Home > EXARC Journal Issue 2020/3 >
Experimental Research on the Neanderthal Musical Instrument from Divje Babe I Cave (Slovenia)

Reviewed Article:

Experimental Research on the Neanderthal Musical Instrument from Divje Babe I Cave (Slovenia)

Persistent Identifier: https://exarc.net/ark:/88735/10522

EXARC Journal Issue 2020/3 | **Publication Date:** 2020-08-21

Author(s): Matija Turk [1] ✉, Giuliano Bastiani [2]

[1] ZRC SAZU Institute of Archaeology, Novi trg 2, 1000 Ljubljana, Slovenia.

[2] Independent researcher, Via Rebez 39, 34075 Pieris, Italy.

The supposition that an unusually perforated femur of a juvenile cave bear found at the Divje babe I Palaeolithic cave site in Slovenia could be a musical instrument led to heated debates. According to its archaeological context and chronostratigraphic position, if made by humans, it could only be attributed to Neanderthals. The crucial question was related to the origin of the perforations. These could only have been made either by the teeth of a carnivore or by

modification of the bone by human intervention. Experimental piercing on fresh juvenile brown bear femora using metal dental casts of wolf, hyaena, and bear showed that the four perforations exactly aligned in the middle of the longitudinal axis of the diaphysis can not be reasonably explained by carnivore biting/gnawing action. Experimental archaeology showed that morphologically identical perforations could be made by replicas of stone and bone tools, found in the Mousterian levels of Divje babe I, without leaving any conventional tool marks (i.e. cuts and micro-striations left by stone tools). Recent musical experiments performed on a replica of the reconstructed find revealed its great musical capability.

> On the reconstructed instrument, it was possible to perform a series of musical articulations and ornamentations such as legato, staccato, double and triple tonguing, flutter-tonguing, glissando, chromatic scales, trills, broken chords, interval leaps, and melodic successions from the lowest to the highest tones. All these can also be played on the CT replica with reconstructed missing parts.

Introduction

In 2017, the National Museum of Slovenia hosted the Arhaeomusica international exhibition, dedicated to the oldest musical instruments of Europe (de Angeli et al., 2018). During the exhibition, the XV international symposium of the ICTM Study Group on Music Archaeology was carried out in Ljubljana, entitled “Music in the Stone Age”. The main topic of the symposium was the Neanderthal musical instrument discovered in 1995 in the Palaeolithic cave site of Divje babe I (western Slovenia) during systematic excavations carried out by the ZRC SAZU, Institute of Archaeology (Turk, 1997; 2014; Turk et al., 2018).

The symposium saw the presentation of the results of research by Ivan Turk, the researcher of Divje babe I cave and his colleagues, who dedicated many years to the research of this artefact. The results, which were primarily based on experimental work, confirmed the possibility that the find, initially designated as a presumed Mousterian flute, was an intentionally made musical instrument. The practical demonstration consisted of Katinka Dimkaroska’s playing on a reconstruction of the Neanderthal musical instrument and making of the instrument by the experimental archaeologist Giuliano Bastiani. On the audience’s suggestion we decided to present the results from experiments on the investigation of the origin of the perforations at the EXARC conference.

The Neanderthal musical instrument

The Neanderthal-made musical instrument (See Figure 1) kept by the National Museum of Slovenia (inventory number D.b. 652) was made from the left femoral diaphysis of a juvenile cave bear. On the posterior side of the diaphysis, there are two complete perforations and one partially preserved perforation. The fourth perforation, located on the anterior side of the bone, is partly preserved. All four perforations were distributed along the middle of the diaphysis in a straight line. The presumption that the semi-circular notch at the distal end of the posterior side indicating the presence of the fifth perforation was not confirmed (Turk et al., 2005). Both ends of the musical instrument were damaged. The mouthpiece, a bevelled sharp blowing edge, was preserved on the proximal part of the bone (See Figures 1 and 2).

The number of perforations, their shape, and positions on the modified bone was not apparently ascertained as being made by carnivores (cf. Brodar, 1985). The perforations were located on the diaphysis where the compact bone is the thickest and is the hardest to penetrate by carnivores. As the find strongly resembles some of the Upper Palaeolithic bone flutes made of mammal limb bones (Omerzel-Terlep, 1997; Morley, 2013), its finders assumed the modified bone might be a flute (Turk et al., 1995). The possibility of the modified bone being an artefact was supported by the context of the find. Namely, it was found in the Mousterian level in the immediate vicinity of a hearth. Considering the radiocarbon dates of samples from the layer containing the find, its age was at first indirectly estimated as approximately 43,000 years (Nelson, 1997). Later, dating using the ESR method revealed that the layer containing the find was deposited between 50,000-and-60,000-years BP (Blackwell et al., 2007). Considering the archaeological context and age, the find would, if it was confirmed as an artefact (i.e. a musical instrument) represent a discovery of exceptional significance. It would provide strong evidence that Neanderthals were capable of musical expression. All artificially perforated bones, interpreted as Palaeolithic musical instruments (whistles or flutes), originate from the Upper Palaeolithic (Morley 2013). They are the product of an anatomically modern human, to which, beside other cultural innovations, the invention of musical expression is traditionally ascribed (d'Errico et al., 2003).

As Neanderthal burials and rare manifestations of art from Mousterian contexts (Bednarik, 2014; Burdukiewicz, 2014) have been subjected to rigorous scrutiny, so was the modified bone. The resulting critical discussions was unfortunately, distinctly one-sided. Ever since the discovery, the key question revolved around whether the perforations in the bone were of carnivore or artificial origins. The discussion was accompanied by strong denial of all arguments speaking in favour of the anthropogenic origin of holes (Turk et al., 2014; 2020). The edges of perforations on Upper Palaeolithic flutes made from mammal limb bones exhibit clear traces of chiselling or drilling. Irregular serrated rims of the perforations on specimen no. 652 (See Figure 7 c, d) were different than on comparable bone flutes from the Upper Palaeolithic. Since the microscopic analysis did not reveal conventional manufacture marks (i.e. striations and cut marks of stone tools) some scholars took this as evidence that the perforations were made by carnivores. To clarify the origin of the perforations, I. Turk and his colleagues undertook the experimental testing of possible carnivore and artificial creation of the perforations (Turk et al,. 2001). Turk et al.’s (2005; 2006; 2018) study’s results, which included computed tomography, found that the modified juvenile cave bear bone originally had four perforations.

