

Extended abstract

Neogene and Quaternary fossil remains of beaked whales (Cetacea, Odontoceti, Ziphiidae) from deep-sea deposits off Crozet and Kerguelen Islands

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Beaked whales (Cetacea, Odontoceti, Ziphiidae) constitute a diversified family of echolocating toothed whales whose extant species prey at great depths, predominantly upon cephalopods, but also fish (McLeod et al., 2003; Tyack et al., 2006; Schorr et al., 2014). Being nearly edentulous, most modern ziphiid species are thought to rely on suction to capture their prey (Heyning and Mead, 1996), and only retain one or two pairs of sexually dimorphic mandibular tusks. Among those, at least 10 species constitute key components of the deep benthopelagic to benthic communities of the Southern Ocean and neighbouring areas (McLeod et al., 2006). Until now, and despite a continuously improving fossil record (e.g. Buono and Cozzuol, 2013; Bianucci et al., 2016; Ramassamy, 2016), inland localities proved to be of little use to trace the prehistorical occupation by beaked whales of the oceanic regions around the Antarctic. On the other side, fossil ziphiid material from deep-sea deposits off South Africa and BANZARE Bank (Indian sector of the Southern Ocean) started to provide a glimpse of the past biodiversity of the family along the northern edge and southern part of this wide area (Bianucci et al., 2007; Gol'din and Vishnyakova, 2012).

Commercial deep-sea longline fishing activities along the seafloor at depths up to 2 000 m off Crozet and Kerguelen Islands recently yielded a large number of ziphiid fossil remains, mostly isolated rostra and partial crania literally hooked together with the targeted fish species, the Patagonian toothfish (*Dissostichus eleginoides*) (Figure 1). Specimens collected were transported to the Muséum national d'Histoire naturelle (MNHN, Paris, France), where the diagnostic remains were studied.

Focusing on the morphology of the rostrum and facial region of the cranium, the systematic study of this deep-sea palaeontological material revealed the presence of more than eight species, from at least seven genera and more than two subfamilies (Figures 2 and 3): the hyperoodontines *Africanacetus ceratopsis*, *Khoikhoicetus kergueleni* (a new species), Hyperoodontinae indet. aff. *Africanacetus*, and *Mesoplodon* sp. aff. *Mesoplodon layardii*, the ziphiines *Izikoziphius rossi* and *Ziphius* sp., and the ziphiids indet. *Nenga* sp. aff. *Nenga meganasalis* and *Xhosacetus hendeyi* (Lambert et al., 2018). Significant similarities with the previously described South African fossil assemblages were demonstrated by the identification of four species (*Africanacetus ceratopsis*, *Izikoziphius rossi*, *Xhosacetus hendeyi* and *Ziphius* sp.) also recorded in South African offshore localities (Bianucci et al., 2007). Such a degree of similarity between Crozet–Kerguelen and South African assemblages expands considerably (several thousand kilometres) the palaeogeographic distribution of the listed taxa, allowing comparisons with recent ziphiid biogeographic ranges in the considered area. It also suggests a similar geochronological age for part of the Crozet–Kerguelen and South African assemblages. Combined with geological data available from both the seafloor and deep-sea drillings around Kerguelen Islands, as well as radiometric dating of *Africanacetus* material from the southwestern Atlantic (off the coast of Brazil), the faunal comparison would indicate a pre-Pliocene (>5.3 Ma) age for a large part of the Crozet–Kerguelen assemblage. This estimation would suggest a relatively early, Miocene colonisation of the Southern Ocean by crown-group beaked whales. Interestingly, as for the

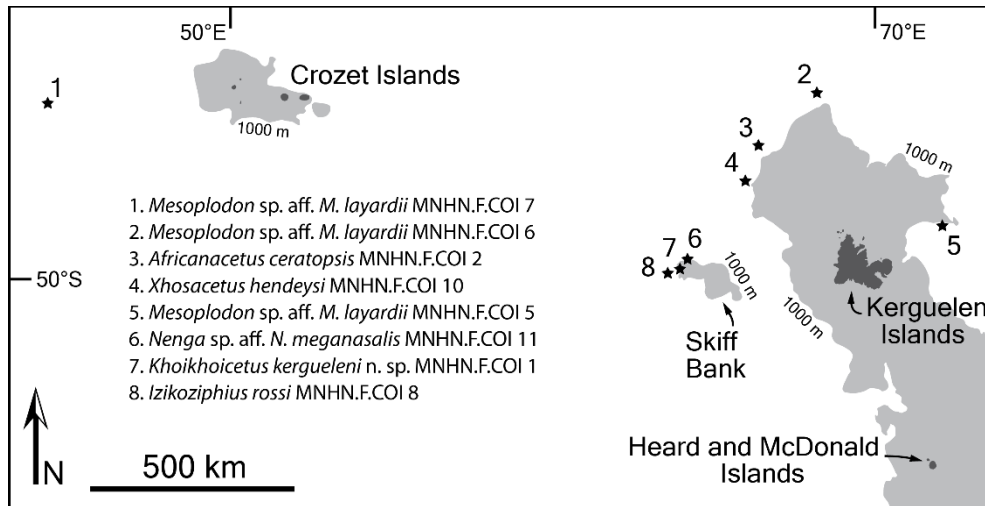


Figure 1: Schematic map of the Crozet and Kerguelen Islands area, showing the main localities where fossil beaked whale specimens (stars) were taken as by-catch during deep-sea commercial bottom longline fishing activities. Light grey shading for areas with a water depth lower than 1 000 m; dark grey shading for islands. Modified from Lambert et al., 2018.

