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Technical Note: Taxonomic identification of petrosal bone morphology

Guy Bar-Oz*[1], Nimrod Marom[2], Ron Pinhasi[3]
[1] Zinman Institute of Archaeology, University of Haifa, Haifa 3498838, Israel
email: guybar@research.haifa.ac.il (corresponding author)
[2] Institute for Maritime Studies, University of Haifa, Haifa 3498838, Israel
[3] Department of Evolutionary Anthropology, University of Vienna, Vienna 1090, Austria

Abstract: *Identification of petrosal bones to taxon is important due to the exceptionally well preserved quantity of endogenous DNA found in them. Here we present practical descriptive criteria to allow reliable differentiation of the petrosal bones of some of the most common domestic and wild mammalian taxa of the Old World. This should simplify the identification and documentation of the bone during initial sorting for analysis and help separately curate specimens for taxon-specific ancient DNA studies.*

Key words: cranium; petrous; animal anatomy; zooarchaeology

Introduction

The petrosal bone of the inner ear in mammals contains the cochlea and semicircular canals, which are critical components in the balance sensory system (Romer 1962). It is a morphologically distinctive pyramidal bone which is connected at the skull base to the occipital bone (**Figure 1**). It is formed entirely *in utero* and is one of the most protected bones of the skeleton (Lam et al. 1999: Table 1; Frisch et al. 1998). The petrosum is the densest bone of the mammalian skeleton and the only one that does not undergo regular bone turnover. Consequently, the accumulation of unmodelled bone matrix preserves a high concentration of ancient DNA molecules and as such, archaeological petrous bones are precious archives of ancient endogenous genomic data (Pinhasi et al. 2015; Gamba et al. 2014; Hansen et al. 2017).

While animal petrous bones recovered from archaeological excavations are of interest to a growing number of scholars (Makarewicz et al. 2017), they are usually not identified to taxon. However, variation in petrosal morphology of the various taxa does allow the correct assignment of petrous bones even for closely-related species such as sheep and goats (Guadelli 1999; O'Leary 2010; Mallet & Guadelli 2013;

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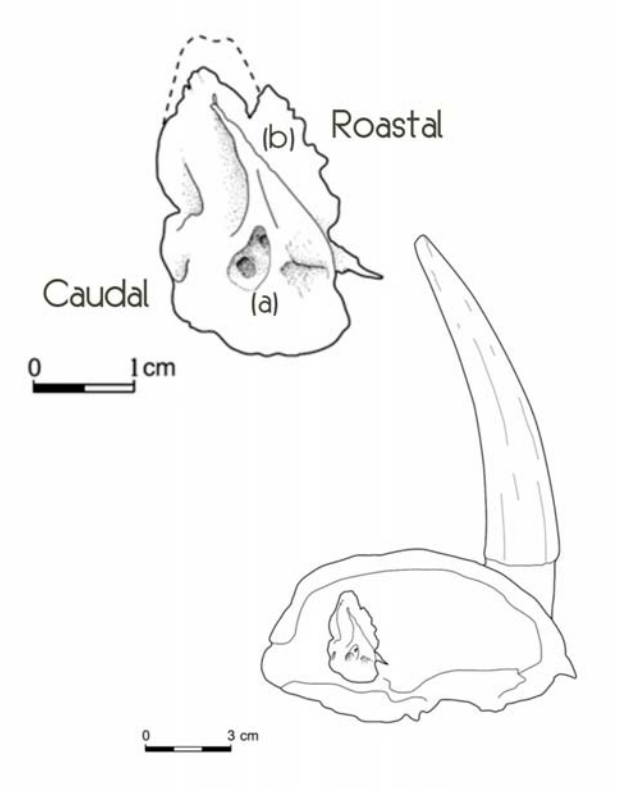

Figure 1. External and inner (left) location of the petrous bone in the gazelle cranium: (a) internal acoustic opening, (b) petrosal crest.

Mallet et al. 2019). The main limitation to developing a system of taxonomic differentiation for the petrosal is that zooarchaeological reference collections almost always comprise complete skulls, in which the petrosum cannot be assessed on the basis of a visual inspection of the internal skull morphology through the foramen magnum. Moreover, bone atlases (e.g. Schmidt 1972) do not include petrosa, although the petrous bone is usually retrieved complete from intensively-fragmented archeological crania (Bar-Oz & Dayan 2007).

We present herein, pictorial and morphological descriptive criteria to allow reliable differentiation of the petrous bones of some of the most common domestic and wild mammalian taxa of the Old World. The material provided should simplify the identification and documentation of the bone by field zooarchaeologists and others.

Material and methods

Petrous bones were removed from modern specimens from the collections of the University of Haifa Archaeozoology Laboratory by sagittal sawing of the crania using an electrical saw and cutting of the occipital bone using a Dremel tool by a professional preparator (R. Shafir). The bones were then hand-drawn to scale (by A. Mark).

