Survey of petrosal bone of the inner ear of Late Miocene baleen & toothed whales from Northwest Caucasus through tomography (First experience).

K.K.Tarásenko[1], E.S. Kovalenko[2], A.V. Pakhnevich[1] , K.M. Podurets[2]

[1]PIN RAS,117997 Moscow, Profsoyuznaya str., 123,
[2]NRC "Kurchatov Institute" 123182 Moscow, Akademika Kurchatova pl., 1

Aims

Cetaceans, unlike all other terrestrial and aquatic mammals, have a number of special specialties associated with the aquatic environment, including the ability to hear underwater, which attracted the attention of many researchers[1-3]. We know that modern odontocetes and mysticetes hear in two different ways: at high and low frequencies (respectively). It is very important to know how these two groups of whales developed hearing abilities in different ways. For Late Miocene baleen & toothed whales of the Eastern Paratetis, the morphology of the petrosal bone has been studied rather well, but the microstructure and morphology of the labyrinth of the petrosal bone has not yet been studied[4-6]. Here, we report the discovery of inner ear of Late Miocene baleen & toothed whales from Northwest Caucasus through Tomography. The goal of this work is researching petrosal bone of baleen and toothed whales from the Late Miocene, choice of methods morphological descriptions obtained reconstructed sections of petrosal bone, as well as the identification of stable and non variability informative morphological characters of the labyrinth structure in petrosal bone.

Method

Synchrotron tomography carried out in NRC "Kurchatov Institute" by using “Kurchatov synchrotron radiation source”, at the station “LIGA”. Filtered synchrotron radiation with a spectrum maximum about 56 keV (a filter Cu 1.5 mm) is used. A frame exposure time was 150 ms; a resolution – 130 µm; step of rotation – 0.5º. A vertical scanning step 1 mm is applied. In the morphological description of virtual sections, it is very important to choose the correct projection of the sample, taking into account the position of the cochlear ducts (the cochlear channels must be dissected by a crossing plane perpendicular to the axis of the stony part of the stony bone. We choose frontal direction with selected sections pass at a small angle (5-7 degrees) to the longitudinal axis of the bone (fig. 1) in contrasting with classical works[1,2]. Another series of cuts made in the latero-medial direction at a slight angle to the part of the cochlea.

Another part of the sample (petrosal bone from smaller toothed whales) was investigated in the Paleontological Institute of Russian Academy of Sciences, on the X-ray micro-CT Skyscan 1172. Microtomography parameters: I=100 mA, U=103-104 kV, a filter – Al (1 mm), a pixel size was from 25 to 34.1 µm, a rotation - 180º, steps of rotation were 0.7º, random movement – 10, frame averaging – 8. TView, NRecon, CTAn programs are used.

Results

In the course of studying and comparing the t3D models for Kurdalagonus sp. and Zygiocetus nartorum Tarasenko, 2013 revealed significant differences in the structure of the semicircular canals of the labyrinth, endolymphatic and perilymphatic structure of channels, as well as in the structure of the facial nerve canal. We occurred that the number of turns of the cochlea in the Eastern Paratethian Cetotherium like whales close to that of herpetocetinae and is about 3 turns. Representatives of the genus Kurdalagonus Zygiocetus differs from the structure of the semicircular canals. In Kurdalagonus lateral semicircular canal on the front side ends with well-defined membranous ampullae adjacent to neighboring ampoule front semicircular canal; and the rear end of the lateral semicircular canal lies beneath the rear base of the semicircular canal ampulae and has virtually no well-defined self-ampoules. In Zygiocetus lateral semicircular canal has its own well-defined vial, ampoule adjacent to the anterior semicircular canal, and 2.5 times greater than its size. The rear edge of the lateral and rear of the semicircular canals, unlike Kurdalagonus, have significantly smaller vial similar in size and underlying the bulge adjacent to a small hillock lying behind the front lateral channel ampoules. The representatives of the genus Kurdalagonus, unlike Zygiocetus, much longer overall membranous leg connecting the front and rear semicircular canals, their ratio is about 5: 1. In general, Kurdalagonus semicircular canal system is more complicated than that Zygiocetus (see. Fig. 2).

