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Pithonellid calcitarch record in the middle? Cenomanian Derdere-A Member, SE Turkey: palaeoenvironmental changes and stratigraphic significance

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Abstract: Pithonellid calcitarchs are studied in the organic-rich limestones of the Derdere-A Member from the middle? Cenomanian deposits of SE Turkey for the first time. Little is known about the distribution of pithonellid calcitarchs in the Cretaceous strata of Turkey. Three morphogroups of pithonellid calcitarchs are distinguished: they are represented by *Pithonella sphaerica* (Kaufmann, 1865) and *P. ovalis* (Kaufmann, 1865), both dominating the pithonellid assemblages, and by *Bonetocardiella conoidea* (Bonet, 1956), this latter being less abundant. Compared to the relative abundance of Upper Cretaceous pithonellid calcitarchs in the study area, the diversity is extremely low. The significant increase in abundance of pithonellid calcitarchs is particularly noticeable in the Cenomanian. We observed a significant increase in abundance of pithonellid calcitarchs in the Derdere-A Member, which is associated with an early transgressive phase of the middle? Cenomanian Arabian Platform. They are present in relative abundance and could therefore represent a potentially useful correlative marker horizon in SE Turkey. Pithonellid calcitarchs have been interpreted as indicators of increased nutrient input. A positive correlation exist between pithonellid calcitarchs abundance and nutrition input in the Derdere-A Member which is a sequence of carbonates deposit under eutrophic conditions, as evidenced by the low diversity and very low abundance of benthonic and planktonic foraminifers, and the high abundance of pithonellid calcitarchs. As a result, the increase of pithonellid calcitarchs indicates the increase of nutrient input in the Derdere-A Member. We noticed that a comparable trophic change also occurred throughout the SE Turkey carbonate platform in the middle? Cenomanian. The increase in the pithonellid abundance reported here may be a possible indicator of such a change.

Key words: Pithonellid calcitarcha, Cenomanian, palaeoenvironment, SE Turkey

1. Introduction

On a global scale, pithonellid calcitarchs represent a major, 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 in 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 palaeoenvironmental reconstruction and, as such, we used them to interpret the conditions that had prevailed

in the Adiyaman, Kilis and Gaziantep areas (SE Turkey). Most allochems of the carbonate ramp facies of the mid-Cenomanian deposits of SE Turkey consist of relics of these phytoplanktonic organisms.

In this study, pithonellid calcitarchs from the carbonate deposits of the middle? Cenomanian carbonate deposits are reported for the first time from the Cretaceous Derdere-A Member in SE Turkey and their local stratigraphic and palaeogeographic implications are discussed.

2. Calcispheres and pithonellid calcitarcha

The term 'calcisphere' is not formally recognised and has remained informal until recent times, although most authors use the term in various approaches, which are summarised hereafter. Initial scientific studies associated these essentially spherical calcareous microfossils with the benthonic foraminifer genus *Lagena* (Kaufmann, 1865). These pithonellid calcitarchs were then assigned

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to various foraminiferal 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) proposed 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; Piryaev et al., 2011; Hussein, 2017), the term *Oligostegina* is still commonly used for pithonellid microfossils in Iran and Iraq.

Finally, in analogy with 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 unknown biological relationship. In the following, we have adopted the nomenclature proposed by Wendler et al. (2013) for Pithonellid Calcitarcha.

3. Geological setting

3.1. Tectonic events

Two major tectonic events had strongly influenced SE Turkey: the Late Cretaceous and Miocene tectonics, which mainly resulted in a controlled deposition (Perinçek et al. 1991; Cater and Gillcrist, 1994; Robertson et al., 2016). These two tectonic phases, evidenced by the Koçali ophiolitic complex and the occurrence of major tectonic faults, are closely related to the convergence of the Arabian and Anatolian plates (Figure 1). The carbonate platform of the Mardin Group (Aptian to early Campanian in age) in SE Turkey developed on the passive, northern margin of the Arabian Platform (Çelikdemir et al., 1991; Cater and Gillcrist, 1994; Yılmaz, 2011; Robertson et al., 2016) and was controlled by the 'mid'-Cretaceous closure of the southern Neotethys Ocean.

The Mardin Group consists of four characteristic formations: the Areban, Sabunsuyu, Derdere, and Karababa Formations respectively (Figure 2). The Areban Formation grades upward into the Sabunsuyu Formation. The Sabunsuyu Formation is conformably underlain by the Areban Formation and unconformably overlain by the Derdere Formation.

The Karababa Formation consists of shallowing-upward carbonate facies characteristic of a ramp depositional environment (Özkan and Altiner, 2019;

Mülayim et al., 2018, 2019, 2020a, 2020b) and had ranged from the early Turonian to the Santonian. The Derdere Formation is partially unconformably overlain by the base of the Karababa Formation, while the top of this formation is unconformably overlain by the Karaboğaz Formation. Based on lithological differences alone, the Karababa Formation is divided into three parts, from base to top: A, B and C respectively. The boundaries between these members are all gradual.

