ГЕОЛОШКИ АНАЛИ БАЛКАНСКОГА ПОЛУОСТРВА ANNALES GÉOLOGIQUES DE LA PÉNINSULE BALKANIQUE	65 (2002–2003)	1–27	БЕОГРАД, децембар 2004 BELGRADE, December 2004

Lithostratigraphy, depositional history and sea level changes of the Cauvery Basin, southern India

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Abstract. The sedimentary sequence exposed in the erstwhile Tiruchirapalli district hosts a more or less complete geological record of the Upper Cretaceous–Tertiary period. Systematic field mapping, collation of data on the micro–meso scale lithology, sedimentary structures, petrography, faunal assemblage and facies relationships of these rocks, in the light of modern stratigraphic concepts, helped to enumerate the lithostratigraphic setup and depositional history of the basin. Spatial and temporal variations of the lithologies and revised stratigraphic units are presented in this paper. Many high frequency sea level cycles (presumably fourth or higher order) which stack up to form third order sea level cycles (six in number), which in turn form part of second order cycles (two in number), including seven eustatic sea level peaks, have been recorded in this basin. Trend analysis of sea level curves indicates a gradual increase of the sea level from Barremian to Coniacian and a gradual decrease from Coniacian to Danian. Such lasting sea level trends had their influence on the sedimentation pattern and facies association. It is inferred that depositional bathymetry was maintained at a shallow–moderate level, primarily influenced by a lack of major subsidence during the depositional history of this basin. The study also revealed a prevalent simple basin filling process and dominant control by sea level changes, rather than tectonic movements over the depositional regime.

Keywords: stratigraphic revision, sedimentary environments, sea level cycles, sequence development, Cauvery Basin, southern India.

Апстракт. Седиментни низ откривен у некадашњем Тиручирапали рејону садржи мање или више целовит геолошки запис горњокредно–терцијарне периоде. Систематским геолошким картирањем, упоређивањем података микро и мезо следа литологије, седиментних структура, петрографије, скупа фауне и стенских фацијалних односа, у светлу модерних стратиграфских схватања, поспешено је стварање литостратиграфских поставки и депозиционе историје басена. У чланку су приказане просторне и временске варијације литолошких и ревидованих стратиграфских јединица. Висока учесталост циклуса колебања ниова мора (по свој прилици четвртог или вишег реда) створила је облике трећег циклуса морског нивоа (укупно шест), а у обрнутом делу циклуса (два), укључујући и седам еустатичних пикова морског нивоа забележених у овом басену. Тренд анализа кривих нивоа мора указује на постепено повећање нивоа од барема до конијака и постепено смањење од конијака до данског ката. Такво трајање трендова морског нивоа је имало утицаја на седиментациони модел и асоцијацију фација. Закључено је да је депозициона батиметрија одражавала умерен плитководни ниво, првобитно узрокован недостатком главног спуштања за време депозиционе историје басена. Студија је такође указала на једноставне процесе пуњења басена и на тектонске покрете као доминантну контролу промене нивоа мора током депозиционог режима.

Кључне речи: стратиграфска ревизија, седиментне средине, циклуси колебања нивоа мора, секвентни развој, Кавери басен, јужна Индија.

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Introduction

The Cauvery Basin, the southernmost basin (Fig. 1) in the Indian peninsular shield of the NE–SW trending Late Jurassic–Early Cretaceous rift basins (Powell *et al*., 1988) was created during the fragmentation of the supercontinent (Jafer, 1996). A more or less complete Upper Cretaceous–Paleocene succession is exposed in the Ariyalur–Pondicherry depression of this basin (Sastry & Rao, 1964). This succession, in view of its lithologic and faunal diversities, has attracted the attention of geologists since the early studies of Kay (1840), Blanford (1862) and Stoliczka (1861–1873). Many hundreds of papers have been published since then, among which the works on microinvertebrates (Chiplonkar, 1987), foraminifers (Govindan *et al*., 1996), ostracods (Bhatia, 1984), ammonites (Ayyasamy, 1990), nannofossils (Jafer & Ray, 1989; Kale & Phansalkhar, 1992; Kale *et al*., 2000), bryozoans (Guha, 1987; Guha & Senthilnathan, 1990, 1996), lithostratigraphy (Ramanadhan, 1968; Banerji, 1972; Sundaram & Rao, 1986; Ramasamy & Banerji, 1991; Tewari *et al*. 1996) and tectonics, (Kumar, 1983; Prabakar & Zutchi, 1993) present a comprehensive account. In general, many of these publications were, to a major part, devoted to a single species or genera, group or formation/member/ lithology and, hence, a generalised depositional model for the whole of the basin has yet to be documented. The economic discoveries of hydrocarbons in this basin demand a more organised classification of these strata which could help in designing improved exploration strategies (Raju & Misra, 1996). As far as the existing stratigraphic classifications of the Cauvery Basin are concerned, as noted by Tewari *et al*. (1996), there is still a reluctance to the recognition of the association of facies based on stratigraphic classifications. Furthermore, there has been no synergic study elucidating the sedimentologic mechanisms which acted during the course of the evolution of this basin. Thus, the goals of this study were:

- to present a workable lithostratigraphy with detailed lithological profiles, including recognisable units so as to produce a realistic meso-micro scale lithological column. This was necessary, primarily because recognition and fixation of any biostratigraphic or chronostratigaphic boundaries rely mostly on the correct recognition of lateral and vertical spatial relationships of the strata, and
- to enumerate the depositional history of the basin with a view of singling out the controls of the depositional and stratigraphic continuum and breaks in order to deduce the differential roles of geological agents and processes.

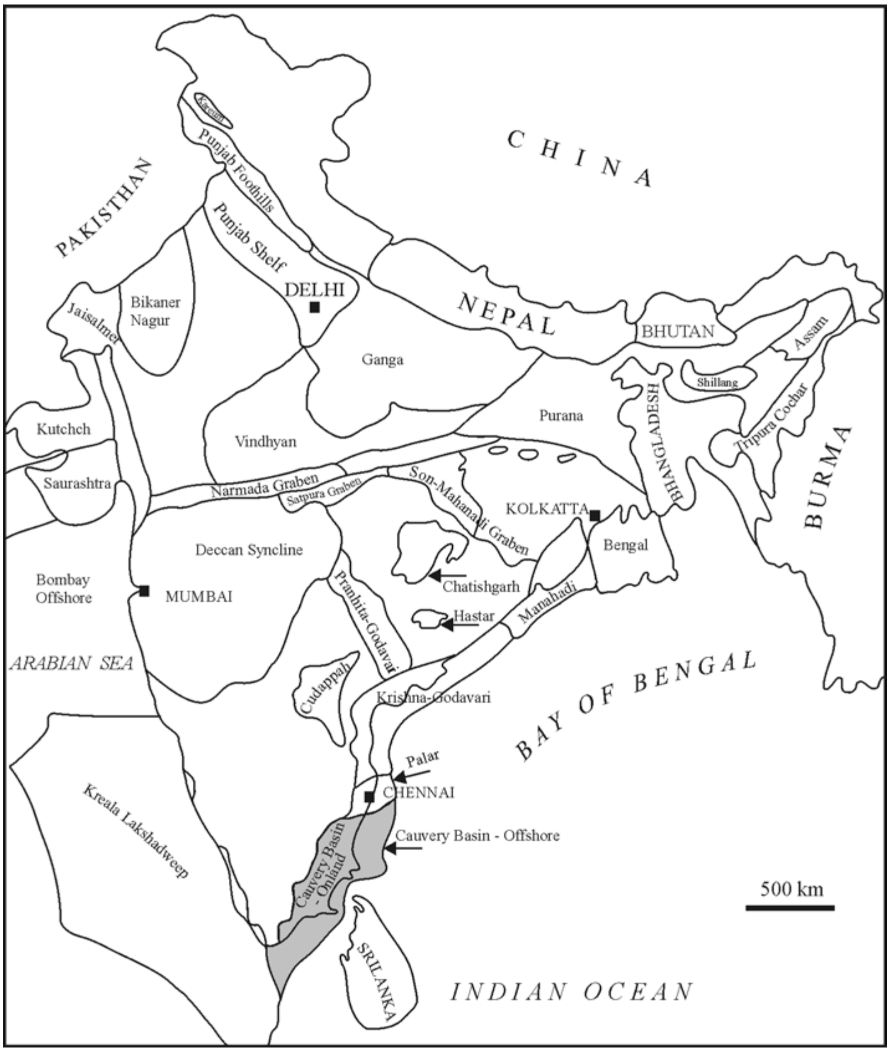

Fig. 1. Sedimentary basins of India.

Methods and materials

Systematic field mapping on the scale of 1:50 000 (the first ever in this part of basin) was conducted in and around the Ariyalur, Perambalur and Tiruchirapalli districts, (erstwhile Tiruchirapalli district) in which the largest exposure (a more complete one than the other exposures located north of it – YADAGIRI & GOVINDAN, 2000) is located. Data on the lithology, sedimentary structures, tectonic structures, facies and faunal association (mega and ichno) were collected from natural exposures, as well as well and mine sections. A total of 308 locations were logged and sampled. The guidelines and norms provided in EYESINGA (1970) and The North American Stratigraphic Code (1983) were followed for the presentation of the systematic stratigraphy. The following procedures for major revision of lithostratigraphy, as suggested by HART *et al.* (2000), were adopted in this study:

- primary field work in the exposed area,
- detailed analysis of the relationships of the intraformational facies,
- hierarchical use of groups, formations and members in accordance with the stratigraphic codes,
- formal definitions of type sections and historical precedent.

The exposed beds were traced laterally and vertically. Gross lithology (meso scale), general faunal and ichnofaunal information, petrography and sedimentary structures were considered when defining the stratigraphic units. The proposed lithostratigraphic setup is presented in Table 1. The lateral and vertical variations of the lithostratigraphic units in the study area are presented in Fig. 2. The geographic distribution of the members is presented in Fig. 5. The stratigraphic information, interpretations of depositional environments, major geological events (such as faulting, sea level changes, depositional breaks, etc.) generated with ground truth data and laboratory analyses and published paleontologic data enabled the elucidaton of the depositional history and prevalent geologic processes.

Table 1. Proposed lithostratigraphy of the Cretaceous–Paleocene strata, Cauvery Basin.

Age	Group	Formation	Member	Thickness (m)
Mio-Pliocene		Cuddalore Sandstone		>150
		Unconformity		
Danian		Niniyur	Periyakurichchi Biostromal	26
			Anandavadi Arenaceous	30
		Unconformity		
	Ariyalur Group	Kallamedu		100
		Unconformity		
		Ottakoil		40
		Unconformity		
Maastrichtian		Kallankurichchi	Srinivasapuram Gryphean Limestone	18
			Tancem Biostromal	8
			Kattupiringiyam Inoceramus Limestone	8
			Kallar Arenaceous	6
		Unconformity		
Campanian		Sillakkudi	Varanavasi Sandstone	270
			Sadurbagam Pebbly Sandstone	80
Santonian			Varakuppai Lithoclastic Conglomerate	45
		Unconformity		
Coniacian		Garudamangalam	Anaipadi Sandstone	215
			Grey Sandstone	80
			Kulakkanattam Sandstone	45
		Unconformity		
Turonian		Karai	Odiyam Sandy Clay	175
			Gypsiferous Clay	275
		Unconformity		
Cenomanian		Dalmiapuram	Kallakkudi Calcareous Sandstone	60
			Olaipadi Conglomerate	65
			Dalmiya Biohermal Limestone	15
Albian			Varagupadi Biostromal Limestone	23
			Grey Shale	7
		Unconformity		
Aptian		Sivaganga	Terani Clay	30
			Kovandankurichchi Sandstone	24
Barremian			Basal Conglomerate	18
		Unconformity		
		Archaen granitic gneiss		

Systematic stratigraphy

TEWARI *et al.* (1996) presented a comprehensive account on the lithostratigraphy of this basin. Following the current practices in stratigraphic terminology, the classification was modified and updated in the present work.

Sivaganga Formation

BANERJI (1982) recorded the extensive occurrence of a conglomerate–sandstone unit in regions far south of the present study area and named it the Sivaganga Formation. BANERJI & RAMASAMY (1991) and BANERJI *et al.* (1996) reported a similar unit in the Tiruchirapalli exposure. These beds mark the first Cretaceous sedimentation in this basin. Three discrete members constitute this formation in the study area.

Basal Conglomerate Member

Nomenclature. This member corresponds to the Kovandankurichchi Conglomerate Member of TEWARI *et al*. (1996). As they named the overlying sandstone member also with the prefix “Kovandankurichchi”, the nomenclature is amended herein to avoid repetition of the same geographic name for two stratigraphic units. Since this member forms the bottommost sedimentary record of this basin, the prefix “Basal” has been added.

Stratotype: It is located at 78°55’48” E; 10°52’36” N in the Kovandankurichchi Mine I, NE wall, Bench IV (mine owned by Dalmia Cements Ltd.).

Lithology, contacts and environment. These beds are lithoclastic boulder conglomerates that contain abundant clasts of granitic gneiss (basement rocks). The clasts are sub-angular to sub-rounded and range in size from 10 m to 60 cm. This lithological unit is clast supported and towards the top shows a reduction in the size of the clast and an increase in the quantity of finer grains. Many such upward fining sequences have been observed to rest over the highly faulted Archaen basement. These sediments are essentially brought by rivers and deposited under high-energy conditions as coastal conglomerates in view of the widespread erosion of the fault scarps (BANERJI, 1983). They may be termed as type II conglomerates according to the classification of PETTIJOHN (1957).

