LETTERS

New flutes document the earliest musical tradition in southwestern Germany

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Considerable debate surrounds claims for early evidence of music in the archaeological record[1–5]. Researchers universally accept the existence of complex musical instruments as an indication of fully modern behaviour and advanced symbolic communication[1] but, owing to the scarcity of finds, the archaeological record of the evolution and spread of music remains incomplete. Although arguments have been made for Neanderthal musical traditions and the presence of musical instruments in Middle Palaeolithic assemblages, concrete evidence to support these claims is lacking[1–4]. Here we report the discovery of bone and ivory flutes from the early Aurignacian period of southwestern Germany. These finds demonstrate the presence of a well-established musical tradition at the time when modern humans colonized Europe, more than 35,000 calendar years ago. Other than the caves of the Swabian Jura, the earliest secure archaeological evidence for music comes from sites in France and Austria and post-date 30,000 years ago[6–8].

Excavations in the summer of 2008 at the sites of Hohle Fels and Vogelherd in Germany produced new evidence for Palaeolithic music in the form of the remains of one nearly complete bone flute and isolated small fragments of three ivory flutes (Figs 1 and 2). On 17 September, an excavator uncovered the most significant of these finds, the bone flute, in the basal Aurignacian deposits of archaeological horizon Vb at Hohle Fels Cave in the Ach Valley, 20 km west of Ulm. The flute was recovered in 12 pieces. The team documented 11 fragments *in situ*, and one was found during water screening. The fragments were distributed over a vertical distance of 3 cm over a horizontal area of about 10 cm by 20 cm. This flute, which we designate Hohle Fels flute 1, is by far the most complete of the musical instruments so far recovered from the caves of Swabia. The flute lay in an 8-cm-thick deposit of clayey silt with limestone clasts that directly overlies a nearly sterile deposit of red-brown, silty clay, separating the basal Aurignacian from the underlying Middle Palaeolithic deposits of archaeological horizon VI (Fig. 3).

The find density in archaeological horizon Vb is moderately high, with much flint-knapping debris, worked bone and ivory, bones of horse, reindeer, cave bear, mammoth and ibex, and burnt bone. No diagnostic human bones have been found in deposits of the Swabian Aurignacian, but we assume that modern humans produced the artefacts from the basal Aurignacian deposits shortly after their arrival in the region, following a migration up the Danube Corridor[9].

The maker of the flute carved the instrument from the radius of a griffon vulture (*Gyps fulvus*). This species has a wing span of between 230 and 265 cm and provides bones ideal for large flutes. Griffon vultures and other vultures are documented in the Upper Palaeolithic sediments of the Swabian caves with several examples identified from Gravettian and Aurignacian deposits at Geißenklösterle.

The preserved portion of flute 1 from Hohle Fels has a length of 21.8 cm and a diameter of about 8 mm (Fig. 1). Comparisons with modern specimens indicate that the unmodified radius had a length