The Derdere Formation consists of shallowing-upward carbonate facies characteristic of a ramp depositional environment (Özkan and Altiner, 2018; Mülayim et al., 2018, 2019a, 2019b, 2020; 2021; Simmons et al., 2020) from the middle to late Cenomanian (Mülayim et al., 2018, 2019b). The Derdere Formation is divided into three parts, from base to top: A, B and C respectively (Figure 2) (Mülayim, 2020). The top of the Derdere-A Member is conformably overlain by the Derdere-B Member, while the base of the Derdere-A Member is partially conformably underlain by the Sabunsuyu Formation. The Derdere-A Member consists of relatively deep marine carbonates (rich in pithonellid calcitarchs, planktonic foraminifers and roveacrinid crinoids) that also contain organic material; the Derdere-B Member consists of dolostones and dolomitic limestones, whereas the Derdere-C Member consists of shallow marine rocks (rudists, bivalves, echinoids, roveacrinid crinoids, algae, and benthonic foraminifers) (Figure 2).

3.2. Biostratigraphy and age

The age of the relatively deeper water deposits of the Derdere-A Member was determined by opportunistic (r-strategists) planktonic foraminifers such as *Muricohedbergella planispira*, *Asterohedbergella asterospinosa*, Hedbergellidae, benthonic foraminifers Gavelinellidae and roveacrinid crinoids (Mülayim et al., 2020) (Figure 3). This assemblage suggests a middle to late Cenomanian age. The same samples studied for biostratigraphy by planktonic foraminifers also contain pithonellids.

4. Material and methods

Micropalaeontological studies had been carried out on 71 thin sections of limestone samples (boreholes and outcrops) to characterise the pithonellid calcitarchs. Subsequently, microfacial textures were determined in the sedimentology laboratory of the Geological Engineering Department of the Middle East Technical University (METU) by means of an Olympus CX31 polarising microscope, using the nomenclature of Dunham (1962) and following the standards of Flügel (2010). Carbonate rock classification was based on the comparison charts for visual estimation percentage composition defined by Terry and Chilingar (1955). By this semiquantitative method and Dunham classification, facies analyses were completed.

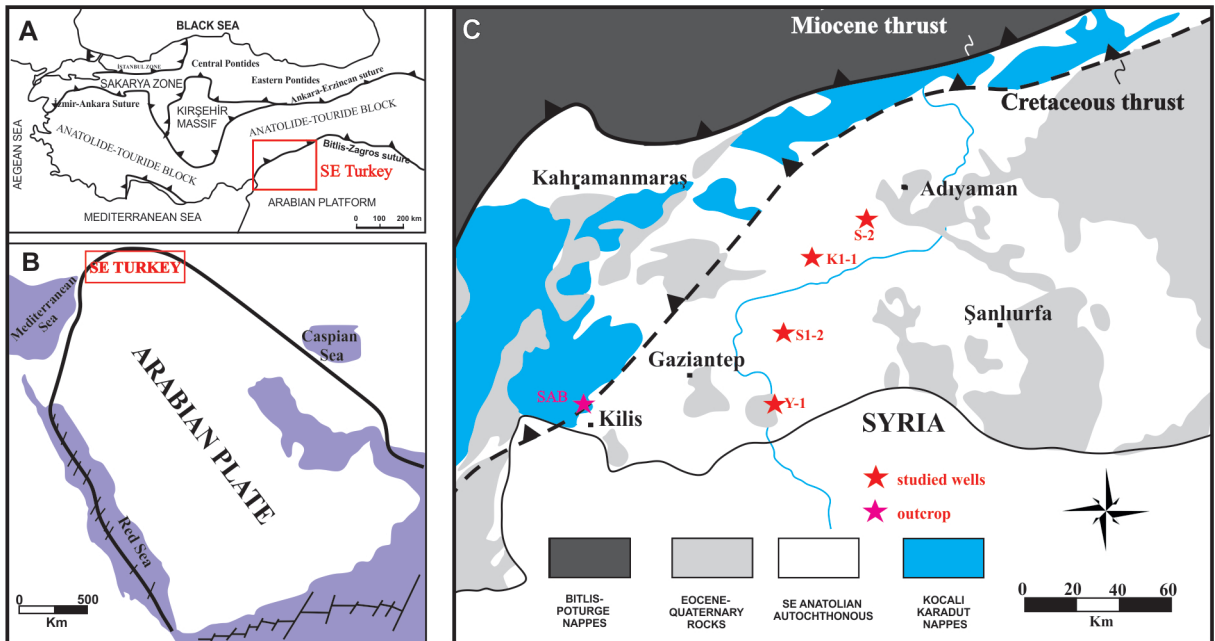


Figure 1. A. Location of the study area. B. Geographic location of SE Turkey in the northernmost part of the Arabian Platform (modified from Sharland et al. 2001; Şenel, 2002; Mülayım et al., 2019b). C. Simplified geological map of the northwestern part of SE Turkey and position of the investigated borehole sections (modified after Mülayım et al., 2019b).

