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Growth of a cod otolith on the crystal level

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Abstract

Stereoscan electron microscopy of surface crystals of sagittal otoliths of a cod (*Gadus morhua* L.) from the western Baltic Sea has revealed nonuniform growth. Crystals deposit preferentially on specific surfaces of otoliths.

Kurzfassung

Über das Wachstum von Dorschotolithen im Bereich der Oberflächenkristalle

Raster-Elektronenoptische Untersuchungen an den Oberflächenkristallen des Sagitta-Otolithen eines Dorsches der westlichen Ostsee zeigten regionale Wachstumsunterschiede. Die Kristalle lagern sich vorzugsweise auf bestimmten Flächen des Otolithen ab.

Introduction

The growth of fish and the growth of their hard tissues are periodic processes whose frequency has often been discussed since the early work of Hoffbauer (1898, 1900) and of Reibisch (1899, 1900). Since Pannella's (1971) investigation of the daily growth increments of fish otoliths many papers have been published concerning the micro-structure of the otolith and its growth layers. Most of these publications have concerned the „circuli" in the otoliths of different species (Pannella 1974; Liew 1974; Williams and Bedford 1974; Blacker 1975; Bingel 1972, 1977).

A picture of the dorsal surface of an unetched otolith of the American eel has been published by Liew (1974), and he comments that „it contains only tubercle-shaped protuberances which vary in size as well as in height" (p. 128). The base of these tubercle-shaped structures was fused to form a solid, non-porous surface. Blacker (1975) noted that he had examined a whole plaice otolith and could not find any relation to the hyaline or opaque zones which are the basis of the use of otoliths for age determination in fish.

In general, it is assumed that the otolith grows most rapidly in the anterior and posterior section and the growth patterns are best expressed on the dorso-ventral sagittal plane (Pannella 1974). On the other hand, it is also well known that the periods of summer and winter correspond to two different production rates of inorganic and organic materials. The rate of production of inorganic and organic material during the fast growing period is high. During the slow growing period less organic material is produced and the rate of $CaCO_3$-production is low (Pannella 1971; Liew 1974). Furthermore Liew (1974) indicated that in summer large but in winter small aragonite crystals were formed. In this work aragonite crystals in different parts of the surface of the sagittal otolith of cod were studied during the so-called slow-growth period (November).

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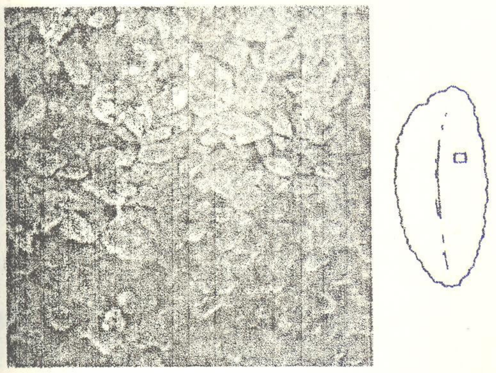


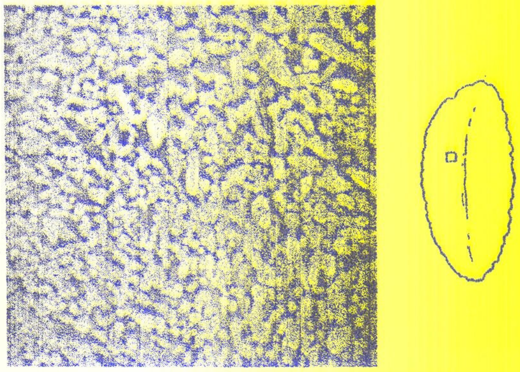
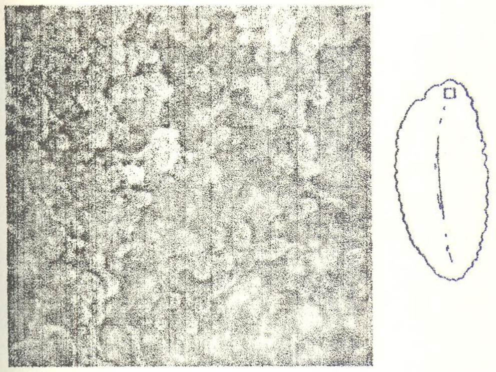