Experimental verification of carnivore hypothesis

To test the hypothesis that carnivores caused the perforations in the bone, metal dental casts of cave bear, hyaena, and wolf dentition were made (See Figure 3). The metal dental casts were used to pierce 29 juvenile and four adult fresh brown bear femora (Turk et al.. 2001).

At Divje babe I, hyena was not represented among the faunal remains, nor was there any other indirect evidence of its presence. It was included in the research as some authors claimed that the perforations were made by a hyaena with its carnassial teeth (Chase and Nowell. 1998; Albrecht et al.. 1998). The results of the experimental piercing tests, do not support the hypothesis that the perforations were made by carnivore dental compression on the bone. Perforations made by the hyaena carnassial teeth were of a more elongated, oval, or rhomboid shape (Turk et al. 2001, Figure 14) (See Figure 4b). D'Errico et al. (1998) recognised only two perforations on the bone (both complete) and that these were made by a cave bear with its canine teeth. This proposal has at least some basis as cave bear was by far the greatest represented carnivore at the site (99.4% of all taxonomically determinable faunal remains). Experimental piercing by the metal dental cast showed that both complete perforations were similar in shape and size to the perforations made by a bear's canine (See Figure 4a). However, in terms of a bear's bite, their orientation is problematic. Namely, bear canines have an oval cross section in the labial-lingual direction (Christiansen 2008, Figure 2). Since the two complete perforations were slightly oval in the direction of the longitudinal axis of the femur, during the biting of the bone the bear would straighten the bone in its snout longitudinally to its jaw. It would have to do this for every perforation individually, which is very difficult, if not impossible (cf. Turk et al. 2001, Figure 10). If both complete perforation were made by a transverse bite, they would have to be made separately since the distance between both complete perforations does not correspond to the distance between the canines of an adult cave bear, nor any other of the considered carnivores (Turk et al. 2001).

It is also very difficult for a carnivore, which would gnaw the bone with canine teeth, to set all the perforations into a straight line in several successive bites, since due to the oval shape of bone, the bone slips while compressed by canines, especially if it is fresh and greasy.

During the compression of a bone it was possible to observe how a bear canine tooth acts on the compact bone. During the penetration, the canine tooth pushes the bone tissue on the convex labial side outwards, and pushes the bone obliquely inside on the concave lingual side. Such features on the edge of the perforations were not present on the juvenile cave bear femur. Furthermore, perforations pierced with canine teeth have smooth edges (See Figure 4a), but the edge of the perforations on cave bear femur was irregular and serrated (See Figure 7c, d).

Compression forces necessary to pierce compact bone were measured at the Faculty of Mechanical Engineering of the University of Ljubljana. The force necessary to pierce 3 to 5mm fresh femoral diaphysis of a juvenile brown bear with a blunt canine tooth was between 2.6 and 6.4 kN. Present-day carnivores are not able to produce such compression forces (Christiansen and Wroe. 2007, Table 1). The force required to perforate fresh bone with sharp canine teeth drops to 1.3–3.0 kN (Turk et al.. 2001, Figure 11), which is barely within the limit of the estimated force that the adult male of cave bear can produce (Grandal-d'Anglade, 2010, Table 3). In almost one half of experimental perforations on brown bear femoral diaphyses, the bone shaft split longitudinally. During the compression with sharp canine teeth, the femur usually cracked longitudinally on one or both sides, even before the compact bone was perforated (See Figure 5). If a femur lacked distal and proximal epiphyses, the bone split apart.

The computed tomography analysis (CT) showed that the crack on the posterior side of the juvenile cave bear femur is only superficial (Turk et al., 2005); thereby suggesting this crack did not occur during piercing of the bone. Cracks related to the piercing of a bone went through the entire thickness of the compact bone and were present on both sides of the perforations. Consequently, the V-shaped fractures, which come out of half-preserved Perforations 1 and 4 (See Figure 1), were not contemporary with them. If they had occurred simultaneously with Perforations 1 and 4, there would have been a crack fracture on the preserved side of both perforations.

Experimental verification of the anthropical hypothesis

Pointed stone tools appropriate for piercing bone were found in several Mousterian levels at Divje babe I. In addition to individual fragments of bone points, *ad hoc* bone tools with a blunt-tips were found in Mousterian levels (Turk M., 2014; Turk and Košir, 2017) (See Figure 6). It should be acknowledged that an experimental archaeologist Giuliano Bastiani and archaeologist François Zoltán Horusitzky, explained how a Neanderthal could have made comparable perforations on animal bones.

G. Bastiani used replicas of pointed Mousterian stone tools from Divje babe I, with which he pierced a recent bear femur in a manner unknown to archaeologists until then (See Figure 10). The new technique used by Bastiani, consisted of chiselling and piercing: a pointed stone tool is used as a chisel and punch at the same time (Bastiani and Turk, 1997; Turk et al., 2001). The edges of these made perforations were irregular and serrated (See Figure 7 a) and morphologically corresponded to the perforations on the modified juvenile cave bear femur (See Figure 7 c, d). Six experimental perforations, produced with this technique, were put under microscopic examination and cut marks were detected on only half of them (d'Errico and Lawson, 2006, p.50). This finding is of great importance since it implies that Neanderthals were able to make perforations on animal bone which lacked conventional manufacture marks. Moreover, the irregular serrated rim of the perforations on the modified juvenile cave bear femur was consistent with the marks left by the manufacture techniques described above.

