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Role of oysters in biostratigraphy: A case study from the Cretaceous of the Ariyalur area, southern India

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ABSTRACT: The Cretaceous sediments of the Ariyalur area, southern India, are the largest and the most important of all the exposures of that system in southern India. Oyster bivalves are common in these Cretaceous sediments. More than twenty species belonging to fifteen genera are known from the Ariyalur area. They are distributed in almost all the rock formations representing ages ranging from Late Albian to Maastrichtian. The abundance, preservation and restricted ranges of these bivalve species in the Cretaceous of Ariyalur area offer scope for biozonation. They seem to play a role as markers of sedimentary units by their apparent accumulation. This study attempts to interpret the palaeoenvironment of deposition based on size, distribution and carbon isotope study of the shells, the petrology of the associated rocks and inferences based on other groups of fossils including invertebrates, vertebrates and plant fossils.

Key words: oysters, biostratigraphy, Cretaceous, Ariyalur, India

1. INTRODUCTION

The Cretaceous sediments of Ariyalur area are well studied in terms of ammonites and foraminifera (e.g., Sastry et al., 1968; Ayyasami, 1990; Hart et al., 2001). *Inoceramus* forms the only other group used for biozonation (Chiplonkar and Tapaswi, 1976; Ayyasami and Rao, 1996). Forbes (1846) first reported three species of oysters. Stoliczka (1871) added 25 species. Chiplonkar and Tapaswi (1979) listed 12 of the already known species in their collection. Later Tapaswi (1987) revised the taxonomic status of many bivalves from Cretaceous of southern India and updated the generic names of 25 species of ostreiids following Moore (1971). The palaeoecological and palaeoenvironmental aspects of bivalves in general was discussed by Tapaswi (1977, 1978) who opined that the ostreiids were deposited in euhaline to stenohaline shallow marine conditions. Fursich and Pandey (1999) studied the genesis and shell concentration of bivalves. The abundance, variety and good preservation of these bivalves offer an opportunity to attempt a biozonation of the Cretaceous rocks based on their distribution in time and space. However, caution is sounded as the use of these bivalves has limited scope in the biostratigraphic study for the following reasons:

1. Casual, not careful, collection of shells
2. Highly variable size and shape of shell
3. Literature - sparse and scattered in many languages
4. Lack of emphasis on its use in biostratigraphy unlike ammonite and inoceramid bivalve

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2. LITHOSTRATIGRAPHY OF THE CRETACEOUS ROCKS

The fossiliferous Cretaceous rocks of Cauvery Basin are distributed mainly in five sub-basins, namely, Pondicherry, Vriddachalam, Ariyalur, Thanjavur and Sivaganga. The Cretaceous rocks of the Ariyalur area are divided into formations and different formational names were proposed by different authors. The latest one by Sundaram et al. (2001) is followed here (Table 1).

The Cretaceous sequence in Ariyalur begins with non-marine Terani Formation (Fig. 1). The unconformity above the Archaean Crystalline basement is sharp at many places, which is indicated by the deposition of conglomerates. The conglomerates are assigned to the Arogyapuram Formation followed by a reefoidal limestone of the Dalmiapuram Formation near Kallakkudi (10°54′N; 78°54′E).

The overlying gypsiferous clay forms the bulk of the Uttattur Group of rocks. The shell limestones and calcareous sandstone are the main constituents of the Trichinopoly Group with minor clay beds. The Ariyalur Group begins with gritty sandstone at its unconformable contact with the Trichinopoly Group and subsequently overlain by the oyster shell bank of the Kallankurichchi Formation. The overlying Kallamedu Formation has marine fossils in the lower sandstone part and fairly common dinosaur bones in the upper part.

3. SIZE, OCCURRENCE AND DISTRIBUTION OF FOSSIL OYSTERS

In the Ariyalur area, it is found that almost all the Cretaceous rocks yielded ostreiid bivalves. Large shells, together with broken specimens, are usually found concentrated in many localities. Articulated valves are common but not frequent. The absence of fossil shells in presumed live position indicates some transportation before burial. Clusters of shells, attached to one another, are common in the Anaipadi Formation. The oyster bivalves are concentrated in the Odiyam Member and Kunnam Member of the Karai Formation and in the Kallankurichchi Formation and form the major constituent of the rocks.

Table 1. Lithostratigraphy of the Cretaceous rocks with the biozonations of ammonites and oysters.