Geographic extension. This member is exposed only in the mine section in this part of the basin. Mine sections expose only a limited portion of this unit, as all

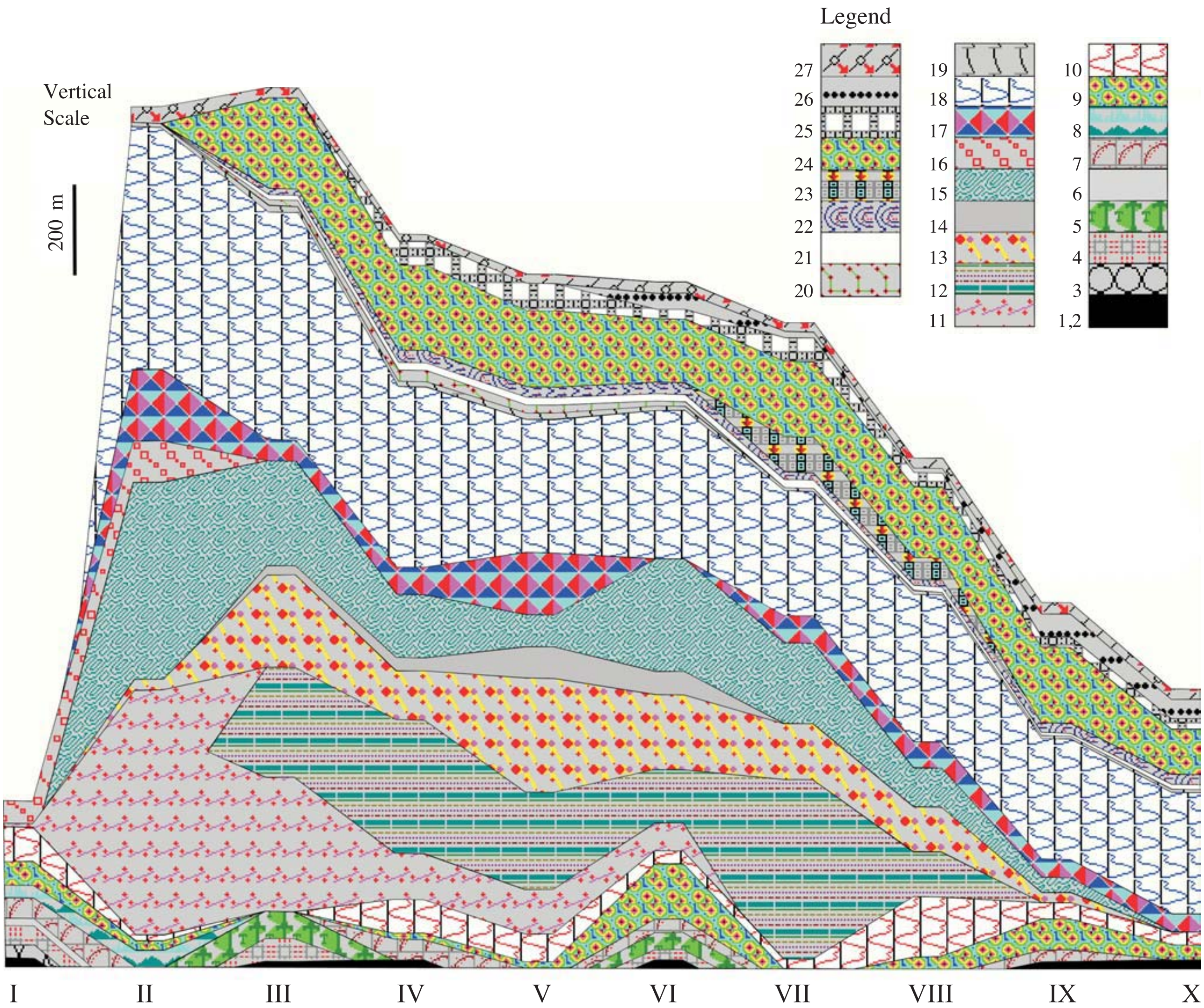

Fig. 2. Spatio–temporal variations of lithostratigraphic units along the traverses. Arabic number against each box refer to the index of different members as given in Fig. 5. Similarly, the roman numbers refer to the transverse line, as drawn in Fig. 5.

the limestone deposits are found only above this unit. All other sub-basins of Cauvery basin, where deep bore wells were drilled, show existence of this member in direct contact with Archaen basement rocks.

Fossils and age. Subsurface counterparts contain Barremian–Aptian fossils of *Globigerina boteriveca* (GOVINDAN *et al*., 1996; RAJANIKANTH *et al*., 2000).

Thickness. 18 m.

Equivalents from other areas. BANERJI (1982) reported extensive exposures of this member in the southern part of this basin.

Kovandankurichchi Sandstone Member

Nomenclature. It has been amended from the nomenclature of TEWARI *et al*. (1996) to reflect its lithology.

Stratotype. It is located at 78°55’51” E; 10°52’34” N in the Kovandankurichchi Mine I, NW wall, Bench III (mine owned by Dalmia Cements Ltd.).

Lithology, contacts and environment. These are grain supported upward coarsening cyclic beds that show parallel, even and thin to thick bedding. Individual bed set ranges in thickness from 20–100 cm. This member rests over the Basal Conglomerate Member having a distinct, non-depositional and erosional unconformity. It differs from the underlying member in terms of the change in lithology and lack of granitic clasts. The sands range in size from granule to coarse silt and are carbonate cemented. The grains are well sorted within each lamina and show rounded-well rounded shape. These represent recurrent sheet flow deposits probably in a subaqueous fan deltaic environment. Towards the north, they grade to argillaceous siltstones and claystones, representing deposition in a basinal setup.

Geographic extension. This member is exposed in the Kovandankurichchi mine and is observed to occur in stream sections, well cuttings and trenches up to the region south of Perali. From south to north, there seems to be a gradual reduction in the thickness and grain size with a simultaneous increase in argillaceous matrix. In the southern regions, these are essentially grain-supported fabrics. Towards the north, the rocks are matrix supported, loosely packed and well cemented.

Fossils and age. Early Cretaceous palynoflora were reported from subsurface sections (bore well samples) of this member (VENKATACHALA, 1974; RAJANIKANTH *et al*., 2000).

Thickness. 24 m.

Equivalents from other areas. BANERJI (1982) reported this member and a Basal Conglomerate Member as conglomerate–sandstone succession of the Sivaganga Formation. The availability of new exposures in the Kovandankurichchi mine and the tracing of them up to the south of Perali, with a distinct stratigraphic break in between them, allowed us also to precisely define the stratigraphic relationships and position. BANERJI (1982) reported isolated outcrops of this member also in Virudhachalam (north of the study area).

Terani Claystone Member

Nomenclature. Amended herein from the nomenclature of TEWARI *et al*. (1996) to reflect its lithology.

Stratotype: It is located at 78°54'01" E; 11°07'42" N in the Terani clay mine (mine owned by Nataraj Ceramics Ltd.).

Lithology, contacts and environment. Traditionally these have been termed as clay deposits resting over the Archaen basement (GOVINDAN *et al*., 1996). However, transition of Kovandankurichchi siltstone and sandstone into basinal clay and argillaceous siltstone, which have contact with Archaen rocks, were observed in new mine sections. This transition might have resulted from a rise in the sea level and the cessation of coarse clastic influx. As these are primarily clays, severe continental weathering was also indicated. The clays are white to pale brown in colour and show the frequent occurrence of alternate bands of red and reddish brown laminae. Less frequent interlayers of thin to thick ferruginous siltstone are also present. These observations indicate the influence/existence of seasonal floods that brought in a significant detrital influx to the depo-center of this member, although this member was deposited in deeper regions of the basin (regions far below the base of a storm weather wave). The prevalence of a faulted basin topography which might have hosted a narrow shelf and a sudden steep slope could explain the bypassing of silts and sands to the basinal setting. Deposition took place principally through suspension settling, except for the siltstone/fine sandstone laminae.

Geographic extension. These beds are generally found to have been deposited in isolated patches in and around Karai. They occur along the westernmost borders of the sedimentary basin. The extensive distribution of their counterparts has been reported from all over the subsurface part of the basin (VENKATACHALA, 1977; MAHESHWARI, 1986).

Fossils and age. The clay beds contain frequent impressions of *Ptilophyllum* sp. MAMGAIN *et al*. (1973) reported two Barremian ammonite species and one inoceramid species, as well as fossils of this plant. SASTRY *et al*. (1977) and RAMASAMY & BANERJI (1991) assigned Aptian age to this member.

Thickness. 30 m.

Dalmiapuram Formation

Grey Shale Member

Nomenclature. The original nomenclature of RAMASAMY & BANERJI (1991) has been restored with an amendment herein. On account of water logging and the non-accessibility during their visit to the mine, TEWARI *et al*. (1996) termed this unit as Grey Siltstone based on only one sample from this mine and another sample from Perali. They mentioned the validity of their term in their paper and reported the non-examination of the more "calcareous nature of the shale" as described by earlier workers. The sampling conducted for this study occurred during a period when dry mine floor was exposed, which allowed this unit to be defined more precisely.

Stratotype. It is located at 78°55'51" E; 10°52'34" N in the Kovandankurichchi mine I, NW wall, Bench III (mine owned by Dalmia Cements Ltd.).

Lithology, contacts and environment. This is principally grey shale with frequent interbeds of fossiliferous grey limestone (the thickness of which increases upwards) and to a minor extent it is composed of a significant admixture of silt-sized siliciclastics. The ubiquitous grey colour is more pronounced where shale without any intercalation or admixture was encountered. Deposition in a periodically restricted shallow marine setting was indicated by lithological and faunal information. The lower contact is an unconformity surface associated with marine flooding and the upper contact is non-depositional and erosional with an overlying biostromal member.

Geographic extension. This member is well exposed in the Kovandankurichchi mine. Diagenetically altered counterparts are exposed in well sections located northeast of Kallagam and south of Perali. Many authors have recorded subsurface extensions of this member (e.g. SUBBARAMAN, 1968; GOVINDAN *et al*. 2000). Deposition of this member in isolated patches restricted the availability of extensive exposures.

Fossils and age. KALE *et al*. (2000) reported a rich assemblage of palyno fossils in this member. This member exposes the *H. planispira* planktonic forminiferal Zone (GOVINDAN *et al*., 2000). Ostracods, bryozoans, gastropod fragments have also been observed in this member (TEWARI *et al*., 1996). These faunal and floral assemblages indicate Barremian to Albian age for this member.

Thickness. 7 m.

Varagupadi Biostromal Limestone Member

Nomenclature. (Proposed herein). RAMASAMY & BANERJI (1991) and TEWARI *et al*. (1996) termed rocks of this member as Dalmiapuram Limestone Formation and Member respectively. As a more complete section of this member occurs in the Varagupadi mine and assigning two lithostratigraphic units with the same name is discouraged, this unit has been termed as Varagupadi Biostromal Limestone Member.

Stratotype. It is located at 78°54'57" E; 11°09'35" N in the Varagupadi mine, Bench I and II (mine owned by Vijay Cements Ltd.).

Lithology, contacts and environment. These are limestone beds containing various proportions of bioclastic and siliciclastic materials. They show wackstone to rudstone fabric and have clasts of redeposited boundstones. Thin to thick bedded, even to parallel, bioclastic limestone beds which have drawn their detritus from reefs predominate. Typical reef cores are absent in this member. These are typical reef flank biostromal deposits deposited under high-energy conditions and show significant lateral variation of facies and texture. These beds are found to be directly overlying the Grey Shale Member, while their reef core counterparts might have been located further west directly over the Archaen rocks, which in turn were eroded during a major mid-Cretaceous faulting (TEWARI *et al*., 1996; YADAGIRI & GOVINDAN, 2000; STEINHOFF & BANDEL, 2000). The interpretation of BANERJI *et al*. (1996) based on field characteristics that "these biostromal deposits were derived from some older biohermal bodies which are no longer seen outcropping", adds further support to this assertion. The information that the Ariyalur–Pondicherry sub-basin had experienced erosion of a ca. 1.5 km thick sediment pile (YADAGIRI & GOVINDAN, 2000) and the occurrence of Olaipadi Member (detailed latter) at 10 km directly west of the Dalmia mine confirm the prevalent but eroded reef counterpart of this biostromal member. Many authors, however wrongly recognised a much younger Dalmia Biohermal Member to be the biohermal counterpart of this member. It is to be noted that the biohermal member was subaerially exposed and underwent karstification. Had it been the counterpart of this member, then how could this member have escaped similar karstification? Based on the common reef mineralogy and their easy susceptibility to subaerial exposure, it is assumed that as the Dalmia Biohermal Member contained highly unstable carbonates and a prevalence of a high host to fluid bulk chemistry ratio, the diagenetic fluid (that moved downwards) attained saturation before reaching the lower member producing less/no recrystallisation of beds of this member. The presence of disconnected vugs and voids in the biohermal member, indicates that the absence of interconnected pores might have thwarted access of meteoric waters to the deeper regions, because of which, the biostromal member, located there, escaped karstification. If so, the biostromal member might be older than the Dalmia Biohermal Member.

The depositional relationship between this member with an eroded biohermal counterpart and the Grey Shale Member could be such that deposition along fault scarps and differential growth of reef and reef derived bioclastic limestone deposits introduced a temporary to long term closure of parts of the depositional setting, whereby more anoxic, fine grained shale and grey limestone deposits were alternatively deposited. Through the passage of time, with the rise in the sea level, more open conditions of sea were introduced which permitted the deposition of bioclastic reef derived limestone only. Faulting, as evident from the Varagupadi mine, where the biostromal limestone beds rest directly over Archaen rocks, may also have influenced this change. However, the occurrence of alternating shale-bioclastic limestone beds indicates that fluctuations in the sea level must have taken place which were probably accompanied by faulting and submergence with the net result that the sea level had an overwhelming influence on the depositional pattern. The occurrence of granitic cobbles at the bottom beds of this member suggests a rejuvenated fresh erosion of basement rocks, implying the cessation of the deposition of the shale member by fault movement, followed by a rise in the sea level and the rejuvenation of bioclastic limestone deposition. From bottom to top, the increase of the thickness of the grey fossiliferous limestone within the shale beds, the concurrent reduction of the thickness of the grey shale bed and the increase of silt admixture in the shale, and the complete cessation of shale deposition and the presence of only limestone at the top and, finally, the occurrence of such an observed biostromal sequence make way for the interpretation of facies variation over time under the major influence of sea level changes.

Geographic extension. In the southern part of the exposed region, these are pure biostromal, bedded limestone deposits, with frequent erosional surfaces. Towards the north, they grade to arenaceous limestone beds with reef derived bioclastics intermixed with siliciclastics of varying proportions and at places also have argillaceous admixture. Good exposures occur all along the western margin of this basin in the mine sections. Basement lithoclasts in the lower portion and argillaceous admixtures towards the top are observed in this member, meaning a gradual increase in the sea level and an associated reduction in the depositional energy conditions. The occurrence of high variation of thickness within short distances and the contact of this member with both older sedimentary rocks and Archaen rocks also confirms the superposition of an icrease in the sea level and the movement of the reef core in a westerly direction, which might also have resulted in a lateral shift of this member.

Fossils and age. The faunal composition of this member constitutes bioclasts of bivalves, rudists, corals, algae, foraminifers, ostracods, and bryozoans and echinoid spines. GOVINDAN *et al*. (1996) assigned Middle Albian age to these biostromal beds.

Thickness. 23 m.

Dalmia Biohermal Limestone Member

Nomenclature. It is proposed herein.

Stratotype. It is located at 78°57'23" E; 11°59'19" N in the Kallakkudi mine II, Northern wall, Bench III and IV (mine owned by Dalmia Cements Ltd.).