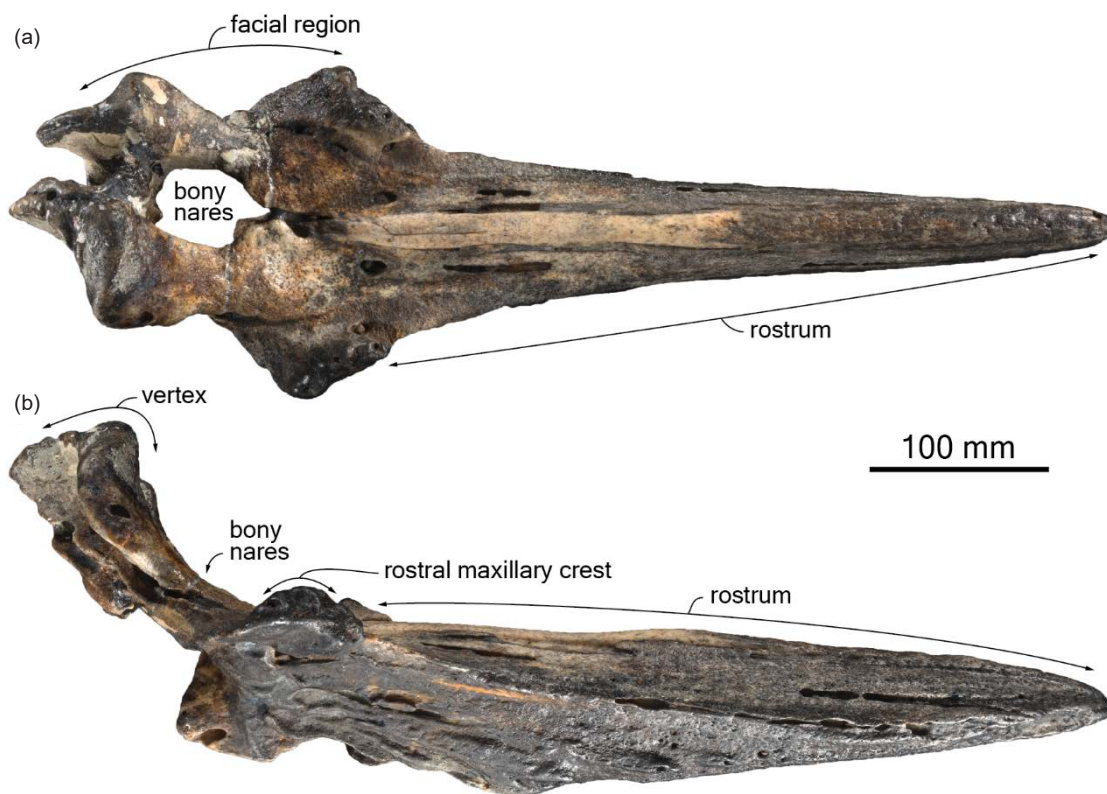


Figure 2: Partial cranium MNHN.F.COI1, holotype of the new hyperoodontine species *Khoikhoicetus kergueleni*. The specimen was collected via bottom longline fishing on Skiff Bank, 370 km SWW to Kerguelen Islands at a depth of 885 m. (a) dorsal view; (b) right lateral view. Photos P. Loubry (MNHN).