The technique of perforation manufacturing was upgraded by F. Z. Horusitzky (2003; Turk et al., 2003), who used the replicas of the *ad hoc* bone tools to perforate bone. By using a pointed stone tool and a bone tool with a blunt tip (See Figure 10), a perforation in the compact bone was made quickly and efficiently. The procedure used was to chisel a dent into the compact bone with a pointed stone tool and then a bone tool with a blunt tip was placed into the dent. This resulted in the bone tool producing a punch of bone after the bone tool was struck with a wooden hammer. The perforations produced by this technique were morphologically identical to the perforations on the modified juvenile cave bear femur and the perforations completely lacked the conventional manufacture marks (See Figure 7 b). Well-pronounced funnel-shaped fractures were observed around the inner edge of the perforations on the experimental bones. These fracture types were observed around the complete Perforation 2 and 3 and partial Perforation 1 and 4 in the modified juvenile cave bear femur (Turk et al., 2005, Figure 6).

Musical verification

From a musical perspective, the modified juvenile cave bone femur was studied by various researchers who confirmed its musical functionality (Kunej, 1997; Kunej and Turk, 2000; Omrzel-Terlep, 1997; Fink, 1997; Atema, 2004; Horusitzky, 2003, 2014). Important findings were reached by the academic musician Ljuben Dimkaroski (2011, 2014), who oriented the instrument differently than the others. Dimkaroski used the proximal part of the diaphysis as a mouthpiece, where a part of the straight cut sharpened edge is preserved and which was not considered by previous researchers (See Figure 1 and 2). With a different orientation of the instrument, the role of Perforation 4, the single perforation on the anterior side, was clarified. In the primary orientation, the location of this perforation was too close to the mouthpiece and thus was dysfunctional. Perforation 4 (See Figure 1) now became useful as a palm hole (to be opened or closed with a palm).

In his musical experiments, Dimkaroski used a replica of the reconstructed musical instrument made on the similar left femur of cave bear cub from Divje babe I (See Figure 8). On the reconstructed instrument, it was possible to perform a series of musical articulations and ornamentations such as legato, staccato, double and triple tonguing, flutter-tonguing, glissando, chromatic scales, trills, broken chords, interval leaps, and melodic successions from the lowest to the highest tones. All these can also be played on the CT replica with reconstructed missing parts (See Figure 1 b). The musical instrument has a range of three and half octaves, and unlike modern wind instruments, it is not tempered (Dimkaroski, 2014). It has three finger holes (Perforations 1–3) on the posterior aspect and a palm hole (Perforation 4) on the anterior aspect of the diaphysis. A mouthpiece with a bevelled sharp blowing edge is located on the anterior proximal part. An opening on the distal part is in the function of bell or closure. With a finger of the right hand, the notch on the posterior distal aspect may be formed into an additional hole. The opening provides the possibility of playing on an open or closed bell, which additionally enriches the tonal range. The sound was created by directed blowing against the sharp edge. The instrument was played two-handed with Perforation 4 being used to extend the air column to twice its length. This was a solution not used by modern wind instruments and implies there is no need for the double length of the instrument and a higher number of holes. According to Dimkaroski (2011, 2014), it is not a flute, but a unique musical instrument whose capability is comparable to modern wind instruments.

Dimkaroski made more than hundred comparable musical instruments, primarily from wood (See Figure 9). He experimented with changing the number, size, and position of the perforations. He came to the conclusion that the number, size, and disposition of the perforations as well as the length of the instrument were deliberately planned with the aim of musical expression. The musical instrument enabled a wide range of sonorities and melodic motions and revealed the artefact as a highly capable wind instrument. Every change in the system, whether changing the length of the instrument, adding or removing holes or the absence of the sharp blowing edge, resulted in poorer musical expression.

Conclusion

Results of the experimental piercings of fresh juvenile bear femurs with metal dental casts from a range of carnivore species indicated that the perforated femur from Divje babe I was not caused by the gnawing/biting actions of carnivores. An animal long bone without epiphyses would split before the carnivore species would be able to perforate it two or more times. Only typical traces of gnawing on both ends of the diaphysis and V-shaped fractures, which were made after the creation of the perforations on the femur, can be interpreted as carnivore damage (Turk et al., 2005; Tuniz et al., 2012).

Archaeological finds from Divje babe I confirm that Neanderthals had appropriate tools for the piercing of bones. Damage such as broken tips and fractures observed on some pointed stone tools (Turk et al. 2018, Figure 13) (See Figures 6, 1c), indicated that they were used to process hard materials. It was proved experimentally that the same type of damage occurs when a wooden hammer hits a tool when chiselling and piercing hard material (Bastiani et al., 2000, p.55, Figure 14; Kunej and Turk, 2000, Figure 15.3; Turk et al., 2001, p.69, Figure 27) (See Figure 10, 3a-c).

Experiments in piercing fresh brown bear bones proved that comparable perforations without conventional manufacturing marks could have been made by Neanderthals with their tools and technology (See Figure 7). The perforations with irregular serrated rims reflected manufacturing using of chiselling and piercing techniques. Thus, such perforations could not be *a priori* attributed exclusively to carnivore gnawing and biting of bones. With the use of pointed stone tools and a bone punch, the Neanderthals could make a hole into the compact bone in a matter of minutes. While anatomically modern humans drill or simply chisel bones to create perforations—these techniques result in longer times and higher energy consumptions to complete the same task.

No Palaeolithic wind instrument has been discovered complete (Morley, 2013). Musical experiments and testing have been carried out on reconstructed instruments. The advantage of the reconstruction of the modified juvenile cave bear femur bone, *i.e.*, the Neanderthal musical instrument, is that its original length was preserved (11.4 cm). Thus, it was possible to reconstruct credibly the missing parts of the artefact. Furthermore, its manufacture, creation of perforations and the sequence of carnivore damage (most probably by a wolf and not a hyaena) on both ends of the diaphysis was adequately explained by Turk et al. (2018, p. 702).

