DOI: 10.17746/1563-0110.2016.44.3.150-157

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An Upper Paleolithic Human Mandible and a First Cervical Vertebra from Afontova Gora II*

The remains (a mandible and an atlas) of two individuals, from the stratified Upper Paleolithic site Afontova Gora II, dating to 16–12 ka BP, are described. The mandible was from a 14–15-year-old female. Certain nonmetric traits indicate its anatomical modernity, and the dimensions are closer to those of modern adolescents than to those of Upper Paleolithic individuals of similar age. In comparison, the mandible of the Předmostí-5 female, while being close in biological age, shows a much greater projective length and a higher and wider ramus. Mandibles of Upper Paleolithic children from Sungir are more robust and show a larger intercondylar width and a higher and wider ramus. The modernity of the dimensions of the Afontova Gora mandible may be due to a diachronic tendency toward gracilization. The dimensions of the atlas suggest that it belonged to a female aged 20–25. However, the paucity of data on first cervical vertebrae from Upper Paleolithic humans makes it impossible to evaluate the taxonomic status of that find.

Keywords: *Mandible, atlas, morphology, Upper Paleolithic, Afontova culture, Afontova Gora II.*

Introduction

Afontova Gora II is one of the most famous Upper Paleolithic sites in Siberia. During rescue excavations carried out in 2014, before construction of a bridge crossing Yenisei River near Krasnoyarsk (Derevianko et al., 2014; Slavinsky et al., 2014), several cultural layers were found at the second and third terraces above the flood-plain. The layers are thought to represent a number of short-term hunting camps. Faunal remains, stone, horn and bone artifacts indicate that the assemblages can be attributed to the Upper Paleolithic Afontovo archaeological culture that existed on Yenisei 16th–12th ka BP.

The atlas, the mandible, and five teeth were found, during works at excavation area No. 24, embedded in the edge of the third terrace in cultural layer 2, associated with the roof of the landslide body. The bones were lying in concordance with the geological layer's slope. Associated archaeological finds included flakes, spalls, and faunal remains. The exceptional preservation of the bone

*Supported by the Russian Science Foundation (Project No. 14-50-00036).

artifacts points towards their rapid archaeologization. The occurrence of skulls of large mammals (reindeer, red deer, and wolf) in the same cultural horizon may imply the way the horizon was formed. The geological body was being formed inside an ancient relief-depression with a seasonal watercourse providing for permanent supply and sorting of sediments (including destruction of blocks of sediments containing artifacts) and a stable water-stand forming iron (II) oxides.

The present study aimed at providing a morphological description, and sex and age determination of the mandible and the atlas.

Fig. 1. The mandible.

Fig. 2. The atlas.

Methods and materials

The mandible and teeth of a young individual were studied. In the right half of the mandible, there were the first and second molars (M_1, M_2) *in situ*, as well as both M_3 molars at the early stage of eruption. Later, we received the isolated left second premolar (P_4) and the first molar (M_1) belonging to the same mandible.

Upon excavating, the mandible was fairly well preserved (Fig. 1). Its body had been subtly deformed *postmortem* transversally by pressure of the soil, which had produced multiple fractures in that direction. During drying, the mandible collapsed into two parts. The fracture line begins from the middle of the right medial incisor socket and passes obliquely, skirting the chin, to the base of the mandible body at the level of space between the right second premolar and the first molar. This fracture through the midline not only allowed correct measurements, but, moreover, helped to avoid the errors usual when measuring a deformed bone.