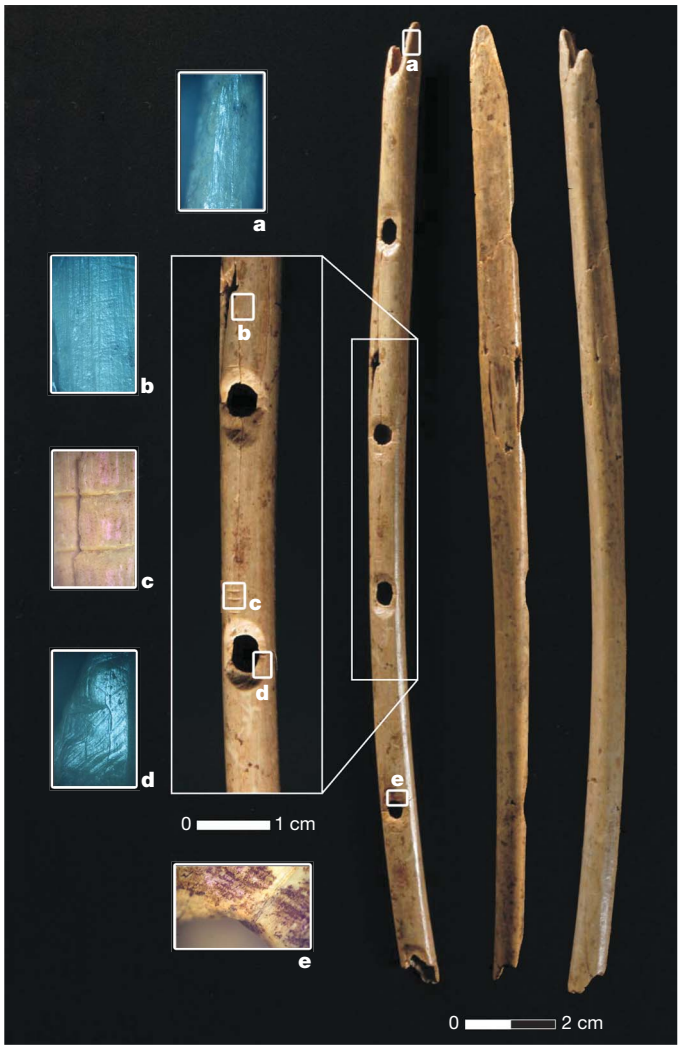

Figure 1 | Bone flute from Hohle Fels archaeological horizon Vb. Photomicrographs documenting striations and notches from manufacture and polish from use: **a**, **b**, **d**, incident-light fluorescence mode (ultraviolet- and violet-light excitation); **c**, **e**, incident light, obliquely crossed polars, λ plate. The photomicrographs were made with a Leica DMRX-MPV SP microscope photometer. The long axis of the micrographs is 2.8 mm long.

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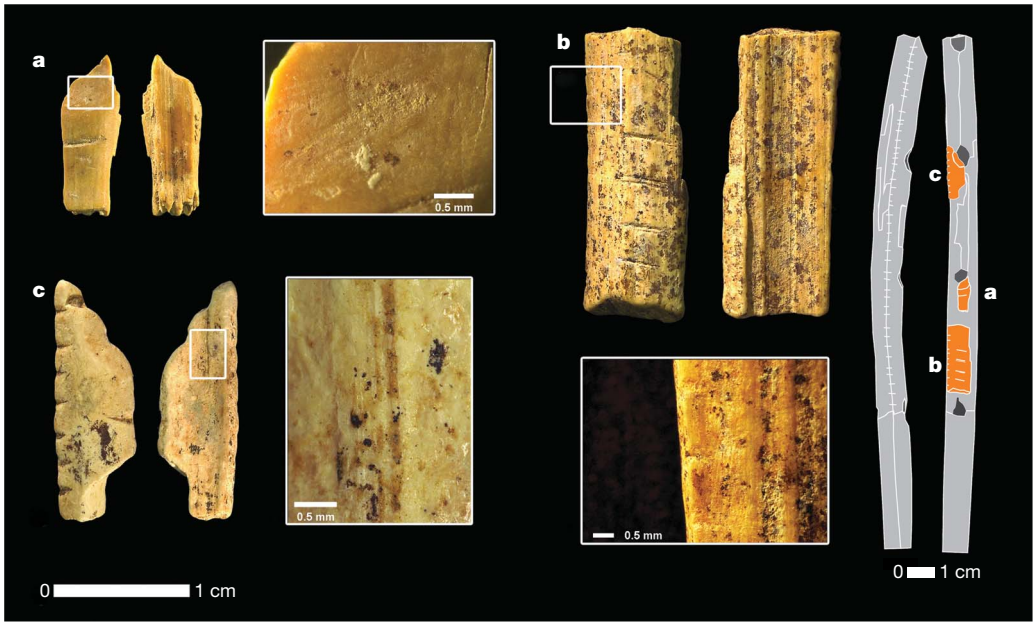

Figure 2 | Fragments of ivory flutes from Hohle Fels and Vogelherd. Photos and micrographs documenting striations and notches from manufacture and polish from use: **a**, Hohle Fels flute 2, from feature 10 of archaeological horizon Va; **b**, Hohle Fels flute 2, from archaeological horizon Vb; **c**, Vogelherd flute 2. Insets show magnified views of the boxed areas in each panel. The image on the right is a schematic superimposition of these finds on the ivory flute from Geißenklösterle; the scale is approximate. The micrographs were made using a Keyence Digital-Mikroskop VHX-500 F with reflected light.

of roughly 34 cm. The surfaces of the flute and the structure of the bone are in excellent condition and reveal many details about the manufacture of the flute. The flute has five finger holes. The maker carved two deep, V-shaped notches into one end of the instrument, presumably to form the proximal end of the flute, into which the musician blew. This end of the flute corresponds to the proximal end of the radius. The other end of the flute is broken in the middle of the most distal of the five finger holes. Several centimetres of the flute are missing from this end. As many as four very fine lines were incised near the finger holes. These precisely carved markings probably reflect measurements used to indicate where the finger holes were to be carved using chipped-stone tools. Only the partly preserved, and most distal, of the five finger holes lacks such markings.

