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The Krapina Occipital Bones

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Abstract

The Krapina fossils are the largest collection of Neandertals known, representing a unique opportunity to examine Neandertal variation at a single place and time. Because of the nature of the assemblage, knowledge about the collection as a whole must be obtained from the analyses of the individual skeletal elements. In this work I present a summary of a subset of the Krapina fragments, the occipital remains. I review their variation and briefly discuss them in the context of Neandertal posterior cranial vault anatomy.

INTRODUCTION

Hominid remains from Krapina were first noted by Gorjanović-Kramberger in association with extinct animals on Husnjak Hill on August 23, 1899, four years after receiving samples of extinct fauna from Josip Rehoric, a local school teacher. Gorjanović's ensuing excavation was remarkably well executed and a good record exists of his day-by-day progress in his notebooks and journals, housed at the Croatian Natural History Museum *(1)*. Additionally, the provenance of the specimens was documented both on paper and on the bones themselves. Level numbers were inscribed on the bones although spacial distribution within the levels was not addressed.

The cultural strata, entirely Mousterian by all descriptions, were designated levels 1 through 9, and a large collection of hominid material was excavated and described by Gorjanović. The vast majority of the hominid material derives from level 3/4 termed the *Homo* zone by Gorjanović, although remains are documented from all of the cultural levels at Krapina. According to Rink and colleagues *(2)*, ESR and U-series analysis suggest a date of approximately 130,000 years for the *Homo* zone, indicating that the site is within oxygen isotope stage 5e. These authors argue that this occupation of the rock shelter may have spanned no more than 20 kyr.

Krapina is an exceptional site because of the number of individuals represented. More than 14 Neandertal burials are suspected *(3)* and the remains may comprise more than 70 individuals *(4)*. Therefore, Krapina is one of the richest Neandertal sites known, a potential treasure trove of information about Neandertal variation, demography and life history. However, the remains were not preserved as discrete burials and there is no clear association between different skeletal elements making it difficult to isolate individuals. Because the collection is so fragmentary, it is organized by skeletal element, and therefore its analysis is complicated. A complete understanding of the variation and demography of the site as a whole must be reconstructed from the compiled analyses of the individual skeletal elements.

In this work I present a summary of a subset of the Krapina fragments, the occipital remains. I review their variation and briefly discuss them in the context of Neandertal posterior cranial vault anatomy.

PRESERVATION

There are 34 occipital elements from Krapina. Most are fragmentary, consisting of less than half of the occipital bone, and their preservation is noted in Table 1. The system of numbering, the alternative catalog designations for many of the specimens, and the specific fragments involved in the cranial reconstructions, follow from Radovčić *et al.* *(5)*, as subsequently modified (*(6)* Table 1).

TABLE 1

Inventory of the Krapina Occipital Bones.

Specimen Number	Preservation (planes present)	Age
2	Relatively complete	Juvenile
3	Right nuchal plane	Adult
5	Relatively complete	Adult
6	Right side	Adult
8	Left nuchal plane	Adult
9	Left nuchal, some occipital	Adult
10	Left nuchal, occipital	Adult
11	Left occipital, some nuchal	Adult
12	Relatively complete	Juvenile
13	Left nuchal plane	Adult
15.1	Right condyle	Adult
15.2	Left condyle	Adult
18.1	Left nuchal plane	Adult
18.2	Right occipital and nuchal	Adult
18.3	Right nuchal	Adult
18.4	Left nuchal, some occipital	Juvenile
18.5	Left occipital plane	Adult
18.6	Right nuchal plane	Adult
18.8	Left nuchal, some occipital	Adult
18.9	Medial nuchal plane	Adult
18.11	Right nuchal plane	Adult
18.12	Left nuchal plane	Adult
18.17	Left nuchal plane	Adult
18.18	Left occipital plane	Juvenile
18.19	Right asterion	Adult
18.20	Right occipital and nuchal	Adult
18.21	Left nuchal, f. magnum	Adult
18.22	Left nuchal, some occipital	Adult
18.23	Left asterion	Adult
18.24	Left occipital plane	Adult
18.26	Occipital plane	Adult
18.28	Left occipitotemporal	Adult
34.8	Left parietoccipital	Adult
39.3	Left occipitotemporal	Juvenile

GENERAL MORPHOLOGICAL PATTERN

While there is variation in the occipital fragments as discussed below, the Krapina occipitals conform to a morphological pattern common in the posterior cranial vaults of Neandertals. Constituents of this pattern and other aspects of fossil hominid occipital morphology have been described by many workers *(7–12)*. As described in Caspari *(13–15)*, this pattern is composed of a coordinated suite of features on both the occipital and nuchal planes. On the nuchal plane, it involves the predominance of the *semispinalis capitis* insertions, and on the occipital plane it involves transversely broad lambdoidal flattening, a weak, bilaterally arched transverse occipital (or nuchal) torus, and a suprainiac fossa.