Species identification was performed using a scanning electron microscope (SEM) in the METU Central Laboratory. The SEM stubs analysed for the present study, the raw sample material, and the processed samples all are housed in the sedimentological laboratory of the Department of Geological Engineering (METU), Ankara (Turkey), under the registration acronym and numbers TPA.01-SAB1-9; the samples from the K1-1, Y-1, S-2, and S1-2 borehole sections are housed in the Research and Development Centre (ARGEM) of Turkish Petroleum Corporation (TPAO), Ankara (Turkey), under the registration acronym and numbers TPA.01-K1-1, TPA.01-Y-1, TPA.01-S-2, and TPA.01-S1-2, respectively.

5. Results and discussion

5.1. Microfacies characteristics

The microfacies indicate a mudstone-wackestone-packstone texture with dominant pithonellid calcitarchs, planktonic foraminifers and roveacrinid crinoids (Figures 4–6). Based on the petrographic analysis of the Derdere-A Member of the Derdere Formation, four microfacies representing middle to outer ramp environments are therefore recognised.

Mf-1 nonlaminated, silty, pelagic, calcareous mudstone

In thin section, finely textured, dark-brown microcrystalline calcite embedded in a silty fabric and, in some places, scattered silt (Figures 4 and 5). The fine

grains are uniformly distributed in a micritic matrix. In addition, the mud matrix exhibits a minor degree of recrystallisation into xenotropic microspar in places and is partially dolomitised. Dolomitisation and silicification are common and result in poorly preserved microfossils. Mf-1 contains organic material in the upper part of the sequence. This nonlaminated, silty, pelagic calcareous mudstone microfacies corresponds to RMF 5 of Flügel (2010). This microfacies was deposited in the vicinity of the outer ramp setting.

Mf-2 pithonellid calcitarch-planktonic foraminiferal wackestone/packstone

These lithologies can be classified as wackestone-to-packstone-textured. Pithonellid calcitarchs are the dominant skeletal grains in these microfacies, and their relative abundance ranges from 20% to 50%. Pithonellid calcitarchs (i.e., *Bonetocardiella conoidea*, *Pithonella ovalis*, *P. sphaerica*, and *P. lamellea*) are the major components (Figures 5 and 6). The relative abundance of planktonic foraminifers ranges from 5% to 15%. They are generally widespread in a fine-grained, dark-brown, micritic matrix with no specific orientation, and are strongly affected by neomorphism and replacement. The presence of stylolites indicates deep burial. Organic matter is moderate to abundant in these rocks, while minor to extensive pyritisation is found in some sections. Pyritisation is associated with microbial mat activity, indicating anoxic conditions. The microfacies of pithonellid calcitarchs and

System	Series	Stage	Formation	Member	Lithology	Microfacial texture	Depositional environment
CRETACEOUS	UPPER	Turonian	Karababa	Karababa-A		Planktonic foraminiferal wackestone/ packstone	outer ramp, low energy
				Derdere-C		Peloidal wackestone/ packstone Bioclastic wackestone/ packstone	inner ramp, shallow marine
		Middle-Late Cenomanian	Derdere	Derdere-B		Dolomudstone Fine/medium/coarse crystalline dolomite mosaics	Recurrent deposition gaps, Dolomitisation
				Derdere-A		Dark-brown organic-matter, pithonellid and roveacrinid rich Dolomudstone	outer ramp, low energy
	LOWER	Albian/ Early Cen.	Sabunsuyu			Dolomudstone	restricted shallow shelf, low energy
Legend				Planktonic foraminifera	Bivalves	Algae	
				Benthonic foraminifera	Gastropods	Peloids	
				Rudist	Roveacrinids	Intraclasts	
				Drowning unconformity		Pithonellids	

Figure 2. Synthetic stratigraphic columnar section of the respective Cretaceous lithostratigraphical units in the study area (modified from Mülayim, 2020; no vertical scale implied). Red square indicates the study interval.

planktonic foraminifers in these packstones is consistent with RMF 5 of Flügel (2010). The combined presence of pithonellid calcitarchs and planktonic foraminifers indicates deposition in the vicinity of the outer ramp setting.