Acknowledgements

The main author acknowledges the financial support from the Slovenian Research Agency (P6-0283) for the participation at the 11th Experimental Archaeology Conference in Trento, Italy, in May 2019. We thank ZRC SAZU Institute of Archaeology for financing the translation of the paper. We also thank Katinka Dimkaroska and Milojka Magajne from Cerkno Museum for providing us with additional photos.

Keywords music & musical instruments

Country Slovenia

Bibliography

Albrecht, G., Holdermann, C. S., Kerig, T., Lechterbeck, J. and Serangeli, J., 1998. 'Flöten' aus Bärenknochen – die frühesten Musikinstrumente? *Archäologisches Korrespondenzbatt 28,* pp.1–19.

Atema, J., 2004. Old bone flutes. *Pan, Journal of the British Flute Society 23*, pp.18–23.

Bastiani, G. and Turk, I., 1997. Results from the experimental manufacture of a bone flute with stone tools. In I. Turk, ed. 1997. *Mousterian »bone flute« and other finds from Divje babel cavesite in Slovenia.* Opera Instituti Archaeologici Sloveniae 2, pp.176–178. Ljubljana, ZRC Publishing.

Bastiani, G., Dirjec, J. and Turk, I., 2000. Poskus ugotavljanja namembnosti kamenih artefaktov iz najdišča Divje babe I (Slovenija): Domneve o uporabi in obrabi nekaterih musterjenskih orodij. / Attempt to establish the purpose of stone artefacts from the Divje babe I site (Slovenia). Hypotheses on the use of and wear to some Mousterian tools (Summary). *Arheološki vestnik 51,* pp.13-69.

Bednarik, R. G., 2014. Pleistocene Paleoart of Europe. *Arts 3*, pp.245-278.

Blackwell, B. A. B., Yu, E. S. K., Skinner, A. R., Turk, I., Blickstein, J. I. B., Turk, J., Yin, V. S. W. and Lau, B., 2007. ESR-Dating at Divje babe I, Slovenia. In I. Turk, ed., *Divje babe I: Upper Pleistocene Palaeolithic site in Slovenia, Part 1: Geology and Palaeontology.* Opera Instituti Archaeologici Sloveniae 13, pp.123–157. Ljubljana, ZRC Publishing.

Brodar, M., 1985. Fossile Knochendurchlochungen. In S. Grafenauer, M. Pleničar and K. Drobne (Eds.), *Ivan Rakovec volume, Razprave 4. razreda SAZU 26*, pp.29–48, Ljubljana.

Burdukiewicz, J. M., 2014. The origin of symbolic behavior of Middle Palaeolithic humans: Recent controversies. *Quaternary International 326-327*, pp.398-405.

Chase, P. G. and Nowell, A., 1998. Taphonomy of a suggested Middle Paleolithic bone flute from Slovenia. *Current Anthropology 39*, pp.549–553.

Christiansen, P., 2008. Feeding Ecology and Morphology of the Upper Canines in Bears (Carnivora: Ursidae). *Journal of Morphology 269*, pp.896–908.

Christiansen, P. and Wroe, S., 2007. Bite forces and evolutionary adaptations to feeding ecology in carnivores. *Ecology 88* (2), pp.347–358.

De Angeli, S., Both, A. A., Hagel, S., Holmes, P., Pasalodos, R. J. and Lund, C. S. (Eds.), 2018. *Music and Sounds in Ancient Europe. Contributions from the European Music Archaeology Project.* EMAP – European Music Archaeology Project.

Dimkaroski, L. 2011. Musikinstrument der Neanderthaler. Zur Diskussion um die moustérienzaitliche Knochenflöte aus Divje babe I, Slowenien, aus technischer und musikologischer Sicht. *Mittelungen der Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte 32*, pp.45–54.

Dimkaroski, L., 2014. Musical research into the flute. From suspected to contemporary musical instrument. In I. Turk, ed. *Divje babe I. Upper Pleistocene Palaeolithic site in Slovenia. Part 2: Archaeology.* Opera Instituti Archaeologici Sloveniae 29, pp.215–222. Ljubljana, ZRC Publishing.

d'Errico, F., Villa, P., Pinto Llona, A. C. P. and Idarraga, R. R., 1998. A Middle Palaeolithic origin of music? Using cave-bear bone accumulations to assess the Divje Babe I bone »flute«. *Antiquity 72*, pp.65–79.

d'Errico, F., Henshilwood, C., Lawson, G., Vanhaeren, M., Tillier, A. M., Soressi, M., Bresson, F., Maureille, B., Nowell, A., Lakarra, J., Backwell, L. and Julien, M., 2003. Archaeological evidence for the emergence of language, symbolism, and music: An alternative multidisciplinary perspective. *Journal of World Prehistory 17/1*, pp.1–70.

d'Errico, F. and Lawson, G., 2006. The sound paradox: how to assess the acoustic significance of archaeological evidence? In G. Lawson and C. Scarre (Eds.), *Archaeoacoustics*, pp.41–57. Cambridge, McDonald Institute for Archaeological Research.

Fink, B., 1997. Neanderthal flute. Oldest musical instrument's 4 notes matches 4 of do, re, miscale. Musicological analysis. [online] Available at < https://web.archive.org/web/20070219094811/http://www.greenwych.ca:80/fl-compl.htm > [Accessed 07/ April 2020]

Grandal-D'Anglade, A., 2010. Bite force of the extinct Pleistocene Cave bear *Ursus spelaeus* Rosenmüller from Europe. *Comptes rendus Paleovol 9*, pp.31–37.

Horusitzky, F. Z., 2003. Les flûtes paléolithiques: Divje Babe I, Istállóskő, Lokve, etc. Point de vue des experts et des contestataires (Critique de l'appréciation archéologique du spécimen no. 652 de Divje Babe I, et arguments pour la défence des spécimens Pb 51/20 et Pb 606 de MNM de Budapest). *Arheološki vestnik 54*, pp.45–66.