Lithology, contacts and environment: These are pure algal and coral facies limestone beds that form a reef core. The occurrence of the reef core stratigraphically above the biostromal limestone deposits, the absence of a reef core counterpart of the underlying biostromal limestone beds and the younger Olaipadi Member over the biohermal member, as well as the direct overlapping of the much younger Kallakkudi Sandstone Member in the Kallakkudi mine are all suggestive of a prevalent progradation of reef colonies over the former deeper regions of the sea concomitant with a fall in the sea level (STEINHOFF & BANDEL, 2000). This 15 m thick, biohermal member contains massive pink to greyish white limestone deposits with abundant vugs and cavity fillings. The growth and movement of coral–algal colonies were suddenly truncated as a result of mid-Cretaceous faulting. The upper contact of this member is a forced regression and associated subaerial exposure surface which has even resulted in meteoric diagenesis of these limestone deposits. The bottom contact is conformable with biostromal limestone and represents a non-depositional surface. The occurrence of lithified carbonates clearly indicates a fall in the sea level (associated with faulting) after the deposition of the biohermal member as the sea level crossed the shelf edge (Type I sequence boundary). The absence of an Olaipadi Member over this member in the Kallakkudi mine and the adjoining regions, as well as the superposition of the much younger Kallakkudi Sandstone Member directly over this limestone member in this region suggests that, in view of faulting, this area became topographically raised and served as a sediment source for the Olaipadi Member. On the contrary, the occurrence of slope failure could also be interpreted as large-scale mass wasting, a phenomenon commonly associated with a fall in the sea level (SARG, 1988). The interpretation whereby slowly prograding reefs moved towards former offshore regions with a falling of the sea level adds support to this view as progradation of reefs could have surpassed the angle of repose and become unstable and might have contributed towards the generation of mass wasting. However, the presence of granitic clasts (more than 10 m diameter) in the younger Olaipadi Member (lithoclastic conglomerate deposits – detailed latter) indicate fresh erosion of continental materials, which paves the way for the interpretation of a fall in the sea level concomitant with tectonic movement, whereby the change in the sea level had an overwhelming influence.

Geographic extension. This member is typically exposed in the Kallakkudi mine. Isolated and highly weathered counter parts are observed in the northwestern region of this basin. Their very limited occurrence, also above the Biostromal Limestone Member, is interpreted as being the result of reef growth along the fault scarp, a large scale fault later associated with erosion, which allowed the preservation of only relatively deeper water biostromal and biohermal limestone deposits.

Fossils and age. The limestone consists of red algae, corals and bryozoans, bioclasts of gastropods, bivalves, echinoid plates, ostracods, foraminifers and sponges. Based on the faunal assemblage, Middle Albian age is assigned to this member (GOVINDAN *et al*., 1996).

Thickness. 15 m.

Olaipadi Conglomerate Member

Nomenclature. After TEWARI *et al*. (1996).

Stratotype. It is located at 79°05'47" E; 11°19'12" N in the Olaipadi mine, Bench I, II, III and IV (mine owned by Ramco Cements Ltd.).

Lithology, contacts and environment. These are essentially basinal silty clays and clays in which chaotic blocks (Fig. 3A) are embedded. The beds contain large blocks of basement rocks (angular and sub-rounded boulders which are often >10 m in diameter), lithified coralline limestone blocks (similar to the underlying biohermal limestones), claystones (Fig. 3B; similar to that of the Terani Clay Member) and lithoclasts of older conglomerates, etc. The occurrence of lithoclastic conglomeratic boulders (1–2 m diameter, extraformational), limestone (intraformational) and basement boulders (extraformational) in an otherwise deep marine silty claystone is indicative of sudden fault movement associated with widespread erosion of coastal/nearshore sedimentary rocks and their transportation by gravity and instability of a newly created slope, bypassing the narrow shelf, to the new depocenters. TEWARI *et al*. (1996) interpreted this member as having been deposited from rapid flows of submarine debris/talus deposits at the foot of eroding fault scarps. The fault movement immediately after the deposition/lithification of the underlying limestone member associated with subaerial erosion is clearly exhibited in the Kovandankurichchi mine and the Kallakkudi mine, wherein offsetting of fault blocks is exposed in terms of displaced bedded limestone deposits (Varagupadi Member).

Geographic extension. This is the most extensive member of Dalmiapuram Formation. The beds extend

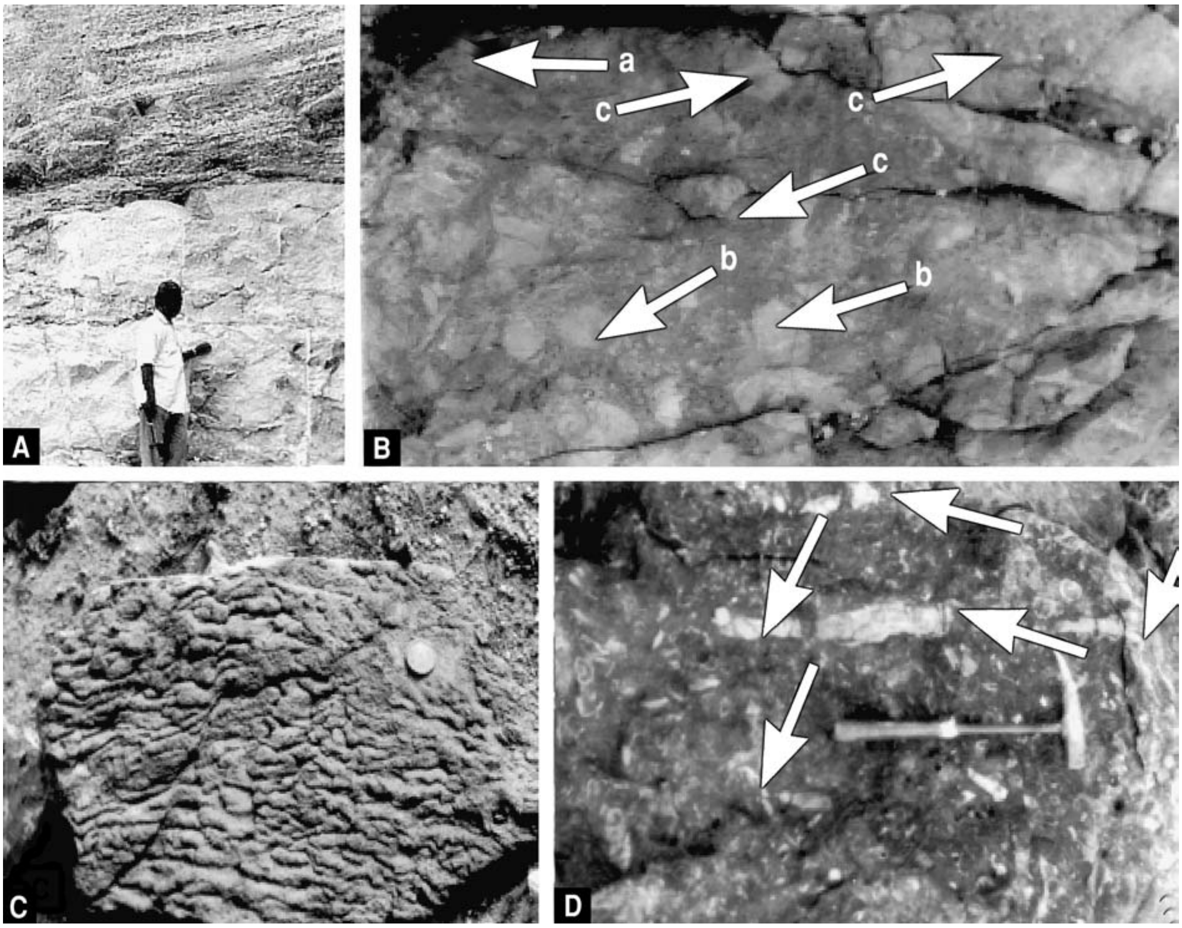

Fig. 3. **A**. Large sized limestone chaotic block (a) embedded in deep marine silty clay (b) of the Olaipadi Member. Note the conformable relationship of silty clay bands with the boundary of lithoclast. Tirupattur quarry. **B**. Close up view of clasts of older sedimentaries in the Olaipadi Conglomerate Member. Note the presence of lithoclasts of every conceivable size and shape. **a** - Hammer (~ 30 cm in length) is placed for scale; **b** - Subangular–subrounded claystone lithoclasts; **c** - Subangular–angular lithoclasts of limestone. Also note the different orientation of the long axes of these clasts. Olaipadi quarry. **C**. Minor scale load casts, slightly deformed by post depositional compaction. Tirupattur quarry. **D**. Close up view of the woody sandstone. Note the presence of petrified wood fragments (arrows) with different orientation and size. Near Garudamangalam village.

continuously from Tirupattur in the south to Govindarajapalaiyam in the north. The granitic gneissic boulders are abundant in the Tirupattur mine. Their size and frequency is reduced towards the north, to be progressively replaced by lithified carbonate boulders drawn from the underlying biohermal member. It should be noted that the lithified claystone conglomerate boulder clasts, which occur in association with other clasts of this member, were not present elsewhere in the exposed area as a distinct lithology/bed. This observation, in addition to the complete absence of biohermal counterparts of Varagupadi Biostromal Member and presence of >10 m large basement clasts, supports the interpretation of the existence of such lithologies further west before faulting and complete erosion of them in view of faulting. Towards the top, deep marine clays grade into calcareous siltstone and include granitic cobbles and minor amounts of siliciclastic sands, which indicate a gradual reduction of the sea level followed by the commencment of the influx of fluvial sediment. The thickness of this member varies within short distances, which is indicative of a fault controlled depositional topography.

Fossils and age. Reworked fauna, namely: belemnites, rudists, corals and serpulids characterize this member. The occurrence of this member at the dawn of the Cenomanian, together with a sudden change in the environment and faulting could be interpreted as beeing the result of a major basin development process.

Thickness: 65 m.

Kallakkudi Sandstone Member

Nomenclature. It is proposed herein. It corresponds to the Kallakkudi Sandstone Member and the Kallakkudi Siltstone Member of TEWARI *et al*. (1996) and the biostromal and reefal deposits of RAMASAMY & BANERJI (1991). Although TEWARI *et al*. (1996) eradicated many discrepancies existing in previous studies with their revision, they overlooked the gradation of faces between sandstone and siltstone members, the repetitive occurrence of alternate sandstone and siltstone beds which grade to each other (may be the result of varying energy and sediment influx and also of minor sea level fluctuations) and lack any stratigraphic break.

Stratotype. It is located at 78°57'23" E; 11°59'19" N in the Kallakkudi Mine II, Bench I and II (mine owned by Dalmia Cements Ltd.).

Lithology, contacts and environment. This is a fine--coarse sandstone member with alternate medium to thick beds of silty clay, calcareous siltstones, bioclastic arenaceous limestone and gypsiferous clay. The intercalations are recurrent and show typical Bouma sequences, normal grading, load casts (Fig. 3C), channel and scour structures. The sandstones are thin to medium bedded and always start over a gypsiferous band and/or arenaceous limestone bed with an erosional surface and grade to finer clastics. Towards the northern regions, this member grades to more silty and clayey, but the gradation and gypsiferous bands are persistent with the addition of ferruginous silty clay bands.

The depositional setting of this member ranges from a shallow coastal to a basinal setting which were under the influence of a major fluvial source near coast and a turbidity current in the basinal part, respectively. The coastal region must have been periodically closed/partially closed to produce evaporitic layers. In the basinal part, deposition took place principally from a high-density turbidity current in a ramp developed over the Olaipadi Member. The talus like platform created a steep sloped turbiditic apron, fed by siliciclastics derived from a fluvial source and eroded carbonate sands, bypassing the narrow slope (newly created by mid-Cretaceous faulting) and reaching to the basinal region. The continued deposition of this member must have been sustained by a prograding apron/talus. The channel orientation, large-scale scour structures and the nature of the bedding, suggest flow from south to north (TEWARI *et al*., 1996).

Geographic extension. Next to the Olaipadi Member, this is a well-developed member of the Dalmiapuram Formation. Its thickness was controlled by depositional topography. In the southern region, these beds show recurrent bands of fining upward sequences of only siliciclastics with calcareous cements. From Varagupadi towards the north, they show a thickening and thinning nature and a cyclic occurrence of bioclastic arenaceous limestone, coarse sandstone–silty clay and evaporitic layers with frequent minor–significant erosional surfaces.

Fossils and age. TEWARI *et al*. (1996) recorded foraminiferal population of the *Rotalipora appenninica* interval Zone to *Rotalipora cushmani* total range Zone, the belemnite species *Tetrabelus seclusus*, *Parahebolites blanfordi* and *Neohibolites* sp., and mid Cretaceous phyloceratid ammonite along with shell debris of *Exogyra*, *Alectryonia*, echinoids and bryozoans. According to these observations, this member ranges in age from Late Albian to Late Cenomanian.

Thickness. 60 m.

Karai Formation

This formation has two members, namely: the Gypsiferous Clay Member and the Odiyam Sandy Clay Member, in stratigraphic order.

Gypsiferous Clay Member

Nomenclature. The nomenclature of RAMASAMY & BANERJI (1991) was restored with an amendment to reflect its lithology.

Stratotype. It is located between 78°54'33"–78°54'58" E; 11°07'22"–11°08'09" N in stream section exposures of a traverse from east of Karai to west of Kulakkanattam.

Lithology, contacts and environment. This member consists of unconsolidated deep marine clays and silty clays. Very thin to thick gypsiferous (synsedimentary) clay beds characterize this formation. These beds contain a thick population of belemnite rostrum and phosphate nodules. The extensive occurrence of gypsum along with celestite makes this member readily recognizable in the field. The deposition of this member took place under increasing sea level conditions. After reaching its maximum, the sea level started declining concurrently with the deposition of relatively coarser siliciclastics and the development of syngenetic gypsum ceased to continue, marking the end of the deposition of this member. While a non-depositional unconformity surface separates this member from the underlying member, the upper contact is non-depositional and erosional.

Geographic extension. This member is best exposed along the Karai–Kulakkanattam road section, where an extensive sprawl of badland topography occurs. From south to north, gradual reductions of depth, number of belemnite and phosphate nodules and frequency of gypsum layers are observed.

Fossils and age. *Gryphaea*, *Tubulostrum*, belemnites and foraminiferal assemblages belonging to *Rotalipora subticinensis* interval Zone to the *Praeglobotrancana helvetica* interval Zone are reported and demonstrate Cenomanian age for this member (GOVINDAN *et al*., 1996).

Thickness. 275 m.

Odiyam Sandy Clay Member

Nomenclature. Proposed herein, amending the nomenclatures of RAMASAMY & BANERJI (1991; Upper Sandy Clay Member) and TEWARI *et al*. (1996; Odiyam Sandstone Member) to maintain uniformity in the stratigraphic nomenclature and to reflect the lithology.

Stratotype. It is located between 78°54'20"–78°55'58" E; 11°07'18"–11°07'22" N in the exposures of stream sections along the Karai–Kulakkanattam road.

