dealt with the stratigraphy of the site, published some old dates newly calibrated with the IntCal13 calibration curve using the OxCal v4.2.3. web tool. Hence, the layer where the artefact was found, and presumably therefore also the artefact itself, is now dated to 22 915 to 22 635 calBP.[17]

A number of radiocarbon dates from bone and teeth samples, place the archaeological layers of the site between 23 000 and 20 000 calBP.[18] This period counts to the Upper Palaeolithic and the at least 4 different phases of occupation[19] took place during the Last Glacial Maximum.[20] Based on the lithic industry and chronology, the site was assigned to the Epigravettian.[21]

Since 2015, the Austrian Archaeological Institute (ÖAI) of the Austrian Acadamy of Sciences (ÖAW) has been surveying and excavating parts of the site. Before that, the find inventory of the past excavations was examined and inventoried.[22] In future, it is expected that annual investigations at the site at Kammern-Grubgraben and ongoing research, including the documentation of Montet-White and Brandtner, will deliver improved insights into, and new conclusions about the site.

3 First reconstructions of the Grubgraben instrument in retrospective

(Bernadette Käfer)

As mentioned above, due to predepositional breaks distally and proximally, there is no clue as to what kind of blowing mechanism the instrument had and thus as to how it was played. Therefore, in 1997, the assumption was made that the perforated Grubgraben artefact was a flute and experiments were conducted to reconstruct the object as a set of end-blown flutes with different blowing mechanisms. The aim of these experiments was to discover which blowing mechanism would be suitable for the original instrument. In the following section, the discussions and conclusions which were made prior to the experiments, as well as the process of the experiment itself, will be described and explained.

14 Einwögerer et al. 1998: 21.
15 Händel et al. 2021: 140.
16 Einwögerer et al. 1998: 21.
17 Haesaerts et al. 2016: 274.
18 Einwögerer 2019: 8.
19 Neugebauer-Maresch et al. 2016: 226.
20 Einwögerer 2019: 8.
21 Montet-White and Williams 1994: 127.
22 Neugebauer-Maresch et al. 2016: 228.

3.1 Observations on the artefact

The bone, which is the right tibia of a ruminant, most probably a reindeer[23], displays three holes arranged in a straight line. The diameters of the three openings vary between 5.1 mm and 5.5 mm and are conical in cross-section. The horizontal grooves on the inner wall[24] indicate that a tool was used in rotating motion.

The similarity of the micromorphology of the edges of all three holes, as well as the only slight variation in the individual diameters, indicate that they were bored using a single tool. The overall picture of this perforated bone fragment conveys the impression that the drill holes were produced in accordance with certain norms, placed deliberately and executed carefully.

3.2 Reflections on how the instrument might have been played as a flute

In 1997, two main possibilities of playing the instrument as a flute were considered. Depending on the angle of blowing, either a side- or an end-blown method of play were possible. However, researchers concluded that if the wind instrument had been originally played as a transverse flute, an additional blowhole, that would have been located at one of the two ends of the bone, must be missing on the artefact. This kind of hole was argued to have been precluded by the natural length of the bone and, therefore, the possibility of the instrument being a transverse flute was excluded.[25] The decision was therefore made to reconstruct the instrument as different types of end-blown flutes, of which the following variants were discussed:

3.2.1 Flute without any special blowing mechanism (oblique)

For this kind of flute, at least one end below the epiphyses would be cut off straight. The most suitable end for this purpose was considered the distal end with its small, rather evenly rounded cross-section. The proximal end, with its pronounced larger triangular cross-section at the end of the bone, was considered less suitable for this purpose.

3.2.2 Flute with a special blowing mechanism (sharpened edge)

For this purpose, the edge of the bone would be cut obliquely on one side, so that a sharp edge is created on which the stream of air, expelled by the player, can break. In principle, it would be possible to make this oblique cut anywhere, but on account of the shape of the bone the distal end seemed preferable for this purpose. Equipped with this kind of blowing mechanism, the flute can be held vertically in front of the body or at an oblique angle directed horizontally to the left or right away from the body, with the oblique edge coming to rest horizontally or vertically, respectively.

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[23] Einwögerer et al. 1998: 21–25; Käfer and Einwögerer 2002: 93.

[24] Einwögerer et al. 1998: 25–26.

[25] The possibility of a fourth hole either as a blowhole or a fingerhole will be discussed in the introduction to chapter 4 as well as in 4.1.1 *The Grubgraben artifact as a transverse flute*.

3.2.3 Flute with a special blowing mechanism (notch)

For this version, a V- or U-shaped cut would be made into one end of the bone, forming a notch. In the case of the Grubgraben instrument, in 1997, the distal end was considered more suitable for this kind of blowing mechanism.

3.2.4 Duct flute

To construct a duct flute, a core of organic material (beeswax, resin, wood) would be inserted into one end of the bone. In addition to that, another opening is needed which acts as aperture and lip/labium. A core of this type could have been placed distally or proximally in case of the Grubgraben instrument.[26]

3.3 Experimental reconstructions of the Grubgraben artefact as an end-blown flute

In 1997, several flutes were constructed as possible reconstructions for the Grubgraben instrument in order to test the blowing mechanisms described above. All of the flutes were constructed to be played from the distal end of the bone. As a result of these experiments, the most successful form proved to be that of a vertical flute with a simple blowing mechanism in the form of an obliquely cut edge at the distal end of the bone combined with a stopped manner of playing.

