Fish otoliths and statoliths of Mesozoic cephalopods: their phylogenetic and environmental significance

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Abstract

Otoliths and statoliths are predominantly aragonite auditory stones that grow inside the middle ear of an animal. Otoliths of teleosts fishes as well as cephalopod statoliths help with the spatial orientation, hearing and sense of balance during animal movement. Otoliths are divided into three pairs: lapilli, sagittae, and asterisci, from which they form an otolith system. In this system, one of the three pairs is always the largest, most complex and best identifiable. Most commonly those largest otoliths are sagittae or lapilli. In most cases the morphological features of the ear stones are species specific for both actinopterygians and cephalopods. Otoliths and statoliths, are best preserved in fine-grained siliclastic sediments i.e., clays, silts, and shales and in some cases also in sands. The first article in this dissertation reports on the first-known Cretaceous statoliths of cephalopods. Previously, they were known to occur abundantly in the Jurassic and less commonly in the Cenozoic. In this article we fill this gap describing four cephalopod statoliths from the Early Cretaceous: one from Wąwał, Poland (Valanginian) and three from Speeton Clays, United Kingdom (Aptian). Our comparison of the Mesozoic statoliths with their modern counterparts has shown their close similarity to the statoliths of recent pygmy cuttlefish (*Idiosepius pygmaeus*), what suggest that they most likely belonged to basal decabrachians or to belemnoids, which are closely related to them. The second article focuses on the Early Cretaceous (Valanginian) otolith assemblage from Wąwał near Tomaszów Mazowiecki. Most otoliths belong to albuliforms and the earliest argentiniforms. We found also otoliths of the youngest known *Archeotolithus* (alleged holostean), as well as elopiforms and osteoglossiforms. Most of the described albuliforms were already known from younger sites in the United Kingdom. The otolith assemblage from the Early Cretaceous of Poland confirms not only that the radiation of teleost fishes occurred earlier, but was also more gradual, and the new groups of teleosts appeared and differentiated gradually over time. In the same assemblage, only one Mesozoic cephalopod statolith was found for more than half a thousand otoliths. The third article focuses on otoliths from the Cassian Formation, lower Carnian, Upper Triassic of Northern Italy. In this assemblage we found four pairs of otoliths of neopterygian, nine otoliths of holostean fishes and an unidentified pair of teleost otoliths, which constitute the oldest known occurrence in the fossil record so far. Otoliths were associated by other microichthyoliths (i.e., hybodont teeth, scales, and spines and jaw fragments of an actinopterygian). The otoliths of neopterygians have been divided into two morphotypes, and the otoliths of holostean fishes into four morphotypes. The fourth and final article is devoted to the Jurassic statolith-otolith assemblages from Poland, Lithuania, Great Britain and Russia. The dominant group of nekton and nekto-benthos throughout the Jurassic period were cephalopods, represented by morphoptype A statoliths sensu Clarke (2003). The fossil record of *Archaeotolithus* have a gap between Middle Jurassic (Callovian) and the Early Cretaceous (Valanginian). On the basis of the morphological diversity of the identified otoliths, we

found out that leptolepiforms were the dominant group of teleost in the Early Jurassic, and from the Middle Jurassic the diversity of some other teleosts started to build up. The oldest albuliforms (*Pteroalbula jurassica*) appeared in the Bathonian. In the Late Jurassic, leptolepiforms were smoothly replaced by albuliformes, elopiforms and osteoglossiforms. The fish otoliths in the Upper Jurassic clays became nearly as common as cephalopod statoliths. The turn of the Jurassic and Cretaceous brought large scale transformation in the nekton related. In the conclusions chapter, I summarized all published information on Mesozoic ear stones assemblages and merged it with the new data resulting from this dissertation showing the diversification pattern and an outline of the complex evolutionary history of teleosts and decabrachians as well some insights in their palaeoecology during the Mesozoic times.