Palaeoenvironmental Significance of Pithonellid Calcitarchs in SE Anatolia: a Discussion on the Use of the Term 'Calcispheres'

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'Pithonellid calcitarchs" (middle? Cenomanian) are found in the organic-rich limestones of the Derdere Formation at SE Türkiye in the northern Arabian Platform. Unfortunately, little is known about the pithonellid calcitarchs in the Cretaceous strata of Türkiye. The diversity or occurrence of "pithonellid calcitarchs' is extremely low in the study area. Three morphogroups of "pithonellid calcitarchs' are distinguished in the study. In the literature, Pithonella sphaerica (Kaufmann, 1865) and P. ovalis (Kaufmann, 1865), both dominant in the pithonellid assemblages, and Bonetocardiella conoidea (Bonet, 1956), less abundant, are mentioned. The marked increase in pithonellids may be related to an early transgressive phase due to sea-level changes during the Cretaceous time, particularly evident in the Cenomanian (Upper Cretaceous). They represent a potentially useful correlative biomarker horizon in the successions of SE Türkiye. 'Pithonellid calcitarchs' have been interpreted as indicators of increased nutrient input and discussed in terms of paleoecology/paleoenvironment and their association with roveacrinid crinoids. In the base of the Derdere Formation, a carbonate succession deposited under eutrophic conditions, there is a positive relationship between "pithonellid calcitarchs" and nutrient input, as indicated by the low diversity or abundance of benthic and planktonic foraminifera. Platform drowning or possibly a mid–Cenomanian event (MCE1) and an anoxic bottom environment could be related to the abundance peak of "pithonellid calcitarchs'. In addition, the terminology of calcisphere is also discussed in this study. Nowadays, the term calcispheres is used inconsistently. To eliminate this confusion, the term "pithonellid calcitarchs" is proposed to be used in both global and regional studies.

INTRODUCTION

On a global scale, pithonellid calcitarchs represent an important, massive petrogenetic contribution to the Late Cretaceous carbonate factory. They are abundant in pelagic/hemipelagic and ramp/shelf carbonate sediments worldwide (Wendler et al., 2022a; 2002b). Pithonellid calcitarchs were abundant during the Cretaceous (Hart, 1991; Dias-Brito, 2000; Versteegh et al. 2009). There are several reports on the Cretaceous deposits of the Arabian Platform and adjacent areas: e.g., Iran (Adams et al., 1967), Israel (Bein and Reiss, 1976), southeastern Turkey (Cros et al., 1991), Jordan (Wendler et al., 2010), and northern Iraq (Hussein, 2017). Pithonellid calcitarchs cannot be used biostratigraphically because they have a wide stratigraphic range. However, they have the potential to be used for paleoenvironmental reconstruction, and therefore we used them to interpret the conditions that prevailed in southern Türkiye. In this study, we discuss the paleogeographic implications of the pithonellid calcitarchs.

CALCISPHERES AND PITHONELLID CALCITARCHA

The term "calcisphere" is not formally recognized and has remained informal until recent times, although most authors use the term in various approaches, which are summarised below. Early scientific studies associated these essentially spherical calcareous microfossils with the benthonic foraminifera genus Lagena (Kaufmann, 1865). These pithonellid calcitarchs were then assigned to various foraminifera groups such as Oligostegina, Fissurina, Orbulinaria, Pleurozonaria, and Stomiosphaera (Colom, 1955). Dias-Brito (2000) summarised that other speculations classified them into tintinnida, calcareous algal spores, chlorophycean algal zoospores, unicellular algae, benthonic algal oogonia, oolitic structures, protozoa, planktonic protists, and planktonic ciliate organisms respectively. However, Wall and Dale (1968) initially suggested interpreting them as calcareous dinocysts. Later, Keupp (1979, 1987) pointed out the same relationship with Mesozoic calcisphaerulids. Wendler et al. (2002b) suggested several origins for Pithonella ovalis and P. sphaerica, including the possibility that they are skeletons of dinoflagellates with a vegetative coccoid life stage, which could explain their predominance over other calcareous dinoflagellates in the Cretaceous assemblages. In recent literature (Farzadi, 2006; Piryaeu et al., 2011; Hussein, 2017), the term Oligostegina is still commonly used for pithonellid microfossils in Iran and Iraq. Finally, analogous to the listing of Acritarcha for organic microfossils of unknown origin, Versteegh et al. (2009) proposed the new group Calcitarcha, which includes all calcareous microfossils with a central cavity of an unknown biological relationship. In the following, we have adopted the nomenclature proposed by Wendler et al. (2013) for pithonellid calcitarcha.