For this specific flute, the tibia of a juvenile deer was used, the proportions of which largely corresponded to the original. The bone was cleaned and dry-stored for several months and was not soaked before being worked. Custom-made stone implements of Nordic flint were used, corresponding in shape to original objects found at the excavation site. The first step involved separating the distal end from the shaft of the bone by making a circular groove around the bone using two retouched flint blades, which went so deep that the end of the bone could be easily struck off with an antler hammer. The other end of the bone was removed in a similar manner. The bone marrow was extracted and the outer edges carefully smoothed with stone implements. Removing the marrow is a work step which would not be necessary for bird bones due to their naturally hollow cavity but is required for a mammal's long bone to be playable as a wind instrument.[27] The next step was to measure the position of the holes from the original and mark them. In order to create a precise starting point for a silex borer on the surface of the bone, which was extremely convex in this area, crosswise notches had to be incised with a flint flake. The actual boring of the holes proved to be particularly difficult as the individual diameters could not exceed an average of 5 mm and to match the original should only taper towards the inside by 0.2 to 0.8 mm. This meant that the borers had to be very long and delicate, which meant they would snap very easily. After only six minutes the first tool had to be resharpened and after another nine minutes it was

[26] If this is possible has to be implemented experimentally in future studies still and will be further discussed theoretically and referenced to in chapter 4.1.2 *The Grubgraben artifact as a duct flute*.

[27] Nonetheless, bone marrow would have most likely been a precious nutrition component for people living in Ice Age conditions and thus the marrow extraction would have been done in some form anyway, not necessarily exclusively for flute construction.

operation/step	time in minutes	tools
severing of the distal end	30	2 retouched blades
severing of the proximal end	41	5 unretouched flakes
making the holes	3 × 57.5	8 borers per hole
finishing the holes	1	2 borers
making blowing mechanism	3	unretouched flake
working time spent on flute	247.5 (~4h 8min)	
making and sharpening of tools	45	
total time	292.5 (~5h)	

Table 1: Working protocol of an end-blown flute, 1997, illustration by Bernadette Käfer

no longer usable. It took 41.5 minutes and a total of six borers to break through the solid bone for the first hole, and another 16 minutes and two borers to complete the hole as can be observed in Table 1.[28] Holes 2 and 3 were achieved in the same way and timeframe. In a final step all three holes were finished using a single borer in order to ensure uniform diameters and degrees of tapering as in the original instrument. The outer form of the flute was completed by adding an oblique blowing mechanism at the distal end. However, the desired sound could only be achieved after the angle of the obliquely cut edge was refined several times. The whole reconstruction of the flute took around four hours and eight minutes, not counting the time needed to make and resharpen the stone implements.

3.4 Acoustic results

Experiments of bones of different sizes have demonstrated that the playability, the pitch, the sound, and the volume of a bone flute depend on factors such as the blowing mechanism and position of the holes but, above all, on the morphology of the bone, its length, cross section and also on the surface quality of the inner wall.

The individual notes of the flute constructed during the experiments conducted in 1997 resulted from various finger combinations and from overblown notes in a stopped or unstopped manner of playing. In this case, the player can modify the pitch by varying factors such as the pressure and the angle of blowing or lip tension. If the sounds obtained are ordered in a series of upper partials corresponding to the stopping pipe, the first overblown note is F_6, followed by D_7, representing the third and the fifth partial when assuming a fundamental note of $B\flat_4$, which is, however, not playable. This corresponds exactly to the principle of an ideal stopped pipe, which contains only uneven overtones. Figure 3 illustrates the pitch range of the instrument. The experiments from 1997 represent pioneering fundamental work on Palaeolithic aerophones and successfully demonstrated that the perforated tibia from the Grubgraben site could have been used for the purpose of making music.

[28] In comparison, perforating bird bones with stone implements takes much less time due to their thinness.