We have not yet been able to produce a replica of the flute, but it is possible that the flute was played by blowing directly into the proximal end without using a mouthpiece. The smaller, three-holed bone flute, made from the radius of a swan, that was recovered from the Aurignacian deposits of archaeological horizon II at the nearby cave of Geißenklösterle can be played by blowing obliquely into its proximal end to produce four basic notes[10–13]. Three additional overtones can be produced by blowing more sharply into the flute. Given that the three-holed flute from Geißenklösterle produces a range of notes comparable to many modern kinds of flute, we expect flute 1 from Hohle Fels to provide a comparable, or perhaps greater, range of notes and musical possibilities[14]. The larger diameter of the bone flute from Hohle Fels would have made its tone deeper than that of the bone flute from Geißenklösterle, and closer to that documented experimentally from a reconstruction of the ivory flute from archaeological horizon II at Geißenklösterle[15].

The 2008 excavations at Hohle Fels also recovered two small fragments of what are probably two ivory flutes from the basal Aurignacian (Fig. 2). One fragment, designated flute 2, is 11.7 mm long, 4.2 mm wide and 1.7 mm thick, and comes from feature 10 at the base of archaeological horizon Va, directly overlying archaeological horizon Vb. The other fragment, which has been designated flute 3, has dimensions of 21.1 mm by 7.6 mm by 2.5 mm and originates from the lowest Aurignacian unit of archaeological horizon Vb. Crew members recovered both finds during water screening. Finds from water screening can be localized to a 10-l volume corresponding to a roughly 3-cm thickness of sediment over an area of 0.25 m^2. Both pieces of worked ivory have been hollowed out and preserve striations from their manufacture on their internal and external surfaces. The fragment of flute 2 includes a portion of a finger hole. The fragment of flute 3 preserves a series of incised lines on the convex outer surface and nine small notches along one of the edges. The greater thickness and larger dimensions of flute 3 relative to flute 2 indicate that the two finds are probably not from the same instrument.

Excavators at Vogelherd in the Lone Valley, 25 km northwest of Ulm, recovered an isolated fragment of another ivory flute, which we designate Vogelherd flute 2, while sorting water-screening samples in the summer of 2008 (Fig. 2). In 2005, we recovered three fragments of a bone flute at Vogelherd, designated Vogelherd flute 1 (ref. 16). The new ivory fragment, which has dimensions of 17.5 mm by 5.8 mm by 1.8 mm, is more heavily weathered than those found at Hohle Fels, and has a hollowed-out form, a partly preserved finger hole and seven small notches along the edge of its long axis.

The characteristics of these three fragments of ivory are known only from the ivory flute from the upper Aurignacian deposits of Geißenklösterle archaeological horizon II (ref. 15). The technology for making an ivory flute is much more complicated than that for making a flute from a bird bone. It requires forming the rough shape along the long axis of a naturally curved piece of mammoth ivory, splitting it open at the interface of the cementum and dentine or along one of the other bedding plains in the ivory, carefully hollowing out the halves, carving the holes and then rejoining the halves of the flute with air-tight seals along the seams that connected the halves of the flute. The ivory flute from Geißenklösterle preserves dozens of finely carved notches along the edges of the two halves to facilitate binding and sealing the flute[15]. Although thousands of pieces of ivory-working debris and hundreds of ivory artefacts have been recovered from the Aurignacian deposits of Hohle Fels, Vogelherd and Geißenklösterle, only the flute fragments have the form described above and preserve a hollowed-out convex morphology, finger holes and series of notches along the edge of the long axis. Thus, we can be confident that these finds represent fragments of ivory flutes similar to the one recovered from Geißenklösterle. We

