**Captions for supplementary Figs and Tables**

**Fig. S1.** Comparisons of two kinds of zero solution correction methods. Left and right columns are the Korean magpie and Japanese tit eggshells, respectively. A–B, raw data. C–D, a zero solution is corrected when it is surrounded by at least six consistent pixels and this step was iterated three times. E–F, a zero solution is corrected when it is surrounded by at least four consistent pixels. Black arrows in A–B mark the zero solution caused by the existence of vesicles in the eggshell (i.e. biological traits) that should not be corrected. White arrows in A–B point the zero solution caused by the overlapping of Kikuchi lines of two adjacent grains that should be corrected (i.e. mechanical artefact). Note that, in C–D, zero solutions marked by white arrows in A–B are usually corrected whereas those marked by black arrows in A–B are preserved. In case of E–F, excessive zero solutions are corrected. Therefore, the conservative approach adopted in C–D is recommendable in order to conserve biological zero solution and eliminate analytical artefact. Scale bars (black rectangle) equal: 50 μm (A, C, E); 25 μm (B, D, F).

**Fig.** **S2.** Misorientation angles of mammillary layer plotted in histograms. Numbers in x- and y-axis represent misorientation angle (degrees) and probability, respectively. Blue bars show the misorientation distribution under neighbour-pair method, while red bars random-pair method. Black lines mark the expected frequency assuming random distribution. The numbers next to blue and red indices are sample sizes of neighbour-pair and random-pair distribution, respectively. A, *Elongatoolithus* sp.. B, *Macroelongatoolithus xixiaensis.* C, *Prismatoolithus levis.* D, *Gobioolithus minor*. E, Rhea (*Rhea* sp.). F, Duck (*Anas platyrhynchos domesticus*). G, Chicken (*Galllus gallus domesticus*). H, Japanese tit (*Parus minor*). I, Korean magpie (*Pica sericea*). Note that in A–B, the neighbour-pair distribution is most positively skewed and have the lowest average.

**Fig. S3.** The method for quantifying ruggedness of the grain boundaries in both squamatic and external zones. A, a 10° grain boundary map of duck eggshell. ML, SqZ, and EZ denote mammillary layer, squamatic zone, and external zone, respectively. Note rugged grain boundaries in squamatic zone reflecting the existence of squamatic ultrastructure. The external zone is characterized by the linear grain boundaries. B–C, a simple segmental trend line (a black solid line) is plotted above the selected grain boundaries. In the case of squamatic ultrastructure, the grain boundaries with the generally linear trend, not the curved trend, were selected in order to avoid the overestimation of the calculated ratio caused by grain shape. a. b, and c are the length of the segmental trend lines. D–E, the actual lengths of grain boundaries are measured by following edges of pixels in the bitmap images. α, β and γ are the actual length of the grain boundaries. The calculated ruggedness ratios are α/a or β/b in the squamatic zone and γ/c in the external zone, respectively.

**Fig. S4.** The d value among the maniraptoran eggshells. The neighbour-pair and random-pair distributions of each eggshell differ with statistical significance (p < 0.001) when the d value exceed the 1.949 (denoted by a blue line). Note that eggshells of Type 1 distribution (dark grey) have much higher d value than those of eggshells of Type 2 distribution (light grey).

**Table S1.** The indexing ratio of the specimen.

**Table S2.** Statistical data of the mammillary layer under neighbour-pair distribution.

**Table S3.** Comparison of grain boundary ruggedness between the different zones of eggshells.