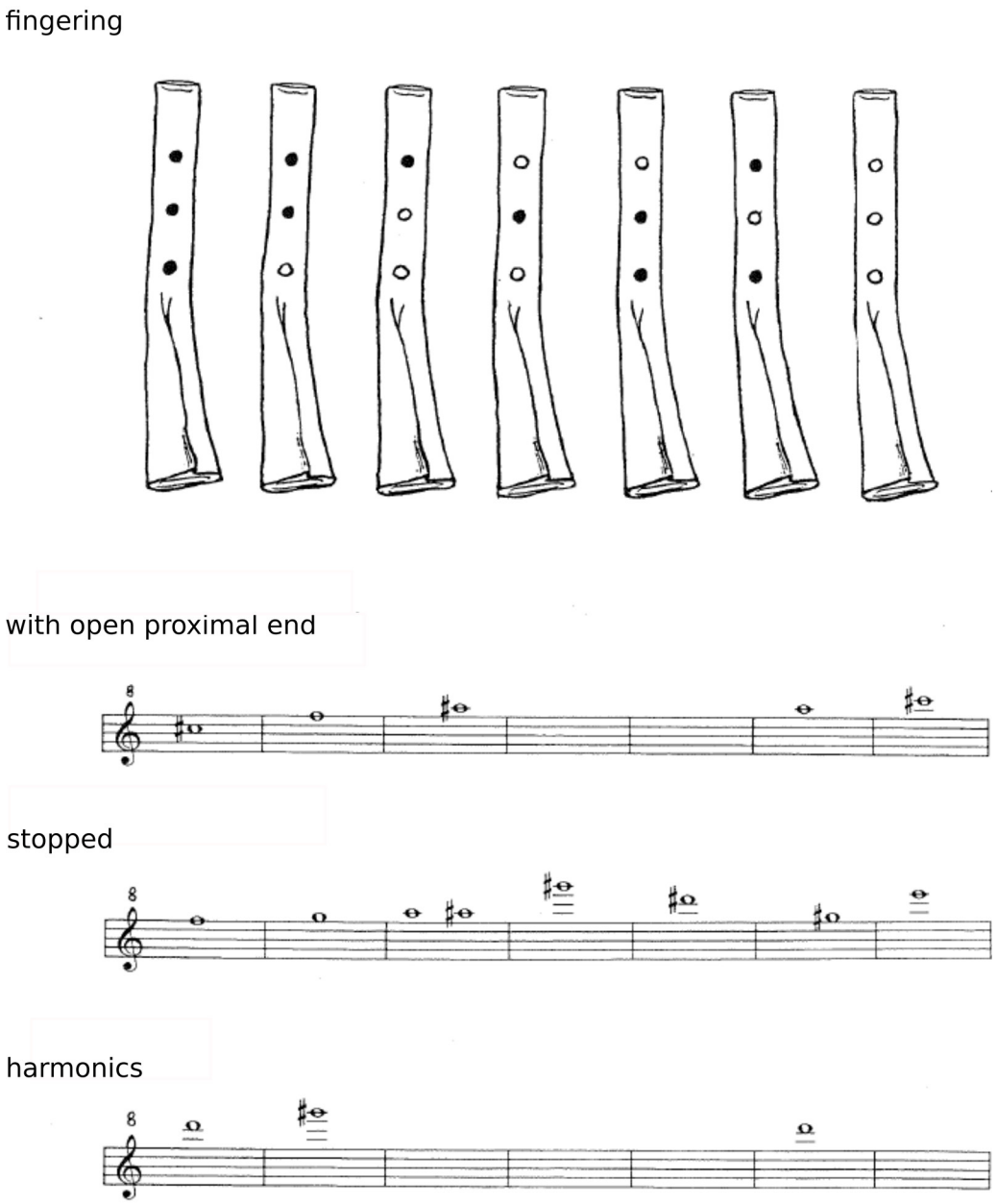

Figure 3: Pitch range of a reconstruction of the Grubgraben instrument as an end-blown flute played from the distal end, 1997. Illustration by Bernadette Käfer

4 The tibia of a ruminant as a wind instrument – new studies on the Grubgraben artefact

(Maria Hackl)

There are different ways to transform a tibia of a medium-sized ruminant, such as a bovid or cervid, into a wind instrument. Constructing a flute from it might be a very (or even the most) plausible method, but it is not the only option. Therefore, for the new experiments since 2015, it was decided to not assume that the Grubgraben artefact was certainly a flute, but to consider a wider range of possible types of instruments.

The Grubgraben object is man-made[29] and most likely represents a musical instrument. However, as it is fragmented, it cannot be reconstructed as a flute with certainty, because the possibility that it is a different type of wind instrument also needs to be considered. Therefore, research on this topic is both difficult and exciting. Another factor, which is hampering research on possible ways the Grubgraben instrument was played in prehistory, is the fact that there are only a few or no other finds of Ice-age mammal long bones with holes, which can be used as comparable and scientifically grounded references.[30]

All the reconstructions, described in the following, were made from fallow deer tibiae, most of them right, some left. (Nonetheless, this does not influence the pitches of the instruments.) All the bones fit well into the range of possible length of the original Grubgraben bone, which is estimated[31] between 165 and 220 mm[32] provided the original bone represents the tibia of an Ice-age reindeer.[33]

All but one of the reconstructions discussed in this paper were made with three finger holes following the measurements and spacing of the original bone artefact. The option of adding a fourth hole on the proximal half of the bone was tried once and proved to expand the pitch range of the instrument upwards. Further research and additional reconstructions are needed in order to prove the presence or absence of a fourth hole. At this point, however, it cannot be definitely excluded for the original.[34] Furthermore, it should be taken into consideration, that – if the original bone is indeed juvenile[35] – it could be possible rather than cutting the bone ends entirely off, to instead drill or cut through them.

4.1 Possible kinds of wind instruments the Grubgraben artefact could represent

Probably the easiest and, at the same time, very effective method to turn a tibia bone into a musical instrument would be to make an end-blown flute out of it. This will be the main topic of this chapter, as discussed in the next section, and was the primary method considered in the experiments conducted during the nineties, too. Before describing the construction and the tonal analysis of different kinds of end-blown flutes, other possible options for wind instruments for the reindeer bone fragment from Grubgraben will be listed and briefly discussed in the following section. By doing so, some variants and options will be added to the ones already described in chapter 3.

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29 Einwögerer et al. 1998: 25–26.
30 Hackl 2020: 9; Praxmarer 2019: 77–84.
31 Käfer 1998: 103.
32 If the original bone tube had been cut obliquely, the length could have been even a little bit less than the remaining 16.5 cm of the artefact.
33 This was proposed in 1998 by Florian Fladerer; Einwögerer et al. 1998: 21–25; Käfer and Einwögerer 2002: 93.
34 It can not be excluded that some other tube had been inserted into the Grubgraben artefact originally to prolong the original length of the Grubgraben bone tube.
35 Einwögerer et al. 1998: 21–25; Käfer and Einwögerer 2002: 93.