Lithology, contacts and environment. These are essentially silty clays and sandy clays deposited in a progressively shallowing basin. This member differs from the lower member in terms of the conspicuous absence of belemnites and the occurrence of ammonites. Load structures and syndepositional slump folds are also observed. There seem to have been a sudden change of the sedimentary source, as well as of the quantity and nature of the sediment influx between the lower member and upper member of the Karai Formation. The upper portion of this member has localised pockets of fine sandstone along with ammonites. While the lower contact with the underlying member is conformable, the upper contact is erosional and signifies a major regression and unconformity.

Geographic extension. This member is absent in the southern part of the study area and has maximum occurrence in the northern regions. The beds progressively thicken from south (Karai) to north (west of Kunnam) and suddenly thin out to become absent further east and north. The beds have regionally varying proportions of a sand and silt admixture and also contain petrified wood logs, the patchy occurrence of bivalve shells and shell fragments. Lenses of calcareous silty clay and siltstone are also observed in the middle portion of this member.

Fossils and age. The fossil population of this member includes *Thalassinoides*, *Pecten*, *Exogyra*, *Alectryonia*, ammonites, foraminifers and serpulids. GOVINDAN *et al*. (1996) recorded a distinct faunal assemblage of species of *Rotalipora, Preaglobotruncana, Whiteinella* and *Hedbergella* and regard this lithological unit to have been deposited during Cenomanian–Early Turonian. TEWARI *et al*. (1996) also determined the same age for this member based on the occurrence of *Whiteinella arahaeocretacea* (PASSAGNO).

Thickness. 175 m.

Garudamangalam Formation

Following BLANFORD (1862), SUNDARAM & RAO (1986) recognised this formation as Trichinopoly Group. This formation, exposed in and around Garudamangalam and the town Trichinopoly located about 40 km away, rest over Archaen rocks and thus, KOSSMAT (1897) named this unit as Garudamangalam. Yet, many authors continued using the old terminology, which made BANERJI (1983) and RAMASAMY & BANERJI (1991) to restore the nomenclature of KOSSMAT (1897). This formation comprises three members.

Kulakkanattam Sandstone Member

Nomenclature. TEWARI *et al*. (1996) proposed this nomenclature and defined this member. In the present revision, the top beds, described by them as carbonate concretions, have been excluded. This member corresponds to the Kottarai Member of RAMASAMY & BANERJI (1991).

Stratotype. It is located between 78°56'22"–78°57'06" E; 11°07'22"–11°22'23" N in exposures along the Karai–Kulakkanattam road.

Lithology, contacts and environment. The rocks of this member are massive, yellowish brown ferruginous sandstones and contain abundant admixtures of silt and clay. Localised concentrations of shell fragments, bivalves and gastropods (resembling a shell bank typical of subtidal to intertidal coastal lagoons) and ammonites are common. BANERJI *et al*. (1996) interpreted this unit as having been deposited under a high-energy wave regime. A significant feature of this member is that the sandstone contains abundant wood fragments (in which a high concentration of bivalve boring and oyster encrustation are observed), which vary in size between 5 cm length and 2 cm diameter to 18 m length and 3.5 m diameter, at places found to be fit enough to term them as woody sandstone (Fig. 3D). Cross bedding, channel courses (1 m deep and several meters across), planar bedding and feeding traces are also common in this member. The depositional surface was strongly bioturbated and riddled roots (BANDEL, 2000). The rocks are well cemented. In the Karai–Kulakkanattam traverse, an angular erosional unconformity was found to separate this member from the underlying Karai formation. BANERJI (1972) and BANERJI *et al*. (1996) recognised this contact as a transgressive onlap.

Geographic extension. This member is totally absent in the northern and southern ends of the study area. From the central south part, it thickens towards the north and from the central north part, it thins down to become absent in the northern extreme. The population of gastropod and bivalve shell fragments is very high in the middle portion. The concentration of large – small wood trunks and fragments is higher in the southern region. While the northern and southern regions show abundant argillaceous admixtures, the middle region always shows a coarse grain supported fabric and a bedded nature with frequent bioclastic arenaceous limestone lenses.

Fossils and age. Abundant wood fragments encrusted with oysters, *Pinna*, *Thalassinoides, Diplocraterion, Ophiomorpha* and others molluscs. Age ranges from Middle–Late Turonian.

Thickness. 123 m.

Grey Sandstone Member

Nomenclature: Proposed herein.

Stratotype. It is located between 79°00'02"–79°00'56" E; 11°00'42"–11°01'24" N in the exposures of the Kalpadi–Ariyalur traverse (Fig. 3; traverse No. IV).

Lithology, contacts and environment. Rocks of this member are highly compact, well cemented, massive and have vertical burrow structures. The member has cyclic, parallel and even bedded alternative layers of barren and highly fossiliferous (small molluscs and whole bivalve and other shells and fragments) sandy layers (Fig. 4A) the thickness of which varies regionally. The sands are well sorted and well rounded. These sediments represent subtidal to supratidal sand bars deposited under wave and tide dominated environments. This member rests conformably over the Kulakkanattam Member and has a distinct erosional and non-depositional surface. The upper contact is a non-depositional surface associated with marine flooding. The deposition of this member immediately over subtidal flat sediments may indicate an advancing deltaic plain due to increased flow and or a stable/regressing sea. The presence of normal grading, cyclic sedimentation, repetitive occurrence of fossiliferous and barren layers of different thickness and planar horizontal bedding are all indicative of a foreshore environment, wherein the sediment influx was controlled by the relative intensity of a fluvial source, often reworked during periods of dry seasons. The difference in the cemented nature of this member compared to the overlying and underlying members confirms the assertion that the sediments of these rocks were exposed and cemented periodically under subaerial conditions, to form beach rocks. At the base, in the northern and southern regions, the deposition of this member started with calcareous cemented pebbly sandstone. TEWARI *et al.* (1996) interpreted this unit as a sign of deposition during transgression in a tidal inlet or a delta plain, or within a barrier succession. BANDEL (2000) interpreted this pebbly sandstone as a shift of the principal depocenter connected with regression and a structural disturbance. In either case, the deposition of this member represents a lowstand system tract above the Karai sequence boundary.

Geographic extension. The shelly layers show regional variation of faunal and bioclastic composition. In the south, the layers constitute essentially gastropods and in the north bivalves. Discrete layers of well-sorted sands with shell fragments in the form of shell lag deposits are also observed. The increase of argillaceous admixture towards the upper part of this member indicates a deepening of the depocenter, may be because of marine flooding. In the southern part, the beds are thin and siliciclastic. Towards the north, they become more calcareous, thick bedded and at places have a very high content of bioclastic materials, which made earlier workers regard this unit as shell limestone (e.g. RAO, 1970).

Fossils and age. *Teredolites* burrows, feeding traces of *Thalassinoides*, oysters, gastropods and molluscs. YADAGIRI & GOVINDAN (2000) assigned Late Turonian as the age of these beds.

Thickness. 35 m.

Anaipadi Sandstone Member

Nomenclature. Authors: TEWARI *et al.* (1996).

Stratotype. It is located between 78°57'40"–78°59'35" E; 11°07'06"–11°07'21" N in the exposures north of Anaipadi–east of Kulakkanattam and west of Kulattur.

Lithology, contacts and environment. The Grey Sandstone Member is conformably overlain by dirty yellow silty sandstone which contains abundant ammonites (many of which are more than 1 m in diameter), *Nautilus*, brachiopods (rhynchonellids), molluscs and bored wood fragments. The massive nature of the rocks, fossil association and lithological characteristics indicate, probably deeper marine conditions. The occurrence of lithoclastic cobbles in the middle portion of this member suggests the prevalence of periodic high-energy conditions, continental erosion and increased terrestrial sediment influx. The presence of intercalated beds with rich fauna dominated by oysters or rhynchonellids indicates the exchange of shallow water environment for open marine condition (BANDEL, 2000). The deposition of this member was truncated by a major regression.

Geographic extension. These are massive and thin-bedded claystones, silty claystones and clayey sandstones in the south that gradually grade to silty clay in the southern center and thin down. Again, from there, the thickness of these beds and sediment grain size increase and contain abundant large ammonites. Further north, these were observed to be clayey siltstones with abundant shell fragments and ammonites.

Fossils and age. A rich assemblage of Coniacian ammonites represented by *Kosmaticeras* gr. *theobaldianum, Kossmaticeras theobaldianum crassicostata, Puzosia* sp., *Damesites* aff. *sugata* and other fossils viz., *Nautilus*, molluscs, bored woods, encrusting oysters and rhynchonellids is present in this member, all typical of Coniacian age. This member corresponds to the *Kossmaticeras theobaldinum* ammonite Zone of AYYASAMY (1990) and the *Marginotruncana* planktonic foraminiferal Zone of GOVINDAN *et al.* (1996).

Thickness. 215 m.

Ariyalur Group

The Ariyalur group is distinct from rest of the stratigraphic units of the Cauvery basin in terms of lithological and faunal diversity. Although BLANFORD (1862) described this stratigraphic unit into a group, it was SASTRY *et al.* (1964, 1968, 1972) who assigned a systematic stratigraphic nomenclature. Yet, different workers continued utilizing varied terminologies and classification systems that posed difficulties in recognising them in the field. Later, CHANDRASEKARAN & RAMKUMAR (1995) reviewed all the existing classification systems of this group and supplemented additional field, petrographic, faunal and sedimentologic data. Their study confirmed the applicability of the classification reported by SASTRY *et al.* (1972) through biostratigraphic, chronostratigraphic and lithostratigraphic boundaries. These are detailed herein.

Sillakkudi Formation

This formation consists of three members.

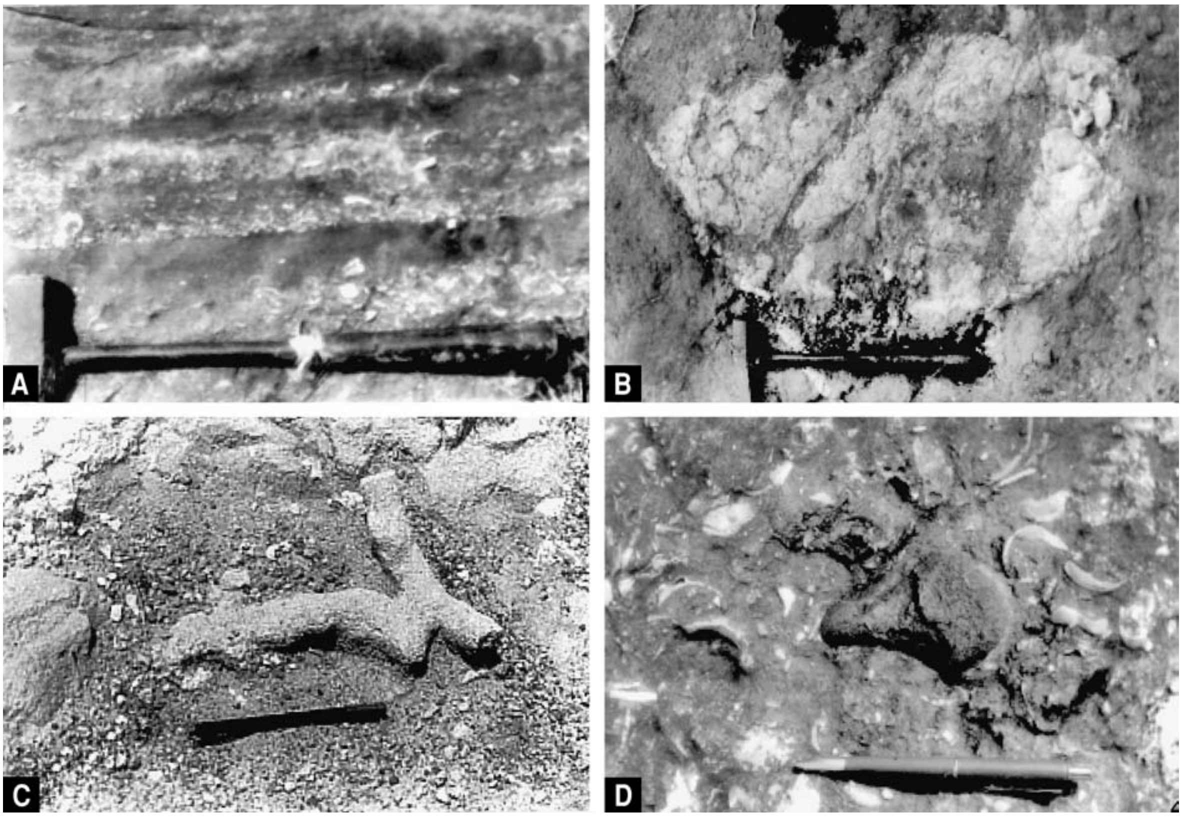

Fig. 4. **A**. Alternate barren and shell rich thin beds of the Grey Sandstone Member. Southwest of Anaipadi Village. **B**. Subrounded lithoclastic boulder in the Varakuppai Member. West of Varakuppai village in a stream section. **C**. Thalassinoid burrow in the upper portion of the Varakuppai Member. West of Varakuppai village in a stream section. **D**. Gravel sized feldspar clast in the Kallar Member. West of Kallankurichchi village in a stream section.

Varakuppai Lithoclastic Conglomerate Member

Nomenclature. It is proposed herein. This member includes the lower beds of the Upper Sandstone Member of SUNDARAM & RAO (1986) and an unnamed fluvial silty sandstone of TEWARI *et al*. (1996). These publications mention only a single exposure and there was not much information on the extent, lateral variations and other characteristics. The detailed mapping conducted in this study allowed a precise description of the rocks and enabled them to be classified into a formal stratigraphic unit.

Stratotype. It is located at 78°55'06" E; 11°01'23" N in exposures of a stream section west of Varakuppai.

Lithology, contacts and environment. Following the deposition of the Anaipadi Member, there was a major regression, possibly associated with the reactivation of basement faults resulting in the movement of the shoreline towards former offshore regions. The period of rejuvenated significant sedimentation after this regression was primarily under a fluvial regime and the fluvial agent was turbulent enough to transport well-rounded basement rocks, quartzite and older sedimentary rock boulders (Fig. 4B; lithoclastic boulders) in addition to unsorted coarse sand-pebble sized siliciclastics into the new depocenter. These deposits are typically reverse graded and show cyclic bedding, large scale cross bedding and lack any body fossils. They rest over older sedimentary rocks with typical erosional surfaces. The erosional intensity was so high that these beds have direct contact with the Karai Formation, thus giving testimony to the prevalent large scale undercutting, recycling and transporting nature of the fluvial channels. Three such major paleochannel courses were recognised with the help of remotely sensed data and field mapping (Fig. 5).

The occurrence of large scale cross bedding, mud drapes, fresh feldspar and sandstone clasts made TEWARI *et al*. (1996) interpret this unit as a fluvial channel fill with some marine tidal influence during periods of seasonal change in discharge. The cross bedded sequence has large lithoclasts of basement boulders along with claystone boulders and this unit is underlain by large scale cross-bedded, coarse lithoclastic sandstone which contains in situ burrow filling (*Thalassinoid* - Fig. 4C). These observations confirm marine influence over a drowning river mouth. The lower portion of this member was devoid of marine influence. The inference of a progressively increasing marine influence towards the top (inferred from the occurrence of sedimentary structures and *Thalassinoid*, typical of shallow coastal regions) of the member indicates the presence of a sequence boundary at its base.