Intra-taxon variability in the morphology of the petrosal facies of the occipital bone is assumed to be low given the functional constraints on the petrosal anatomy. On the other hand, inter-taxon variability is expected to be high since the mesial surface of the petrous has a highly-distinct morphology dictated, to a large extent, by the sagittal stretch along the rostral surface (Mallet & Gaudelli 2013:3). This part of the petrosum is also well-preserved archaeologically and is often found disconnected from other parts of the occipital bone, making it a practical unit for morphological identification. We chose to describe the morphology of the petrous bone qualitatively since obtaining a sample size needed for geometric or metrical study would involve sawing apart a large number of cranial specimens from study collections, which is not feasible on curatorial grounds.

Results

The medial face of the petrous bones of the left side of different taxa is shown in **Figures 2** and **3**. All bones are shown in the same position. The posterior surface, which forms the base of the pyramidal-shape part of the bone is at the bottom and the anterior surface above.

The most distinct part of the bone is its posterior part where the large orifice of the internal acoustic opening (*Meatus acusticus internus*) can be seen. The size and shape of the opening varies considerably among taxa. In some taxa, like the wild boar and dog, the opening is clearly divided by a major crest into two separate orifices. In bovids and equids, on the other hand, the crest has a more moderate shape and it is less pronounced. Note that the opening in gazelle is divided into three orifices. In cervids and felids the crest is absent and only a single orifice is shown.

The margins of the acoustic opening also differ among taxa. Most margins are smooth and rounded while the ones of the wild boar have a more trilateral shape. The outline of all other taxa is asymmetrical with a distinct, uneven, oval shape.

Another anatomical criterion that allows differentiation between taxa is the length and shape of the anterior surface or the rostral face (*facies rostralis*) or petrosal crest. In some taxa the surface is long and has a sharp end. This is most pronounced in gazelle and fallow deer, roe deer and to some extent in other bovids and equids. The anterior surface of the *Felis*, *Capra* and *Ovis* petrous, on the other hand, is shorter and the shape of the bone is less rectangular and more rounded.

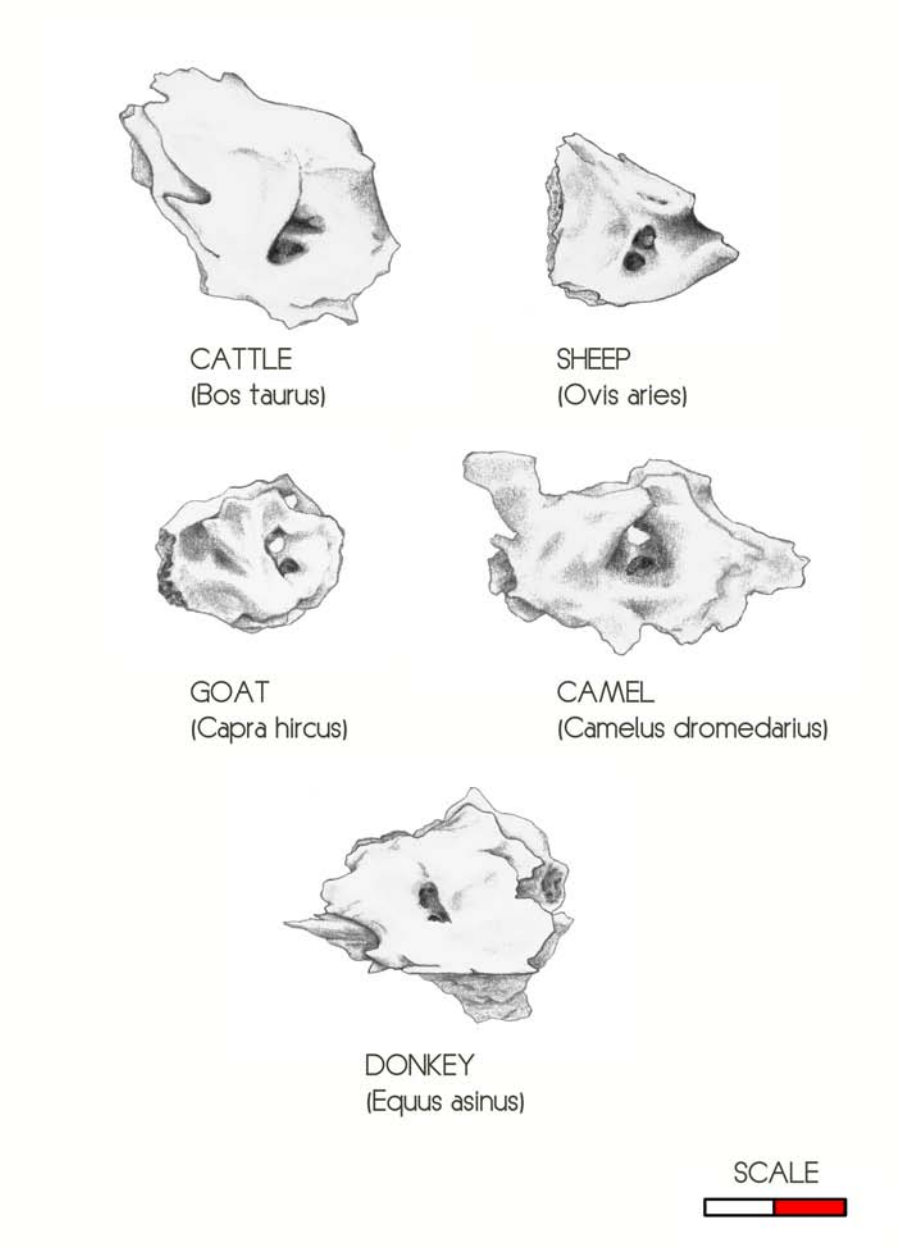

Figure 2. Medial representation of the left petrous bone of domestic cattle, sheep, goat, camel and donkey.