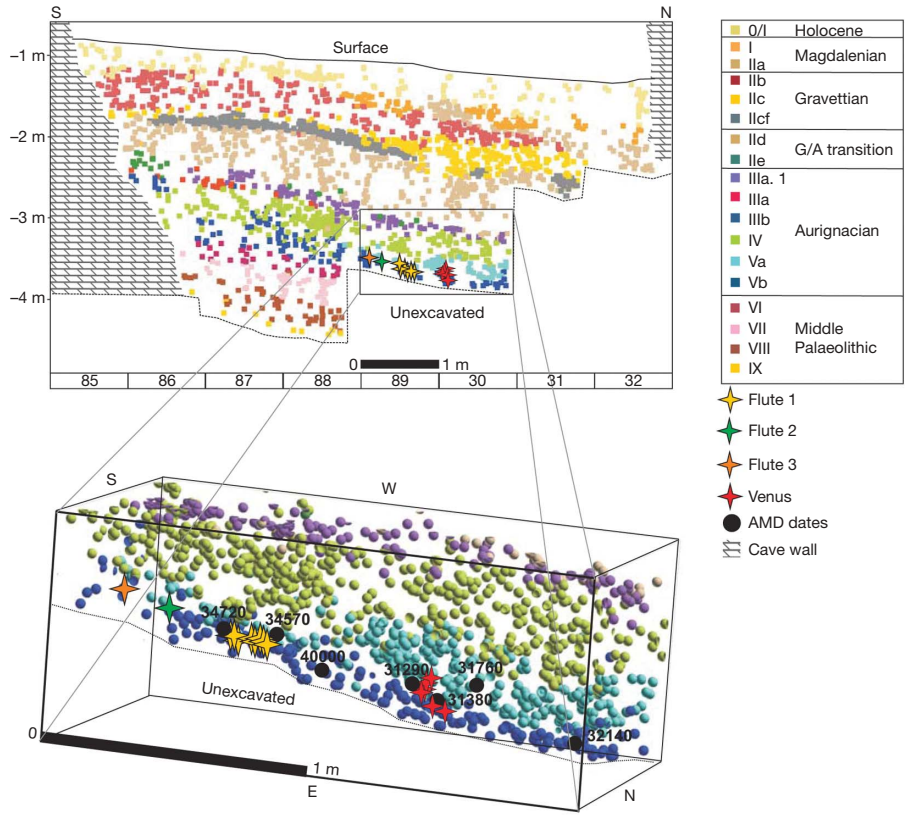

Figure 3 | The stratigraphic positions of flutes 1–3 from Hohle Fels and associated radiocarbon dates. AMS, accelerator mass spectrometry (dates in non-calibrated years before present); Venus, Venus of Hohle Fels[21].

recovered the ivory flute from Geißenklösterle in 31 small fragments. Given the tendency of delicate ivory artefacts to break into many pieces, it is not unusual to find such pieces in isolation.

The issues related to dating the Swabian Aurignacian have been a matter of considerable discussion[9,17–20]. The three flutes from Hohle Fels come from clearly documented archaeological contexts relating to the earliest Upper Palaeolithic occupation at the site (Fig. 3). Flute 2 comes from feature 10, which separates archaeological horizons Va and Vb, whereas flutes 1 and 3 come from the deepest Aurignacian stratum, archaeological horizon Vb. Several dozen radiocarbon dates from the Aurignacian of Hohle Fels have been published[21]. The Aurignacian deposits are roughly 1 m thick and include six distinct archaeological horizons and a dozen intact features. Refitting, micromorphological studies and many archaeological and geological observations indicate that deposits have not experienced significant reworking.

The ten accelerator-mass-spectrometry radiocarbon dates from archaeological-horizon-Va feature 10 and archaeological horizon Vb fall between 31 and 40 kyr ago. The radiocarbon measurements were made on collagen extracted from anthropogenically modified bone or charcoal at the Oxford Radiocarbon Accelerator Unit and the Leibniz Laboratory, Kiel[21]. The bones dated were all well preserved and produced good yields of collagen. The seven dates measured in Oxford were determined using ultrafiltration; the Leibniz Laboratory follows a slightly different filtering procedure[22,23]. Many studies demonstrate that radiocarbon dates before ~30 kyr ago vary owing to factors including differential preservation, differences in sample preparation, taphonomic mixing, fluctuations in levels of atmospheric radiocarbon and imperfect reproducibility in laboratory and measuring procedures. The highly variable radiocarbon signal at Hohle Fels echoes the situation at the well-studied site of Geißenklösterle and many others dating from this period. Although there is at present no universally accepted calibration for radiocarbon dates earlier than 30 kyr ago, available calibrations and independent controls using thermoluminescence and other methods indicate that dates of approximately 32 kyr ago correspond to roughly 36 kyr ago in calibrated years[17,24]. Thus, we can be certain that the flutes from Hohle Fels pre-date 35,000 calendar years ago. The dates from the samples closest to flute 1 are some of the earliest in this series (Fig. 3).