Geographic extension. These beds are typically exposed in the regions south and northwest of Alundalipur, north of Melarasur and south and west of Sadurbagam in stream and road sections. Further east, north and south, they rapidly die out. In a stream section across a bridge which connects Alundalipur–Kallakkudi, these are excellently preserved and rest directly over the Karai Formation.

Lithology, contacts and environment: The contact between the Varakuppai and the Sadurbagam Members is a marine flooding surface. The resting of the Sadurbagam Member over Archaen rocks and the Varakuppai Member clearly affirms that, on flooding, areas that had not been previously transgressed were brought under marine conditions. SUNDARAM & RAO (1986) also stated that

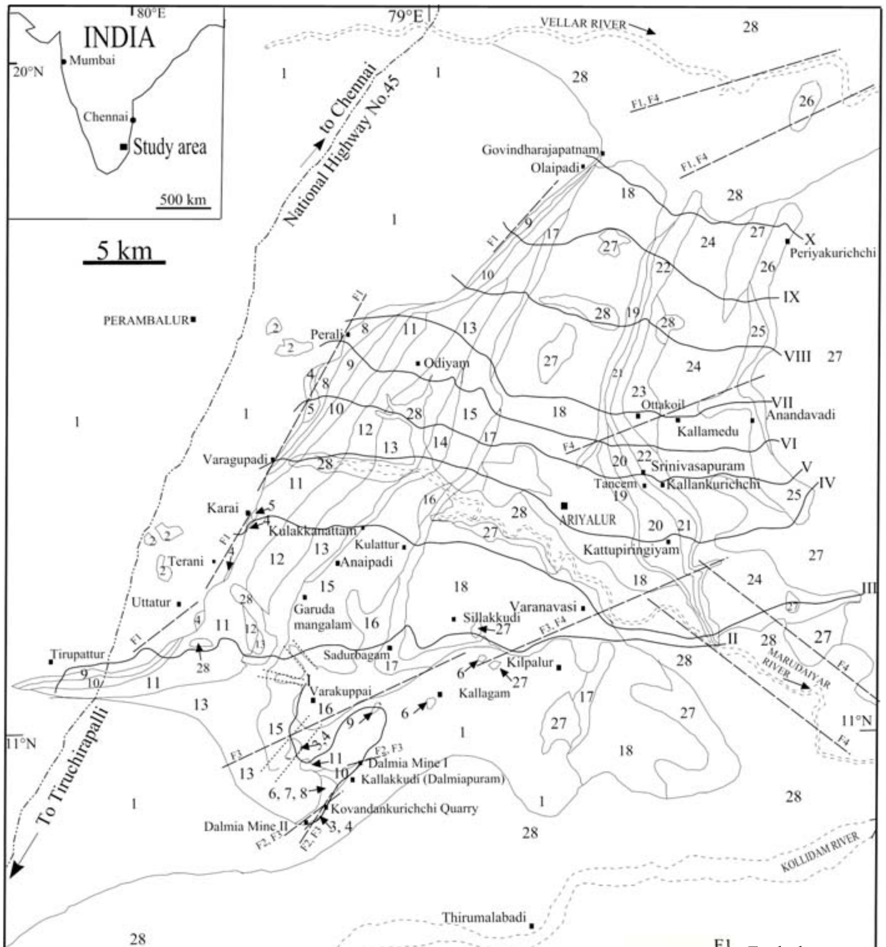

Fig. 5. Geographic distribution of the members of the Cauvery Basin. Legend:
F1 = Initial block faulting,
F2 = Faulting during Cenomanian,
F3 = Faulting during Santonian,
F4 = Faulting during post Danian,
1 = Unclassified gneiss,
2 = Charnockite & Gneiss,
3 = Basal Conglomerate Member,
4 = Kovandankurichchi Member,
5 = Terani Member,
6 = Grey Shale Member,
7 = Varagupadi Member,
8 = Dalmia Member,
9 = Olaipadi Member,
10 = Kallakkudi Member,
11 = Gypsiferous clay Member,
12 = Odiyam Member,
13 = Kulakkanattam Member,
14 = Grey Sandstone Member,
15 = Anaipadi Member,
16 = Varakuppai Member,
17 = Sadurbagam Member,
18 = Varanavasi Member,
19 = Kallar Member,
20 = Kattupiringiyam Member,
21 = Tancem Member,
22 = Srinivasapuram Member,
23 = Ottakoil Formation,
24 = Kallamedu Formation,
25 = Anandavadi Member,
26 = Periyakurichchi Member,
27 = Cuddalore Sandstone,
28 = Alluvium.

Fossils and age. No *in situ* fossils were observed, except a few *Thalassinoides* in the upper portion of the member. Subsurface sections indicate a *Marginotruncana coronata – Dicarinella asymmetrica* zone (GOVINDAN *et al*., 1996) of Santonian age.

Thickness. 45 m.

Sadurbagam Pebbly Sandstone Member

Nomenclature. It is proposed herein.

Stratotype. It is located at 78°54'25" E; 11°03'52" N in a stream section east of Sadurbagam.

the regions had remained structurally and topographically high since the inception of this basin were brought under marine influence during Late Santonian–Early Campanian as a result of a fault movement. At the top, a distinct non-depositional surface separates this member from the overlying member, which could be interpreted as the maximum flooding surface created at the dawn of the Campanian. Coarse siliciclastics with abundant marine fauna, shell fragments, and varying proportions of a calcareous matrix were deposited concomitantly with the rising of the sea level along the western margin of the newly established coasts which forms this member. At the base of this member, an erosional surface followed by a distinct cobble-pebble quartzite conglomerate is observed, which marks the beginning of the sedimentation of this member. The rocks show massive, thick to medium, even and parallel bedding and rest over the Varakuppai Member. At places, pockets of shell rich carbonate lenses with an abundant siliciclastic admixture are found to occur, which made earlier workers, (SUNDARAM & RAO, 1986; TEWARI *et al.* 1996) interpret this member as Lower Limestone Member and Kilpaluvur Grainstone Member, respectively. CHANDRASEKARAN *et al.* (1996) recorded load casts, slump folds, pillow structures and synerasis cracks in this member. The sandstone beds frequently show normal grading and low angle cross bedding. The occasional development of algal mounds, intimately associated with fault scarps of older sedimentary rocks, is also found to signify this member. The sedimentary structural and lithological information suggest a subtidal to intertidal clastic depositional environment for this member.

Geographic extension. The thickness of this member varies drastically in the south, may be reflecting the depositional topography as created by the fault scarp. The rocks are monotonously pebbly sandstones with massive bedding in the north and are continuously bordered by the Paleo Sea except in the region northwest of this member, where the younger Varanavasi Member rests directly over the Anaipadi Member.

Fossils and age. The fossil composition of this member includes inoceramids, rhynchonellids, terebratulids, *Nautilus*, echinoids, crinoids, fragments of corals and bivalves and algal mounds, indicative of Late Santonian age.

Thickness. 80 m.

Varanavasi Sandstone Member

Nomenclature. It is proposed herein.

Stratotype. It is located at 79°04'09" E; 11°04'58" N in a stream section southwest of Varanavasi.

Lithology, contacts and environment. These are planar sheet sands, primarily consisting of featureless, massive, thick bedded, coarse to medium grained sandstones. They rest over the pebbly sandstone member with a non-depositional surface, may be due to flooding by marine waters. AYYASAMY (1990) recognised a hiatus between Santonian (Sadurbagam Member) and this member based on the ammonite zonation. The beds contain intermittent fine pebble-coarse sand laminae and show normal grading to reestablish the deposition of thick, massive, medium sand deposits, probably representing periods of higher energy and sediment influx. The sands are loosely packed and cemented by a calcareous medium. Towards the top, serpulid colonies are frequently observed which survived in a slowly waning sea (RAMKUMAR, 1997). The upper surface of this member represents an erosional surface associated with regression.

Geographic extension. These are the most extensive lithologies in this part of the basin, developed mainly due to a constant supply of sediment and stable shelf conditions, the duration of which was longer than before or after. They show the development of monotonous, thick to very thick beds with coarse-medium sands in all the regions, except an argillaceous admixture and less grain-to-grain contacts in the north. Periodic higher energy conditions, marked by the deposition of very coarse sandstone lenses, pockets of shell hash, intraformational lithoclastic bounders in association with vertical cylindrical burrows and resedimented petrified wood logs are observed in the middle portion. In the type section of this member, thin to medium, cross-bedded siliciclastics are recorded. This member has a more or less uniform thickness.

Fossils and age. Important fauna of this member include inoceramids, serpulids, *Turritella*, *Globotruncana arca*, *Globigerinelloides, Marginotruncana marginata*, *Whiteinella baltica* and *Archaeoglobigerina* and indicate Campanian age. GOVINDAN *et al.* (1996) recorded typical Campanian benthonic foraminifer *Bolivinoides culverensis* and *B. decoratus* in this member. This member also belongs to the *Karapadites karapadense* ammonite Zone (SASTRY *et al.*, 1968; 1972) and the *Globotruncana elevata - G. ventricosa* planktonic foraminiferal Zone (GOVINDAN *et al.* 1996).

Thickness. 270 m.

Kallankurichchi Formation

Recently, RAMKUMAR (1999) reported the lithostratigraphic setup of this formation with four members, which are detailed herein.

Kallar Arenaceous Member

Nomenclature. Amended with a prefix from the nomenclature of RAMKUMAR (1999).

Stratotype. It is located at 79°07'24" E; 11°08'32" N in a Kallar river section.

Lithology, contacts and environment. This member consists of conglomerates in which clasts of basement rocks, fresh feldspar (Fig. 4D), resedimented colonies of serpulids and other older sedimentary rocks, which range in size from coarse sand to boulders, are observed. The clasts are well rounded and show characteristics of redeposition. The beds show typical normal grading. The sediments were brought to the depocenter during high velocity flows (*sensu* CANYBARE & CROOK, 1968) and are primarily channel deposits and coastal conglomerates (HART & PLINT, 1995). The occurrence of redeposited lithoclasts of serpulid sandstone (which occurs in situ on top of the Sillakkudi Formation) along with fresh feldspar cobbles indicates severe erosion of both older sedimentaries and distally located basement rocks. The upper portion of this member shows colonisation of gryphean shells and a reduction of the proportion of siliciclastic sediment. The lower contact of this member is an erosional surface. The upper contact is a non-depositional surface resulting from marine flooding. The occurrence of larger foraminifera in this unit, as described by HART *et al.* (2000), and their counterparts in ther neritic regime of modern seas indicates the initiation of the deposition of this member in very shallow bathymetry with a slow increase in the sea level (as evidenced by the colonisation of gryphea over the conglomerate bed).

Geographic extension. This member rests directly over the Sillakkudi Formation and could be readily recognized in the field by distinct changes in lithology, colour, fauna, sedimentary structures, etc. Laterally, the proportion of siliciclastics varies to produce localized lenses of siliciclastic conglomerates and limy conglomerates.

Fossils and age. Orbitoids and sideralolites constitute the dominant microfaunal composition. *Gryphaea* and *Alectryonia* are the major fauna of this member. The fossil assemblage indicates Lower Maastrichtian age (RADULOVIĆ & RAMAMOORTHY, 1992). Based on the large occurrence of foraminiferal, HART *et al.* (2000) assigned very uppermost Campanian to very Early Maastrichtian age and equated the initiation of the deposition of this member with a global eustatic sea level rise.

Thickness. 6 m.

Equivalents from other areas. Based on the study of subsurface borehole samples, NAIR (1974, 1978) reported this unit 50 km south from the present study area.

Kattupiringiyam Inoceramus Limestone Member

Nomenclature. Amended with a prefix from the nomenclature of RAMKUMAR (1999).

Stratotype. It is located at 79°09'30" E; 11°07'31" N in the Kattupiringiyam mine NE Wall, Bench I (mine owned by Fixit Co. Ltd.).

Lithology, contacts and environment. This member consists of dusty brown friable carbonate sands (Fig. 6A) with parallel, even and thick to very thick bedding, which contain only inoceramids and bryozoans. This member has a pronounced diagenetic bedding and abundant geopetal structures filled with mm to cm sized dog tooth spars of low magnesian, non-ferroan calcite. Based on standard microfacies analysis, RAMKUMAR (1995) interpreted this member as having been deposited in a middle to outer shelf. This member has a non-depositional surface at the bottom and a distinct erosional surface at the top.

Geographic extension. This member is well developed in the south and dies out in northern regions. It shows monotonous, massive dusty brown limestone beds with inoceramids all over the exposed regions without any lateral or vertical variation and also without any break in sedimentation.

Fossils and age. This members hosts thick populations of inoceramids and bryozoans and was deposited during Early Maastrichtian.

Thickness. 8 m.

Tancem Biostromal Limestone Member

Nomenclature. Amended with a prefix from the nomenclature of RAMKUMAR (1999).

Stratotype. It is located at 79°07'32" E; 11°09'26" N in the Kallankurichchi Mine I, Bench I and II (mine owned by Tancem Ltd.).

Lithology, contacts and environment. The beds have local concentrations of fragments of *Inoceramus*, *Gryphaea*, *Exogyra*, *Stigmatophygus*, *Alectryonia*, terabratulids and bryozoans, in the order of decreasing proportion, and are interpreted as having received their source materials from adjacently located shell banks. Sporadic admixture of siliciclastics and intraclasts are observed. The sorting is generally poor and the roundness varies from angular to well rounded. The size differs between fine sand to cobble and shows lateral and vertical gradation. These are the products of periodic and long lasting high-energy conditions, related with temporal regression, storm events and associated erosion and redeposition. They show a thin to thick, parallel, even bedded nature, cross bedding, normal grading, hummocky cross stratification, feeding traces, escape structures and tidal channel structures and range in depositional environment from tidal channel to middle shelf. This member rests over the Inoceramids Limestone Member and the gryphaean limestone beds of the Arenaceous Member with a distinct erosional surface. The upper surface is non-depositional and at places erosional.

Geographic extension. These beds occur all over the exposed area. They show lateral variation in composition and concentration of shell fragments.

Fossils and age. Except *Stigmatophygus* and *Planolites*, no whole fossils are present in this member. MITROVIĆ-PETROVIĆ & RAMAMOORTHY (1993) interpreted this unit as having been deposited during Early Maastrichtian.

Thickness. 8 m.

Equivalents from other areas. These are the fragmental limestones of NAIR (1974, 1978) who reported them 50 km south of this location and also from offshore bore wells.

Srinivasapuram Gryphaean Limestone Member

Nomenclature. Amended with a prefix from the nomenclature of RAMKUMAR (1999).