Horusitzky, F. Z., 2014. Analyse acoustique de la flûte avec souffle proximal. In I. Turk, ed. *Divje babe I. Upper Pleistocene Palaeolithic site in Slovenia. Part 2: Archaeology.* Opera Instituti Archaeologici Sloveniae 29, pp.223–233. Ljubljana, ZRC Publishing.

Kunej, D., 1997. Acoustic findings on the basis of the reconstruction of a presumed bone flute. In I. Turk (Ed.), *Mousterian »bone flute« and other finds from Divje babe I cave site, Slovenia.* Opera Instituti Archaeologici Sloveniae 2, pp.185-197. Ljubljana, ZRC Publishing.

Kunej, D. and Turk, I., 2000. New perspectives on the beginning of music: Archaeological and musicological analysis of a Middle Palaeolithic Bone 'Flute'. In N. L. Wallin, B. Merker and S. Brown, eds. *The Origins of Music*, pp.235–268. Cambridge MA, London, MIT Press.

Morley, I., 2013. *The Prehistory of Music*. Oxford, University Press.

Nelson, D. E., 1997. Radiocarbon dating of bone and charcoal from Divje babe I cave. In I. Turk, ed. *Mousterian 'bone flute' and other finds from Divje babe I cave site, Slovenia.* Opera Instituti Archaeologici Sloveniae 2, pp.51–64. Ljubljana, ZRC Publishing.

Omerzel-Terlep, M., 1997. A typology of bone whistles, pipes and flutes and presumed palaeolithic wind instruments in Slovenia. In I. Turk, ed. *Mousterian 'bone flute' and other finds from Divje babe I cave site, Slovenia.* Opera Instituti Archaeologici Sloveniae 2, pp.199–218. Ljubljana, ZRC Publishing.

Tuniz, C., Bernardini, F., Turk, I., Dimkaroski, L., Mancini, L. and Dreossi, D., 2012. Did Neanderthals play music? X-ray computed microtomography of the Divje babe 'flute'. *Archaeometry 54/3*, pp.581–590.

Turk, I. (Ed.). 1997. *Mousterian »bone flute« and other finds from Divje babe I cave site, Slovenia.* Opera Instituti Archaeologici Sloveniae 2. Ljubljana, ZRC Publishing.

Turk, I. (Ed.). 2014. *Divje babe I. Upper Pleistocene Palaeolithic site in Slovenia. Part 2: Archaeology.* Opera Instituti Archaeologici Sloveniae 29. Ljubljana, ZRC Publishing.

Turk, I., Dirjec, J. and Kavur, B., 1995. The oldest musical instrument in Europe discovered in Slovenia? *Razprave 4. razreda SAZU 36*, pp.287–293.

Turk, I., Dirjec, J., Bastiani, G., Pflaum, M., Lauko, T., Cimerman, F., Kosel, F., Grum, J. and Cevc, P., 2001. New analyses of the 'flute' from Divje babe I (Slovenia). *Arheološki vestnik 52*, pp.25–79.

Turk, I., Bastiani, G., Blackwell, B. A. B. and Horusitzky, F. Z., 2003. Putative Mousterian flute from Divje babe I (Slovenia): Pseudoartefact or true flute, or who made the holes? *Arheološki vestnik 54*, pp.67–72.

Turk, I., Pflaum, M. and Pekarovič, D., 2005. Results of computer tomography of the oldest suspected flute from Divje babe I (Slovenia): Contribution to the theory of making holes in bones. *Arheološki vestnik 56*, pp.9–36.

Turk, I., Blackwell, B.A.B., Turk, J. and Pflaum, M., 2006. Résultats de l'analyse tomographique informatisée de la plus ancienne flûte découverte à Divje babé I (Slovénie) et sa position chronologique dans le contexte des changements paléoclimatiques et paléoenvironnementaux au cours du dernier glaciaire. *L'Anthropologie 110*, pp.293–317.

Turk, I., Dirjec J. and Turk, M., 2014. Flute (musical instrument) 19 years after its discovery. Critique of the taphonomic interpretation of the find. In I. Turk (Ed.), *Divje babe I. Upper Pleistocene Palaeolithic site in Slovenia. Part 2: Archaeology.* Opera Instituti Archaeologici Sloveniae 29, pp.235–268. Ljubljana, ZRC Publishing.

Turk, M., 2014. Typology of stone artefacts. In I. Turk (Ed.), *Divje babe I. Upper Pleistocene Palaeolithic Site in Slovenia. Part 2: Archaeology.* Opera Instituti Archaeologici Sloveniae 29, pp.153–170. Ljubljana, ZRC Publishing.

Turk, M. and Košir, A., 2017. Mousterian osseous artefacts? The case of Divje babe I, Slovenia. *Quaternary International 450*, pp.103-115.

Turk, M., Turk, I., Dimkaroski, L., Blackwell, B. A. B., Horusitzky, F. Z., Otte, M., Bastiani, G. and Korat, L., 2018. The Mousterian musical instrument from the Divje babe I cave (Slovenia): Arguments on the material evidence for Neanderthal musical behaviour. *L'anthropologie 122*, pp.679–706.

Turk, M., Turk, I. and Otte, M., 2020. The Neanderthal Musical Instrument from Divje Babe I Cave (Slovenia): A Critical Review of the Discussion. Applied Science 10, pp.1-11.

