Electron Backscatter Diffraction Seeds Light on Dinosaur Eggshell Growth

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The relation between eggshell structure and eggshell formation is well established in avian eggs, but has never been studied in depth in non-avian dinosaurs. All dinosaur eggshells are formed by the growth of calcite crystals that radiate out of protein nucleation centers known as organic cores. Some of these crystals grow towards the outer part of the egg forming a columnar layer that comprises most of the eggshell. Competitive growth has been postulated to be the general mechanism leading to the characteristic columnar construction in eggshell (García-Ruiz & Rodríguez-Navarro, 1994). This process establishes that radiating crystals grow freely until they reach neighbouring crystals. Only the crystals whose angle of growth is parallel to the general direction of eggshell growth will survive, annihilating all other neighbours (Grigor'ev, 1965). In this context, the number of surviving crystals in the eggshell will be reduced following a power law as they reach the outer surface of the eggshell. The speed of this process will be controlled by the initial distance between crystals –i.e. organic core distance. Here we analyse the eggshell structure of both ornithopod and non-avian theropod eggshell with orientation contrast imaging and electron backscatter diffraction in order to ascertain whether competitive growth can explain the development of the columnar structure in eggshell in non-avian dinosaurs (see Moreno-Azanza et al., in press for a detailed description of methods). Our results show that the avian model of eggshell crystal growth fits the theropod and ornithopod eggshell structure, but interseed distance cannot be directly correlated with organic core spacing as the model predicted. In addition, our results suggest that ornithischian dinosaurs, or at least hadrosaurs, have active biological control of the growth and formation of the eggshell, via a looser spacing of organic cores. These features reduce competition between crystals and allow the eggshell units to grow discretely, likely making the egg more fragile than the theropod egg. Also, the lack of space for the crystals and the low angle relation between neighbours result in a high number of low angle boundaries in the ornithopod eggshell, which are not present in the theropod eggshell, thus weakening the general structure even more.These features ease the eggshells to be broken by hadrosaur hatchlings of hadrosaur dinosaurs, which seem not to sit on their eggs and do not need hard-shelled eggs. On the other hand, tighter organic core distribution may have helped the non-avian theropod dinosaurs to strengthen the eggshell, allowing different strategies of egg incubation.

References

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