This is part of a broader posterior cranial vault complex that includes the parietal and temporal bones as well. A component of this complex is low and poorly defined parietal eminences which represent the anterior and lateral extent of lambdoidal flattening. Parietal eminences are poorly defined because of the general, even, curvature of Neandertal crania; it is often difficult to isolate the point that divides superior and lateral surfaces. Lambdoidal flattening is often extensive in Neandertals in both the transverse and anteroposterior dimensions, occurring broadly across the posterior cranial vault, and often extending from the parietal eminences anteriorly, over much of the occipital plane of the occipital bone posteriorly. When lambdoidal flattening encompasses most of the occipital plane, it renders a short posterior aspect to the cranium (Figure 1). Therefore, many Neandertals have short posterior »faces« on the occipital bone. This posteriorly facing aspect of the occipital is dominated by the transverse occipital torus and the suprainiac fossa.

The sides of the skull, inferior and posterior to the parietal eminences, angle infero-medially from the eminences curving inward above the mastoid process. This contributes to the rounded appearance of Neandertal skulls in *norma occipitalis* (Figure 1). As depicted in Figure 1, the width of the lambdoidal flattening reflects the width of the top of the skull, which is widest at the parietal eminences and then tapers back. Crania with particularly wide areas of lambdoidal flattening have more area on the roof of the vault, and relatively less on the sides. Thus, the lateral extent of lambdoidal flattening influences many relevant features of the posterior cranial vault, and is a critical factor discriminating Neandertals from the non-Neandertal Early Upper Paleolithic Europeans that follow them in time in Central Europe.

Although occipital bunning is frequently considered a unique Neandertal characteristic, it is actually not a feature that distinguishes Neandertals from non-Neandertals. Occipital bunning refers to a morphological complex

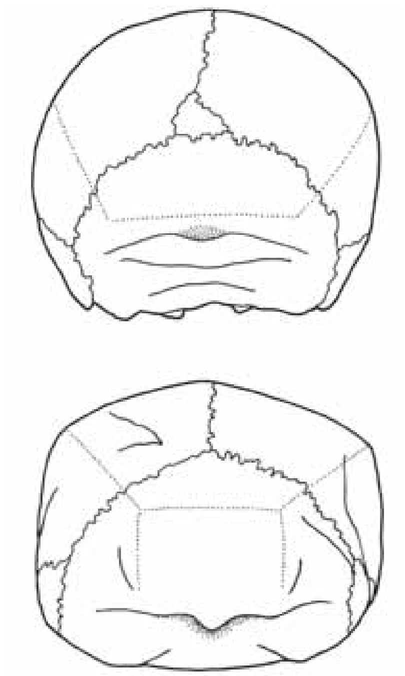

Figure 1. *General Occipital Morphology. Neandertal (above) and early Upper Paleolithic non-Neandertal occipital patterns in* norma occipitalis. *The Neandertal pattern (above) includes extensive lambdoidal flattening both transversely and anteroposteriorly, extending well onto the occipital bone. The parietal eminences are low and in an anterior position; below them, the walls curve medially demonstrating the rounded contour characteristic of many complete Neandertal crania. The posteriorly facing aspect of the occipital plane (above the superior nuchal line) is short and dominated by a bilaterally developed transverse occipital torus and a suprainiac fossa. The pattern of lambdoidal flattening results in transversely broad occipital buns when they occur. The early Upper Paleolithic pattern (below) includes less lambdoidal flattening, both transversely and anteroposteriorly, rarely extending low on the occipital plane. Therefore the posteriorly facing aspect of the occipital bone is taller. This pattern results in tall, medially situated occipital buns when they occur. See text for further discussion.*