Fig. 1. Left. Surface crystals of the sagittal otolith of a young cod and the section of examination. 1 = 13.4 cm; 5. 11. 1975; magnification 10 000, KV 10, lens current 065/085, work distance 11, f-II, γ 2, PMV 3.24, rotation and dumping 0°. *Fig. 2. Right.* Surface crystals of the sagittal otolith of a young cod and the section of examination. PMV 3.27, other data as in fig. 1



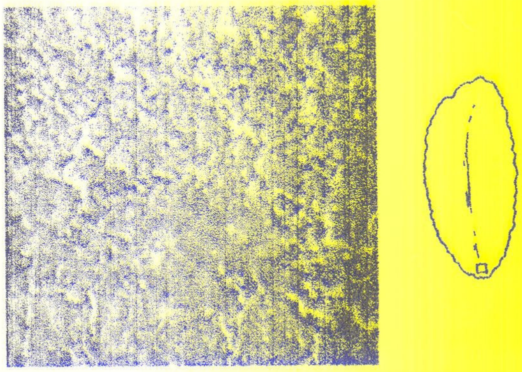


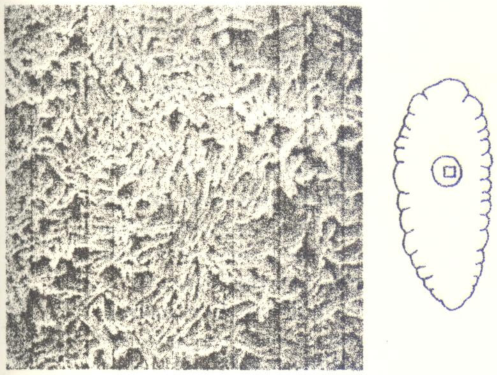
Fig. 3. Left. Surface crystals of the sagittal otolith of a young cod and the section of examination. 1 = 13.4 cm; 5. 11. 1975; magnification 20.000, KV 10, lens current 065/085, work distance 11, f-II, γ 2, PMV 3.28, rotation and dumping 0°. *Fig. 4. Right.* Surface crystals of the sagittal otolith of a young cod and the section of examination. PMV 3.35, other data as in fig. 3

Material

Sagittal otoliths were taken from a cod of 13.4 cm length caught in November 1975 in Kiel Bight. These otoliths were washed carefully in water and preserved in alcohol till the time of preparation for scanning examination. For this purpose the otoliths were dried before coating with carbon and gold. The examination was undertaken in the Geological Institute at the University of Kiel, Germany.

Results and discussion

Aragonite crystals of the otolith appear to be formed by epiaxial growth on a protein matrix with their long axes arranged roughly perpendicular to the outer margin. They run



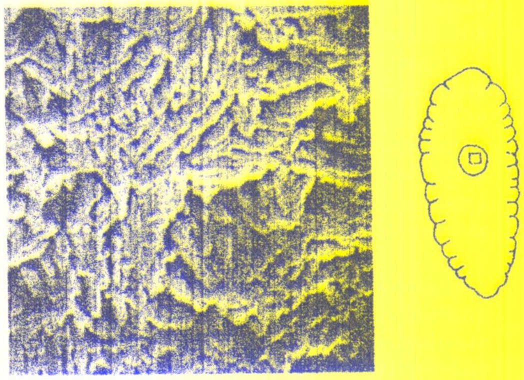
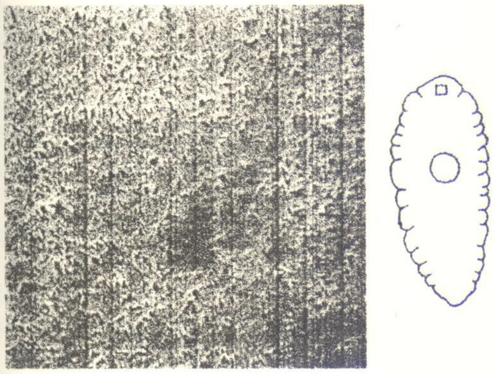