Stratotype. It is located at 79°07'38" E; 11°09'44" N in the Kallankurichchi mine II, northern wall, Bench I and II (mine owned by Tancem Ltd.).

Lithology, contacts and environment. This member consists of uniform, parallel, thick-very thick-bedded gryphaean shell banks which have a very high population of *Gryphea* (Fig. 6B), *Exogyra*, terebratulids, bryozoans and sponges. Non-depositional surfaces are observed occasionally in this member in an otherwise continuous, massive unit. A shoreward movement of the shell banks is observed which may be interpreted as adjustments of shell colonies in response to a prevalent sea level rise. The upper contact of the member shows a distinct erosional surface. Based on the occurrence of extensive boring in the gryphaean shells, synsedimentary cementation, colonies of encrusting bryozoa over gryphaean shells and micritization of bioclasts, as well as the lifestyle of gryphaeans, RAMKUMAR (1996, 2000) interpreted this member as having been deposited within 50 meters bathymetry under open sea conditions in a distally steepened ramp setting.

Geographic extension. These are the most extensive beds of this formation and have a distinct very high population of *Gryphaea*. Towards the top, admixture of siliciclastics and an increased proportion of shell fragments were observed, which indicate a fall in the sea level and an associated increase in energy as a result of which shell banks were eroded and redeposited.

Fossils and age. *Gryphaea*, *Alectryonia*, terebratulids, bryozoans, ostracods, sponges and ammonites. RADULOVIĆ & RAMAMOORTHY (1992) assigned Lower Maastrichtian age to this member. This member belongs to the *Hauriceras rembda* ammonite Zone (SASTRY *et al*., 1972; AYYASAMY, 1990).

Thickness. 18 m.

Equivalents from other areas. NAIR (1974, 1978) reported these beds from 50 km south of this location and also from offshore regions.

Ottakoil Formation

Nomenclature. After SASTRY *et al*. (1972) and CHANDRASEKARAN & RAMKUMAR (1995).

Stratotype. It is located at 79°07'12" E; 11°01'26" N in a stream section east of Ottakoil.

Lithology, contacts and environment. These are coarse to medium sized, well-sorted, fossiliferous, low angle cross-bedded and planar to massive bedded sandstones. They also show recurrent upward fining sequences. The rocks contain abundant echinoids and a few trace fossils. The rocks are loosely cemented with a calcareous medium. These lithological and faunal characters indicate deposition in marginal marine settings in a shallowing basin. This formation rests over the Kallankurichchi Formation with disconformity and overlapping by the Kallamedu Formation. This formation marks the end of marine Cretaceous deposition in this part of the basin.

Geographic extension. It developed only in the central region of the exposed area and ubiquitously contains *Stigmatophygus elatus* in thick populations. The calcareous admixture varies regionally. The lower portion of this member shows a medium-bedded nature that grade to a massive and very thick-bedded nature towards the top.

Fossils and age. The faunal composition includes *Stigmatophygus elatus, Durania mutabilis, Thalassino-*

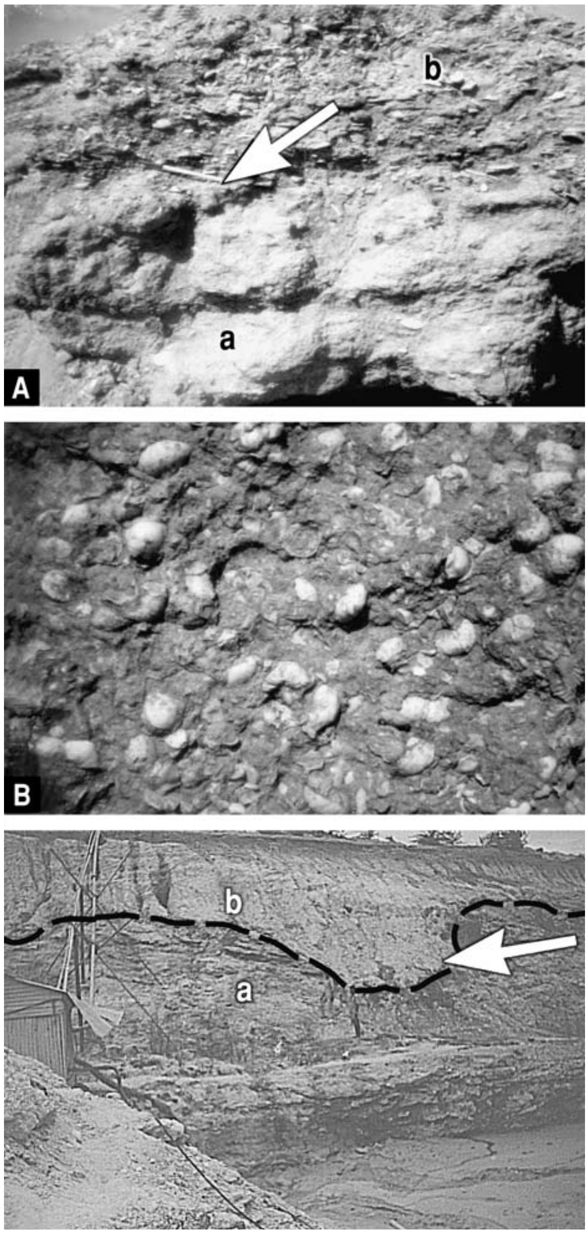

Fig. 6. **A**. Carbonate sand beds (a) overlain by a fragmented shell limestone bed (b) with a sharp erosional surface in between (pen placed for scale rests on this surface, indicated by an arrow). These are the products of short–long lived periodic high energy conditions prevalent during the deposition of the Tancem Member of the Kallankurichchi Formation. Tancem mines, west of Kallankurichchi village. **B**. Thick population of insitu gryphean shells. These constitute the bulk of the Srinivasapuram Member of the Kallankurichchi Formation. Tancem mines, south of Srinivasapuram village. **C**. Conformable, but erosional surface contact between the Kallankurichchi Formation (a) and the Kallamedu Formation (b) as exposed in a mine located southeast of the Kallankurichchi Formation. Note the scour structure, (indicated by an arrow) presumable representing a cross section of a fluvial channel, in which the poorly consolidated sandstones were filled.

ides, Ophiomorpha, Dactyloidites, Nautilus and fragments of *Gryphaea* and *Alectryonia*. RADULOVIĆ & RAMAMOORTHY (1992) and MITROVIĆ-PETROVIĆ & RAMAMOORTHY, (1993) interpreted this formation to have been deposited during middle Maastrichtian. This formation belongs to the *Pachydiscus otacodensis* ammonite Zone (AYYASAMY, 1990) and the *G. gansseri* foraminiferal Zone (GOVINDAN *et al*., 1996)

Thickness. 40 m.

Equivalents from other areas. NAIR (1978) reported the occurrence of this formation in offshore regions through a study of borehole samples.

Kallamedu Formation

Nomenclature. After Sastry *et al*. (1972) and CHANDRASEKARAN & RAMKUMAR (1995).

Stratotype. It is located at 79°08'39" E; 11°11'46" N in stream sections north and northeast of Kallamedu.

Lithology, contacts and environment. This formation consists of loosely packed sands drawn from older sedimentary rocks. The sediments are well rounded, poorly sorted and non-consolidated and are barren except for a few fragments of dinosaurian bones. The local occurrence of clays and silts with dispersed detrital quartz grains and sandy streaks, its non-bedded nature, rare lamination and mud cracks are all indicative of prevalent sedimentation as over bank deposits associated with a channel. This formation primarily consists of white, coarse to medium grained immature, often pebbly sands with a clay matrix and localized clay lenses. These characteristics indicate primary deposition in and around shallow channels (Fig. 6C). Towards the top, this formation shows the development of soil and a return to continental conditions. Thus, the upper surface represents a non-depositional and erosional surface and also forms a sequence boundary.

Geographic extension. Next to the Sillakkudi Formation, this is the most extensive formation of the Ariyalur Group. It covers the whole region between the Kallankurichchi and Niniyur Formations. It shows development of monotonous, massive, loosely packed sands with localised and isolated patches of clayey soil. In the bottom portion, along the central region of the study area, higher frequencies of texturally matured resedimented pebbles are observed along with a few dinosaurian bone fragments. Towards the top, these rocks grade from medium to thin bedded, relatively highly argillaceous sandstones.

Fossils and age. Relatively barren except for a few dinosaurian bone fragments belonging to *Carnosaur* (YADAGIRI & AYYASAMY, 1987). MITROVIĆ-PETROVIĆ & RAMAMOORTHY (1993) and GOVINDAN *et al*. (1996) assigned Late Maastrichtian age to this formation. This formation represents the *Abathomphalus mayoroensis* planktonic foraminiferal Zone (TRIPATHI & MAMGAIN, 1987) and is consistent with Upper Maastrichtian palynoassemblage (VENKATACHALA & SHARMA, 1974) which includes *Aquilapollenites bengalensis, Cranwellia cauveriensis, Araucariacites australis, Tricolpites microreticulatus* and *Triporopollenites minimus* (SAHNI *et al*., 1996).

Thickness. 100 m.

Equivalents from other areas. MASTHAN (1978) reported subsurface extension of this formation in offshore regions.

Niniyur Formation

At the beginning of Danian, sedimentation started again to be associated with a rise in the sea level in this basin. The presence of a conformable relationship between this formation and the Kallamedu Formation suggests the absence of major tectonic activity and indicates simple sea level fall and sea level rise. This formation comprises two members.

Anandavadi Arenaceous Member

Nomenclature. It is proposed herein.

Stratotype. It is located at 79°10'52" E; 11°11'22" N in stream sections south and northeast of Anandavadi.

Lithology, contacts and environment. It consists of isolated coral mounds, impure arenaceous limestone, sandstone and clay lenses. The deposition of this member might have taken place in a restricted marine regime under subtidal to intertidal regions. The occurrence of localised concentrations of shell fragments, well-indurated coralline limestone and reef-derived talus deposits are characteristics of this member. This member rests over the Kallamedu Formation with a distinct disconformity and is exposed in stream sections, road cuttings and well cuttings located in the southern part of the study area. The upper contact is an erosional surface associated with marine flooding.

Geographic extension. While it is principally isolated coral algal colonies, they are connected through thin veneers of bioclastic and arenaceous counterparts in the south. More arenaceous coral algal limestone deposits signify this member towards the north.

Fossils and age. SASTRY & RAO (1964) recorded a drastic decrease in fossil population from the underlying Cretaceous beds to this member. The fossil composition consists of corals, algae, serpulids, bivalves and gastropods. This member was deposited during Danian (SAHNI *et al*., 1996).

Thickness. 30 m.

Equivalents from other areas. NAIR & VIJAYAM (1980) reported an extensive occurrence of this member in offshore subsurface regions.

Periyakurichchi Biostromal Member

Nomenclature. It is proposed herein.

Stratotype. It is located at 79°12'38" E; 11°17'54" N in the southern wall Bench I, II and III of the Periyakurichchi Mine (mine owned by India Cements Ltd.).

Lithology, contacts and environment. This is the most well-developed member of this formation and consists primarily of medium to thick, even to parallel bedded alternate biostromal limestones and marls. Different concentrations of shell fragments and whole shells of bivalve, gastropod and remains of amphibia, pisces, algae, foraminifera and ostracoda are also observed. The deposition of this member occurred during a sea level highstand under open marine conditions. At the top, the sudden truncation of deposition followed a fall in the sea level and widespread erosion, the restoration of a continental environment and the prevalence of a tropical climate are evidenced by the presence of the Cuddalore Sandstone Formation of Miocene to Pliocene age with distinct unconformity over this member. The end of the deposition of this member marks the end of marine sedimentation in this part of the basin.

Geographic extension. Good exposures of this member are found in the Periyakurichchi and Ichangadu mines. Beds of this member are traced to the east of lower members and they gradually thicken eastwards and northwards. Contact between this member and the underlying member is an erosional surface. A thick arenaceous bioclastic limestone bed rests over this surface and towards the top, alternate limestone and marl beds of medium, parallel, even bedded nature typify this member. Good exposures of this member are limited only to mine sections owing to the presence of very thick piles of overlying Cuddalore Sandstone Formation and Recent alluvium.

Fossils and age. Fossil assemblage of this member comprises of algae, corals, bivalves, amphibiae, pisces and gastropods. Fossil assemblage with the nautiloid *Hercoglossa danica* indicates Danian age (NAIR & VIJAYAM, 1980; SAHNI *et al*., 1996).

Thickness. 26 m.

Equivalents from other areas. NAIR & VIJAYAM (1980) reported extensive occurrence of this member in offshore subsurface regions.

Discussion on systematic stratigraphy

While the present study enables the exposed strata to be defined into 22 members and 9 formations, it was not felt possible to "accommodate" them into groups, as the existing terminologies of groups are either non-relevant or rest over Archaen rocks. For example, the Uttatur Group as envisaged by TEWARI *et al*. (1996), is found to be untenable. While TEWARI *et al*. (1996) eliminated the use of the term Trichinopoly on the grounds that it is far from the exposed area and rests over Archaen rocks, they themselves termed the Dalmiapuram and Garudamangalam Formations as the "Uttatur" Group after the village name "Uttatur", which in turn rests over Archaen rocks. In another case, a single formation (the Sivaganga Formation), which too is not typical of its original characteristics of the type area (Sivaganga area located south of the present study area) could not be assigned with a Group as was done by TEWARI *et al*. (1996). The established guidelines of lithostratigraphy specifically state that "while the members need to be grouped under a formation, it is not necessary to put different formations into a group" (EYESINGA, 1970; North American Stratigraphic Code, 1983). Thus, we exclude the terms Gondwana Group (assigned to the Sivaganga Formation) and the Uttatur Group, (assigned to the Dalmiapuram and Garudamangalam formations) of TEWARI *et al*. (1996). While their study largely eradicated the discrepancies existing in the literature, it erred in small counts. As reported by them in their paper, their study was limited only to "key locations" and "rarely individual beds are traced", which in turn has necessitated the present study. Any meaningful lithostratigraphic report should contain information on lithologic types, their lateral and vertical variations, fauna and other criteria, such as sedimentary structure and stratigraphic breaks, which could be recognized and traced in the field are necessary. The mapping of the study area on a 1:50 000 scale and the tracing of individual beds all over the exposed area (assisted by the availability of newer mines, trenches and road sections), allowed a more accurate documentation of the stratigraphic setup of the area. The total thickness of the exposed strata in the study area is 1696 m. However, the subsurface counterparts of these strata account for about 5000 m and, hence, this onland exposure could be considered as a condensed section. GOVINDAN *et al*. (1996) state that in the deeper part of the basin, the strata are similar to the ones established in the Tiruchirapalli–Ariyalur outcrops, except for the thicknesses of the individual beds. Thus, the revised lithostratigraphic classification presented in this paper could also be put to use for offshore subsurface counterparts.