consisting of posterior bulging of the occiput coupled with varying degrees of lambdoidal flattening *(16)*. It affects the contour of both internal and external tables, and is thus not a part of any cranial buttressing system that involves thickened vault bone. Rather, buns reflect internal cranial shape. Bunning has been described by Trinkaus and Le May *(17)* as a posterior projection of the occipital squama, »evenly rounded in norma lateralis« and compressed craniocaudally. Trinkaus and LeMay argued that bunning is dependent on the timing of brain growth relative to the development of the vault bones. According to their model, bunning results when additional cerebral expansion occurs after cranial bones attain their adult curvature. Post-natal brain growth is largely posterior, and the additional osteogenesis associated with this cerebral expansion occurs along the still-open lambdoidal suture. According to their model, this creates bunning because when the new bone is laid down horizontally, it sharply contrasts with the curvature of the parietal and occipital squama, causing the »lambdoidal depression« uniquely associated with bunning.

Many non-Neandertals exhibit occipital bunning, and some Neandertals do not have occipital buns. Rather, the features discussed above (lambdoidal flattening and the position of the parietal eminences) influence the *shape* of occipital buns, so that the Neandertal form of bunning, when it does occur, appears unique. Figure 1 contrasts the Neandertal pattern with that of Early Upper Paleolithic associated Europeans, in this case from Mladeč. Both specimens have occipital buns (occipital buns are common in modern humans as well as Neandertals), but the different pattern of lambdoidal flattening and the position of the parietal eminences, render the occipital bun in the Upper Paleolithic pattern taller and more medially situated than in Neandertals.

The Neandertal pattern of posterior cranial vault morphology, (i.e., extensive lambdoidal flattening, short sides and posterior aspect of the cranial vault) is associated with distinctive occipital bone morphology. On the nuchal plane, *semispinalis capitis* insertions are well marked and laterally extensive while the superior nuchal line is poorly developed. On the occipital plane, a weak nuchal torus and suprainiac fossa define the posterior aspect of the cranial vault. I have suggested that the morphology of the different portions of the posterior cranial vault are interrelated, with the pattern of muscle insertion coupled with the unique shape of Neandertal crania accounting for the Neandertal pattern of torus development and suprainiac fossa formation *(13–15)*.

The Krapina occipitals conform to the Neandertal pattern described above. The more complete crania exhibit the lambdoidal flattening, short posterior aspects of the occipital that are defined by the transverse occipital torus and the suprainiac fossa, and nuchal planes with wide *semispinalis capitis* insertions. The superior nuchal lines are weakly developed. The fragmentary occipital pieces are more or less uniform regarding aspects of this pattern as well. Most fragments preserve aspects of the nuchal plane; those that encompass the asterionic region confirm the lateral extent of the *semispinalis capitis* insertions, and those that preserve the medial parts of the bone have well delineated suprainiac fossae associated with weak transverse occipital tori, which define the posterior aspect of the occipital bone. Nevertheless there are features that vary on the occipital bones from Krapina which provide information about the age, sex and number of individuals represented.

VARIATION

Size

Because the Krapina occipitals are so fragmentary, there are few landmarks preserved and therefore few opportunities for standard size comparisons. Table 2 presents their dimensions compared to later Central European Neandertal occipitals, those from Vindija and Salzgitter-Lebenstdt. Only two Central European Neandertal fos-

TABLE 2

Selected Occipital Dimensions for Upper Pleistocene Hominids.

	Occipital Plane Length	Nuchal Plane Length	Half-Breadth to Asterion[1]	Biasterionic Breadth
Krapina 2 (juvenile)	59.6	42.0	68.6	120.7
Krapina 12 (juvenile)			63.7	110.5
Krapina 5	62.3		71.5	124.6
Krapina 6			66.8	119.9
Krapina 8			67.7	
Krapina 18.2			59.5	
Krapina 18.5	54.6			
Krapina 18.11			64.5	
Vindija 299			61.0	
Vindija 301		44.0	58.0	
Salzgitter-Lebenstedt	60.5	42.1	66.2	122.0
Western Neandertal Female				
Mean (n)	59.0 (6)	45.6 (3)	69.3 (5)	115.1 (5)
Range	51.0–65.0	42.1–47.6	64.0–74.0	108.5–122.0
Western Neandertal Male				
Mean (n)	64.9 (6)	44.5 (3)	72.4 (4)	125.4 (5)
Range	58.0–68.2	41.0–46.9	67.0–76.0	123.0–129.0

[1] Taken from the highest position of the superior nuchal line, as projected to the midline.