MATERIALS AND METHODS

Micropaleontological studies were carried out on 71 thin sections of limestone samples (boreholes and outcrops) to characterise the pithonellid calcitarchs. Subsequently, microfacies textures were determined in the sedimentology laboratory of the Geological Engineering Department of Middle East Technical University (METU) with an Olympus CX31 polarising microscope using the nomenclature of Dunham

(1962) and following the standards of Flügel (2010). Carbonate rocks were classified using the comparison tables defined by Terry and Chilingar (1955) for visual estimation of percent composition. Facies analyses were performed using this semiquantitative method and Dunham classification. Species identification was performed using a scanning electron microscope (SEM) in the METU central laboratory. The SEM slabs, raw sample material, and processed samples analyzed for the present study are all located in the sedimentology laboratory of the Department of Geological Engineering (METU), Ankara (Turkey), under the registration code and numbers TPA.01-SAB1-9; the samples from the K1-1, Y-1, S-2, and S1-2 well sections are located at the Research and Development Centre (ARGEM) of the Turkish Petroleum Corporation (TPAO), Ankara (Türkiye), under the registration code and numbers TPA.01-K1-1, TPA.01-Y-1, TPA.01-S-2, and TPA.01-S1-2, respectively.

RESULT

Palaeoenvironmental Synthesis

The distribution of pithonellid calcitarchs was under the control of accompanying tectonic phenomena, climatic conditions, paleoceanographic changes, and facies-determining environmental factors (Brass et al., 1982; Dias-Brito, 1982; Hay, 1988; Woo et al., 1992). These conditions were highly favourable for opportunistic, r-selected pithonellids, allowing them to thrive and evolve. They thrived in oligotrophic, mesotrophic carbonate ecosystems in association with other pelagic organisms such as roveacrinid crinoids. The pithonellid calcitarchs were thermophilic planktonic organisms associated with fine-grained carbonates deposited in ramp/shelf environments. Therefore, their distribution was controlled by both latitudinal and environmental factors (Dias-Brito, 2000). The increasing abundance of Pithonella ovalis, P. sphaerica, and Bonetocardiella conoidea has been linked to the drowning of the SE Anatolian carbonate platform, as reported by Mülayim et al. (2019a, 2019b) at several sites in the region. Long-term sea-level rise has been extensively documented (Dias-Brito, 2000), and widespread drowning of Middle Eastern carbonate platforms has been noted for the middle Cenomanian (Ziegler, 2001; Sharland et al. 2001), with this drowning coinciding with that of the SE Anatolian carbonate platform (Mülayim et al., 2019a, 2019b). In the study material, the pithonellid calcitarchs are associated with small, simple morphologies of r-strategist planktonic foraminifera that are surface-dwelling species such as the genera Heterohelix, Globigerinelloides, and Muricohedbergella (Hart, 1980a, 1999; Jarvis et al. 1988; Leckie, 1987; Leckie et al., 1998, 2002; Keller and Pardo, 2004). The low salinity tolerance of hedbergellids (such as Muricohedbergella planispira) and the low oxygen tolerance of heterohelicids have been extensively documented (Hart, 1980b, 1999; Leckie, 1987; Leckie et al., 1998, 2002; Keller and Pardo, 2004; Mülayim et al., 2020). In the study material, the pithonellid calcitarchs could be considered opportunistic forms by their association with small r-strategist planktonic foraminifera. The latter are cosmopolitan, opportunistic, and adapted to eutrophic environments as documented by Leckie (1987), Premoli Silva and Sliter (1994), Coccioni and Luciani (2004), and Caron et al. (2006).