A comprehensive description of the mandible follows. In addition to its main dimensions, measured according to R. Martin's standard methodology modified after V.P. Alekseyev and G.F. Debets (1964) (see *Table*), the bony relief of the external and internal surfaces was also described. A compilation of published data on infants' mandible measurements relevant to the present study (Alekseyev, 1978: 229, tab. 43) was used as a reference dataset, along with measurements of the Upper Paleolithic skulls Sungir 2 and 3 and Předmostí 5. For interpretation of the bone relief pattern in the individual from Afontova Gora II, we used mostly descriptions of morphological variation in the mandible in modern populations from the dentistry literature (Persin, Elizarova, Dyakova, 2003; Tarasenko, Dydykin, Kuzin, 2013; Tarasenko, Kuzin, Mikoyan, 2014). The age of the individual was determined according to D. Ubelaker's permanent teeth crown formation and eruption scheme (1978: Fig. 62).

Another interesting osteological specimen from Afontova Gora II is a human first cervical vertebra (atlas). The bone is well-preserved, missing only a small part of the right superior articular facet and a piece of supero-anterior part of the vertebral arch. The spongy bone is partially naked here (Fig. 2).

The sex of the individual to whom the atlas belonged was determined using the recommendations of L. Dubreuil-Chambardel, who found substantial sexual differences in width of the atlas (1907); and also the technique developed by E.A. Marino, which involves more dimensions, and provides sex determination accuracy up to 75–85 % (1995). The vertebra was measured following the described methodology (Huggare, 1989, 1991; Huggare, Kylamarkula, 1985a, b; Gómez-Olivencia et al., 2007).

For age determination, the data on ossification-center emergence and fusion in the atlas were used (Schintz et al., 1951; Standards…, 1994).

Morphology of the mandible

The mandible, as an object of paleoanthropological studies, has received undeservedly little attention.

Metric variables and indices of the mandible from Afontova Gora II, and the reference data

Variable	Afontova Gora II		Sungir		Teshik-Tash, 9–10 years (late Pleistocene)	Kostenki XV, 5–7 years (25–21 ka BP)	Kostenki XVIII, 9–11 years (21 ka BP)	Mayak-2, 5–8 years (11–10 ka BP)	Předmostí			Modern children				
	Right part of the mandible	Left part of the mandible	No. 2, boy, 11–14 years (28–23 ka BP)	No. 3, girl, 9–11 years (28–23 ka BP)					No. 2, 6–7 years (27–25 ka BP)	No. 7, 12–14 years (27–25 ka BP)	No. 5, female, 15–16 years (27–25 ka BP)	9–11 years	12–14 years	14–15 years	15–16 years	15–17 years
65. Mandibular condylar width	107.0		113.0	109.0	122.0	88.0	–	–	100.0	101.0	–	99.8	104.1	105.2	106.3	110.2
66. Mandibular angular width	85.0		89.0	87.0	83.0	77.0	95.0	–	76.0	82.0	–	84.2	89.5	89.5	89.5	95.0
67. Mandibular anterior width	45.0		45.0	46.0	50.0	41.0	–	–	–	–	–	–	–	–	–	–
68. Mandibular length from angles	74.0		88.0	74.0	68.0	61.0	–	–	–	72.0	–	61.2	68.1	68.1	68.1	72
68 (1). Mandibular length from condyles	95.0		106.0	88.0	–	81.0	–	–	–	99.0	105.0	–	–	–	–	–
69. Symphyseal height	30.0		35.0	29.0	26.0	25.0	26.0	–	–	–	–	21.5	26.8	26.8	26.8	27.0
69 (1). Mental foramen height	25.5	24.0	26.8	27.2	26.0	23.0	26.0	20.0	–	–	–	21.1	24.2	24.6	25.0	25.7
69 (2). Height at the level of the second molars	22.0	21.4	–	–	–	–	–	–	21.5	–	–	–	–	–	–	–
69 (3). Mental foramen breadth	11.4	11.3	11	11	15	10.5	14.5	12	–	–	–	10.8	11	11.2	11.2	11.2
70. Ramus height	43.0	48.0	57.0	58.0	50.0	42.0	–	46.0	–	51.0	50.0	41.2	43.7	46.2	48.7	52.0
71a. Minimal ramus breadth	33.0	30.0	37.0	34.0	30.0	27.0	–	30.5	–	29.0	37.0	27.3	28.9	29.9	30.8	31.3
79. Ramus inclination angle	124.0	119.0	–	–	–	128.0	–	–	–	–	–	–	–	–	–	–
C. Chin angle	71.0		80.0	69.0	62.5	–	–	–	–	–	–	–	–	–	–	–

