Mechanical properties of echinoderm skeleton as a function of its chemical composition (Mg/Ca): taphonomic and paleobiological perspectives

The echinoderm skeleton is composed of magnesium-calcite with some organic inclusions. Seawater is considered the main source of calcium and magnesium ions in their skeletal formation process. The seawater Mg^{2+}/Ca^{2+} molar ratio has varied in geological time (from ~ 1, e.g. in the Cretaceous, to ~ 5.2 [mol/mol] in modern seas), affecting the chemical composition of the echinoderm skeleton. Due to the fact that magnesium content in the skeleton may affect its mechanical strength, decreasing magnesium ions in seawater could potentially negatively affect the mechanical strength of the skeleton. However, current state of knowledge on the impact of decreased seawater Mg^{2+}/Ca^{2+} ratio on the mechanical properties of the echinoderm skeleton is limited to the larval stage of sea urchins.

In this project we plan to conduct an experiment on the spines of adult sea urchins. Firstly, the spine tips of the specimens of selected species will be cut at the mid-height to induce regeneration. After that, sea urchins will be kept in seawater with three different Mg^{2+}/Ca^{2+} molar ratios (~ 5.2, ~ 2.5, ~ 1.5 [mol/mol]), and after the incubation period their regenerated spines will be examined to determine their chemical composition, and later their mechanical properties through nanoindentation. The latter method, originally applied in materials science, is currently gaining more popularity in the biomaterial research due to the fact that it enables precise determination of mechanical parameters (hardness and elasticity) of small biological samples. Relations between magnesium and nanomechanical properties of the echinoderm skeleton will be further explored through investigation of spines from field-collected dried specimens belonging to a few geographically distant species.

The results of the research should allow to determine if mechanical properties of biocalcite (such as echinoid spine) are positively related to its magnesium content and consequently, whether the skeletons of echinoderms with decreased Mg content from the so-called calcite seas (e.g., Cretaceous period) displayed lower mechanical strength in their evolutionary history. Understanding of mechanical properties of the skeleton observed at the nanoscale (such as hardness) may – paradoxically – have “macro” ecological and evolutionary implications (survivorship of prey in the case of predatory attack, by invertebrates in particular). Hardness of the skeleton and its Mg content influence also the intensity of post-mortem taphonomic processes (resistance to abrasion, cracking, dissolution) thus affecting the probability of preservation of the skeleton in the fossil record.