4.1.1 The Grubgraben artefact as a transverse flute

A transverse flute should, according to the author of this chapter, also be taken into consideration, and should not be completely ruled out as it was in 1997. Playing a deer tibia as a transverse flute actually does work, regardless of whether one of the three perforations in the Grubgraben instrument is used as a blowhole, or whether another additional hole is added to the bone and used as a blowhole.[36] In both ways the bone can be played when held sideways, either with one end closed or open as depicted in Figure 4 A and B.

When the most proximal of the holes is used as blowhole, four different pitches can be played. These are, for example, for a flute with a tube length of 169 mm, $F\sharp_6$ – $A\sharp_6$ – C_7 – $C\sharp_7$.

An extra blowhole on the proximal end of the bone leads to a bigger range of different playable pitches and much lower ones, too, compared to using one of the three perforations copied from the original bone as blowhole as described above. One flute was constructed in 2021 as a transverse reconstruction of the Grubgraben instrument measuring 190 mm in tube length. The proximal end of the diaphysis was closed and the blowhole was drilled into the section of the bone where the Crista tibiae of the deer bone is not too thick by using a hand-held metal drill.[37] The playable pitches from this instrument are F_5 – $F\sharp_5$ – G_5 – $G\sharp_5$ and, additionally, a deeper pitch can be reached by closing the tube on the distal end with the palm of one hand, which makes $A\sharp_4$ sound.[38]

4.1.2 The Grubgraben artefact as a duct flute

Bernadette Käfer and Michael Praxmarer both theoretically address in their work the possibility of the Grubgraben instrument being a duct flute.[39] Jelle Atema conducted some reconstruction experiments searching for possible ways to replicate a flute from La Roque, Dordogne. According to him, the original artefact is made from mammalian bone[40] and traditionally dated into the Perigordian period, but it could also stem from Middle Ages.[41] He reconstructed it as a duct flute from a deer ulna.[42] It must not be ruled out that the Grubgraben wind instrument works as a duct flute, a possibility which needs to be explored experimentally in the future. In this case, the distal end would likely be the more suitable one. If a core is inserted on the proximal end of the bone tube, the window would have to be placed onto the *Christa tibiae* section of the bone, which is very thick and irregularly shaped. A lot of material would have to be removed in a specific way to achieve a proper window and labium in order to make the bone sound as a duct flute.

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36 A simple thumb-flute is not an option because therefore one single hole in the tube would be enough and the Grubgraben artefact shows three perforations.

37 Constructing a flute this way would, most probably, also work when the proximal end of the bone is not cut off before. Then this end of the bone would stay naturally closed.

38 To this moment, it has not been tried to drill the additional hole into the *Christa tibiae* section of the bone using a flint tool. This will, most likely, be possible and is yet to be scientifically proven by experiment.

39 Käfer 1998: 111; Praxmarer 2019: 86.

40 There seems to be some contradiction within literature concerning the kind of bone which is discussed by Praxmarer (2019: 84).

41 According to Atema (2014: 32), it would be necessary to accurately date the object scientifically.

42 Atema 2004: 19; Atema 2014: 31–32.

4.1.3 *The Grubgraben artefact as an end-blown trumpet*

Playing a deer tibia as an end-blown trumpet works as well. Though, this way of making the bone sound produces more noise than defined pitches, which makes this way of playing the bone rather unlikely, according to the author of this section, assuming that the aim of the finger-holes was to make different pitches sound.

4.1.4 *The Grubgraben artefact as a reed instrument*

Changing the bone into a reed instrument is another possibility, too, as was found out by experiment in 2021.[43] Due to the diameter of the hollow long-bone, a narrower bird-bone with its end cut obliquely was attached into the proximal end of the tibia, which was closed with a chunk of beeswax (Figure 4 C). After that, as a reed, both birch bark and a thin fragment of horn were tried in succession. Both mouthpiece-variants resulted in very loud and rather hard to control pitches.[44]

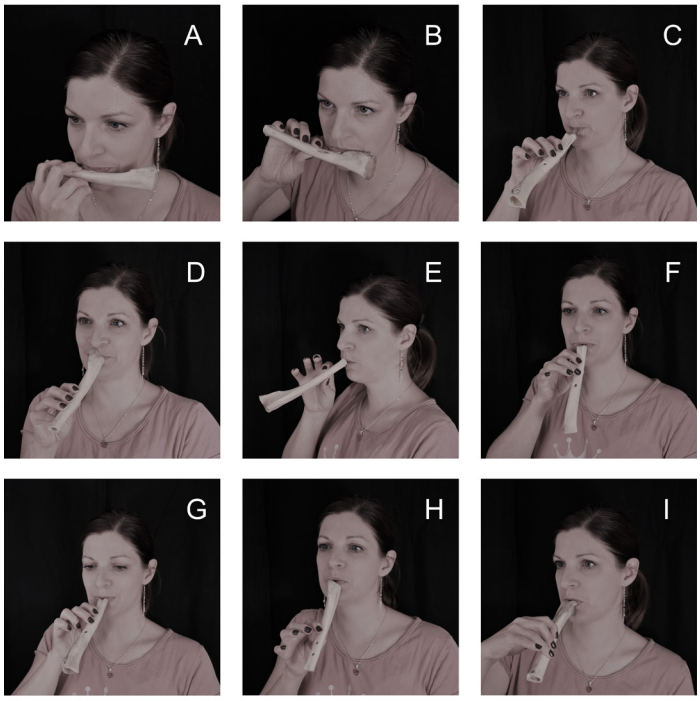

Figure 4: Overview of possible ways to play a ruminant tibia as a wind instrument, 2021. Illustration by Maria Hackl