Note: The data on Sungir, Teshik-Tash, Kostenki, and Mayak are given after (Gerasimova, Astakhov, Velichko, 2007), data on Předmostí and modern children are given after (Alekseyev, 1978). In the reference data, measurements of both sides of the mandible are combined.

American anthropologist A. Hrdlička, in a comprehensive article, underlined the unique features of the mandible (1940). In his opinion, it is one of the most interesting parts of the human skeleton, from both phylogenetic and ontogenetic points of view. It still plays an important evolutionary role, as shown by its involutive temporal changes. It also demonstrates a strong correlation with the morphology of the upper jaw, and with the rest of the face and cranial base; provides unique information about age changes and sexually dimorphic features; reproduces features of distant ancestors; and is capable of functional adaptation (Ibid.: 281).

Nevertheless, at the present stage of development of physical anthropology, the human mandible receives close attention only in an evolutionary context, and mainly from the point of view of anatomical elements related to speech. Important information about interspecific differentiation of *Homo sapiens*, which can be obtained by studying mandibular morphology, is only superficially used by craniologists. While data on the size and shape of the adult mandibles are usually published, the morphological descriptions rarely include information on either bone-relief or asymmetrical variation. Juvenile individuals are mostly ignored, since typological complexes are usually described for the *adultus-maturus* age cohort. Owing to this fact, information about ontogenetic changes in the size and shape of the mandible, and the position of the nutrient foramina, canals, and tuberosities, is almost absent in the paleoanthropological literature.

Determination of age. The age of a buried individual can be reliably determined via the status of the dentition. In this case, all permanent teeth have emerged (excluding the third molars that exhibit the stage of leaving the socket, which usually occurs at about 15 years of age). The root of the second premolar is fully formed, which is typical of 15±3 years of age (Ubelaker, 1978: Fig. 62), i.e. 12–18 years. Taking into account the absence of attrition at the occlusal surface of the crown, and the weak development of the distal contact facet, it is possible to limit the biological age of the individual to the period between 14 to 16 years of age. The roots of the first molars are also fully formed. The initial stage of dental attrition is observed in both teeth: a subtle polishing of the cusp apices, and attrition of some small elements of the cusps. At the apex of the protoconid of the right tooth, there is a barely visible spot of naked dentine. The dental status described above is usually observed in modern populations at the age of 14–15. This age determination is further confirmed by absence of attrition of the second molars that also display fully formed roots. Summing up, basing on the status of the dentition, an age of 14–15 years can be assigned to the individual.

Determination of sex. The mandible morphology can be used as a criterion for assessing the sex of a specimen. Growth of the mandible generally ceases after full eruption of the permanent dentition. Thus, the size of the Afontova Gora II mandible can be considered close to the typical size in the population to which the individual belonged. The combination of apparent gracility of the mandible with fairly developed attachment site of the mimic musculature may indicate that the individual was of female sex.

Metrics of the mandible. Our opinion on the sex of the individual is further confirmed by the metric characteristics of the mandible (see *Table*). In this connection, it is notable that reference data for that age cohort (14–16 years), which could be used for statistical analysis, are very scarce in the literature. Adult mandibles cannot be used for this purpose. Though growth of the studied mandible is almost complete, it cannot be compared directly with adult mandibles, since the final shape of the mandible is affected by functional masticatory adaptation between 16–18 and 30–35 (*adultus*) (Alekseyev, Debets, 1964) years of age (Holmes, Ruff, 2011).