LITHOSTRATIGRAPHY			AMMONITE	OYSTERS	OYSTER ZONES	AGE
Ariyalur Group	Kallamedu Fm. (for the lower marine part)		*Eubaculites vagina* Zone	Agerostrea ungulata	*Agerostrea ungulata* Zone	Maastrichtian
	Kallankurichchi Fm.		*Hauericeras rembda* Zone	*Agerostrea ungulata, Ceratostreon pliciferum Planospirites ostracina, Pycnodonte (Phygraea) vesicularis, Rastellum (Arcostrea) pectinatum*	*Pycnodonte (Phygraea) vesicularis* Zone	
	Sillkkudi Fm.	Kil Palavur Member	*Karapadites karapadense* Zone	*Ostrea zitteliana*	*Ostrea zitteliana* Zone	Campanian to Latest Santonian
Trichinop-oly Group	Anaipadi Fm.[1]		*Kossmaticeras theobaldianum* Zone	No characteristic oyster	Unnamed zone	Coniacian
			Lewesiceras anapadense Zone	*Exogyra(Costagyra) fausta, Lopha (Actinostreon) diluviana*	*Exogyra(Costagyra) fausta* Zone	Middle Turonian
	Kulakkalnattam Fm.		*Romaniceras (Yubariceras) ornatissimum* Zone	*Exogyra haliotoidea*		
Uttattur Group	Karai Fm.	Kunnam Member[1]	*Pseudaspidoceras footeanum* Zone	*Rhynchostreon suborbiculatum*	*Rhynchostreon suborbiculatum* Zone	Lower Turonian
			Eucalycoceras pentagonum Zone	*Pycnodonte vesiculosa*	*Pycnodonte vesiculosa* Zone	Upper Cenomanian
		Odiyam Member	*Calycoceras newboldi* Zone	*Exogyra (Costagyra) costata*	*Exogyra (Costagyra) costata* Zone	Middle Cenomanian
	Dalmiapuram Fm.		*Mantelliceras vicinale* Zone	*Pycnodonte* sp.	Unnamed Zone	Lower Cenomanian
			Mortoniceras rostratum Zone	*Rastellum (Arcostrea) carinata, Ostrea* sp.	*Rastellum (Arcostrea) carinata* Zone	Upper Albian
	Arogyapuram Fm.		No ammonite	No recognizable oyster		
	Terani Fm.		*Australiceras jacki* Zone	No oyster		Upper Aptian
	CRYSTALLINE BASEMENT		------	------		Archaean

[1]Author now recognizes faunal break with/without unconformity

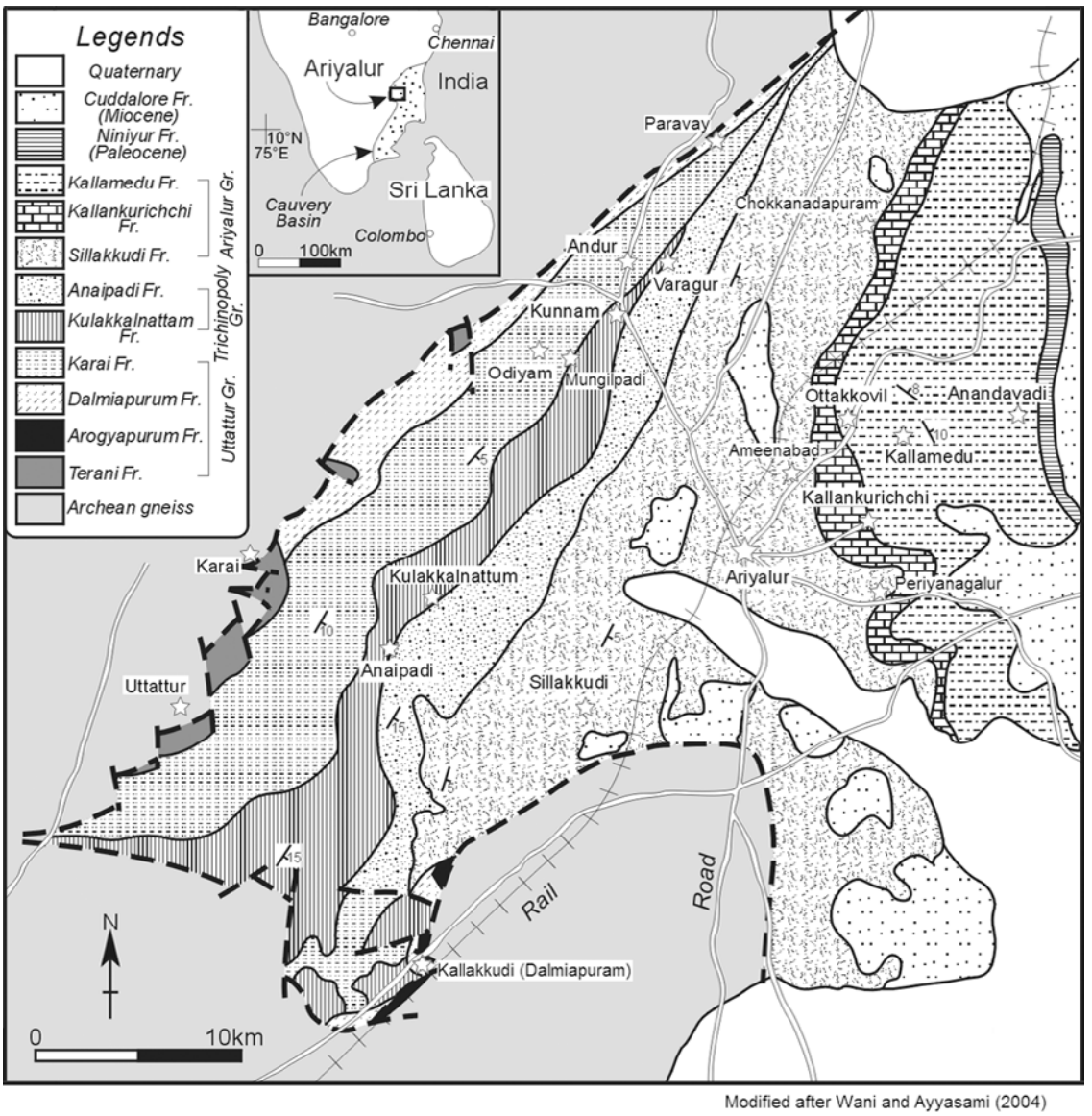

Fig. 1. Geological map of the Cretaceous rocks of the Ariyalur area.