Mf-3 pithonellid calcitarch-roveacrinoidal wackestone

The main components of this microfacies are pithonellid calcitarchs and roveacrinid crinoids. The proportion of roveacrinid crinoids ranges from 5% to 30% (Roveacrinidae indet.) (Figures 4 and 5). The chambers are generally filled with sparite. Skeletal grains are uniformly distributed in a micritic matrix of wackestone texture. Other subordinate grains are roveacrinid crinoidal bioclasts. The matrix is

generally an earthy to dark-brown micrite. Organic matter is uniformly distributed throughout this microfacies. These lithologies exhibit minor to strong pyritisation. The pyrite is associated with the organic matter and probably formed under anoxic conditions. The bioclasts are often very small, making identification difficult. The microfacies of the pithonellid calcitarch-roveacrinoidal wackestone microfacies corresponds to RMF 7 of Flügel (2010). The presence of pithonellid calcitarchs and roveacrinid crinoids within Mf-3 suggests deposition in middle to outer ramp settings.

Mf-4 Bioclastic roveacrinoidal wackestone

This microfacies shows a wackestone texture. The relative abundance of grains is between 20% and 30%.

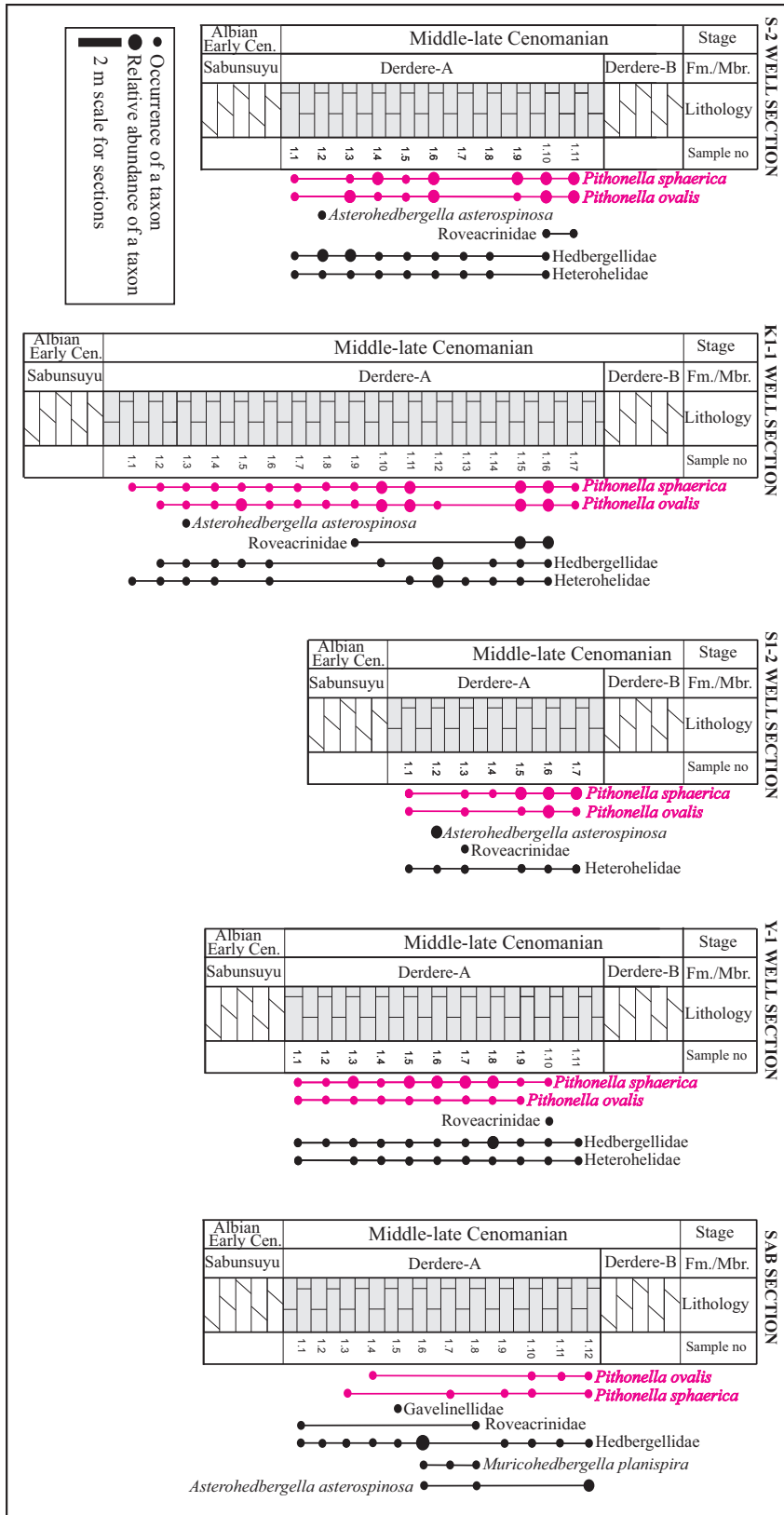


Figure 3. Stratigraphic correlations between the four borehole sections and SAB outcrop section in the Derdere-A Member. Stratigraphic distribution of some planktonic foraminifers, roveacrinids and pithonellid calcitarchs.