The most prominent pitches for a deer bone with 196 mm tube length and an inserted piece of swan radius jutting out 23 to 34 mm are around G♯$_5$ and A$_5$. It takes quite some force to play the bone as a clarinet in this way, even when using birch bark, but at the same time, this is the loudest option for making the deer bone sound. Still, the whole construction is rather complicated and not very durable. The Ice-age weather and living conditions seem to make this kind of instrument reconstruction rather unlikely. This aspect was also discussed by Wyatt, who states that the weather during this period would have quickly led to unplayable instruments due to a warped or destroyed reed.[45]

4.1.5 *The Grubgraben artefact as a kazoo/mirlitone*

A tube kazoo or mirlitone would be another option and the idea of using a membrane to distort the sound of the instrument (or the human voice) should not be neglected. It has not been tried

[43] Jean-Loup Ringot and Michael Praxmarer have also demonstrated this playing technique, but for thinner Palaeolithic bird-bone instruments; Ringot 2011: 188–98; Ringot 2012: 389–91; Both 2018: 15; Praxmarer 2019: 86–87.

[44] Thanks to Jean-Loup Ringot for his advice and demonstration how to attach birch bark to a bone mouthpiece.

[45] Wyatt 2012:394.

yet, but has been suggested and explained by Jean-Loup Ringot, as well as by Michael Praxmarer for other Palaeolithic wind instruments.[46] Ringot reconstructed a bird-bone wind instrument from Hohlefels as a clarinet with a membrane over one of the holes. This changed the sound, limiting the pitches but, at the same time, made the instrument easier to play.[47]

4.2 Different options of end-blown Grubgraben flutes

Playing a deer tibia as an end-blown flute is possible from both ends of the diaphysis with or without modification as indicated in Figure 5, which could also be shown during reconstruction experiments carried out between 2015 and 2021. A modification could be a sharpened edge or a notch. Most of the depicted ways of playing the bone can be also played in a stopped manner.

4.2.1 End-blown flutes from the proximal end

In addition to the research conducted in the late nineties, which was based on playing the bone from the distal end only, new experiments have shown, that a deer tibia bone can be played from the proximal end without any modification by blowing straight onto the bone (Figure 4 H). By doing so, it is very easy to play scales and tunes as well as glissandi. However, it is difficult or impossible to play harmonics.

In order to create a more concrete sound with less hissing, a little V-shaped notch can be carved into the bone. Reconstructions have been successfully made with either a notch on the Crista tibiae or a notch which was placed further to the side.[48] In order to simplify the direction of the air-stream onto the notch, beeswax can be applied to partially close the proximal end. This, however, will result in an alteration of the pitch.

[46] Ringot 2011: 192–96; Praxmarer 2019: 88.
[47] Ringot 2011: 195.
[48] Carving the notch laterally offset the axis of the fingerholes offers the possibility to get more length of the bone because for an in-line front notch the bone needs to be cut shorter, to be able to carve the notch beneath the thickest section of the *Crista tibiae*.

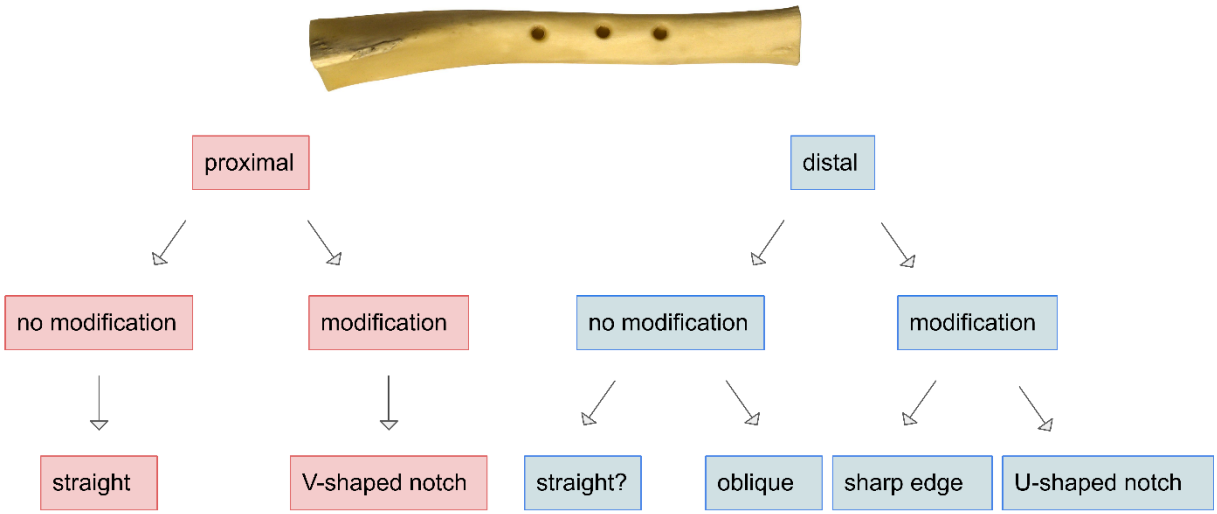

Figure 5: Different ways of constructing an end-blown flute from a ruminant tibia, 2021. Illustration by Maria Hackl

4.2.2 *End-blown flutes from the distal end*

Some bones can be played straight onto the distal end without modification, too. A question mark was added for this option in Figure 5, since this does not work with the majority of flutes constructed by the author.[49]

Playing a deer tibia from the distal end in oblique technique also works well (Figure 4 E), as has been described in the previous section. The sound is slightly weaker, as compared to other playing techniques, and it strongly resembles the sound of the small Palaeolithic bird-bone flutes.