The *Pycnodonte* shellbearing limestone of Kallankurichchi Formation is an excellent example which is exhaustively discussed by Fursich and Pandey (1999). Ayyasami and Banerji (1984) have reported the occurrence of beds of approximately a meter thickness at two levels in the Kunnam Member of Karai Formation with abundant *Exogyra* which are mined for constructive material. The *Ostrea* bearing gypsiferous shale of Karai Formation has abundant oyster shells along with belemnoids and worm tubes.

3.1. Size

The size of the shells varies from genera to genera. Most of the *Pycnodonte* and *Rastellum* valves of the Kallankurichchi Formation are large (~200 mm in length), thick and well preserved. The next smaller shells of *Lopha* (~8 cm in length) are found in the Anaipadi Formation. The *Rhynchostreon* and *Pycnodonte* shells from the Kunnam Member of the Kari Formation and *Exogyra* from the Kallankurichchi Formation are approximately 5 cm in length. The *Ostrea* shells of Karai clay are about 2 cm in length.

3.2. Occurrence

The nature of occurrence of oysters may be divided into four groups:

1. Individuals, much abraded –in lower part of Kallamedu Fm.
2. Individuals, well preserved –in Kunnam Member of Karai Fm.

3. Colonies, attached to objects –in Kulakkalnattam Fm.
4. Individuals, abundant forming thick layers –in Kallankurichichi Fm.

3.3. Distribution

Abundance of bivalves in the Kallankurichchi Formation is a classic example, where the shell bank extends about 40 km in a north-south direction from Perianagalur (11°07′N; 79°09′E) to Chokkanadapuram (11°16′N; 79°08′E). This forms a prominent horizon and is easily marked on the map. The deposits are readily mined for their concentration of bivalves that give a cement grade for the carbonates, though the rock is basically composed of sandy siltstone. Concentration of bivalves in the Kunnam Member of the Karai Formation is observed, in spite of its small thickness, for nearly 10 km in a North-South direction from Mungilpadi (11°12′N; 79°00′E) to Paravay (11°17′N; 79°02′E). The concentration of bivalves in the Karai Formation near Uttattur (11°04′N; 78°51′E) and Karai (11°08′N; 78°53′E), for a distance of nearly 5 km, is confined to the clays, though their concentration in some of the interbedded limestone bands is seen in some places. It may be due to weathering that the shells are concentrated in the surface clay. At all these levels where a concentration of oyster shells is observed for a considerable distance, it is possible to notice the break in succession with an unconformity. The oyster shells in the lower part of the Karai Formation indicate the beginning of marine sedimentation in the area, overlapping the Terani plant beds. A bed bearing *Rhynchostreon* near Kunnam (11°04′N; 79°01′E) and its continuity in strike direction (NE-SW) possibly indicate inundation of the palaeoshoreline. They overlap the older beds to the North of Kunnam to Paravay to rest directly on the coral-algal reefoidal limestone near Paravay. The characteristic large oysters of the Kallankurichchi Formation may represent a break in sedimentation, as conglomerates are seen at the base of the formation near Ameenabad (11°10′N; 79°05′E) in a well section, to the west of the road to Ottakkoil (11° 11′N; 79°06′E).

4. BIOZONATION

The abundance of oysters at many levels offers scope for biozonation of these sediments that range from Albian to Maastrichtian. As most of the southern Indian Cretaceous oysters show their morphological characters that are distinct, identification of form is comparatively easy and justifiable. The distribution of these bivalves is usually concentrated at certain stratigraphic levels, for example, in the Kallankurichchi Formation. All the oyster biozones are recognized as acme zones (Table 1) where individual species dominate the megafossil occurrences. In all, eight oyster zones are identified with two unnamed zones where no characteristic ostreiid has been collected. These are: *Agerostrea ungulata* Zone, *Pycnodonte (Phygraea) vesicularis* Zone, *Ostrea zitteliana* Zone, *Exogyra(Costagyra) fausta* Zone, *Rhynchostreon suborbiculatum* Zone, *Pycnodonte vesiculosa* Zone, *Exogyra (Costagyra) costata* Zone and *Rastellum (Arcostrea) carinata* Zone. The ranges of these zones compare well with that of ammonite zones.

5. BIOSTRATIGRAPHY

The biostratigraphy of the Cretaceous rocks of Ariyalur area has been suggested on the basis of ammonites (Satry et al., 1968), foraminifera (Banerji, 1972) and inoceramids (Chiplonkar and Tapaswi, 1976). An attempt is being made to utilise the ubiquitous oysters for biozonation. The conglomeratebearing Arogyapuram Formation contains highly worn-out shells and therefore, their specific identification is impossible. The overlying Dalmiapuram Formation has yielded *Rastellum (Arcostrea) carinata* (Lamarck), *Ostrea* sp. in the grey shale unit where *R. (A.) carinata* continues through the limestone unit. *Exogyra (Costagyra) costata* Say is the index fossil for the overlying Odiyam Member of the Karai Formation in the vicinity of Karai and northwards. The calcareous sandstone unit of the Kunnam Member yielded many wellpreserved specimens of *Pycnodonte vesiculosa* (Sowerby). The fossiliferous sandstone unit with abundant *Rhynchostreon suborbiculatum* (Lamarck) occurs in two distinct horizons (Ayyasami and Banerji, 1984). *Exogyra haliotoidea* Sowerby is the characteristic oyster of the shell limetone and interbedded clays of the Kulakkalnattam Formation. *Exogyra (Costagyra) fausta* Stoliczka, *Lopha (Actinostreon) diluviana* (Linne) are the oyster fossils common in the lower part of the Anaipadi Formation. The upper Anaipadi Formation did not yield any characteristic ostreiids. The frequent occurrence of fossilwood at this level may suggest the influx of terrestrial matter into the sea. This is also the level at which no foraminifera was reported (Sastry et al., 1968). The gritty sandstone of the Sillakkudi Formation yielded *Ostrea zitteliana* Stoliczka. The Maastrichtian shell bank of oysters in the vicinity of Kallankurichchi, Periyanagalur, etc. yielded many ostreiids including *Agerostrea ungulata* (Schlotheim), *Planospirites ostracina* Lamarck, *Pycnodonte (Phygraea) vesicularis* (Lamarck) and *Rastellum (Arcostrea) pectinatum* (Lamarck). Fursich and Pandey (1999) illustrated specimens of *Ceratostreon pliciferum* (Dujardin) and *Agerostrea ungulata* (Schlotheim) from this horizon. Many eroded and broken specimens of *Agerostrea ungulata* (Schlotheim) may be found in the lower part of the Kallamedu Formation. The upper part is of non-marine in nature and yields dinosaurian remains.

