

SEM plays an important role in the study of fossil clam shrimps

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Clam shrimps are large branchiopod crustaceans with laterally compressed bodies enclosed by a bivalved chitinous (1) or complex chitin-mineral carapace (2). They can be found on all continents except Antarctica. They generally inhabit seasonally astatic wetlands such as playas, vernal pools, rice field, inundated road ruts or fishless lakes (3). Because their resting eggs are able to survive dormant for several years under dry conditions, they are able to rapidly colonize seasonal water pools after flooding (4). Thus they are important components of the ephemeral water ecosystems, and indicate the alternation of a wet/dry seasonal climate.

Fossil clam shrimps are more widely distributed [even on Antarctica] (5) in the deep time of earth history. They have a geological history that extends back to the Devonian. Initially, their evolution was centred on Europe but during the Mesozoic they diversified more rapidly in Asia. During the Cenozoic they gradually declined in both numbers and variety (6). Fossil clam shrimps are commonly abundant and widely distributed in sediments that accumulated in quiet, freshwater environments. As a result, they can be useful index fossils for biostratigraphic subdivision and correlation of non-marine successions. However, other taxa may occur in deposits of the same age in different drainage basins, reflecting local geographic and climatic variations and/or differences in the physical and chemical conditions within the water (3).

Fossil clam shrimps are commonly preserved as calcium phosphate carapace (5) or their external or internal moulds. The fossilized soft parts of clam shrimps are very rare (7). This means that the taxonomy of fossil clam shrimps is mainly based on the structure and features of the fossilized carapace, which nowadays have been accommodated in four suborders (3): i.e. Laevicaudata, Spinicaudata, Estheriellina and Leaiina. F Scholze and JW Schneide (8) introduced improved methodology for the description of fossil clam shrimps. Although the taxonomic features, such as the carapace size and outline, the umbo size and its position, are easy observed by the help of light microscope, the more delicate ornamentation on the carapace cannot be clearly observed under a light microscope.

Nowadays scanning electron microscopes [SEMs] are widely available and play a more important role in the taxonomy of fossil clam shrimps. The previous studies of fossil clam shrimps were mainly based on the observation under a light microscope. This makes the description of carapace ornamentation features unprecise, and thus taxonomic relationships cannot be determined clearly. OF Gallego et al. (9) re-illustrated the geographically and stratigraphically widely distributed Early Cretaceous species *Martinesstheria codeensis* using an SEM, and found two pattern ornamentation on growth bands: i.e. the polygonal reticulation in the dorsal part and scarce shallow ovate cavities filled with minute puncta in the ventral part of the carapace. Thus, the species was moved out of the genus *Lioestheria* and was designated as a type species of the new genus *Martinesstheria*. The genus *Migansia* was reported from the Upper Jurassic Penglaizhen Formation of Sichuan Province, southwestern China. A new SEM imaging of the type material of *Migansia sichuanensis* has revealed the similar carapace ornamentation as in *Qinhaustheria* from the Kimmeridgian Hongshuigou Formation of Qinghai Province, northwestern China. They both have radial lirae, cross bars and puncta. Thus, *Migansia sichuanensis* should be assigned to *Qinghaustheria* (10). This research result supports the correlation of the Penglaizhen Formation of Sichuan with the Hongshuigou Formation of Qinghai.

More SEM studies suggested that serrated growth lines are only of taxonomic significance for the generic or subgeneric level, not for the family

rank. Although many previous studies suggested that the serration along the lower margins of growth lines was a diagnostic feature for the family Afrograptidae, this feature has been recovered in many fossil clam shrimp taxa: such as *Cratostracus* (11), *Ordosestheria* (12), *Porostracus* (11) of the family Fushunograptidae, *Estherites* (13), *Euestherites* (13) of the family Estheriidae, *Dictyestheria* (14), *Halysesstheria* (14), *Plectestheria* (14), *Tylestheria* (15) of the family *Halysesstheriidae*. The list would be much longer if further SEM studies would be undertaken. Thus, YB Shen (16) has moved many taxa out of the family Afrograptidae and reassigned them to different families.

Recent SEM studies of fossil clam shrimps have discovered more delicate ornamentation on growth bands. G Li et al. (1) have found small punta on growth bands, which have not been discernable under a light microscope. YL Li et al. (17) re-examined *Diestheria longinqua* from the Lower Cretaceous Yixian Formation of western Liaoning Province, northeastern China. More delicate morphological features on the carapace have been revealed: 1) growth lines with fine ridges; 2) radial lirae intercalated with small irregular reticulation on the growth bands in the postero-middle part of the carapace. G Li et al. (18) re-examined the specimen of *Ganestheria longnanensis* from the Upper Cretaceous of southeastern China under an SEM, and revealed morphological features on the carapace that had not been recognized previously: widely spaced radial lirae on growth bands intercalate large-sized polygonal reticulation, within which small-sized reticulation also occurs.

The use of an SEM is essential in the study of fossil clam shrimps, so that the species and genera can be adequately compared with each other and also their biostratigraphic value can be increased (19-21). There are a lot of similar issues and problems in this area that are waiting for being resolved. So that the distribution pattern and biogeography of fossil clam shrimps can further be discussed (3). The journal "Environmental Geology" can be a great place to share the achievements of modern researchers in this field.

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