The studied mandible is markedly asymmetrical (see *Table*): the left ramus is 5 mm taller, 3 mm narrower, and has a smaller angle of inclination as compared to the right side. All measurements of the body are greater on the right side. While asymmetry of the mandibular body could have been compensated during functional adaptation to masticatory loading, the asymmetry of the ramus would probably not have changed, and would have remained the same for the rest of the individual's life.

The transverse (condylar and angular widths) and sagittal (lengths from the condyles and angles) measurements of the mandible (see *Table*) are typical of modern adolescents at the age of 14–17*. The mandibular body is a bit more massive and the ramus is wider as compared to the modern sample.

The mandible from Afontova Gora II differs substantially from the Upper Paleolithic specimens from Sungir 2 (boy, 11–14 years) and 3 (girl, 9–10 years). The latter display a greater condylar width and a taller and wider ramus. The mandible of the Neanderthal boy from Teshik-Tash differs even more from the studied specimen, in the same dimensions but to a greater extent (even taking into account the interspecific differences—absence of the chin and a smaller angle of protrusion of the chin). The Předmostí 5 mandible (Czech Republic), while being similar in terms of age and sex, displays a much greater projectional length from the condyles, wider and taller ramus. As the specimens from Sungir and Předmostí are dated to the 28–23 ka BP, some 10 thousand years before Afontova Gora II, the above-

*Unfortunately, these modern reference data were published for both sexes combined (Alekseyev, 1978: 229, tab. 43).

mentioned differences can be explained by the secular trend towards gracilization of the mandible, which in the studied individual has almost reached the modern level.

Macroscopic anatomical features. On the inner surface of the mandibular body, there is a groove in the medial plane preserved at the location of synostosis of the two parts of the mandible. The groove forms in the first year of postnatal life. The mental spine (*spina mentalis*) displays a complex morphology: its upper part appears as a tuberosity with a large nutrient foramen, while the lower part forms a well-defined tubercle (Fig. 3, *a*). In modern mandibles, the foramen is observed in 100 % of cases when the frontal teeth are present (Tarasenko, Dydykin, Kuzin, 2013); its location varies, but in most cases it is found in the upper part of *spina mentalis* (Gladilin, 2013: 74). There is also a prominent nutrient foramen in the left part of the mandibular body, just lateral from the digastric fossa (Fig. 3, *b*).

The fossae (*fossa digastrica*) are well-pronounced, which points to a strong development of their anterior venters. There are enthesopathies on the surfaces of the fossae—traces of sub-pathological bone-reaction in the muscle and connective tissue attachment-sites (Fig. 3, *c*). The etiology of the enthesopathies is not clear, owing mainly to the absence of reference data on normal variation of *fossa digastrica*.

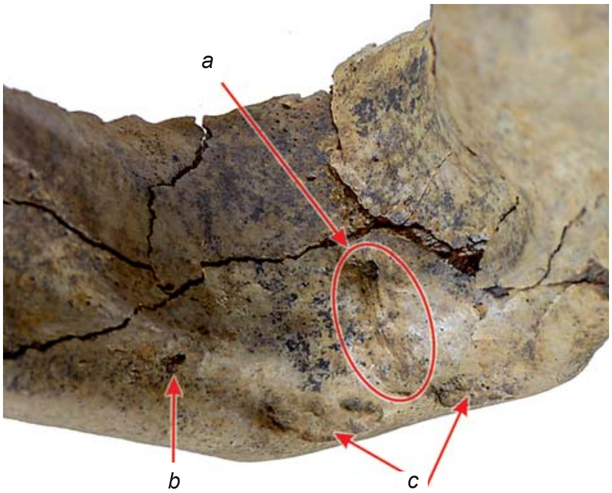

Fig. 3. Internal surface of the body of the mandible.
a – mental spine; *b* – supplementary nutrient foramen;
c – digastric fossae.

The sublingual fovea (*fovea sublingualis*) (the lodge of the sublingual salivary gland) is substantially wider, deeper, and subtly porous in the right part of the mandible. The left submandibular fossa (*fovea submandibularis*), in which one of the salivary glands (submandibular) is also lodged, displays some porosity as well.