Chiplonkar and Tapaswi (1979) listed 12 species of oyster bivalves and presented a table showing their distribution in the three major lithounits – Uttattur, Trichinopoly and Ariyalur Groups. They showed *Pycnodonte vesiculosa* (Sow-

erby) to be present in all the above three groups. However, *P. vesiculosa* with its characteristic lobe is confined to the Kunnam Member of the Karai Formation as seen in the present study.

6. CARBON ISOTOPE STUDY

The carbon isotope ($\delta^{13}C$) study carried out on the shells is of preliminary nature and is being interpreted with limited exposure to such geochemical pattern of analysis of sediments and fossils. Few carbon isotope studies were done on the oyster shells. Four specimens collected from the four formations, namely, Odiyam and Kunnam Members of Karai Fm., Sillakkudi Fm. and Kallankurichchi Fm. were analysed for $\delta^{13}C$ along with three analyses done on belemnite, brachiopod and *Carbicula* bivalve (Table 2).

Plotting of these values of $d^{13}C$ isotopes against $\delta^{18}O$ in a binary plot against the similar values on dinosaur egg shells from the Cretaceous of Central India by Mohabey (2001), shows the clustering of the values of oyster shells around the average Cretaceous marine limestone (Fig. 2).

Incidentally, the *Carbicula* bivalve from the upper part of the Kallamedu Formation falls within the domain of non-marine dinosaur eggshell values, thus, supporting its fluvial origin. No oyster has been reported from non-marine Kallamedu Formation.

7. PALAEOENVIRONMENT AND DISCUSSION

Ostreiids are known to be marine shallow water inhabitants in the Present. The fossils also suggest similar environment by the embedded shells in predominantly sandy or sandy clay sediments. The substrate needs to be firm as they are sessile benthos and are attached to the subsurface in most of the cases. The dispersal takes place rapidly in the larval stage and later in life they are attached to stratum, plant debris or even other shells. Clusters of ostreiids are common in the Anaipadi Formation where *Lopha* is the dominant genus. Articulated valves are less common in the clayey beds while the separation of valves is frequently

Table 2. Stable carbon- and oxygen- isotopic analysis of fossil samples from the Cretaceous sediments of Ariyalur area.

Sl. No.	Sample number	Fossil	Formation	Locality	$\delta^{13}C$‰ (V-PDB)	$\delta^{18}O$‰ (V-PDB)	$\delta^{13}C$‰ (V-SMOW)
1	ARI/2002/1	Belemnite	Odiyam Member of Karai Fm.	Karai	0.6	-2.1	28.7
2	ARI/2002/2	Ostrea	Odiyam Member of Karai Fm.	East of Nambakkurichchi	0.7	-2.1	28.7
3	ARI/2002/3	Corbicula	Upper Kallamedu Fm.	North of Kadugur	-8.9	-7.6	23.1
4	ARI/2002/4	Rastellum	Kallankurichchi Fm.	East of Hastinapuram	-1.8	-5.4	25.3
5	ARI/2002/5	Rhychostreon	Kunnam Member of Karai Fm.	East of Odiyam	2.1	-3.7	27.1
6	ARI/2002/6	Ostrea	Sillakkudi Fm.	Karapadi	-2.1	-2.9	27.8
7	ARI/2002/7	Rhynchonella	Upper Anaipadi Fm.	Siranattam	-3.1	-3.6	27.2