Depositional history

The rift between India–Australia–Antarctica during Late Jurassic–Early Cretaceous resulted in block faulting of Precambrian terrain of India, creating a series of sedimentary basins along the east coast, among which the Cauvery basin is the southernmost sedimentary basin. The basement tectonics, as enumerated by PRABAKAR & ZUTSHI (1993), details that this basin continued to evolve until the end of Tertiary through rift, pull-apart, shelf sag and tilt phases, during which many episodes of transgression, regression, erosion and deposition took place to fill the basin. Seismic sounding and deep borehole log data revealed that this basin consists of a number of subbasins (Fig. 7), differentiated by many highs (SASTRY *et al*., 1977; KUMAR, 1983). The Pondicherry sub-basin is

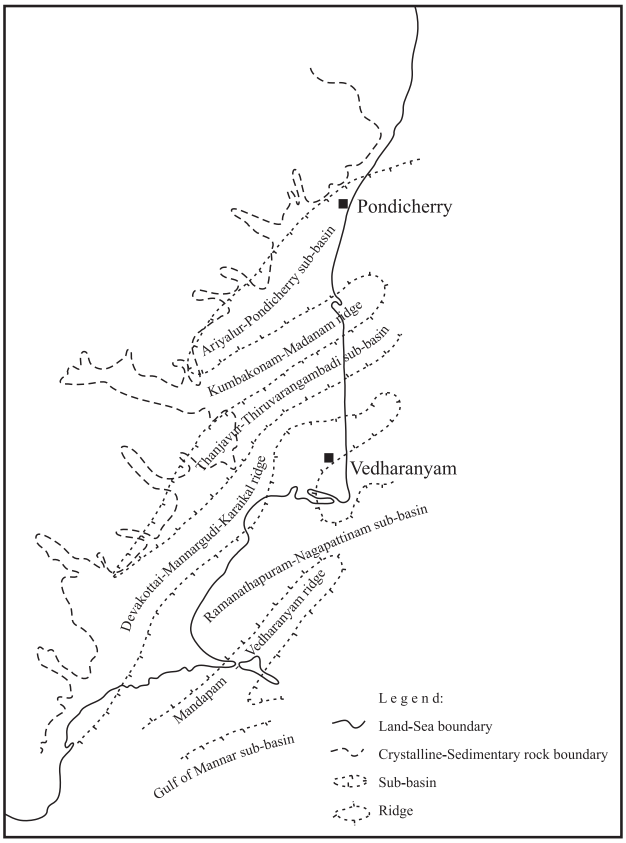

Fig. 7. Structural configuration of the Cauvery Basin (after Chandra, 1991).

the northernmost and contains three main exposures mappable in outcrops. The structural grains mapped in the field are presented in Fig. 5. It is a general phenomenon in this basin that the folding and fracturing of the rocks were always associated with faulting. Based on field criteria and lithological association and displacement, the basin scale tectonic movements that occurred in the study area were interpreted viz., initial block faulting (Refer F1 in Fig. 5), movement of fault blocks during Cenomanian (F2 in Fig. 5), reactivation of older fault blocks and creation of new fault during Santonian (F3 in Fig. 5) and reactivation of fault blocks during post-Danian–pre-Quaternary (F4 in Fig. 5). It should be stated that, in addition to these major fault movements, there were minor and local scale tectonic movements, all of which were confined only to the adjustment of fault blocks along the pre-existing fault planes. The difference in trends of post-Danian fault movements affected the Miocene to Pliocene sandstones, Danian limestones and Maastrichtian deposits, as depicted in Fig. 3. The sedimentary response to the prevalent major tectonic and other geologic processes in the light of present observations are detailed herein.

All along the western margin of the basin, the basement rocks show typical northeast to southwest fault lines, which mark the initial block faulting. As a result of this faulting and the associated down-throw of the Pondicherry sub-basin, widespread transgression was affected and the sedimentation of the Sivaganga Formation commenced. The Precambrian basement rocks, located farther west of the basin margin fault lines, were severely eroded and transported to the depocenter before inheriting alteration and maturity and, thus, fresh sub-angular basement rock boulders and cobbles with feldspathic pebbles are found to occur in this formation. As the intensity of the energy conditions were reduced, the sediment grain size was also reduced. Significant sedimentation commenced with the establishment of a fluvial source onland and a submarine fan delta in the basin (represented by the Kovandankurichchi Sandstone Member). Gradation of this sandstone member into a deep marine claystone–siltstone member (the Terani Member) indicates stable environmental conditions up to the end of the deposition of the Terani Member. The deposition of the Terani member was brought to an end due to renewed faulting introducing an angular unconformity associated with erosion and resedimentation of older sedimentary rocks. The rejuvenated sedimentation was through the deposition of shale and shale–limestone alternate beds of the Grey Shale Member of the Dalmiapuram Formation. The depocenter was partially and periodically closed, during which time grey shale was deposited. Whenever open conditions of sea circulation were introduced, bioclastic limestone bands were deposited. The thickness of the limestone interbeds increases towards the top, indicating an increase in the duration of the openness of the sea, which culminated in the development of a biostromal member over it. This biostromal member contains principally coral clasts and algal fragments with varying proportions of clasts of bryozoa, bivalvia and gastropoda, in addition to reef-dwelling microfauna. Siliciclastic admixture is significant to minor in proportion and vary randomly. The beds of this member are parallel, even to uneven, thin to thick bedded and have frequent erosional surfaces in between. All these features signify deposition under a photic zone and the principal depositional loci to be between subtidal and storm weather wave base. Typical coral reef deposits developed over this member that moved gradually towards offshore regions owing to a fall in the sea level. At the top of this biohermal limestone member, a major erosional surface associated with faulting and regression is observed. This faulting exposed the subtidal–storm weather wave base deposits to subaerial conditions which led to karstification. It also paved the way for the deposition of the Olaipadi Conglomerate Member which contains large boulders (many of which are more than 10 m in diameter) of basement rocks, lithoclasts of similar size, drawn from underlying bioclastic and coral limestone, Terani claystone and lithoclasts of older sedimentary conglomerates, all embedded in basinal clay sediments. The angular to sub-rounded nature of the boulders, the possession of basement as well as lithified lithoclasts of older sedimentary rocks in the basinal sediments clearly indicate a major faulting event, the creation of a steep slope and a short transportation distance. The presence of argillaceous siltstone over these boulders with lamination parallel to the boulder boundaries indicates the restoration of normal depositional conditions and a gradual increase in the sea level. The deposition of argillaceous sediments was ended by rejuvenation of the fluvial source, resulting in a persistent influx of coarse to finer clastics and a suspended sediment load. This new set of environmental conditions led to the deposition of the Kallakkudi Calcareous Sandstone Member. This member is sandy in the southern region and clayey in the northern region. The occurrence of recurrent Bouma sequences, which always top with a gypsiferous layer, followed by an erosional surface and again by an another Bouma sequence in this member indicates the dynamic nature of the depocentre, the episodic closure of the sea, the exposure of sediments to subaerial conditions, rejuvenation of the deposition with a rise in the sea level, deposition under the influence of turbidity currents and the gradual facies change from near shore to deep sea. On the whole, the interpretation could be that the deposition of this member took place in a slowly sinking basin and/or deposition with episodic rises and falls coupled in the sea level with active fault block adjustment (to a minor degree) after major movement.

With the sinking of the coastal basin and/or sea level rise, deep marine conditions were established and thick piles of the Karai Formation clays were deposited. The deposition of about 450 m of thick clay alternated with ferruginous silty clays and gypsiferous layers suggests a well developed fluvial system onland which continuously supplied a suspended sediment load to deep marine regions. The thick population of belemnites, silty admixture, alternate thin-thick laminae of ferruginous silty clay and gypsiferous clay bands are frequent in the southern region, which is indicative of the deposition in shallower regions of palaeosea also. The shallower southern regions were periodically exposed subaerially due to minor sea level oscillations to produce evaporites. The top surface is marked by a pronounced erosional surface, which suggests major regression at the end of the deposition of this formation. This erosional surface is overlain immediately by subtidal–supratidal ferruginous sandstones along with shell banks typical of an estuary and shell hash typical of shallow water shoals/distributary mouth bars that represent the Kulakkanattam and Grey Sandstone Members of the Garudamangalam Formation. Together, their occurrences indicate a retreat of the shoreline and an associated advancement of a fluvial system over the former offshore areas. This inference is substantiated by the sudden appearance of large tree trunks in these sandstones. Although the boundary between the Karai clays and the Kulakkanattam sandstones is an erosional unconformity, the presence of a conformable relationship and near parallel bedding planes of rocks between them suggests a simple variation of the sea level and the introduction of newer environmental conditions, rather than a fault-controlled environmental change across the boundary. Deep-water conditions were restored again in this part of the basin with the introduction of the deposition of the Anaipadi Sandstone Member which shows a gradual increase in the sea level. A break in the sedimentation, probably influenced by major regression was witnessed at the end of the deposition of the Anaipadi Member.

Renewed transgression initiated during the Middle Santonian covered the regions located north and south that had not been transgressed previously. This widespread transgression, associated with downwarping of fault blocks, submerged coastal tracts up to Pondicherry in the north, resulting in generation of Archaen–Campanian contact (faultline located north of Kilpalur – refer Fig. 5). This period was associated with widespread erosion of basement rocks and older sedimentaries and resedimentation of them in the newly created depocenters. The Sillakkudi Formation of Ariyalur Group, which was the product of this widespread transgression, has three members. The lowermost member is a fluvial unit and shows gradual transition to deposition under marine influence towards the top. Major channels that cut older sedimentary rocks (Fig. 5), having a width of more than a kilometer and 30 m deep, were recognised in the field. The strata of this member have reverse grading and are predominantly basement boulder and lithoclastic conglomerates. They also show large scale advancing cross beds, alternated with ferruginous s.st. foresets. The continuing increase in the sea level submerged the fluvial/estuarine mouth sediments and a typical coastal marine member started to develop, in which the prevalent deposition was in subtidal to intertidal environments. Towards the top, the Varanavasi Member shows the frequent occurrence of pebbly sandstone layers (may be as a result of prevalent periodic higher energy conditions), erosional surfaces and reworked fauna. The localised serpulid colonies found at the top of this member indicate the cessation of sediment supply, a reduction in the sea level, a reduced circulation and lower energy conditions. A major erosional unconformity separates this formation from the overlying Kallankurichchi Formation.

The renewed transgression during the Latest Campanian–Early Maastrichtian was marked by widespread erosion of basement rocks and older sedimentaries. However, the size of the basement boulders and lithoclasts of older sedimentaries in the basal conglomerate member of this formation rarely exceed 30 cm and are more rounded than their older counter parts. Furthermore, these clasts seemed to be recycled from older sedimentaries rather than sourced fresh from basement rocks. Thus, the Kallar Arenaceous Member has lithoclastic conglomerate deposits at its base and rests over the underlying Sillakkudi Formation with distinct angular erosional unconformity. The Kallankurichchi Formation is essentially a carbonate unit that denotes the cessation of a suply of fluvial sediment which existed during Santonian–Campanian. As the initial marine flooding started to wane, the deposits show a reduction in the proportion and size of siliciclastics, which were increasingly replaced by gryphean colonies marking the beginning of a carbonate sedimentation. As the sea level gradually increased, the gryphean bank shifted towards shallower regions and the locations previously occupied by coastal conglomerates became middle shelves, on which typical inoceramid limestone started developing. The break in the sedimentation of this member was associated with a regression in the sea level, which transformed the middle to outer shelf regions into intertidal to fair weather wave base regions. These newer depositional conditions resulted in the erosion of shell banks and middle shelf deposits and their redeposition into biostromal deposits (the Tancem Biostromal Member). As the energy conditions were high and the deposition took place in shallower regions, frequent non-depositional and erosional surfaces, punctuated with cross-bedded carbonate sand beds and tidal channel grainstones and storm deposits with HCS (hummocky cross stratification) were deposited. Again, the sea level rose to create a marine flooding surface and as a result of which, gryphean shell banks started developing more widely than before, whereby the Srinivasapuram Gryphean Limestone Member was formed. Towards the top of this member, shell fragments and minor amounts of siliciclastics are observed that may indicate the onset of regression and associated introduction of higher energy conditions. The occurrence of a non-depositional surface at the top of this formation and the deposition of shallow marine siliciclastics (the Ottakoil Formation) in a restricted region immediately over the predominantly carbonate depocenter and conformable offlap of much younger fluvial sand deposits (the Kallamedu Formation) are all suggestive of a gradual regression associated with the re-establishment of a fluvial system at the end of Cretaceous Period. Towards the top of the Kallamedu Formation, paleosols are recorded, implying the abandonment of a river system and the restoration of continental conditions at the end of Cretaceous. At the beginning of Danian, transgression occurrerd which covered only the eastern part of the Kallamedu Formation. The presence of a conformable contact of the Anandavadi Member with the Kallamedu Formation and the initiation of carbonate deposition from the beginning of Danian are indicative of the absence of any fluvial sediment supply and the absence of tectonic activity at this time. The increase in sea level and the establishment of a shallow, wide shelf with open circulation paved the way for the deposition of the Periyakurichchi Member. At the top, this member has distinct erosional unconformity, which in turn, when interpreted along with the presence of a huge thickness of continental sandstone (>4000 m the thick Cuddalore Sandstone Formation), clearly indicates the restoration of continental conditions in this basin. The absence of any other marine strata over the Cuddalore Sandstone Formation (Miocene to Pliocene in age) suggests that the sea regressed at the end of Danian and has never returned.

Sea level changes

The present day interest in sedimentary response to sea level changes owes its origin to the stratigraphic concepts evolved from the work of SLOSS (1963) by VAIL *et al*. (1977). A sequence is interpreted to have been deposited during a cycle of eustatic sea level change, starting and ending in the vicinity of the inflection points on the falling limbs of the sea level curve. The development of the theory of sequence analysis proceeded from higher to lower orders of sea level change. Thus, the first sea level chart of VAIL *et al*. (1977) dealt with 3rd order cycles, the first major revision of it by HAQ *et al*. (1987) incorporated fourth order cycles. Later, it was shown by CARTER *et al*. (1991) that the fifth order cycles correspond closely to the Exxon SSM and there is abundant evidence from the studies of post-glacial sediments that the facies patterns of sea level cycles are characteristic of a few thousand years, i.e., an infraseventh order sea level cycle. Based on these principles and the methods developed by earlier workers, attempts have been made to analyse the prevalent sea level changes during the deposition of the Cretaceous–Paleocene strata under study, using information drawn from lithology, sedimentary and tectonic structures, environments of deposition, petrography and fossil assemblage.