The mylohyoid line **(***linea mylohyoidea*), the lodge of the mylohyoid muscle (*m. mylohyoideus*), is weakly pronounced and asymmetrical. On the left side, it shows a ridge-like appearance, and it is disrupted at the level of the roots of the first molar. A disruptive pattern of this structure in modern mandibles is observed in 16 % of cases (Ibid.: 39). On the right side, the line is continuous, and in its lower parts it appears as a tuberosity; such morphology is observed in 48 % of modern specimens (Ibid.).

The attachment-sites of the medial and lateral pterygoid muscles involved in mastication also show asymmetry. The tuberosity of the medial pterygoid muscle (*tuberositas pterygoidea*) on the inner (lingual) surface of the mandibular angle is substantially more pronounced on the right side. The pterygoid fovea (*fovea pterygoidea*), the attachment site for the lateral pterygoid muscle, is also strongly expressed in the left condylar process neck. One-side contraction of these muscles moves the mandible to the right, and it is thus probable that the individual preferred chewing by the right side.

The mandibular foramina *(foramen mandibulae)* (Fig. 4), through which the nerves and vessels enter the mandible, are very large, just like the corresponding *lingula mandibulae.*

The mandibular torus *(torus mandibularis)* is weakly developed. The mental protuberance (*protuberantia*

Fig. 4. The mandibular foramina.

Fig. 5. Area of the mental protuberance of the mandible.

mentalis) and the mental tubercles *(tuberculum mentale)* are well-defined but asymmetrical—the right one is developed better (Fig. 5). They are separated from the main part of the body by fairly deep fovea, of which the left is strongly pronounced and has two small nutrient foramina. The mental foramina (*foramen mentale*) are oval-shaped, and reside in the spaces between the first and second premolars, which is the predominant pattern in modern populations. The external oblique line (*linea obliqua*) is mildly expressed in both sides of the mandible. It starts (in projection view) from the middle of the first molar socket, and does not reach the mental foramen.

The masseteric tuberosity (*tuberositas masseterica*), the masseter's attachment site on the external surface of the mandibular angle, is moderately expressed on both sides. The angles are weakly expanded outwards. The attachment sites of the temporal muscles *(m. temporalis*) are moderately pronounced on both sides. Contraction of both muscles results in elevation of the mandible, and in the individual from Afontova Gora II they were functioning symmetrically, in contrast to the muscles moving the mandible in the transverse direction.

Morphology of the atlas from Afontova Gora II

Macroscopic anatomical features and determination of age. The anterior tubercle of the atlas is fairly large, while the posterior tubercle is weakly developed. Behind the superior articular surfaces, there are marked grooves for the vertebral arteries. The transverse foramina are single.

The *fovea dentis* is of oval shape, and the long axis of the oval goes parallel to the anterior arch. The superior articular surfaces are smooth, and the left is divided into two parts by a groove. The tuberosity of the transverse ligament attachment site is pronounced moderately. On the inferior articular surface, subtle traces of porosity are observed. There is also marginal lipping up to 1 mm around the articular surface of the *fovea dentis*, superior and inferior articular surfaces.

On the basis of the timing of the appearance of ossification centers and fusion of the atlas, an age of 20 or more years was assigned to the individual. The complete fusion of the epiphyses of the transverse processes to the vertebral body, which is observed in the atlas from Afontova Gora II, usually occurs at this age and during the following several years (Schintz et al., 1951). Additional confirmation of the above is a complete fusion of the inferior epiphyseal ring of the vertebral body, which typically starts at 17–19 and finishes by 25 years of age (Buikstra, Gordon, St. Hoyme, 1984). The marginal lipping around both superior and inferior articular surfaces of the vertebra also indirectly points to the same age. Summing up, the individual was 20–25 years old or older.