For the author, the most comfortable way of playing a tibia from the distal end is with a U-shaped notch, but a sharpened edge works, too. This is consistent with the description of the research from the nineties. This playing technique produces a high, shrill sound concerning the higher pitches and a rather weak sound when playing lower pitches.[50] When the bone is closed with the palm of one hand on the proximal end, the higher pitches playable like this sound clearer and louder but lower pitches are hard to play.

4.3 *Sonic results from end-blown Grubgraben flutes drawn from new experimental studies*

If the sonic results of deer tibiae played straight distally and proximally are compared, some notable differences appear. These become the most obvious, when the playable pitches obtained from playing each end of the same bone are compared with one another.

This is illustrated in Figure 6 with a flute which is played both proximally, without any mouthpiece, and distally while blown straight onto a small V-shaped notch. As is observable in Figure 6

[49] Most probably this is due to how the bone-ends breaks after cutting a ring notch around the bone when removing it with by snapping it off.

[50] Due to the physics of the bone, when switching between the second and the third playable note, it is necessary to adapt the lip tension and the blowing angle a little bit, to get a smooth change from one pitch to the other.

in the first line, indicated by the different bone profiles, the fundamental pitches from the proximal and distal ends (all finger holes closed) vary slightly ($A\sharp_5$ and B_5). This effect is most probably due to the different angle of the air stream hitting the edge of the bone and the morphology of the medullary cavity. Additionally, the fundamental pitches can be modified in both cases more or less by oral glissando[51].

When played from the distal end in an oblique manner, with the specific bone used for this analysis, the deepest playable note is $G\sharp_6$.

To illustrate the tonal possibilities and limits of the bone flutes, the pitches, when played from the proximal end, are described as approximate notes connected with a glissando line, or simply as tonal ranges, which can be seen in the second line of Figure 6 (as the flute analysed in Figure 6 can be found again in Figure 7 as "flute 12"). When playing the flutes from the proximal end, the pitches can be modified to a large extent. With some practice of the player, a glissando over nearly the whole range from the lowest playable tone to the highest playable tone (without harmonics) can be achieved for most of the flutes. The pitch range can be expanded downwards by partially shutting the tube with a finger and upwards with one or two harmonics; one harmonic in the case of the depicted flute.

[51] Oral glissando is a term introduced and used by Anna Friederike Potengowski when musically researching the bone- and ivory instruments from Schwäbische Alb/Germany. It describes the phenomenon, that the pitch of a certain fingering can be altered by changing both blowing angle and lip tension and it occurs not only with the Aurignacien wind instruments from the Schwäbische Alb region, but also with reconstructions of the Grubgraben bone when played as an end-blown flute as was found by the author of this section; Münzel et al. 2015: 35–37; Münzel et al. 2016: 231–32.