sils preserve the full length of the nuchal plane, the inion-opisthion dimensions (Table 2). These are Salzgitter-Lebenstedt (42.1 mm) and Krapina 2 (42.0 mm). Both of these fall at the low end of the Western European Neandertal range for this dimension (mean of 45.1 mm, range 41.0 – 47.6 mm for 6 specimens), but Krapina 2 is a juvenile. While small size may reflect the young age of Krapina 2, the Salzgitter-Lebenstedt specimen is fully adult and quite robust. Among adults from Krapina, there is considerable variation in size in comparable dimensions that likely reflects sexual dimorphism. Occipital bone thickness, another measure of size, is discussed below under morphology because it was treated categorically rather than metrically. Metric comparisons of thickness are difficult because so few specimens preserve the same points; as discussed below, only thickness at asterion can be compared metrically and this can be a misleading metric because of the confluence of the transverse sinus and asterion in some, but not all, specimens. Nevertheless, relative thickness is an important aspect of occipital bone variation.

Morphology

There are a number of features of these occipital fragments that vary systematically, depicted in Figures 2 and 3: thickness of the bone, the size of the transverse occipital torus, the morphology of the bone surface under diffuse areas of muscle attachment, the morphology of the suprainiac fossa, the development of muscle markings under restricted attachments (i.e., along the superior nuchal line), the morphology of the inferior nuchal line and the fusion of ossicles or extrasutural bones. Some of these features vary with sex and/or age; others may reflect variation in habitual loading and other factors. In this summary, emphasis is placed on variants that may provide information about relative age or sex, necessary for estimating number of individuals as well as other demographic parameters. The occipitals were seriated and scored for each of the morphological traits listed above; these are discussed in more detail below.

Variants for 7 cranial features:

1. **Thickness:** The Krapina occipitals were seriated by thickness of the bone, based on visual inspection. Where possible the observations were supported by measurements *(15)*. It was difficult to compare these specimens metrically, however, since the only common landmark preserved is asterion. Since asterion is sometimes, but not always, associated with muscle markings for (*splenius capitis and sternocleidomastoid)*, and internally, the ridge marking the transverse sinus, measurements may not reflect cranial thickess alone. Therefore seriation and categorization into thin, medium and thick categories was more reliable. Homology is maintained by observing the region rather than a specific point. Specimens were assigned scores of 1, 2 or 3 (thin, medium or thick), sometimes with + or – designations. When combined with other factors discussed below, thickness may be one indicator of relative age.
2. **Size of the transverse occipital torus:** In this study, size reflects the projection of the torus, not its height. Torus size was scored as small (1), medium (2) and large (3). These were seriated and some +/– designations were additionally used to reflect smaller differences between specimens.