Fig. 5. Left. Surface crystals of the sagittal otolith of a young cod and the section of examination. l = 13.4 cm; 5. 11. 1975; magnification 5.150, KV 10, lens current 06/025, work distance 10.5, f-I, γ 2, PMV 3.03, rotation and dumping 0°. *Fig. 6. Right.* Surface crystals of the sagittal otolith of a young cod and the section of examination as a point in the middle of the square. l = 13.4 cm; 5. 11. 1975; magnification 10.250, KV 10, lens current 065/085, work distance 10.5, f-I, γ 2, PMV 3.33, rotation and dumping 0°



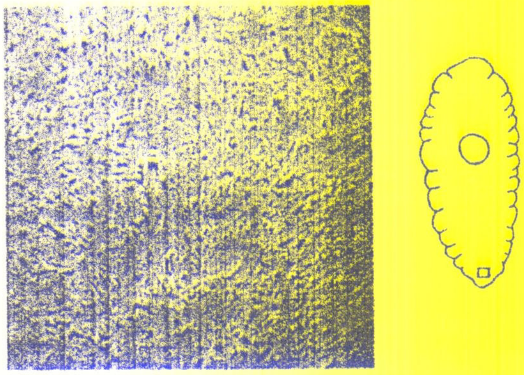


Fig. 7. Left. Surface crystals of the sagittal otolith of a young cod and the section of examination. l = 13.4 cm; 5. 11. 1975; magnification 5.000, KV 10, lens current 06/075, work distance 11, f-I, γ 2, PMV 3.10, rotation and dumping 0°. *Fig. 8. Right.* Surface crystals of the sagittal otolith of a young cod and the section of examination. PMV 3.20, other data as in fig. 7

from the centre to the margin of the otolith without any interruption (LIEW 1974). These aragonite crystals can indeed be seen on the surface of the otolith (figs. 1 to 8). In most cases the aragonite crystals lie like wind blown sand on a beach. However most interesting is the size of the crystals in different sections of a single otolith of the cod. Two pictures of the same magnification observed from the convex side of the otolith are shown in figures 1 and 2. The photographed regions are from similar positions on the otolith and originate from the sides of the nucleus which is observable as a dark point under light penetration. Figures 3 and 4 show two other examples from the convex side. Here the aragonite crystals are close-packed in some regions and form a series of „mountains". The „valleys" look like craters. It seems that on the convex side the anterior ends of the sagittal cod otoliths contain smaller aragonite crystals than the posterior ends. The posterior crystals are seen to be approximately twice as large. The crystals from the concave side of the otolith are more uniform in size though they are bigger in the region of the nucleus. On the concave side the crystals of the posterior and anterior ends are about the same size (figs. 5, 6, 7 and 8).

Thus one may conclude that a sagittal otolith of cod which was caught in November carries on the surface crystals of different sizes in the period of so-called „slow growth" or „no growth". It was observed that in November a little more than 50 % of the cod in the western Baltic Sea had already completed their hyaline growth bands. Although the rate of growth decreased, there was a remarkable increase in otolith size. The otolith of the young cod grows remarkably in the late atumn (BINGEL 1972). Therefore the observed crystals cannot be considered a residue of the previous growth season.

The different size of the crystals on the surface of an unbroken otolith shows that the formation of otolith growth is not uniform. It would seem that the otolith grows more on the concave side at the posterior and anterior ends where the smallest crystals are detectable. This is confirmed by the fast absolute and relative growth rates at the anterior end posterior ends. Fast deposition on a certain face of a crystal will increase the thickness of the layer but not the area of the face. The neighbouring face at angles to the first one where deposition is less frequent will, however, increase its area (MOORE 1972, p. 828).

As shown in figures 5 and 6 the largest crystals are to be found at about the same position as the nucleus of the cod otolith. Therefore it may be concluded that the sizes of otolith crystals differ not only in the opaque and the hyaline growth zones, but also in the same growth band in different parts of the otolith. The crystal sizes on the outer margin suggest sections of favourable growth and the deposition of these sections in a fixed order.

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