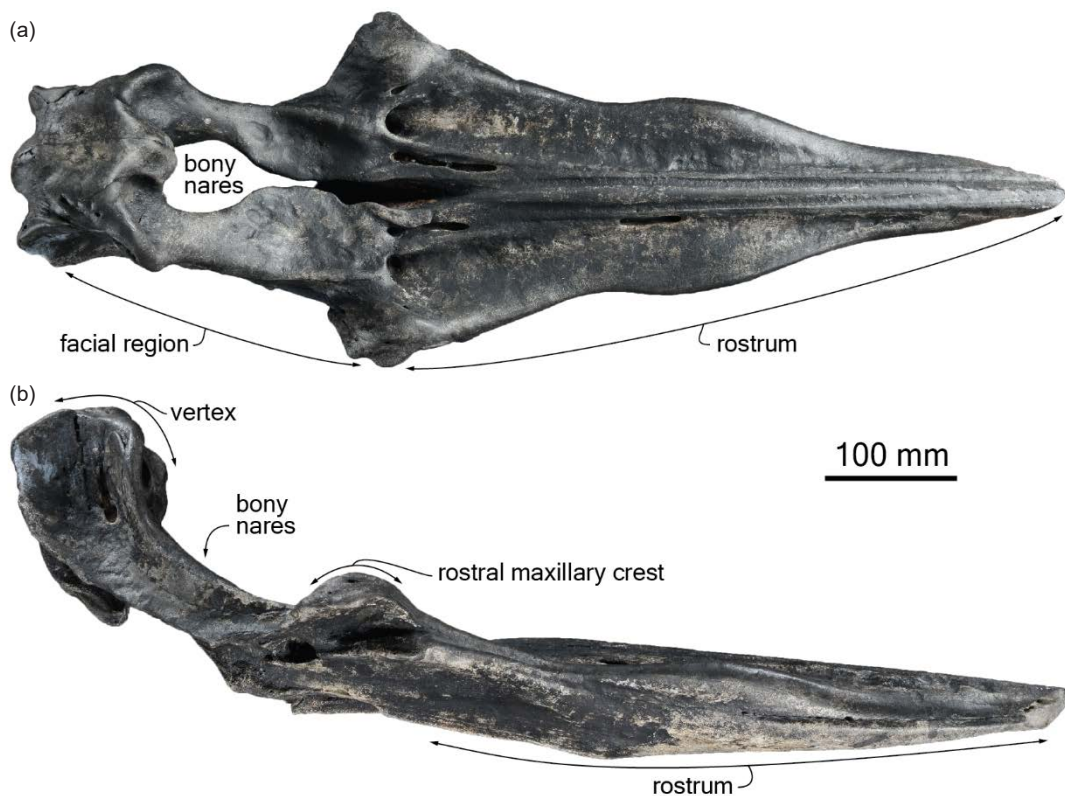


Figure 3: Finely preserved partial cranium MNHN.F.COI8, referred to the ziphiine species *Izikoziphius rossi*, first described based on material from the sea floor off South Africa (Bianucci et al., 2007). The specimen was collected via bottom longline fishing on Skiff Bank, at a depth of 2041 m. (a) dorsal view; (b) right lateral view. Photos P. Loubry (MNHN).

South African assemblage, no stem ziphiid is recorded, further supporting the hypothesis that early branching ziphiid lineages did not invade the Southern Ocean (Lambert et al., 2018), being for now mostly limited to the North Atlantic and central Pacific.

Body length estimates for the taxa from the Crozet–Kerguelen area provide a size range similar to that of the South African assemblage (Bianucci et al., 2008), from small (about 4 m long for *Khoikhoicetus kergueleni*) to very large species (beyond 8 m for *Ziphius* sp.).

Three rostra from the studied sample identified as *Mesoplodon* sp. aff. *Mesoplodon layardii* contrast markedly with others at the level of the external aspect, the bone being whiter, less compact and more crumbly. Such a preservation difference, suggesting a considerably younger geochronological age as compared to most other specimens from the Crozet–Kerguelen sample, lead to radiocarbon (^{14}C) dating for two of these specimens. Obtained ages (10 270–10 200 and 12 670–12 575 cal BP, i.e. before 1950 AD) indicate that a close relative of the extant strap-toothed whale *Mesoplodon layardii* lived in the Southern Ocean during the latest Pleistocene to earliest Holocene (Lambert et al., 2018). Morphological similarities with the latter species at the level of the

dorsal margin of the rostrum suggest that some individuals (presumably adult males) of this Quaternary taxon were equipped with long postapical mandibular tusks, surrounding the upper jaw as they do in *M. layardii*, and could therefore be conspecific with this extant species (= chronospecies). Finally, if it actually represents a different species, either it went extinct during the last 10 000 years, or it still exists today and could not yet be identified. Such a possibility should not be rejected too easily, considering the low number of strandings for beaked whales living in remote oceanic regions, the recent description of several new extant ziphiid species (e.g. Reyes et al., 1991; Dalebout et al., 2002), and the relatively minor morphological differences observed with the cranium of *M. layardii* (suggesting that the external aspect of this *Mesoplodon* species may not be too different from the latter, presumably making those two species difficult to distinguish at sea).

As a perspective, the detection on the Kerguelen Plateau (and neighbouring parts of the Indian sector of the Southern Ocean) of taxa previously not recorded along South African coasts (including a new species) should be taken as an impetus to keep collecting and studying fossil ziphiid remains from this vast oceanic region. New finds should be expected in the future, and this will undoubtedly be facilitated by the constructive,

long-term cooperation between fishermen and scientists working there. From a methodological viewpoint, new techniques should be applied to precise the geochronological context of these important finds (e.g. Ichishima et al., 2017; Nozaki et al., 2017), in a way to improve our understanding of the timing of the early colonisation of the Southern Ocean by deep-diving cetaceans and its physical drivers.

Keywords: beaked whale, deep-sea deposits, fossil, Miocene, Quaternary, Ziphiidae

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