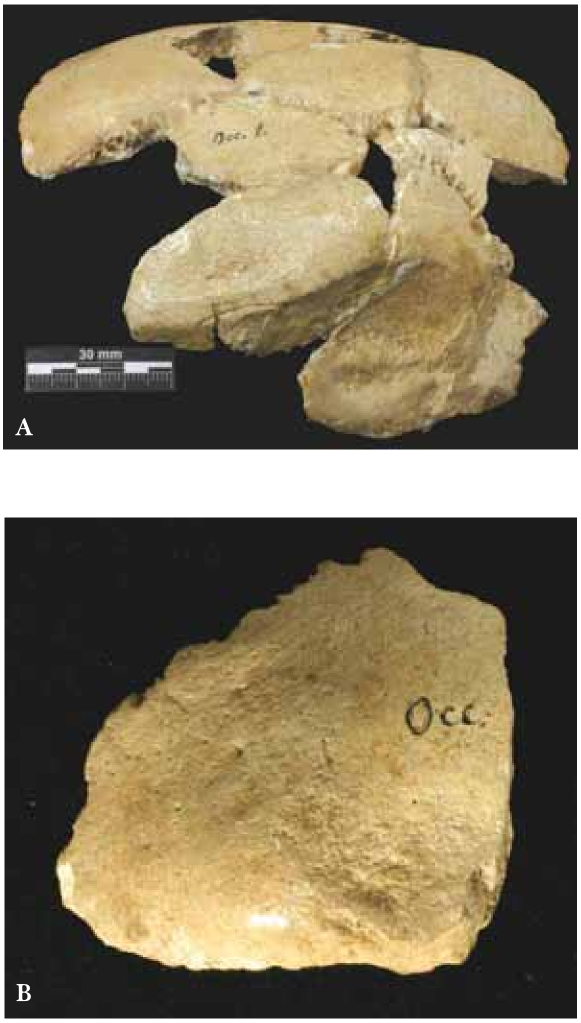

Figure 2. *Adult Occipital Bones. Depicted are relatively complete and more fragmentary adult occipital remains: Krapina 5 (A), a large, relatively complete male posterior cranium, and 18.5 (B), an occipital plane fragment with suprainiac fossa that is probably female. Krapina 5 is the best preserved adult male in the collection, with thick cranial bones, well developed transverse occipital torus and relatively well developed superior nuchal line. Note the well defined* **semispinalis capitis** *insertions; however, neither the muscle marking, nor the suprainiac fossa is strongly pocked. Krapina 18.5, is considered female because of its small size; however, it has thick bone, and a well developed superior nuchal line medially. Its suprainiac fossa is slightly more pocked than that of Krapina 5 and has a less elliptical shape. See text for details.*

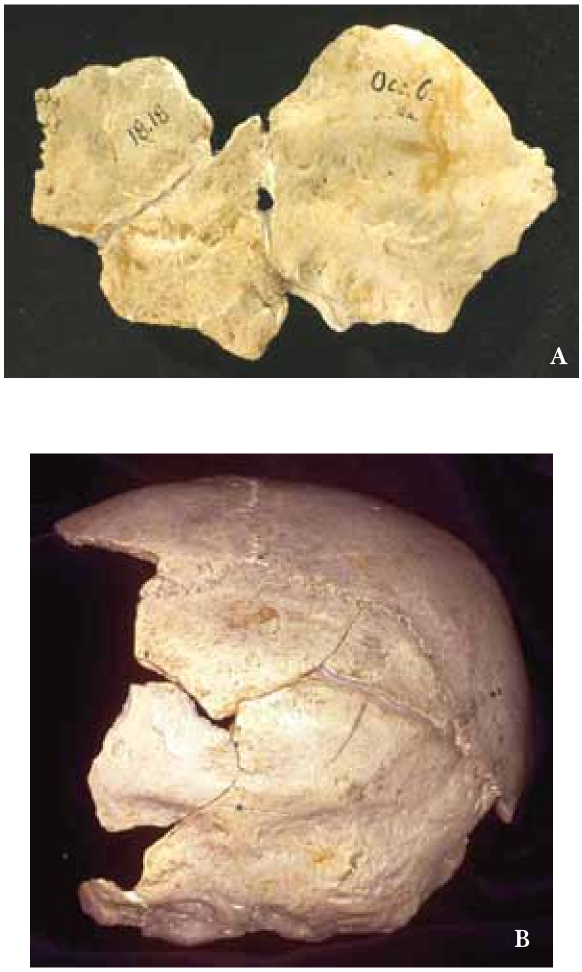

Figure 3. *Juvenile Occipital Bones. Juvenile occipitals Krapina 12 (A) and Krapina 2 (B). Juvenile crania are thin with well defined and »pocked« suprainiac fossae. Krapina 12 is likely a constituent of Krapina 1 (23), between 6–8 years old. Krapina 2 is somewhat older. Although large metrically, its occipital bone is thin.*

3. **Muscle markings (restricted attachments – rugosity of the superior nuchal line):** Specimens with strong superior nuchal lines were scored as 1, with an indication of whether it was medial (under insertions for *trapezius* and the *ligamentum nuchae*) or lateral (under *sternocleidomastoid* and *splenius capitis*). Weak expression was scored 0. The morphology was scored if it showed any extra periosteal deposition or signs of strain, or if the *tuberculum linearum* was apparent.

4. **Muscle markings (diffuse attachments – degree of »pocking«):** This trait reflects the morphology of the bone under areas of diffuse muscle attachment, in particular, *semispinalis capitis*, the major contributor to second layer nuchal musculature. The bone surface under these attachments varies in rugosity; here, rugosity is expressed as a roughened, pocked surface that reflects resorption, a reaction to strain caused by muscles that have diffuse attachments. In contrast, strain generated by restricted attachments results in deposition *(18)*. Pocking was scored from 0–3, where 0=no scars at all, 1=trace, 2=medium, 3=strongly pocked.