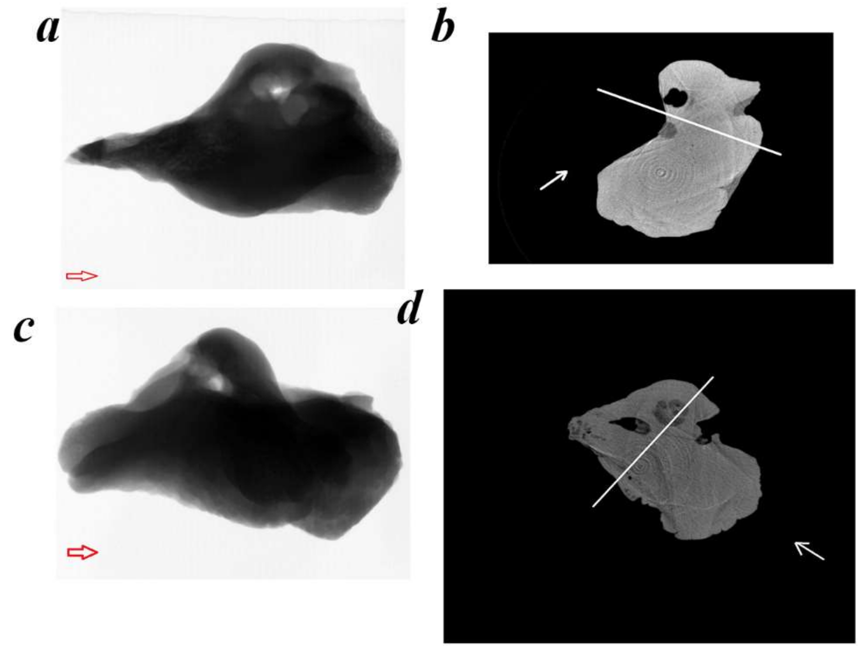

Figure 1: The direction of the oriented investigated samples: a-b Zygiocetus nartorum Tarasenko, 2014; c-d Kurdalagonus sp.

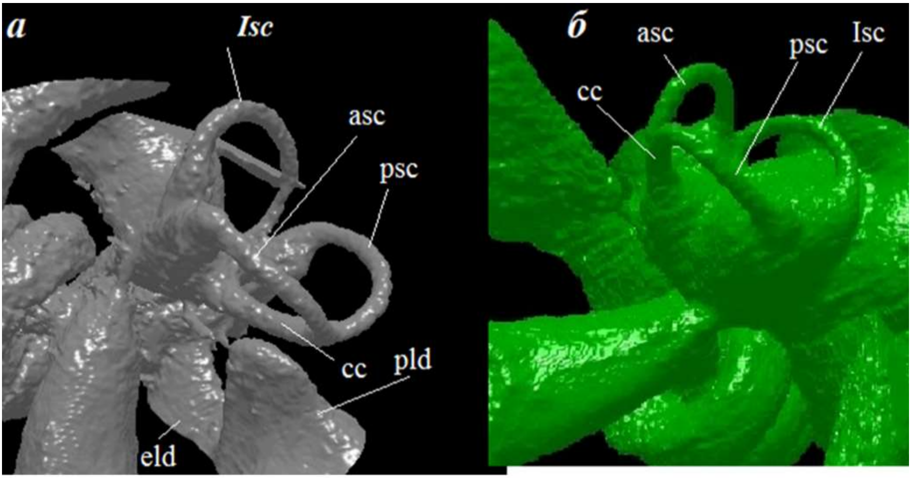

Figure 2: 3D model of the semicircular canals Kurdalagonus (a) and Zygiocetus (b): Isc - lateral semicircular canal; Asc - front semicircular canal; Psc - posterior semicircular canal; Ss - common webbed leg (crus commune); Eld - endolymphatic duct; Pld is the perelymphatic duct.

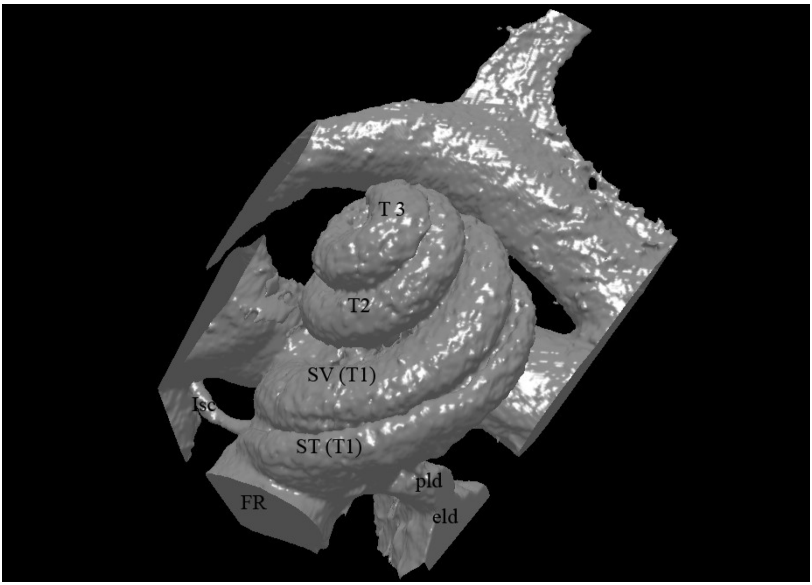

Figure 3: 3D model of the turns cochlear canals Kurdalagonus : Isc - lateral semicircular canal; Eld - endolymphatic duct; Pld is the perelymphatic duct; FR – fenestra rotunda; ST (T1) – scala tympani of thethird cochlear turn; SV (T1) – scala vestibule (including scala cochleari) of the first cochlear turn; T2 – the second turn of cochlear canal; T3 – the third cochlear turn.

