The "*Bradleya* problem", the spearhead of ostracod-based paleoceanography – contribution and outcomes

Cristianini T. Bergue[1] and Michael A. Kaminski[2]

[1]*Departamento Interdisciplinar, Universidade Federal do Rio Grande do Sul, Centro de Estudos Costeiros, Limnológicos e Marinhos – Ceclimar, Avenida Tramandaí, 976, 95625-000, Imbé, RS, Brazil*
email: ctbergue@gmail.com
[2]*Geosciences Department, King Fahd University of Petroleum & Minerals, PO Box 5070, Dhahran, 31261, Saudi Arabia*
email: kaminski@kfupm.edu.sa

INTRODUCTION

Since their origin in the Ordovician, ostracods have radiated to several different aquatic and even semiterrestrial environments, evolving under influence of both extrinsic (ecological) and intrinsic (genetic) factors. The deep ocean does not constitute an exception to these controls, no matter how different the concept of deep-sea might be among students of Paleozoic and post-Paleozoic ostracods. Once integrated to the bathybic biotas (i.e., from bathyal to abyssal depths, including guyots), ostracods followed a particular pattern of diversification and dispersal in response to climatic and tectonic events.

Research on deep-sea ostracods, which began with Brady (1880), broadened our comprehension of paleoceanography, marine ecology and crustacean evolution (e.g., Benson et al. 1984; Jellinek et al. 2006; Cronin et al. 2010; Hunt et al. 2010; Brandão 2013; Cronin et al. 2014; Yasuhara et al. 2014; Yasuhara et al. 2015; Yasuhara et al. 2018). This thematic issue presents an updated approach on deep-sea ostracod research, with papers on several aspects on this important theme of micropaleontology. It results from contributions of specialists from various countries and includes papers on Paleozoic, Mesozoic, and Cenozoic ostracod assemblages from different oceanic regions.

The publication of this issue in the year of 2022 has special importance due to its significance for deep-sea ostracod research history. It marks the fiftieth anniversary of publication of a classic work on marine podocopid ostracod research: "The *Bradleya* problem", by Richard Benson, in 1972. This remarkable monographic paper, unique in providing transparent plastic plate overlays depicting diagrams of pore conuli positions, is a true benchmark in deep-sea ostracod research. Much more than its innovative printing, Benson's paper brings invaluable taxonomic contributions, such as the description of *Poseidonamicus*, an icon of deep-sea assemblages, and establishes a connection between its evolution and that of close relatives – the genera *Bradleya* Hornibrook and *Agrenocythere* Benson – to oceanographic events.

THE DEEP-SEA OSTRACODS

In a simplistic approach, ostracod evolution is marked by three main ecological radiations. The first one was the adoption of the planktonic habit, possibly during the mid Silurian (Siveter et al. 1991). Afterwards, by the late Silurian–early Carboniferous the ostracods started their second invasion, this time toward non-marine environments, which represent their most significant ecological and evolutionary step (Horne 2003; McGairy et al. 2021). It was between these two events, i.e., during the Devonian that ostracods apparently began to radiate to deeper waters, when a distinctive Thuringian Mega-assemblage evolved which was morphologically different from the shallower Eifelian Mega-assemblage (Crasquin and Horne 2018). The occurrence of Paleozoic deep-water assemblages is also reported in other studies (e.g., Kozur 1991a,b; Yuan et al. 2007).

Paleozoic deeper ostracod assemblages were arguably different from Cenozoic ones, although it is not clear whether they were or were not psychrospheric (i.e., inhabiting deep and thermally stratified water). In spite of that, this event represents a remarkable ecological shift in ostracod evolution, and deserves special attention by ostracodologists. Therefore, this thematic issue opens with the study by M.-B. Forel (2022) which reviews the diversification of deep-sea ostracods during the Late Paleozoic and Triassic, and discusses the influence of climatic events on taxa migration, and characterization of off-shelf ostracod faunas. Moreover, Forel's paper offers also taxonomic contributions in terms of taxa review and the description of a new genus.

Through the Mesozoic the most conspicuous modifications in deep-sea ostracods occurred during the Cretaceous when downslope migrations allowed the evolution of faunas that would characterize the deep-sea assemblages during the Cenozoic. In the second paper of this volume, R.V. Dingle (2022) presents an updated review of this process based on detailed discussion on speciation and dispersal of two important deep-sea dwellers – *Abyssocythere* Benson and *Dutoitella* Dingle – during the Late Cretaceous–Paleogene. These trachyleberidids are typical constituents of deep-sea ostracod faunas especially in the South Atlantic Ocean, and Dingle's taxonomic and paleozoogeographic analysis of the two genera gives absorbing insights on podocopid evolution.

It was during the Cenozoic, however, that deep-sea ostracods became more diverse and widespread, possibly in consequence of the inception of the psychrosphere which led to a stratified ocean (Benson 1975; Zachos et al. 2001). Climatic events exerted strong influence on the diversification of Cenozoic deep-sea ostracods which were influenced in variable degrees by thermal and productivity variations. While Dingle's paper in this volume covers also important Paleogene and Neogene events, the Cenozoic deep-sea ostracods are presented in more detail with four papers on Quaternary assemblages. The first of them by R. Maia et al. (2022) analyze Pleistocene chemosynthetic communities from the Pelotas Basin, the southernmost Brazilian marginal basin. The study, which is reinforced with foraminifera data, discusses the influence of bathymetry and gas seepage on benthonic communities. Towards the other extreme of the planet, in the Arctic Ocean, T.M. Cronin et al. (2022) bring a detailed paleoclimatic analysis between the MIS 5 and 1 based on the genus *Rabimilis* Hazel. The authors discuss the influence of Arctic ice cover on the depth distribution of *Rabimilis mirabilis* Brady 1868 and on the concept of deep-sea species.

The volume ends with two papers on North Atlantic deep-sea ostracods. In one of them M. Huang et al. (2022) present a study on a typical deep-sea inhabitant *Poseidonamicus* Benson. The paper reviews the taxonomy and discusses (paleo)ecological aspects of this emblematic psychrospheric taxon, based on North Atlantic data, describing a new species, and analyzing paleozoogeographic aspects of the *Poseidonamicus*. And finally, A. Jöst et al. (2022) present an inventory on deep-sea ostracod species of the North Atlantic. This region is one of the most studied for deep-sea ostracods, and the detailed diversity analysis presented in this paper provides invaluable data for assessment of deep-water formation in high latitudes and paleoclimatic application.

Fifty years have elapsed since the publication of "The *Bradleya* Problem", and its influence on the ensuing deep-sea ostracod research has inspired analogous titles for challenging subjects, such as "The *Krithe* problem" (Whatley and Quanhong 2003) and "The ´*Oxycythereis*´ problem" (Yasuhara et al. 2013). Above all, this research field has revealed along these fifty years the huge diversity, dynamism, and importance of the deep-sea ostracods for the understanding of past and present oceanic environments. We hope this thematic issue will inspire ostracod researchers to continue investigating and improve upon this fascinating research field.

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