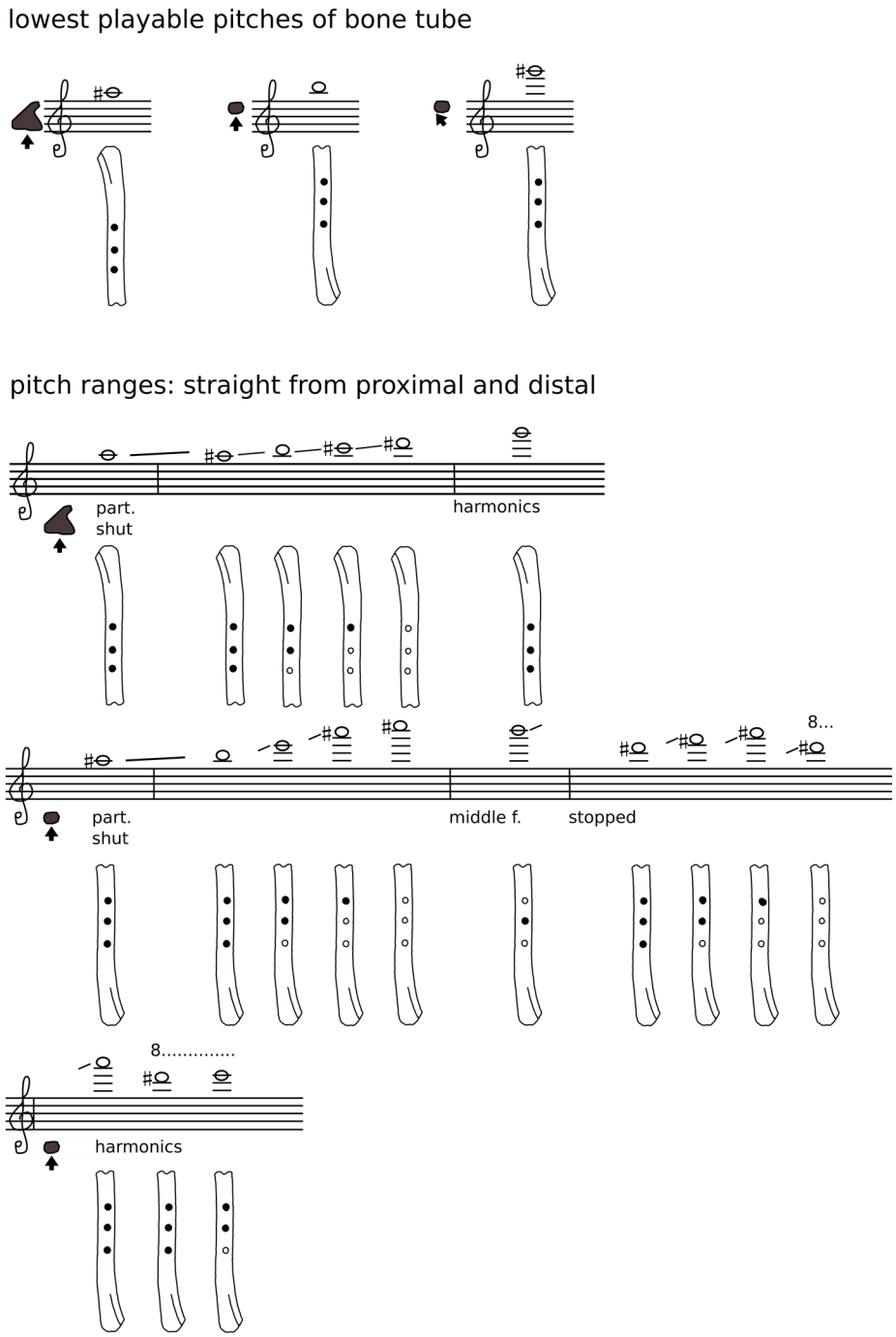

Figure 6: Overview of pitch ranges of a reconstruction of the Grubgraben instrument as an end-blown flute played from both distal and proximal, 2021. Illustration by Maria Hackl

In contrast, as depicted in Figure 6 and Figure 7, the pitches when played from the distal end appear different to those from the proximal one. The pitch range can also be expanded by partially shutting the tube. Lip glissando is also possible, but not to such an extent as when blowing the bone from the proximal end. Lines three and four in Figure 6 show the playable pitches when played from the distal end. When playing glissando, the tone breaks at a certain blowing angle.

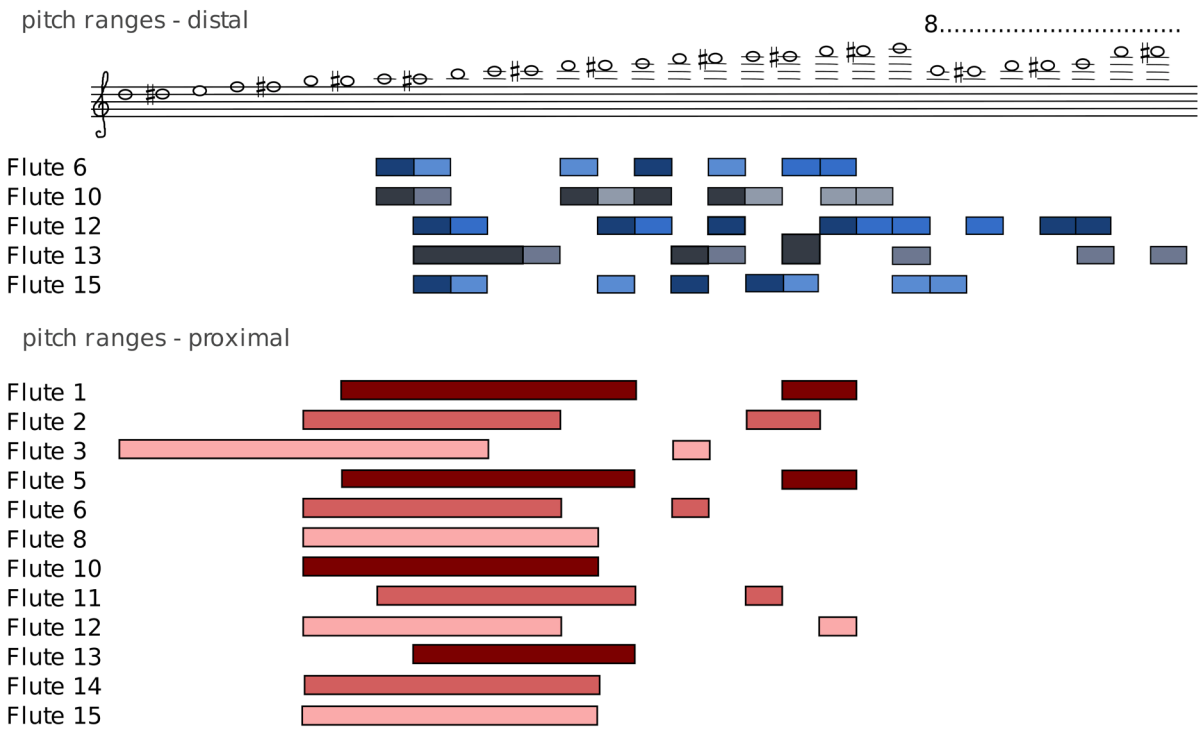

Figure 7: Pitch ranges of different reconstructions of the Grubgraben instrument as end-blown flutes played from the distal end and/or from the proximal end, 2021. Illustration by Maria Hackl)

When this exemplary flute (Figure 6) is put into a wider range of flutes and data, it can be seen that these data patterns occur for the other Grubgraben flutes constructed by the author of this chapter, too. In Figure 7, the pitch ranges of 12 different flutes with different lengths are depicted, both when played straight from the distal end as well as from the proximal one.