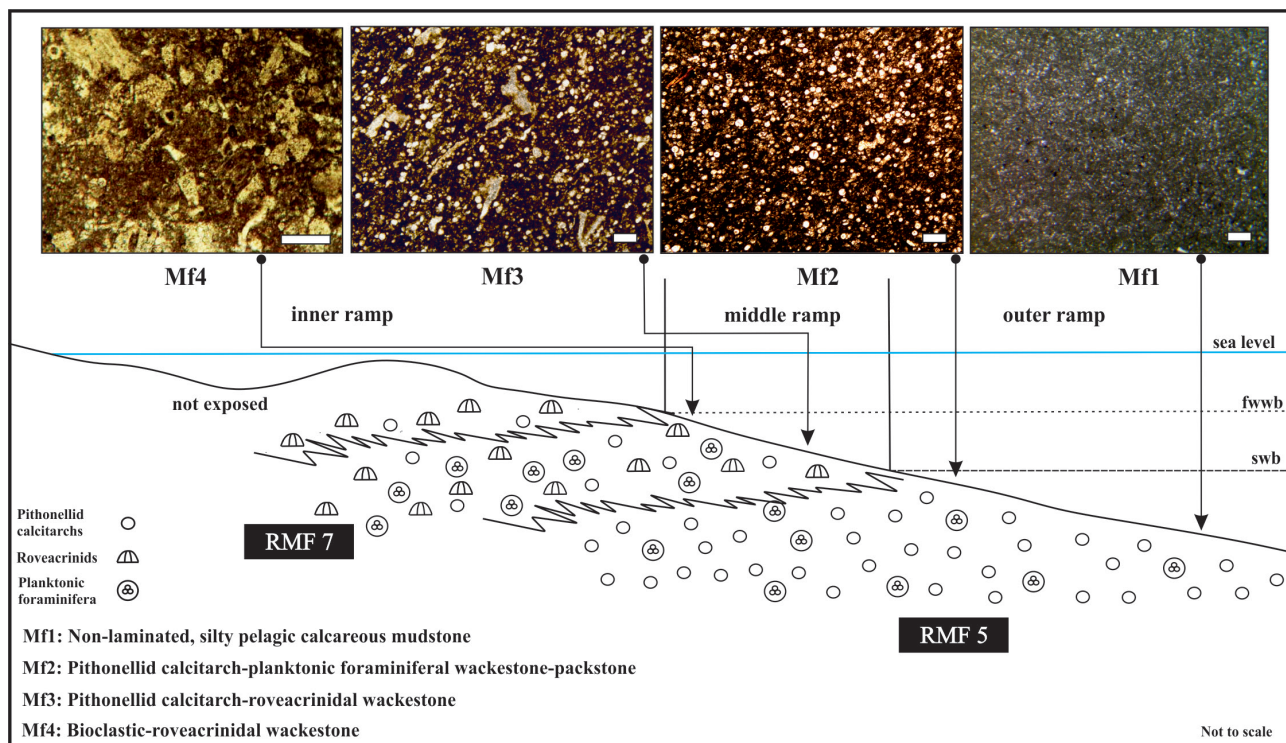


Figure 4. Depositional model showing microfacies distribution and faunal components for the middle Cenomanian succession in the study area. The pithonellid calcitarchs are the main elements of the homoclinal carbonate ramp that thrived in the mid-ramp setting and passed laterally into a deeper facies with planktonic foraminifers and roveacrinitids in the outer ramp. FWWB: fair weather wave base, SWB: storm wave base.

This microfacies contains various bioclasts, including mainly bioclasts of echinoderms (brachial and thecal plates of roveacrinitid crinoids, lateral plates of ophiuroids and echinoid spines) and bivalves, rare planktonic and benthonic foraminifers, and fine peloids (Figures 4 and 5). No organic matter is preserved. These bioclasts are mostly broken. The echinoderm spines and plates are degraded due to abrasion during reworking. Benthonic and planktonic foraminifers are very rare. Bioclasts are concentrated at various locations in the matrix. All components of the fauna are micritised around the edges and some of the fossil shells are partially replaced by neomorphic spar. Bioclastic roveacrinitoidal wackestone microfacies correspond to RMF 7 of Flügel (2010). The bioclasts are interpreted to have been deposited in middle/outer ramp settings.

5.2. Palaeoenvironmental synthesis

The distribution of pithonellid calcitarchs was under the control of accompanying tectonic phenomena, climatic conditions, palaeoceanographic changes, and facies-determining environmental factors (Brass et al., 1982; Dias-Brito, 1982; Hay, 1988; Woo et al., 1992). These conditions were very favourable to opportunistic, r-selected pithonellids, and allowed them to thrive and evolve. They

thrived in oligotrophic, mesotrophic carbonate ecosystems in association with other pelagic organisms such as roveacrinitid 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).