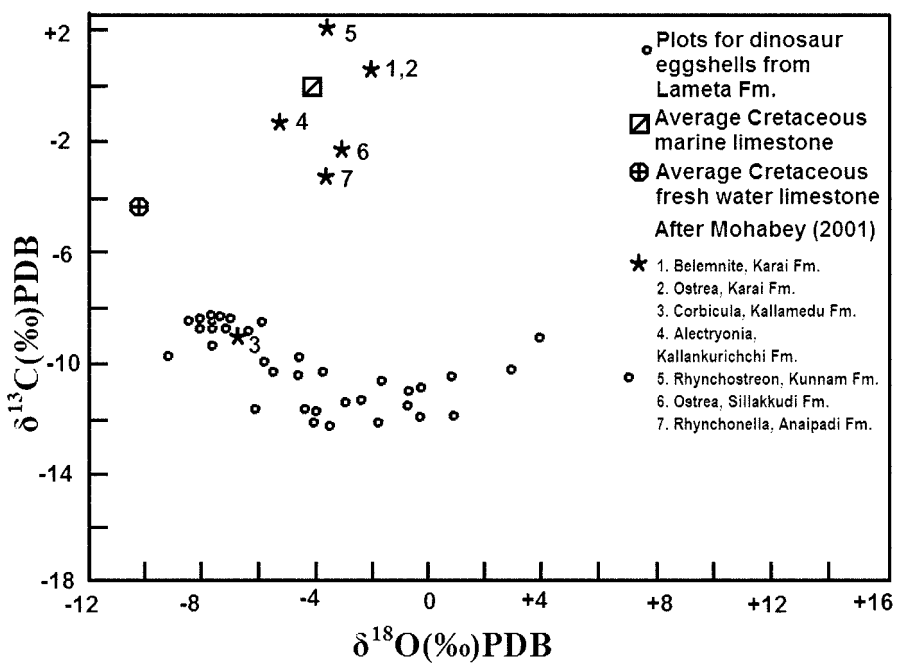

Fig. 2. Binary plot of the values of $\delta^{13}C$ isotopes against $\delta^{18}O$ isotopes for the samples collected from different Cretaceous formations of the Ariyalur area against similar values for the dinosaur egg shells from the Cretaceous of Central India.

Table 3. Inferred mode of deposition of sediments and the mode of occurrence of ostreiids.

LITHOSTRATIGRAPHY			INFERRED MODE OF DEPOSITION (Sundaram et al., 2001)	Mode of occurrence of ostrids
Ariyalur	Kallamedu Fm. (for the lower marine part)		Shallow marine conditions	Much eroded, incomple specimens
	Kallankurichchi Fm.		Molluscan shell hash	Well preserved but rarely articulated
	Sillkkudi Fm.	Kil Palavur Member	As a mobile substrate, dune bed forms and a littoral shallow subtidal assemblage	Common osterids, separated individuals
Trichinopoly	Anaipadi Fm.		Distal shelf deposition with regressive trend in the upper part	Clusters of oysters occasionally
	Kulakkalnattam Fm.		Transgressive, littoral to shallow marine environment	Rare, much eroded
Uttattur	Karai Fm.	Kunnam Member	Shoaling conditions	Abundant, Well preserved
		Odiyam Member	Offshore, high strand deposits	Common but concentrated by weathering
	Dalmiapuram Fm.		Abraded mollusk shell debris and transgression	Common
	Arogyapuram Fm.		Flanglomerate deposits that accumulated rapidly	Rare, much worn-out
	Terani Fm.		------	------
	CRYSTALLINE BASEMENT		------	------

noted in the sandy rocks. Even in the thick shell bank of the Kallankurichchi Formation, articulated valves are rare, though the fossils are well preserved. The worn out shells in gritty and conglomeratic horizons suggest their transportation before burial.

The inferred mode of deposition suggested by Sundaram et al. (2001) and the mode of occurrence of ostreiids in the Cretaceous of Ariyalur area are given in Table 3.

The abundance of ostreiids in the Odiyam Member of the Karai Formation marks the beginning of the Cretaceous sediments near Uttattur and Karai. The accumulation of many oysters in the body chamber of an ammonite (Plate 1a) in the Karai Formation suggests the quick burial of the shells in a hollow chamber of a coiled shell by sea currents that were strong enough to preserve both. The concentration of *Pycnodonte vesiculosa* (Sowerby) is seen in Kunnam Member of Karai Formation to the north of Mungilpadi (Plate 1b). The *Rynchostreon suborbiculatum* yielding beds of the Kunnam Member of Karai Formation (Plate 1c), representing the Early Turonian, overlaps the older sediments towards north of Kunnam and extends up to Paravay. This suggests a clear faunal break. This stratigraphic interval could be equal to the *Neocardioceras juddi* Zone of Earliest Turonian of the Standard European Ammonite Zone (Kennedy, 1984). Similarly, the *Pycnodonte vesicularis* (Plate 1d) bearing Kallankurichchi Formation extends as a wide band overlapping the Sillakkudi Formation in the northern part of the outcrop area and probably suggests a faunal break. The time span could be the upper part of Campanian or the lower Maastrichtian. In all the above examples, the ostreiids are suggestive of the transgressive nature of the deposition of sediment and were occupying the new environmental niche created by the incursion of sea on to the land. The abundant rhynchonellid brachiopods and inoceramids are the other invertebrates, possibly similar to the oysters, indicate a transgressive nature of sediments of the Upper Anaipadi Formation (Ayyasami and Rao, 1984) and the Sillakkudi Formation (Blanford, 1862; Ayyasami and Rao, 1980).