Corresponding Author

Matija Turk
ZRC SAZU Institute of Archaeology
Novi trg 2
1000 Ljubljana
Slovenia
E-mail Contact

Gallery Image

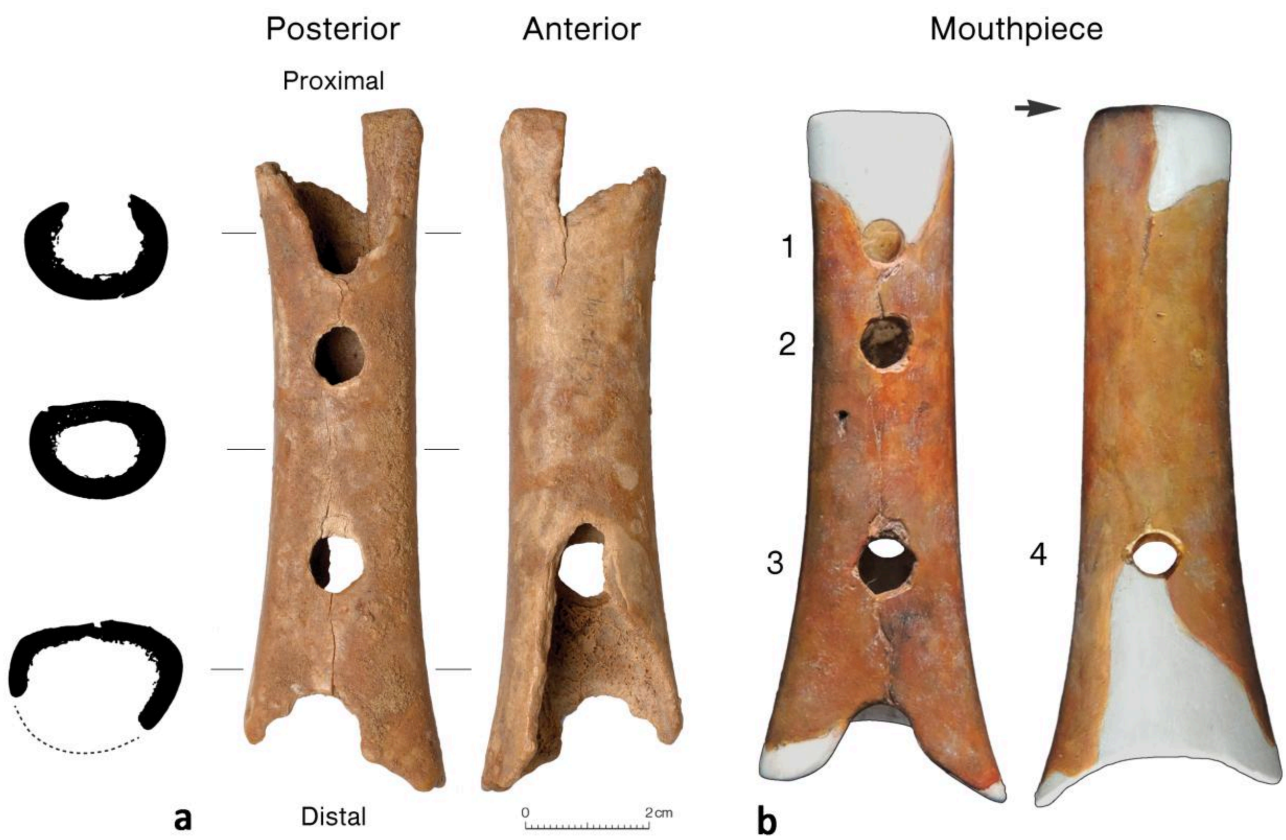

FIG 1. NEANDERTHAL MUSICAL INSTRUMENT (A) AND ITS RECONSTRUCTION WITH DESIGNATED PERFORATIONS (HOLES) (B). THE ARROW INDICATES THE PRESERVED BEVELLED SHARP BLOWING EDGE ON THE MOUTHPIECE. PHOTO BY TOMAŽ LAUKO, NMS

FIG 2. PRESERVED BEVELLED SHARP BLOWING EDGE ON THE MOUTHPIECE. PHOTO BY TOMAŽ LAUKO, NMS

FIG 3. BRONZE CAST OF HYAENA (A) AND WOLF DENTITION (B) USED IN THE EXPERIMENTAL PIERCING OF FRESH JUVENILE FEMORA OF BROWN BEAR. PHOTO BY BOJAN TAVČAR, CERKNO MUSEUM