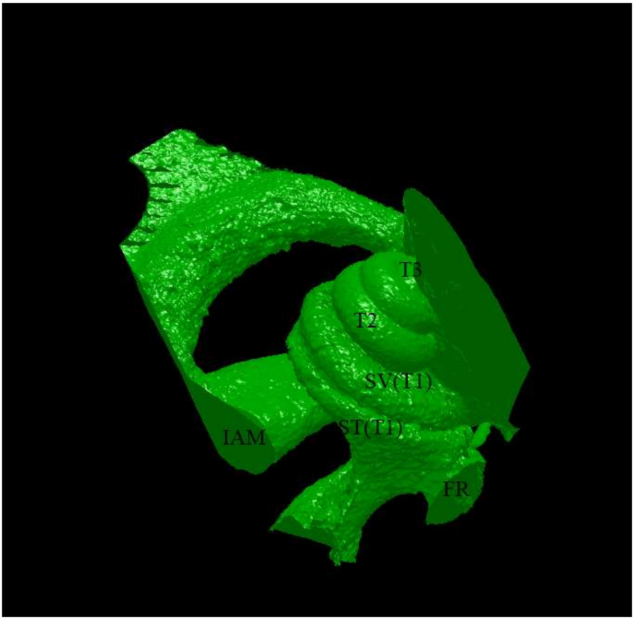

Figure 4: 3D model of the turns cochlear canals Zygiocetus : IAM - internal auditor meatus; Isc - lateral semicircular canal; Eld - endolymphatic duct; Pld is the perelymphatic duct; FR – fenestra rotunda; ST (T1) – scala tympani of thethird cochlear turn; SV (T1) – scala vestibule (including scala cochleari) of the first cochlear turn; T2 – the second turn of cochlear canal; T3 – the third cochlear turn.

Another important morphological feature distinguishing Kurdalagonus from Zygiocetus and Cetotherium is the structure of the round window (Fig. 3, 4). It is considerably wider and longer than Zygiocetus and Cetotherium, and has a circular shape in cross section in contrast to the more oval in Zygiocetus. In Herpetocetus threshold (spherical vestibule sensu Geisler et Luo) has a rounded shape, unlike Kurdalagonus, which is more flattened, with clear and distinct ampoules semicircular canals, and from Zygiocetus front part which, together with ampoules of the semicircular canals form a remarkable expansion. In the work it was noted that the number of cochlea turns in whales of Eastern Paratethis is close to that of herpetocetinae and is about 3 turns (fig. 3, 4). As we can notice, no cetaceans other Herpetocetus & cetotherium like whale has more over 2,5 turns of cochlear[2,3,7,8]. However, close to this condition, perhaps, in Parietobalaena palmeri, Metopocetus durinasus[9].

As for the third sample (Vampalus sayasanicus PIN № 5341-4), most of the cavities was packed with highly absorbent mineral X-rays, tomography at an energy of about 60 keV turned uninformative. Therefore, neutron tomography was performed, for which the restriction is not met, but it has a lower resolution, at the moment about 170 μm.

Also, in the course of this study, virtual sections of the stony bone of the Late Miocene toothed whale from Caucas were described (Fig.5). The cochlear channels were partially filled with a matrix, which in places lowered the image quality.

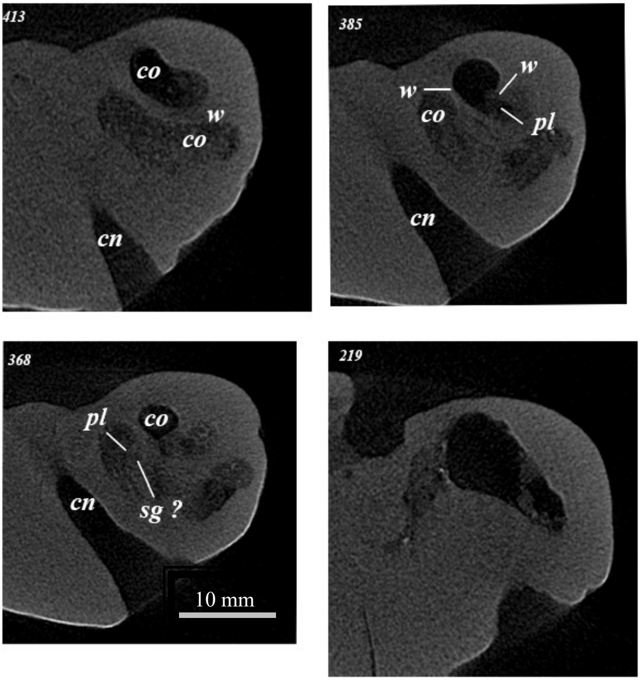

Figure 5: Original CT slices through petrosal bone Late Miocene odontoceti from Caucas (Numbers refer to specific CT slices): cn – canal for cranial nerve VIII within modiolus; co –cochlea; pl – primary bony lamina; sg – canal for spiral ganglion within primary bony lamina; w – wall separating successive turns of cochlea.

Conclusion

Thereby, In the course of the experiment 3D models petrosal bones from Late Miocene toothed & baleen whale, demonstrating some important diagnostic features that can be used in diagnosis of diagnosis genera and species taxa. However, these morphological features need to be verified by examining similar structures in a wide variety of material. This is planned to be done on a new extensive paleontological material.

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