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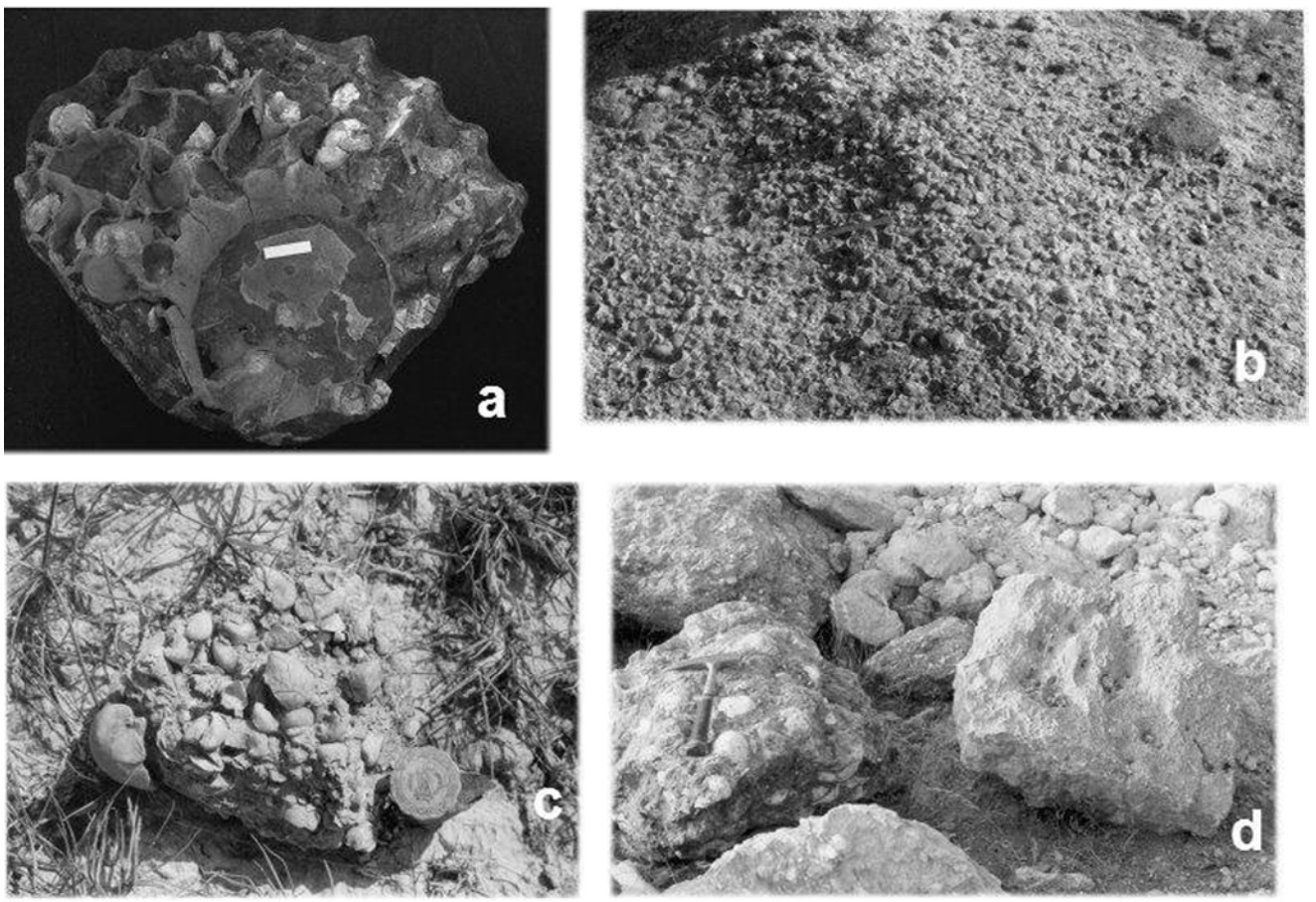

Plate 1. a: Concentration of oyster shells in the body chamber of an ammonite. Odiyam Member of Karai Fm., Karai, b: Debris of *Pycnodonte vesiculosa* (Sowerby) in the Kunnam Member of Karai Fm. Mungilpadi, c: *Rhynchostreon* shells in the Kunnam Member of Karai Fm. Kunnam, d: *Pycnodonte vesicularis* (Lamarck) in the Kallankurichchi Fm. Periyanagalur.