Blown from the proximal end, all the instruments' pitch ranges gather around A♯$_5$ and B$_5$. On the basis of this data, it can be stated that the Grubgraben instrument, if it had been played as an end-blown flute from the proximal end of the bone tube, would have also shown a pitch range including these notes. Scales and melodious tunes are easily playable.

The pitches from blowing straight into the distal bone end do not form a continuous line but rather a cluster.[52] In general, it is possible to also play scales, but this action is far more complicated than playing the bones from the proximal end, because the player has to combine different playing techniques when doing so. From looking at Figure 7, it can be observed that the five flutes which can be played from the distal end show some similarities, but there are also some notable differences. These are rooted in factors like the respective bone morphology, technological reasons, and the specific kind of modification or embouchure used for every flute.

To summarize the pitch analyses of both directions of blowing into the bones, it becomes obvious, that from the distal end, higher notes can be reached, whereas from the proximal end, the

[52] What is illustrated in Figure 8 with lighter bluish colours, are the deepest playable pitches produced by simply opening the finger holes and all darker bluish colours symbolize the use of additional playing techniques as explained before.

pitch ranges start with slightly deeper notes and, as discussed before, do not show "gaps" between the playable notes.

5 Conclusion and Outlook

The series of new experiments add to those conducted in the late nineties and show once more that the Grubgraben artefact represents not only a unique archaeological item, but gives a lively statement on the musical possibilities of Epigravettian reindeer hunter communities. Whereas the artefact had been reconstructed in 1997 as a set of end-blown flutes played from the distal end of the bone with different blowing mechanisms, it was demonstrated within the recent experiments that it could be reconstructed as other types of instruments. Sonic results were discussed for a transverse flute, an end-blown trumpet and a reed instrument. Further types of instruments as possible versions of the Grubgraben instrument were theoretically described in this paper, namely a duct flute and a kazoo/mirlitone, which should also be taken into account.

In addition, the reconstructions as end-blown flutes showed first of all that both directions of playing the bone are equally plausible, despite blowing into the proximal end of the bone having been ruled out in former research, as set forth in the previous section. One argument for playing a ruminant's tibia bone from the proximal end is that this can easily be achieved without any modification, as shown in the new experiments. The pitch ranges from the Grubgraben reconstructions – which are all within the possible original length for the artefact which has a considered length of 165 to 220 mm – are around the notes $A\sharp_5$ and B_5. Glissando is very easy when playing this way, whereas playing glissandi from the distal end is only possible with a smaller range, and not with every note.

In the near future Maria Hackl and Veronika Kaudela plan to review the bone fragments from the exact quadrants and layer from which Brandtner took the block in which the object was found. The goal is to find some fragments which fit with the fragmented bone, in order to clarify how the mouthpiece would have looked and how the instrument was played. But there are some aspects which have to be taken into consideration, for example, if the place where the artefact was discovered is the same place where it was fragmented. As already mentioned, we know from ongoing research that Brandtner's excavations were not up to today's standard, the sediment was not sieved, and big bone fragments and silices are still found in the excavation residues. Therefore, it is to be hoped that all or most of the bone splinters were recovered. Rediscovering the lost pieces might also shed light upon the cause of the fragmentation of the perforated long bone. It could be that the object fragmented due to an accident because of material weakness of the bone, but it is also possible that it was intentionally destroyed, which would open up further research and interpretation approaches.

Furthermore, when looking into the finds, an examination of the reindeer antler with which the instrument was found covered should be undertaken. Maybe it bears marks of use which could possibly be linked to music activities itself, as is the case within an artefact assemblage from Mezin,

Ukraine. Among mammoth bones, interpreted as a percussion set, a beater made from a reindeer antler was discovered.[53] Another approach for interpreting the antler's function could be that of a covering. There are finds of burials covered with mammoth scapulas on the Gravettian (Pavlovian) sites of Krems-Wachtberg and Dolní Věstonice/Pavlov. One could compare the intentional deposition of the fragmented instrument under the cover of the reindeer shovel with the covered burials of these Pavlovian sites,[54] but the authors think that this comparison may be too far-fetched. Unfortunately, the exact circumstances of the discovery remain unclear and, as long as no investigations are carried out into the micromarks of the reindeer shovel, the interpretations of the setting of the instrument and the shovel remain speculation.

Concerning the tonal research on the instrument, it is hoped that it will be possible to put into contact all the researchers who have been or are currently working on the topic of the Grubgraben instrument and regularly playing replicas of it. The aim is to construct an acoustic database of all possible playing techniques which can be applied to the instrument, as well as to collect the tonal possibilities. It will be interesting to see if the tonal output varies with different craftsmen on the one hand, and different musicians on the other.

Additionally, as nearly all replicas were made from some kind of deer bone, reconstruction experiments should be planned with reindeer tibiae or other close species.

Still, this fascinating Epigravettian object leaves many questions unanswered, but will hopefully provide more answers and insight in the musical culture of our ancestors in the near future.

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[53] Lbova et al. 2013: 27–30; Bibikov 2008: 77; Kossykh 2018: 34–39.

[54] For Example Svoboda 2006: 15, 16, 17; Einwögerer et al. 2006: 285; Einwögerer 2017: 86.

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