5. **The suprainiac fossa (degree of pocking):** The suprainiac fossa is also a surface that reflects resorption and is variably pocked. It has been suggested that it is a byproduct of remodeling associated with the development of cranial shape and transverse occipital torus formation *(13, 14)*. Fossae were scored from 1–3, where 1 represented very few or no scars, 2, scattered scars and 3, considerable pocking.

6. **The inferior nuchal line:** The inferior nuchal line presents as a line between second and third layer nuchal muscle insertion areas. Since these muscles have diffuse attachments, their insertion areas are depressed having undergone resorption, and the region between them stands out as a raised line of bone. The aspect of the inferior nuchal line scored here actually represents morphology just above the superior border of the inferior nuchal line, on the inferior edge of the *semispinalis capitis* insertion. This trait reflects rugosity. In some individuals there is an indented line, or what I have described as a »knit groove,« likely caused by Sharpey fiber insertions. It was scored from 0–3, where 0=absent, 1=weak, 2=medium and 3=strong.
7. **Ossicles:** Extrasutural bones are very common in this sample. They are also commonly found in other Neandertal crania such as Saccospastore 1 *(19)* Over half of the scored fragments exhibit them, and it is likely that their absence in some others is due to preservation. While most of the occipital fragments provide little information about sutural closure, different degrees of ossicle fusion may reflect relative age. Many of the ossicles are unfused or are only represented by »holes« along the suture, while a few individuals have ossicles that are fused to rest of the bone. Ossicles were scored as present (P), holes (H) or fused (F).

Variation in the seven features discussed above provides information about sex, age and cranial modifications in response to strain related to activity. In this summary, focus is placed on those aspects that potentially provide demographic information. Several features are likely to vary with age and/or sex and these were used to place individual occipital bones into one of six possible categories discussed in the section below. These categories were useful for estimating the number of individuals represented by the occipital bones. The categories, their criteria and constituents are listed in Table 4. The categories, their criteria and constituents are listed in Table 4.

There is a wide range of variation in occipital bone thickness among these fragments. Although measurements may not be homologous as discussed above, thickness ranges from below 3 mm to over 11 mm at asterion. Thickness of cranial bone varies with age, although diet, endocrinological and mechanical factors may also affect

TABLE 3

Occipital Variants.

Specimen	Thickness (1–3)	Torus (1–3)	Superior Nuchal Line (0–1)**	Inferior Nuchal Line (0–3)	Ectocranial Pocking – *Semispinalis* (0–3)	Ectocranial Pocking Suprainac Fossa (0–3)	Ossicles (P.H.F)
2	1	2	0	1	3	3	P
3	2	Na	0	1+/2–	Na	Na	H
5	3	3	1 (m; l)	Na	1+/2–	1	H
6	2	2–	0	1+/2–	2	2	P
8	3		1 (m; l)	1	0/1–	Na	F
9	1	2+	0	0	0	1+	H
10	3	3	0	0	0	Na	
11	3	3	0	1–		Na	H
12 (18.18)	1	1	0	2	2	3	P
13	2+	3	0	1–	0	1	
18.1	2		0				
18.2	3	3	0/1			2+	H
18.3	2		1 (lateral)		2		H
18.4	1	1	0		3	3	
18.5	3*	3	1 medial			1	
18.6	3		0				F
18.8	1		0				P
18.9	2	2+/3–	0/1	Na	2	2	
18.11	2	Na	1 (lateral)	3	Na	Na	
18.12	3	Na	0	3	Na	Na	F
18.17	2+	Na	0	Na	1	Na	
18.28	2		1 (lateral)				
39.3	1						

* It should be noted that only the occipital plane is preserved on 18.5, limiting the comparisons possible. Most other specimens preserve some aspect of the nuchal plane. Comparisons with other specimens are limited to those with occipital plane preserved.

** The position of superior nuchal line development is also noted where relevant. M indicates development medially; L, development laterally.

TABLE 4

Demographic Categories.