Metrics of the atlas and determination of sex. Unfortunately, there is still a lack of solid reference data on the atlas metrics of Paleolithic *Homo sapiens*, and this makes applying statistical methods of comparison complicated. Accumulation of such data in future will help to integrate the morphology of the atlas from Afontova Gora II in the context of Paleolithic variation of this vertebra. Measurements of the atlas follow (in mm):

Maximum dorsoventral diameter (MaxDVDi)	39.4
Maximum transverse diameter (MaxTrDi)	67.0
Superior transverse diameter (SupTrDi)	47.3
Inferior transverse diameter (ITrDi)	41.9?
Canal dorsoventral diameter (M10)	30.3
Canal transverse diameter (M11)	26.3
Distance between the tuberosities for attachment of transverse ligament (DtTubTrLg)	17.3
Maximum craniocaudal diameter of the anterior tubercle (MaxCrCdDiAntA)	10.5
Maximum dorsoventral diameter (thickness) of the anterior tubercle (MaxDVDiAntTub)	5.7
Maximum transverse diameter for the facet for the dens (MaxTrDiFaDn)	11.0
Maximum craniocaudal diameter (height) of lateral mass (MaxCrCdDiLMa)	17.4
Maximum craniocaudal diameter of posterior tubercle (MaxCrCdDiPTub)	6.8
Maximum dorsoventral diameter of the posterior tubercle (MaxDVDiPTub)	3.1
Craniocaudal diameter of the groove for the vertebral artery (CrCdDiGr)	6.4
Upper articular facet: sagittal diameter (UFaSgDi)	22.7
Upper articular facet: transverse diameter (UFaTrDi)	11.7
Lower articular facet: sagittal diameter (LwFaSgDi)	13.8
Lower articular facet: transverse diameter (LwFaTrDi)	13.1

The sex of the individual can be reliably determined according to its dimensions. The maximum transverse diameter is 67.0 mm, and this is in the range typical of females (65–76 mm) and above the lower limit for males (74–90 mm) (Dubreuil-Chambardel, 1907).

We also used E.A. Marino's method for sex determination (1995), which is based on multiple regression and discriminant analysis of eight metric variables of the atlas: if the values of functions are ≥ 0.5, the individual should be assigned female sex, and if it is < 0.5, male sex. In our case, we obtained values higher than 0.5, and so we can be confident that the individual was a female.

Conclusions

The skeletal remains found during excavation of the Afontova Gora II site represent two individuals. The study of the mandible lead us to the conclusion that it belonged to an adolescent girl 14–15 years old. Many morphological features of the mandible (complex morphology of the mental spine and a large nutrient foramen in its upper part, weak development of the mandibular torus, well-defined mental protuberance and the mental tubercles, shape and development of the mylohyoid line) are typical of modern human mandibular morphology. The metrics of the mandible from Afontova Gora II are closer to those of modern adolescents than to those of the Upper Paleolithic specimens. The Předmostí 5 mandible, while being similar in terms of age and sex, displays a much greater projectional length from the condyles, and a wider and taller ramus. The specimens of younger biological age from Sungir are more massive, and show a greater condylar width and a taller and wider ramus. As the burials in Sungir and Předmostí are some 10 thousand years older than the layer in Afontova Gora II in which the mandible was found, the above-mentioned differences can be explained by the secular trend towards gracilization of the mandible, which in the studied individual has almost reached the modern level.

According to the metrics of the atlas, the sex of the second individual can was definitely female. The fusion of most parts of the atlas to its body and a marginal lipping around articular surfaces of the vertebra suggest an age for the individual not less than 20–25 years. A lack of solid reference data on the atlas metrics from Paleolithic *Homo sapiens* makes applying statistical methods of comparison complicated. Accumulation of such data in future will help to integrate the morphology of the atlas from Afontova Gora II in the context of Paleolithic variation of this vertebra.

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Received June 18, 2015.
Received in revised form December 14, 2015.