The paleoecological significance of the roveacrinid crinoids and their connection to the pithonellid calcitarchs

The roveacrinid skeletons were not transported far, not even stirred up by bottom currents, and their crumbled, disarticulated pieces were locally dismantled and scattered in the (lower? to middle Cenomanian) mud-supported sediments of SE Türkiye (Mülayim et al., 2018). They are considered opportunistic organisms because their abundance is positively correlated with that of carbonate producers (pithonellid calcitarchs and heterohelicids) (Ferré, 1995; Ferré et al., 1997). In SE Türkiye, roveacrinid crinoids are more abundant along with pithonellid calcitarchs in the outer ramp environments (Mülayim et al., 2018). This relative rarity could be due to gradual environmental changes in the most likely progressive sedimentary environments of the basin, detrital input, and, less likely, nutrient depletion, resulting in restricted ecological niches and declining diversity (Ferré et al., 2005). In SE Türkiye, the mid-Cenomanian interval documents a peak in diversity and abundance of both pithonellid calcitarchs and roveacrinid crinoids. This quantitative aspect coincides with a global eustatic peak in sea level (Haq, 2014). Ferré (1995) demonstrated that the abundance peaks of roveacrinids, pithonellid calcitarchs, and planktonic foraminifera coincide. In the context of these paleoenvironmental conditions inferred from microfaunal associations, roveacrinid crinoids thrived in environments where they often developed abundant opportunistic populations that most likely fed on pithonellid calcitarchs (Ferré et al., 1997; Ferré et al., 2017; Mülayim et al., 2018). Their wide paleogeographic distribution and global (at least Tethysian-wide) dispersal reflect an early planktonic stage as echinoderm broods or juveniles. Later, they sank to the seafloor as benthonic (bentho-pelagic), bottom-dwelling adults, possibly swimming to escape predatory pressure (Ferré et al., 2016). They are thought to feed on pelagic sinking nutrients (as epibenthonic hemipelagic dredges), and their abundance levels correlate with blooms of calcareous dinocysts, pithonellid calcitarchs, and heterohelicids. Consequently, they can be used to complement sedimentary deposits as well as the eustatic context or highly productive events. While anoxic events have attracted much of the stratigraphic attention (Ferré et al., 2018), such roveacrinoid debris levels can be interpreted as one of the first stirrings of surface productivity and an anoxic bottom environment. This ecological coincidence has also been documented in SE Türkiye, where “middle” Cretaceous deposits are considered anoxic in some places (Mülayim et al., 2019a, 2019b), which is related to sea-level changes. Such accumulation beds have high potential value as field marker beds for at least regional and even Tethysian wider, long-range correlation. At the very least, we can suggest that this underappreciated fossil group offers potential fossil signposts to detect even minor ecological disturbances and constrain some key crises.

CONCLUSION

The pithonellid calcitarchs in SE Türkiye are characterized by low diversity: only three taxa are recorded. Bonetocardiella conoidea, Pithonella ovalis and P. sphaerica are good biomarkers for the middle? Cenomanian. The stratigraphic level with the highest occurrence of pithonellid calcitarchs can also be used as a correlative tool for the base of Derdere in petroleum exploration.

Pithonellid calcitarch were opportunistic Tethyan organisms that thrived in warm, saline, and CaCO3-rich surface waters. Therefore, they are a useful paleoceanographic tool for identifying Cretaceous pelagic carbonate ecosystems in the Tethys.

Being highly dependent on carbonate ecosystems, they could have thrived under changing water conditions and under the influence of fluctuations in relative sea level. It was the most opportunistic and, living in waters with varying nutrient levels and tolerating higher stress conditions.

Keywords: pithonellid calcitarcha, calcispheres