The stratigraphic situation suggests that the flutes from the basal Aurignacian of Hohle Fels date from the initial Upper Palaeolithic settlement of the region, about 40,000 calendar years ago[9,17]. These flutes pre-date the two bone flutes and the ivory flute from the upper Aurignacian at nearby Geißenklösterle[15,21]. The fragments of an ivory

Table 1 | Aurignacian musical instruments from the Swabian Jura

Site	Flute	Archaeological horizon	Cultural group	Material	Number of pieces	Excavated	First publication
Geißenklösterle	1	II	Upper Aurignacian	Swan radius	23	1990	Ref. 10
Geißenklösterle	2	II	Upper Aurignacian	Bird bone, swan size	7	1973	Ref. 10
Geißenklösterle	3	II	Upper Aurignacian	Mammoth ivory	31	1974–1979	Ref. 15
Hohle Fels	1	Vb	Basal Aurignacian	Griffon vulture radius	12	2008	—
Hohle Fels	2	Va. 10	Basal Aurignacian	Mammoth ivory	1	2008	—
Hohle Fels	3	Vb	Basal Aurignacian	Mammoth ivory	1	2008	—
Vogelherd	1	—	Aurignacian	Bird bone	3	2005	Ref. 16
Vogelherd	2	—	Aurignacian	Mammoth ivory	1	2008	—

and a bone flute from Vogelherd are from reworked contexts, but the vast majority of the finds from the site are from secure Aurignacian contexts. Vogelherd has produced the largest Aurignacian assemblage in central Europe, and only modest amounts of material from later Upper Palaeolithic contexts are documented at the site. Numerous radiocarbon dates from the Aurignacian at Vogelherd fall between 30 and 36 kyr ago[25]. The fragment of an ivory flute and the three fragments of a bone flute discovered in 2005, like hundreds of other diagnostic finds from the Aurignacian at Vogelherd, pre-date 30 kyr ago.

Apart from that found in the caves of the Swabian Jura, there is no convincing evidence for musical instruments pre-dating 30 kyr ago. One of the 22 Upper Palaeolithic bird-bone flutes from the important site of Isturitz in the French Pyrenees could be of Aurignacian age, but it was recovered during poorly documented excavations from the early twentieth century[1,6,7]. The other flutes have been attributed to the Gravettian, Solutrean and Magdalenian deposits at the site. The only other musical instrument of roughly comparable age is a bone flute from the open-air site of Grubgraben in the Wachau of Lower Austria, which dates from about 19 kyr ago[8].

Good evidence for both bone and ivory flutes now exists from the Swabian caves of Geißenklösterle, Hohle Fels and Vogelherd. These are the only Palaeolithic cave sites in the region where systematic water screening of all archaeological deposits has been conducted. The other Aurignacian sites in the region were excavated before the 1970s without employing excavation methods appropriate for locating small, highly fragmented finds.

When the discovery of two bone flutes from the Swabian Aurignacian was reported in 1995, these finds seemed to be exceptional and unique[10]. The subsequent discovery of additional evidence for flutes from two more sites brings the total to four bone flutes and four ivory flutes (Table 1). We can now conclude that music played an important role in Aurignacian life in the Ach and Lone valleys of southwestern Germany. Most of these flutes are from archaeological contexts containing an abundance of organic and lithic artefacts, hunted fauna and burnt bone. This evidence suggests that the inhabitants of the sites played these musical instruments in diverse social and cultural contexts and that flutes were discarded with many other forms of occupational debris. In the case of archaeological horizon Vb at Hohle Fels, the location of the bone flute in a thin archaeological horizon only 70 cm away from a female figurine of similar age suggests a possible contextual link between these two finds[21].

The flutes from Hohle Fels, Vogelherd and Geißenklösterle demonstrate that a musical tradition existed in the cultural repertoire of the Aurignacian at the time modern humans settled in the upper Danube region more than 35,000 calendar years ago. The appearance of a musical tradition in the Aurignacian accompanied the development of early figurative art and numerous innovations, including a wide array of new forms of personal ornaments and new lithic and organic technologies[25,26]. The presence of music in the lives of early Upper Palaeolithic peoples did not directly produce a more effective subsistence economy and greater reproductive fitness. Viewed, however, in a broader behavioural context, early Upper Palaeolithic music could have contributed to the maintenance of larger social networks, and thereby perhaps have helped facilitate the demographic and territorial expansion of modern humans relative to culturally more conservative and demographically more isolated Neanderthal populations[27].

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