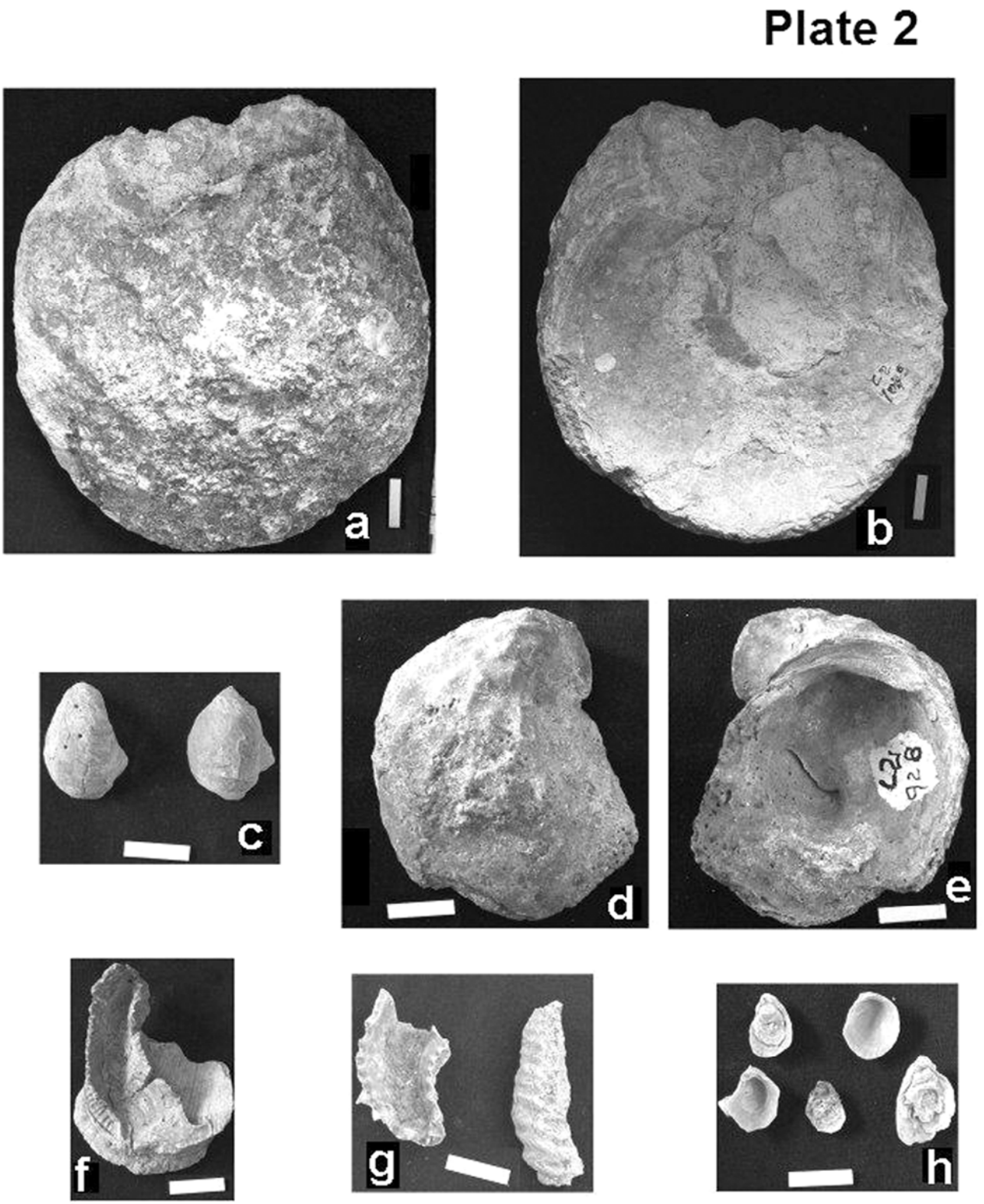

Plate 2. (Bar scale indicates 20 mm). a, b: Outer and inner views of *Ostrea* sp. Dalmiapuram Fm., Kallakkudi, c, h: Outer and inner views of another smaller species of *Ostrea* sp. from the Karai clay, Karai, d, e: Outer and inner views of *Exogyra costata* Say. Karai Fm., west of Kallakkudi, f, g: Outer and inner views of *Rastellum carinata* (Lamarck), Dalmiapuram Fm., Kallakkudi.