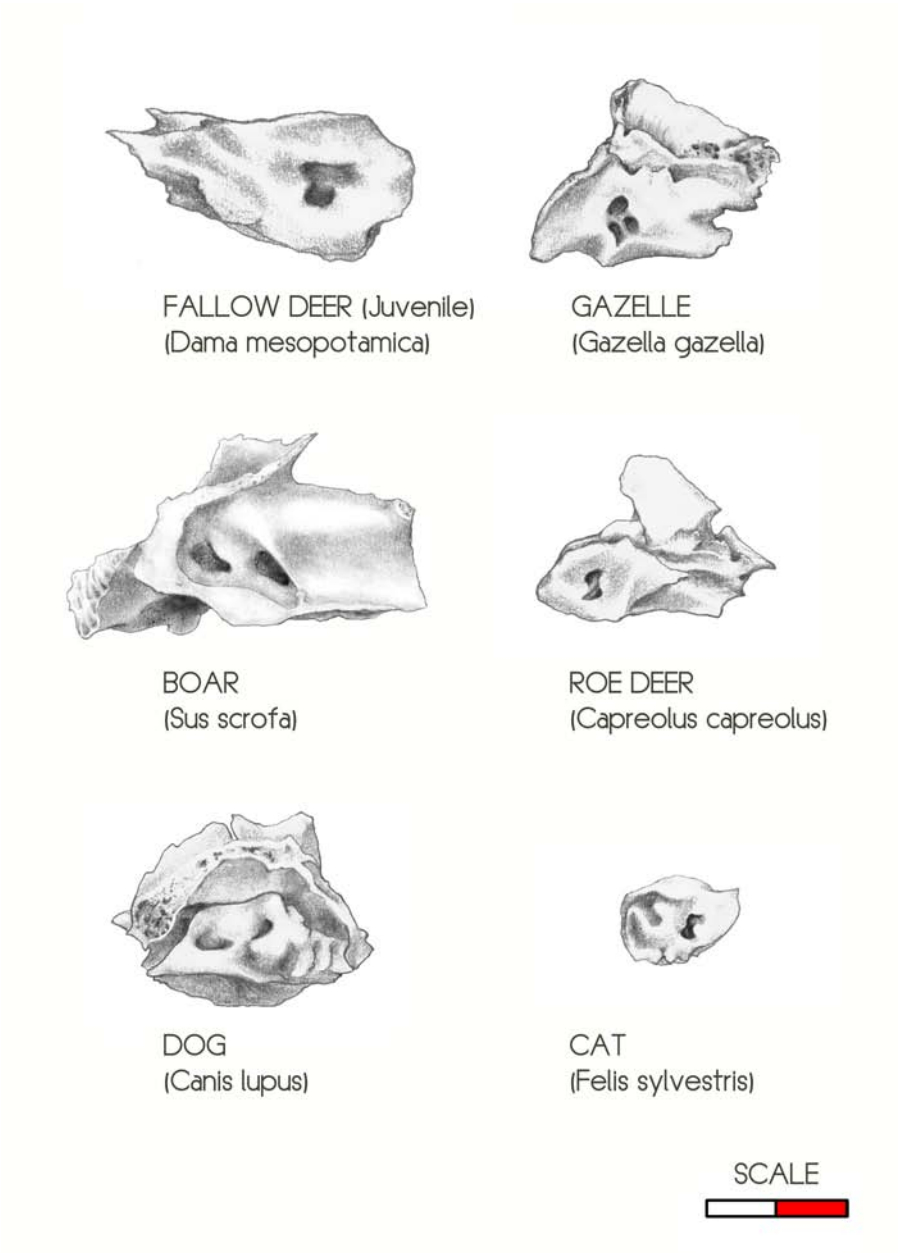

Figure 3. Medial representation of the left petrous bone of fallow deer, mountain gazelle, boar, roe deer, dog and cat.

Finally, another distinct inter-specific differentiating feature is variation in bone size. The measurement of the dorso-ventral dimension versus the rostro-caudal dimension shows no overlap between sheep and goat (Mallet & Guadelli 2014: Fig. 14).

Conclusion

The distinguishing characteristics of the medial face and the shape of the posterior surface provide a useful tool to identify isolated mammalian petrous bones to at least the level of the Genus. The descriptive and graphical description of these morphological characteristics, which are missing from bone atlases, fills a lacuna in the field archeozoologist's toolkit. Their straightforward application to fragmented archaeological bone assemblages during initial sorting for analysis can help separate specimens for taxon-specific ancient DNA studies.

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