Increasing abundance of *Pithonella ovalis*, *P. sphaerica*, and *Bonetocardiella conoidea* is associated with the drowning of the SE Anatolian Carbonate Platform when the shallow-water deposits of the Sabunsuyu Formation were terminated by the organic-rich carbonate deposits of the deeper water hemipelagic Derdere-A deposits. Platform flooding was reported by Mülayım et al. (2019a, 2019b) at several locations in the region. Long-term sea-level rise was extensively documented (Dias-Brito, 2000), and widespread drowning of Middle East Carbonate Platforms was recorded for the middle Cenomanian (Ziegler, 2001; Sharland et al. 2001), with this drowning event coincident with that of the SE Anatolian Carbonate Platform (Mülayım et al., 2019a, 2019b).

In the study material, the pithonellid calcitarchs are associated with small, simple morphologies of r-strategist planktonic foraminifers that are surface-dwelling

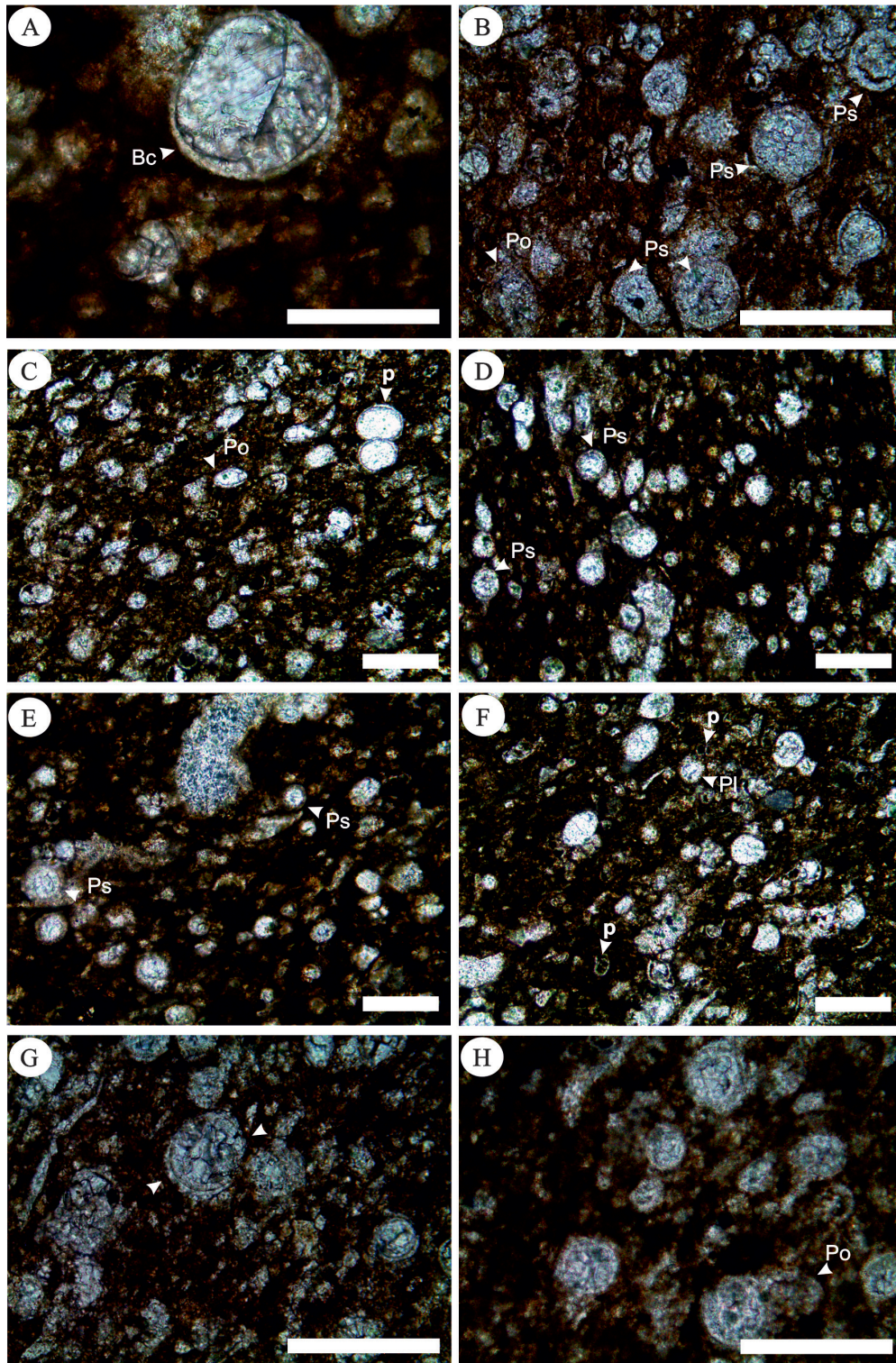


Figure 5. Thin section photographs of pithonellid calcitarchs, Middle Cenomanian, study area, SE Turkey. A. Cone-shaped form, *Bonetocardiella conoidea*, Bc, core sample 370039. B. Thick-walled spherical form with typical pithonelloid crystal-orientation - *Pithonella sphaerica*, Ps; right middle and upper corner: organic walls are preserved, and the bottom on the middle, core sample 370034. C. Centre - *Pithonella ovalis*, Po, core sample 370025. D. left (10 o'clock above centre) and others on the left: *Pithonella sphaerica*, Ps, core sample 370030. E. left = very clear *Pithonella sphaerica* with nicely visible crystal orientation core sample 370022. F. multilayered form, the *Pithonella lamellata* form spectrum, an archeopyle, spiralling fine striations and perforations, p: planktonic foraminifers, core sample 370021. G. multilayered type, this type is different from the *Pithonella sphaerica* form spectrum by its darker appearance and the brownish crystals, core sample 370019. H: *Pithonella ovalis*, core sample 370005. Scale bar: 100 μm and 200 μm .