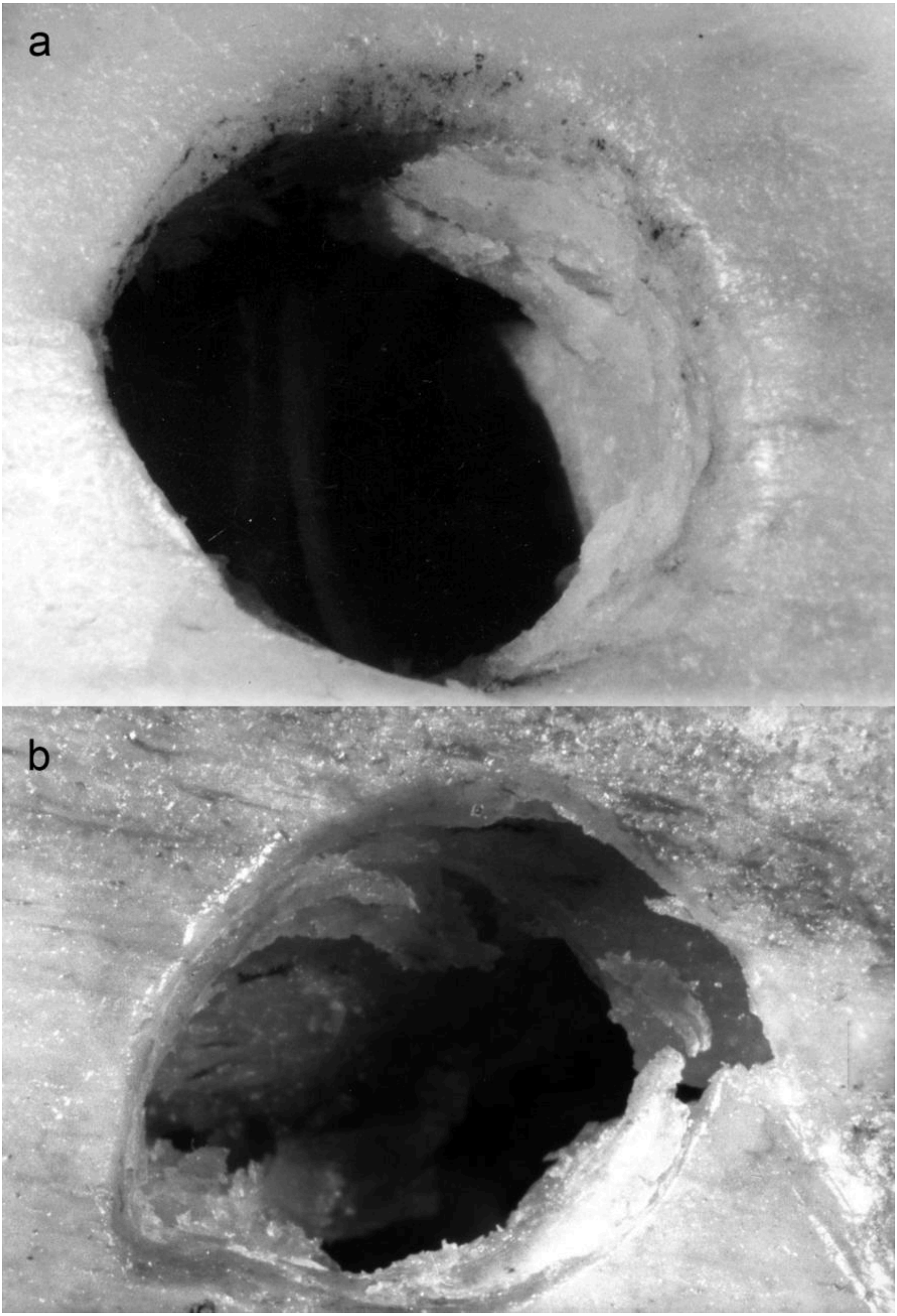

FIG 4. EXPERIMENTAL PERFORATIONS ON A FEMUR DIAPHYSIS OF JUVENILE BROWN BEAR MADE BY A BEAR'S CANINE TOOTH (A) AND HYAENA'S 3RD UPPER PREMOLAR TOOTH (B) (ZRC SAZU, ARCHIVE OF THE INSTITUTE OF ARCHAEOLOGY)

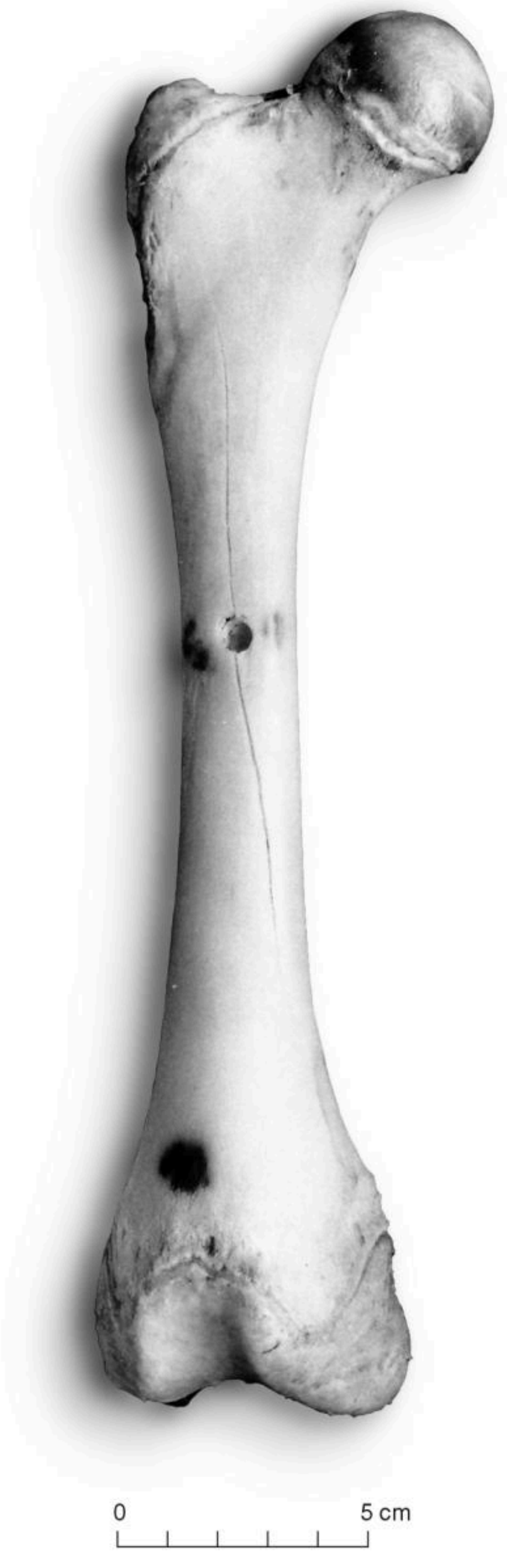

FIG 5. PERFORATED FEMUR DIAPHYSIS OF JUVENILE BROWN BEAR AND THE RELATED TYPICAL LONGITUDINAL CRACK ON BOTH SIDES OF THE PERFORATIONS (ZRC SAZU, ARCHIVE OF THE INSTITUTE OF ARCHAEOLOGY).