Category	Criteria	Occipitals	# Individuals
1 (juvenile)	Thin / pocked	39.3, 18.4, 12, 2*, 18.8*	4–5
2 (older adult? F?)	Thin / unpocked	9	1
3 (young adult)	Medium / pocked	6, 18.1, 18.3, 18.28 18.9	2–4
4 (older adult – F?)	Medium / unpocked	18.17, 13 (3)	2–3
5 (young adult–M)	Thick / pocked	18.2	1
6a (older adult)	Thick/unpocked	18.5**, 5, 10, 11	4
6b (oldest adult)	Thick/ unpocked/ ossicles fused	8, 18.6, 18.12	2–3

* Krapina 2 and 18.8 are both considerably older than the other members of category 1. They may be the same age – even the same individual, and are probably over 10 years old. Krapina 12 is probably between 6–8 years (Minugh-Purvis, *et al.*, 2001); 18.4 is a much thinner specimen and so is probably younger. 39.3 is the youngest, based on temporal bone morphology and cranial thickness.

**18.5 is thick, but is considerably smaller than the other members of the category and I think it is female. If so, cranial thickness is a poor sexing criterion, and it may imply that age is the primary influence on cranial thickness. If so, Krapina 9 may be a younger individual without significant pocking.

it. Juvenile bone is thinner than adult bone, and cranial bone in some cases increases in thickness with senility *(20)*. In this sample, variation in cranial bone thickness varies systematically with some other variables. Among these is the size of the transverse occipital torus. Although size of the torus is related to a number of factors including cranial shape and mechanical load, it is also closely associated with cranial thickness in this sample. It was therefore not used as a separate criterion for assigning specimens to age/sex categories. Small tori (those that hardly protrude at all), are exclusively found in juveniles. Medium tori are usually associated with the thinner adults, and large tori usually with the thicker specimens. Categorical variation in cranial bone thickness was a primary criterion for constructing the categories in Table 4 that reflect age/sex.

The superior nuchal line is rarely well developed in Neandertals; even some of the most robust specimens have poorly marked superior nuchal lines. There are two areas where the line may be well developed: medially, under insertions for *trapezius* and the *ligamentum nuchae* the superior nuchal line and the *tuberculum linearum* may be pronounced, and laterally, under insertions for *sternocleidomastoid* and *splenius capitis* it may also be well developed. This morphology is linked with sex and activity, but is not clearly associated with cranial thickness or torus size. Two of the seven specimens with medium cranial thickness have marked superior nuchal lines; four of the eight thick specimens have well developed superior nuchal lines. It is suggested this is one reflection of sexual variation, but it is not useful in the designation of specimens to age categories.

The ectocranial surfaces under diffuse muscle attachments (the four second and third layer nuchal muscles which insert on the nuchal plane of the occipital bone) vary in terms of their rugosity, which is expressed as a rough, pocked surface reflecting osteoclastic activity due to remodeling. In this sample, most specimens preserve some of the *semispinalis capitis* insertion; deeper nuchal muscle markings are rare. It is interesting that there is an inverse relationship between pocking and bone thickness. With only two exceptions (Krapina 18.2 and Krapina 9), pocking and bone thickness are inversely related and both criteria appear to be good indicators of relative age. Pocking is found in juvenile specimens and some thinner adults, perhaps because thinner bone is more likely to experience strain, and therefore remodeling, than thicker bone. In addition, young individuals are more predisposed to skeletal modeling and remodeling response than older ones.

Pocking, therefore, was the second major criterion used to construct the categories in Table 4. In designating specimens to the categories in Table 4, scores of 0 and 1 were considered unpocked, and scores of 2 and 3 were pocked. Like the morphology under *semispinalis* insertions, suprainiac fossae scars are inversely related to cranial thickness. Suprainiac fossa scoring was strongly associated with diffuse attachment scoring when both were present, and for category designation both kinds of pocking were classified together. Therefore specimens were pocked or unpocked based on lumped criteria. In only one case was there some ambiguity; Krapina 5 was unpocked on the basis of suprainiac fossa comparisons, but was scored as a 1+/2– in terms of *semispinalis* pocking. Because its degree of *semispinalis* pocking was less marked than any other individual with a score of 2, Krapina 5 was placed in category 6 (thick/unpocked) and not with 18.2, the only thick occipital bone at Krapina with significant muscle or suprainiac fossa scars.

The inferior nuchal line variation does not appear to be related to other variables; pronounced expression occurs in both thick and thin occipital bones (e.g. Krapina 18.12 and 12 respectively) and there is also no relationship with superior nuchal line development in this sample. Its variation is unlikely to reflect age or sex.

Finally, most of the Krapina occipitals exhibit evidence of extrasutural bones, or ossicles in the lambdoidal suture. While lambdoidal ossicles occur in all kinds of specimens, ossicle fusion may be an indicator of age, representing some degree of sutural closure. The specimens with fused ossicles represent a subset of individuals who may be older within category 6 (Table 4).