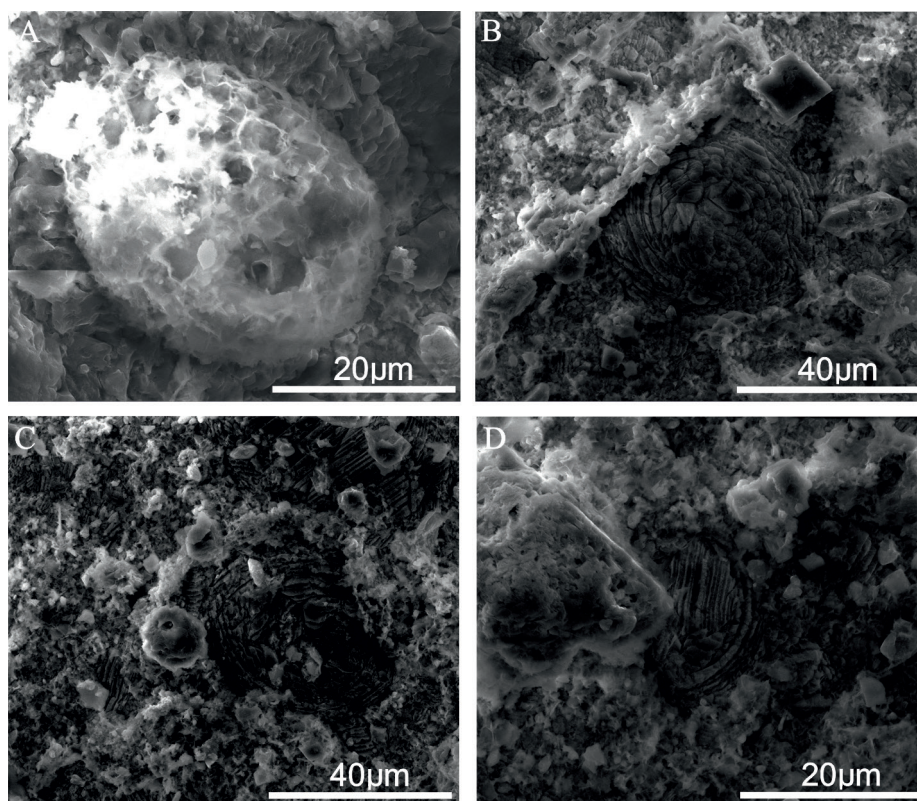


Figure 6. SEM photographs of pithonellid calcitarchs, middle Cenomanian, study area, SE Turkey. A. typical pithonelloid wall type. On the left and right sides of the sphere, the crystals are uniformly inclined towards a point of the sphere at around 11 o'clock, sample 2023. B. *Pithonella sphaerica* with a spiral crystal arrangement, sample 2011. C and D. *Pithonella sphaerica* with blocky cement infillings (the parallel lines are cleavage lamellae) samples 2002 and 2003, respectively.

species such as 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 foraminifers. These 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).

5.3. Nutrient availability

The distribution of pithonellid calcitarchs along the carbonate ramp can be related to nutrient availability and water depth. The pithonellid calcitarchs appear to have been an opportunistic group, abundance of which probably reflects an increase in nutrient availability (Jarvis et al., 1988). Wendler et al. (2002b) found that

the distribution of pithonellid calcitarchs on the shelf was dependent on water depth or nutrient availability. Noel et al. (1995) interpreted pithonellids in particular as productivity indicators. Pithonellid calcitarchs show temporal changes in abundance as a function of nutrient availability. We observed a marked change towards dominance of pithonellid calcitarchs during the middle Cenomanian in the study area. Therefore, it seems more plausible that environmental differences such as gradients in nutrient availability controlled the spatial occurrence of pithonellid calcitarch assemblages. On the other hand, nutrient depletion during this period could have actually been triggered by drowning platforms, thus reducing sources of nutrient input (Weise et al., 2015; Mülayim et al., 2019a).