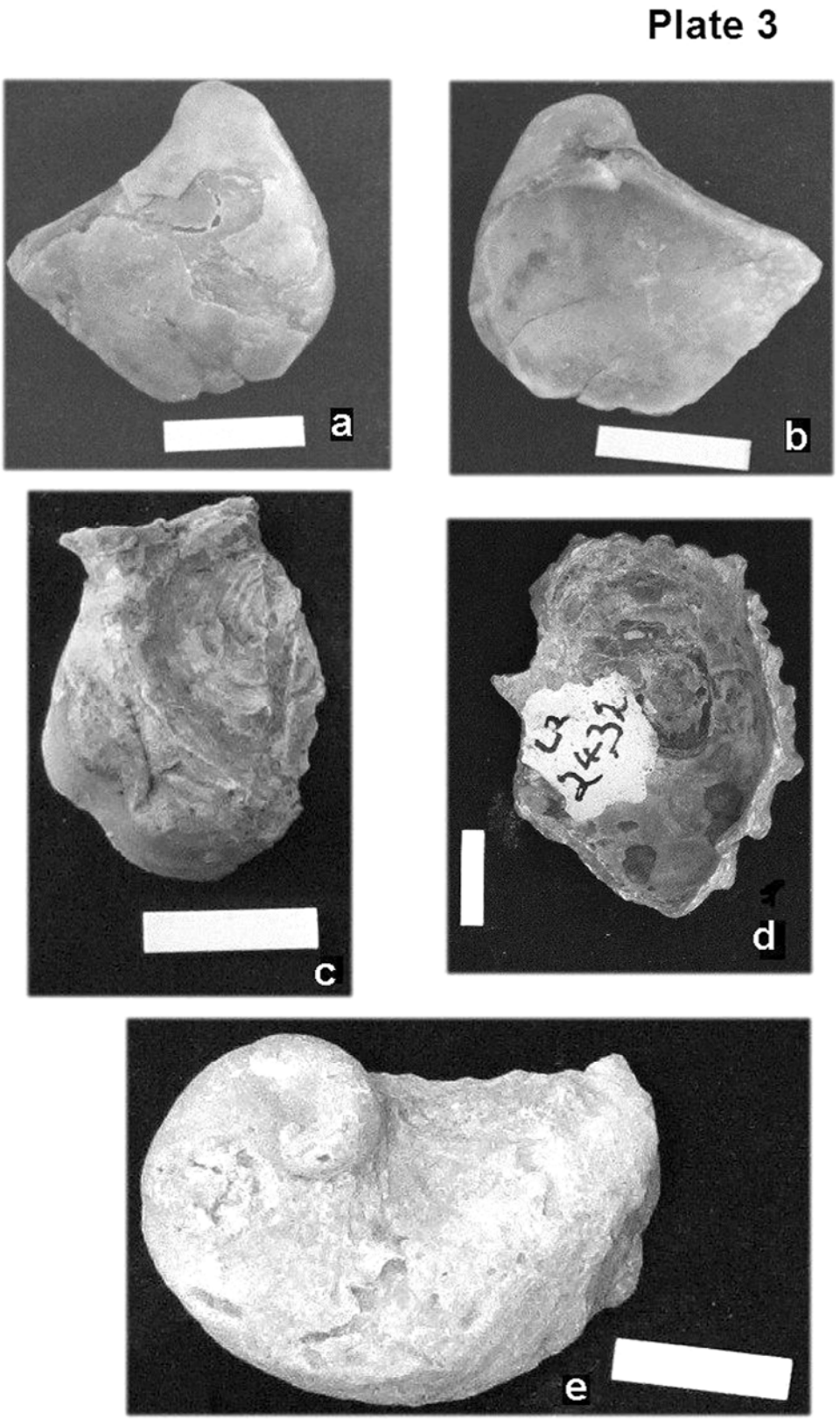

Plate 3. a, b: Outer and inner views of *Rastellum (Arcostrea) carinata* (Lamarck), Kunnam Member of Karai Fm. Kunnam, c: Outer view of *Ostrea zitteliana* Stoliczka. Sillakkudi Fm. Melmattur, d: Inner view of *Exogyra (Costagyra) fausta* Stoliczka. Lower part of Anaipadi Fm. Saradamangalam, e: Outer view of *Planospirites ostracina* Lamarck. Kallankurichchi Formation. Kallankurichchi.

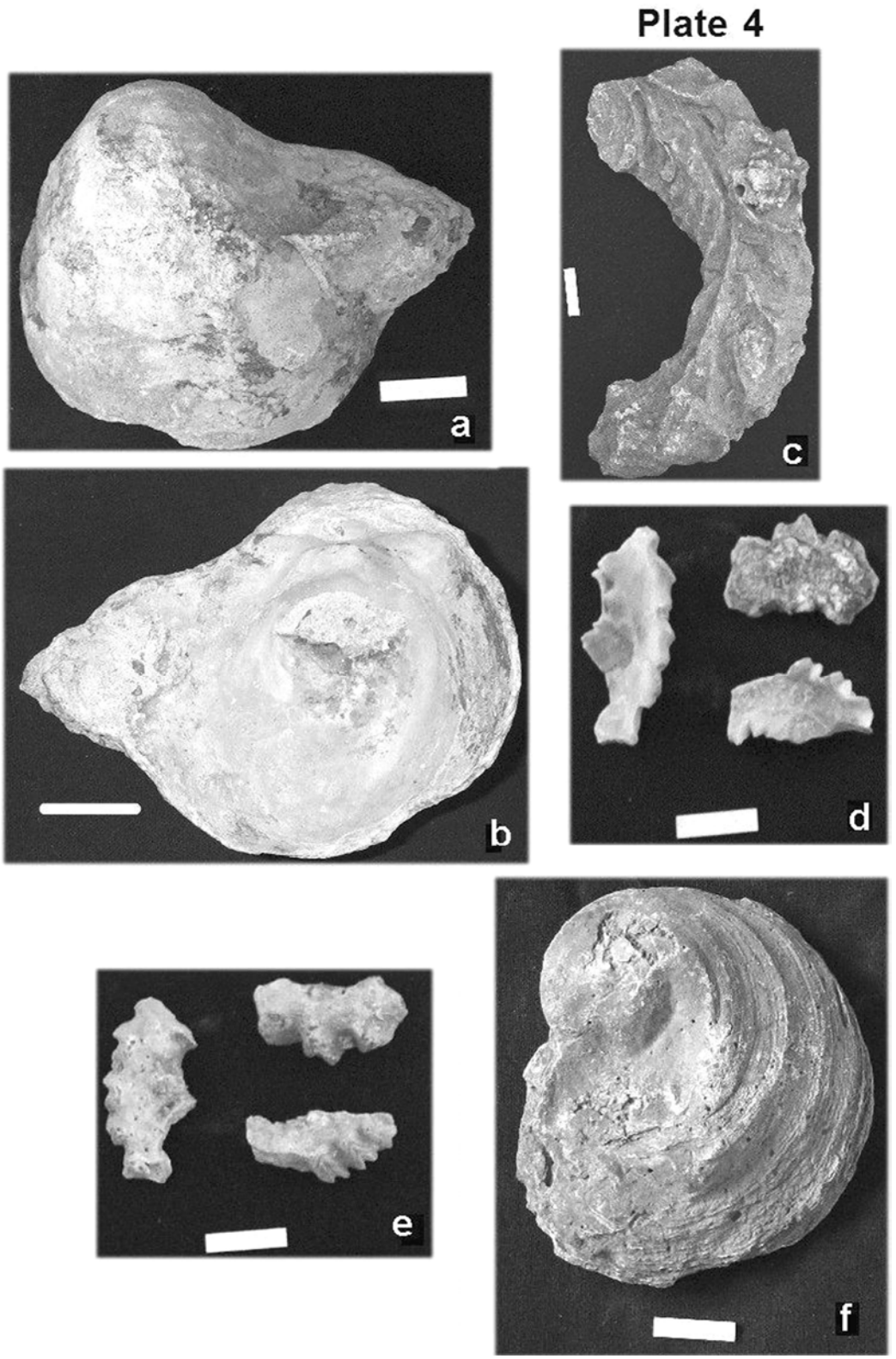

Plate 4. a, b: Outer and inner views of *Pycnodonte (Phygraea) vesicularis* (Lamarck). Kallankurichchi Fm. Kallankurichchi, c: Outer view of *Rastellum (Arcostrea) pectinatum* (Lamarck). Kallankurichchi Fm. Kallankurichchi, d, e: Outer and inner views of *Agerostrea ungulata* (Schlotheim). Lower part of Kallamedu Fm. Ottakkoil, f: Outer view of *Exogyra haliotoidea* Sowerby. Kulakkalnattam Fm. Garudamangalam.