Sex and Age

As in all hominid populations, much of the variation within the Krapina occipitals is related to age and sex; however, *both* age and sex influence robusticity, a major aspect of occipital variation. It is not always possible to determine which of these factors is the principal source of variation in this small sample of unknown age and sex. Of the occipital bones, very few are associated with more complete crania. Krapina 3 and 6 are two of the most complete crania in the collection and are likely females *(21)*. Krapina 5 is a relatively complete male posterior cranium. The other two crania, Krapina 1 and 2, are juveniles. There are limited data preserved that reflect sex and age for most of the occipital collection. Of the variables discussed above, pocking and cranial bone thickness are most closely associated with age, since juveniles consistently show a high degree of pocking and thin cranial bone. Therefore, categories based on these variables may be demographically valuable. In cases where pocking and thickness criteria do not co-vary as expected based on age, (i.e., where both thicker and thinner specimens are associated with similar amounts of pocking or vice versa), sex may be implicated to account for the variation in cranial bone thickness. Based on this, relative age and (in some cases) sex are *tentatively* suggested for the categories listed in Table 4. This is a young sample; none of the older adults are very old. There is no sign of sutural closure in any member of category 6a, so that members of that category, while old relative to the sample, are nevertheless young adults.

Variation in size as well as superior nuchal line development reflect sex, although both of these variables are of limited value. Because of the fragmentary nature of the sample, size is difficult to assess and compare for most individuals. Of the few that preserve standard dimensions, Krapina 5 is the largest. This specimen has been described as a male, well within the male Neandertal range for most cranial dimensions *(22)*. Krapina 2 is surprisingly large (Table 2), given that it is juvenile with very thin cranial bone. Because of its size, it may be male. Superior nuchal line variation is of limited value because the variation is minimal. There are few rugose individuals and one of them is a probable female (Krapina 18.5). The following specimens in Table 4 have scores higher than 0 for superior nuchal line development: Krapina 18.3 and 18.28 in category 3; Krapina 18.2 in category 5; and Krapina 18.5, 5 and 8 in category 6. Some of these are clearly male, such as Krapina 5 and 18.2. Krapina 18.5 in category 6 also has well defined superior nuchal line expression medially, but given its very small size it is likely to be an older female *(13, 15)*.

MINIMUM NUMBER OF INDIVIDUALS

Twenty-two of the 34 fragments were placed in one of 6 categories based on thickness (and associated transverse occipital torus development) and degree of pocking, both of which are associated with age and/or sex. These categories were used to estimate the number of individuals represented by the occipitals. The presence of fused ossicles, probably associated with the degree of sutural closure, further divided category 6 into older and younger individuals. The remainder of the occipitals lacked diagnostic or comparable morphology; each of these undiagnostic bones could potentially belong to a number of the individuals listed in Table 4. Including them would not change estimates of the number of individuals.

The occipital fragments represent a minimum of 13 individuals, based solely on number of overlapping elements. However, if morphological variation is taken into account to construct age/sex categories, the number of individuals is more probably between 16 and 21. As shown in Table 4, the Krapina occipitals represent a *minimum* of 4 juveniles, 3 young adults, 7 older adults, and 2 oldest adults. Therefore, based on the criteria discussed above, at least 16 individuals are represented by the occipital fragments. This is similar to the estimated number of burials *(3)*.

CONCLUSION

The 34 occipital bone fragments at Krapina represent the remains of at least 16 individuals. They vary in degree of preservation, with most fragments comprising less than half of the occipital bone. They vary systematically in several criteria, including thickness, rugosity of muscle markings, and in the surface morphology of the suprainiac fossa. Variation in these characteristics reflect sex and age. The occipital remains represent at least 4 juveniles and 12 adults of varying ages. It is a young sample; most sutures are open, with a minimum number of only two individuals in the oldest category, where lambdoidal ossicles are fused in the sutures. The Krapina occipital bones exhibit a morphological pattern common in Neandertals that includes extensive lambdoidal flattening, wide *semispinalis capitis* insertions, and a relatively short posterior aspect of the occipital bone defined by the occipital torus and the suprainiac fossa. Their study contributes to the body of information relevant to understanding the Krapina hominids, and combined with the details of other skeletal elements may provide insights into the demography and adaptation of the early Neandertals.

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