Wendler et al. (2002a, 2002b) interpreted Cenomanian pithonellid-calcitarch assemblages as a consequence of climatically driven shifts between stratified and mixed water columns, i.e. marl-limestone and dark-light alternations, respectively. Thus, internal cycling, as well as changes in water temperature, variable water turbulence, and other perturbations within the biosedimentary system,

rather than nutrient availability, could have potentially triggered changes in carbonate bioproductivity and flora composition.

5.4. Upwelling

Pithonellid calcitarch biota can be a great marker of sedimentation in the neritic-oceanic transition zone (Colom, 1955; Adams et al., 1967; Bein and Reiss, 1976; Spadini et al., 1988). During the middle Cenomanian, several areas in the Tethys Ocean had been affected by coastal upwelling (Parrish and Curtis, 1982; Kruijs and Barron, 1990; Patzkowsky et al., 1991; Wendler et al., 2002b; Reijmer, 2021). Pithonellid calcitarch-rich, calcareous sediments have been interpreted to be linked to upwelling in the 'mid'-Cretaceous (Pennant, 1972; Robaszynski et al., 1993; Saïdi et al., 1997; Reijmer, 2021). Accordingly, we hypothesise that the studied area is additionally an upwelling area. Throughout the Tethys Ocean, high temperatures were suggested (Alsenz et al., 2013). Thus, the cool waters must have mixed sufficiently with the warm Tethysian waters to remain within the temperature range required by pithonellid calcitarchs. In conclusion, the studied material indicates that the limestones of the Derdere-A Member were maintained under eutrophic conditions in mixed surface waters.

5.5. Significance of the roveacrinid crinoids in terms of palaeoecology and their connection with 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 within the (lower? to middle Cenomanian) mud-supported sediments of SE Turkey (Mülayim et al., 2018). They are considered opportunistic organisms because their abundance is positively correlated with that of carbonate producers (pithonellid calcitarchs and heterohellicids) (Ferré, 1995; Ferré et al., 1997).

In SE Turkey, 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 most likely prograding sedimentary environments in the basin, detrital input and, less likely, nutrient depletion, which resulted in restricted ecological niches, and decreasing diversity (Ferré et al., 2005). In SE Turkey, the mid-Cenomanian interval documents a peak in diversity and abundance of both the pithonellid calcitarchs and the roveacrinid crinoids. This quantitative aspect coincides with a global eustatic high sea-level (Haq, 2014). Ferré (1995) demonstrated that the abundance peaks of roveacrinids, pithonellid calcitarchs, and planktonic foraminifers coincide. In the context of these palaeoenvironmental conditions inferred from microfaunal associations, roveacrinid crinoids thrived in environments where they often developed abundant opportunistic populations that

fed most likely on pithonellid calcitarchs (Ferré et al., 1997; Ferré et al., 2017; Mülayim et al., 2018).

Their wide palaeogeographic distribution and global (at least Tethysian-wide) dispersal reflect an early planktonic stage as echinoderm broods or juveniles. Later in life, they sank to the seafloor as benthonic (benthopelagic), bottom-dwelling adults, possibly actively swimming to escape predatory pressure (Ferré et al., 2016). They are thought to feed on pelagic sinking nutrients (as epibenthonic hemipelagic dredgers) and their abundance values correlate with blooms of calcareous dinocysts, pithonellid calcitarchs, and heterohellicids. Consequently, they can be used to complete 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 anoxic bottom environment. This ecological coincidence has also been documented in SE Turkey, 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 underestimated fossil group offers potential fossil guides to detect even minor ecological disturbances and to constrain some key crises.

6. Conclusions

The pithonellid calcitarch-rich deposits of the Derdere-A Member may derive from environmental conditions triggered by the early transgressive phase that had flooded the Northern Arabian Carbonate Platform (SE Turkey) during the middle? Cenomanian. The Derdere-A sediments are characterised by pithonellid calcitarchs interpreted as opportunistic organisms dwelling in eutrophic, ramp environments, together with other opportunistic forms such as r- or r/k-strategist planktonic foraminifers and roveacrinid crinoids.

The pithonellid calcitarch record from the middle Cenomanian of Derdere-A Member (SE Turkey) is represented 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 roveacrinids and pithonellid calcitarchs can also be used as a correlation tool for the Derdere-A member in petroleum exploration.

Biogeographic distribution is controlled by several interrelated factors; a direct correlation appears most probable between roveacrinid calyces and pithonellid calcitarchs. This phenomenon is tentatively explained as a possible link within the marine food chain. The filter-

feeding roveacrinid crinoids would have fed on pithonellid calcitarchs that sink to the seafloor after initial larval stage and subsequent skeleton mineralisation. The roveacrinid crinoids would have filter-fed on pithonellid calcareous algal cysts sinking to the seafloor.

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