FIG 6. TOOLS APPROPRIATE FOR PIERCING BONE FOUND IN THE MOUSTERIAN LEVELS OF DIVJE BABE I: POINTED STONE TOOLS (1A–C). NOTE THE ONE WITH THE BROKEN TIP (1C). BONE TOOLS WITH BLUNT TIPS (2A-B). PHOTO BY TOMAŽ LAUKO, NMS

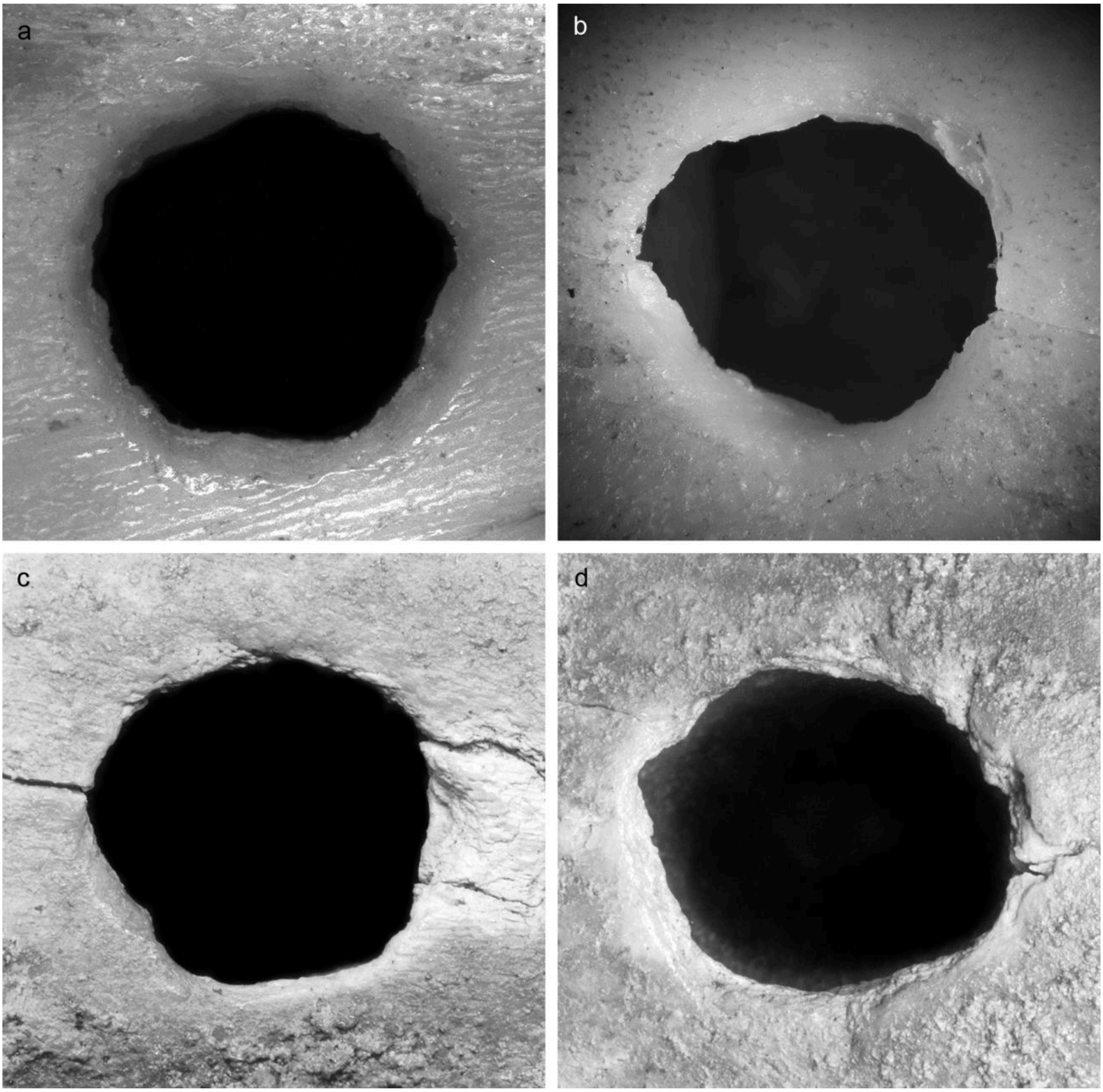

FIG 7. EXPERIMENTAL PERFORATIONS IN COMPARISON WITH THE PERFORATIONS ON THE NEANDERTHAL MUSICAL INSTRUMENT (JUV. CAVE BEAR FEMUR): THE EXPERIMENTAL PERFORATION WAS MADE BY A POINTED STONE TOOL (A), THE EXPERIMENTAL PERFORATION WAS MADE BY A POINTED STONE TOOL AND BONE PUNCH (B), PERFORATION NO. 3 (C) AND PERFORATION NO. 2 (D) ON THE NEANDERTHAL MUSICAL INSTRUMENT (ZRC SAZU, ARCHIVE OF THE INSTITUTE OF ARCHAEOLOGY).

FIG 8. LJUBEN DIMKAROSKI PLAYING ON A REPLICA OF THE RECONSTRUCTED NEANDERTHAL MUSICAL INSTRUMENT MADE ON THE LEFT FEMUR OF JUVENILE CAVE BEAR FROM DIVJE BABE I. PHOTO BY TOMAŽ LAUKO, NMS

FIG 9. MUSICAL INSTRUMENTS MADE BY LJUBEN DIMKAROSKI FOR HIS MUSICAL EXPERIMENTS AND TESTING. PHOTO BY KATINKA DIMKAROSKA

FIG 10. EXPERIMENTAL TOOLS USED FOR PIERCING AND CUTTING THE FEMUR OF JUVENILE BROWN BEAR (1A-B): A BONE PUNCH (2) USED TO PIERCE AND ENLARGE THE UPPER PERFORATION ON THE FEMUR, AFTER A DENT WAS CHISELLED INTO THE COMPACT BONE WITH A POINTED STONE TOOL. POINTED STONE TOOLS (3A–C) WITH TIPS, DAMAGED AND BROKEN DURING CHISELLING AND PUNCHING THE LOWER PERFORATION ON THE FEMUR. DENTICULATED FLAKE USED FOR CUTTING (SAWING) THE BONE (4). PHOTO BY MATIJA TURK