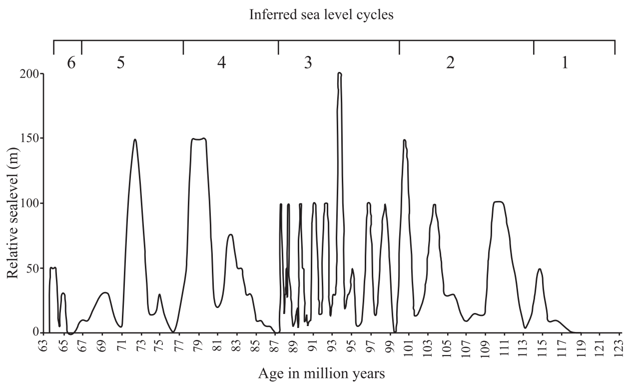

Fig. 8. Relative sea level changes in the Cauvery Basin.

Facies analysis, interpretation of palaeoenvironment and depositional history, provided information on the sea level changes during the evolution of the basin, from which a sea level curve for the strata under study was constructed and is presented in Fig. 8. This curve agrees on the whole with the sea level curve constructed by RAJU & RAVINDRAN (1990) and RAJU *et al.* (1993), except that the present study recognised the occurrence of high frequency cycles in addition to second order cycles (detailed below). This figure shows the occurrence of six sea level cycles of 3rd order within which many higher frequency cycles could be recognised. The period from Barremian to Coniacian shows the frequent occurrence of sea level lows and highs that may be interpreted as prevalent high frequency higher order cycles. The period from Coniacian to Danian shows a gradual sea level rise and fall, punctuated with lowerer frequency higher order cycles. The sea level rise during Santonian–Early Campanian shows a steadily increasing pattern, which coincides with the period of the initiation of the reduction in tectonic activities in the basin. While global sea level peaks during 104 Ma (Early–Late Albian), 93.7 Ma (±0.9; Middle to Late Cenomanian), 92.5 Ma (±1; Early to Middle Turonian), 86.9 Ma (±0.5; Early to Late Coniacian), 85.5 Ma (±1; Early to Late Santonian), 73 Ma (±1; Late Campanian), 69.4 Ma (Early to Late Maastrichtian) and 63 Ma (±0.5; Early to Middle Danian) were shown to occur typically in this basin (RAJU *et al.*, 1993), the occurrence of many other peaks within these cycles (except for a few, which co-incide with basinal and local scale tectonic movements) indicate sea level cycles on a local and regional scale too.

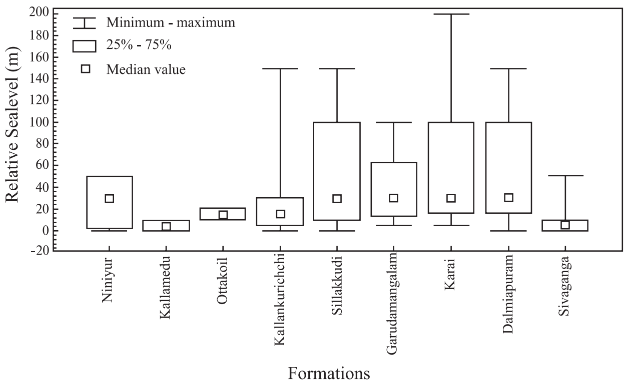

Fig. 9. Relative sea level of different formations.

The 3rd order cycles are separated by Type I sequence boundaries (i.e., recognized through shifts of the shoreline crossing shelf breaks, explicit lithologic information, contact relationships between strata; evidence of subaerial exposure and erosion, advancement of fluvial channels over former offshore regions, etc.), giving ample evidence for the interpretation of the depositional pattern in this basin being controlled by the sea level. Such a pattern is further substantiated by Figs. 9 and 10, which portray the different sea level conditions for each lithostratigraphic formations (Fig. 9) and members (Fig. 10). The average relative sea levels of different chronostratigraphic units are presented in Table 2. It shows the highest relative sea level (RSL) during Campanian and the lowest during Barremian. The standard deviation of the RSL for different ages indicates the prevalence of highly varying sea levels during Cenomanian and comparatively stable depositional conditions during Aptian. The occurrence of periodic high energy conditions associated with sea level changes led to the deposition of storm beds during Campanian (Varanavasi Member of the Sillakkudi Formation) and lower Maastrichtian (Tancem Member of the Kallankurichchi Formation) as was interpreted on the basis of independent lithological and sedimentary structural analyses, which in turn are confirmed by the high standard deviation values of these members (Table 2). When the grand average values of the RSL and the standard deviation are considered, it could be said that the deposition occurred in a shallow marin environment for most of the history of the basin and that there were

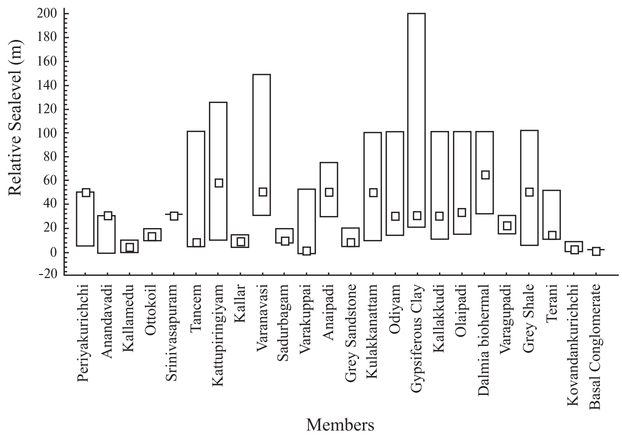

Fig. 10. Relative sea level of different members.

Table 2. Statistics of the relative sea level in the Cauvery Basin.

Age	Mean relative bathymetry	Standard deviation
Danian	26.88	22.51
Maastrichtian	36.79	45.77
Campanian	61.05	53.63
Santonian	20.00	33.70
Coniacian	56.07	29.17
Turonian	32.50	34.82
Cenomanian	56.82	57.71
Albian	50.00	47.06
Aptian	12.86	17.29
Barremian	0.00	0.00
Grand average	**43.39**	**45.19**

dynamic sea level fluctuations during the entire duration of deposition.

While the absolute values of the relative sea level changes show six third order sea level cycles, the trend lines, drawn with the help of a statistical noise reduction technique, indicate the prevalance of depositional controls during the evolutionary history of the basin. Since the sedimentation took place on an epicontinental sea, the bathymetry was kept at shallow to modest levels throughout the history of the basin (<50 m – as indicated by the linear curve in Fig. 11). Although, variations allowed the attainment of either supratidal (0–2 m bathymetry) or basinal (~200 m) levels, the shallow nature of the basin was maintained (an interpretation supported by the grand average value of the RSL – Table 2). This observation confirms the limited influence of tectonic forces in the basinal history. The moving average trend line, which shows the values at fixed intervals and projects the normal course of future change, supports this interpretation. If any non-fit between the moving average curve and the actual relative sea level curve are observed, then, they may be considered to be the result of a sudden change, due either to basinal subsidence or uplift or to a multifold increase of the sedimentation rate and the resultant reduction of the depositional bathymetry. This means that the gradual increase or decrease of the sea level was superseded or overwhelmed by causes other than eustatic sea level changes. Using this assumption, it is concluded that a marked shift between these two curves occurs whenever major tectonic activity or fault block adjustment occurred during the deposition (for example, during Aptian, Albian and Cenomanian). It is interesting to note that such mismatches between the RSL curve and the moving average curve are either not large or absent during the period between Campanian–Danian, a period interpreted as having had more stable (tectonically) depositional conditions than its older counterpart. These inferences support the interpretation of a sea level controlled depositional history of this basin. The polynomial trend line, which tracks and follows the actual data trends and assigns a most likely trend by way of a polynomial fit, indicates the presence of distinct peaks of the sea level during Albian and Turonian and distinct lows during Cenomanian and Maastrichtian (Fig. 11).

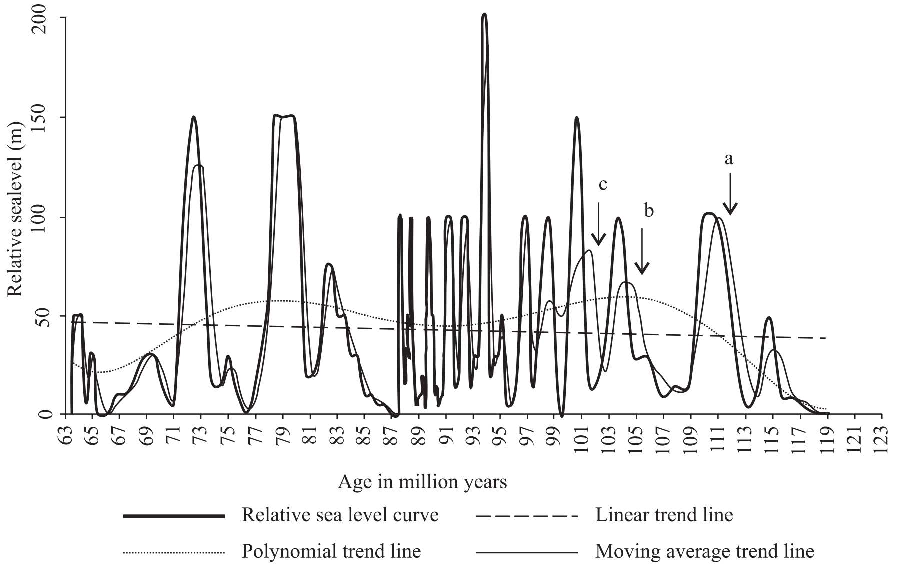

Fig. 11. Pattern of relative sea level changes in the Cauvery Basin. **a**. Non-fit of actual the RSL curve and the moving average trend line during Aptian; **b**. Non-fit of the actual RSL curve and the moving average trend line during Albian; **c**. Non-fit of the actual RSL curve and the moving average trend line during Cenomanian.

Conclusions

Following the current practices in stratigraphic classification and terminology, revision, amendment and reorganization of the existing lithostratigraphic setup were attempted. In the present study an updated lithostratigraphic setup of the area with 22 members and 10 formations (Table 1) is presented.

Enumeration of the tectonic structures and history of the Cauvery Basin indicates that after the initial block faulting and the commencement of sedimentation during Late Jurassic–Early Cretaceous, the intensity of tectonic control over the sedimentation was small, although the basin continued evolving till the end of Tertiary.

Sedimentation in this basin commenced in a shallow water environment and most of the deposits represent deposition in a shallow epicontinental sea, punctuated with slope and basinal deposits. An increase of the sediment-starved nature of the basin from older to younger strata has also been inferred.

The sedimentation history of the basin was dominated by prevalent sea level changes, many of which were eustatic in nature. Six 3rd order cycles were recognised, within which many higher order cycles are embedded. These higher order cycles correspond to the lithostratigraphic members. Based on the average duration of the members, it could be interpreted that the high frequency cycles may belong to 4th order cycles. The polynomial trend line drawn over the sea level curve indicates that the third order cycles form part of presumably second order cycles. The stacked-up nature of these cycles of different orders is in conformity with the observations of GRAMMER *et al*. (1996).

Acknowledgements

MR acknowledges the financial assistance of the Alexander von Humboldt Foundation, Germany and the Council of Scientific and Industrial Research, New Delhi, India. Prof. H. S. PANDALAI, Professor and Head, Prof. P. K. SARASWATI and Prof. D. CHANDRASEKARAM, IIT–Bombay, are thanked for academic support and laboratory facilities. Mr. NICKOLOSKI prepared thin sections for the petrographic study. Dr. V. SUBRAMANIAN, Reader, Department of Geology, National College, Tiruchirapalli, India, is thanked for his help and logistic support during the initial stages of this study. Mr. T. SREEKUMAR, Department of Geology, National College is thanked for assistance during the field survey. Permission to collect samples was accorded by the managers and geologists of the mines: Dalmia Cements Pvt. Ltd, Tancem Mines, Ramco Cements, Nataraj Ceramics Ltd., Vijay Cements, Fixit Mines, Parveen Mines and Minerals Ltd., Alagappa Cements, Rasi Cements, Tan–India Mines, Tamin Mines and Chettiyar Mines. The editor of this journal is thanked for his keen interest and suggestions that have improved the style and content of this paper.

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Резиме

Литостратиграфија, еволуција депозиционих средина и промена морског нивоа Кавери басена (јужна Индија)

Кавери Басен, најјужнији рифт платформе Индијскога полуострва, пружа се правцем североисток–југозапад. Настао је фрагментацијом Гондванскога надконтинента током горње јуре и доње креде. Овом басену припада депресија Аријалур–Пондичери у којој је развијена скоро комплетна сукцесија творевина горње креде и палеоцена. О овом басену објављене су бројне публикације, које се баве или само једном врстом или родом, једном формацијом, чланом или одређеном литологијом, док је у овом раду представљен један свеобухватан депозициони модел, те синтеза седиментолошких механизама који су деловали током развоја овог басена. Дате су литостратиграфске карактеристике

и детаљни литолошки стубови, укључујући препознатљиве јединице на тим профилима. Назначени су фактори важни за депозициону еволуцију басена. Приказани су стратиграфски континуитет и дисконтинуитет, као последица деловања бројних агенаса. Овим су олакшане регионалне и глобалне стратиграфске корелације, а унапређена је и стратегија везана за истраживање угљоводоника у овом басену.

Коришћењем савремених стратиграфских сазнања, систематско картирање, упоређивање литолошких података на разним нивоима, седиментационе структуре и састав фауне, као и фацијална корелација, омогућили су сагледавање литолошког састава и депозиционе историје овог басена. Овакве анализе су, у оквиру проучаваних наслага, омогућиле издвајање 10 формација са 22 члана. Ревидирана стратиграфија, дата у овом раду, омогућила је усаглашавање ставова изнетих у ранијим радовима. Опис литолошких промена (у правцу и управно на правац пружања), уз њихов стратиграфски контекст, олакшали су корелацију слојева заступљених у овом басену. На основу теренских података о литолошким асоцијацијама и тектонским покретима у оквиру овог басена, извршена је интерпретација процеса, почев од блоковског раседања, реактивације раседних блокова током ценомана, реактивације старијих раседних блокова, формирања раседа током сантона и реактивирања раседних блокова у интервалу после данског ката, а пре квартара. Треба навести да су уз главне покрете дуж раседа, постојали и мањи, локални, тектонски покрети, везани за прилагођавање раседних блокова уз раније постојеће раседне равни. На основу тектонских структура се чини да је после иницијалног раседања блокова и почетка седиментације током касне јуре и доње креде, утицај тектонике у односу на седиментацију био мањи у Кавери басену.

Свеукупна анализа фација, фаунистичких асоцијација и животне средине, дала је податке о релативној батиметрији појединих депозиционих јединица, које, посматрано у целини, говоре о променама нивоа мора током историје овог басена. Бројни циклуси морског нивоа високе учесталости (посебно циклуси четвртог или вишег реда), заједно формирају циклусе трећег реда (укупно шест), који представљају делове цилуса другог реда (укупно два) и обухватају укупно седам еустатучких колебања (пикова) нивоа мора овога басена. Период од барема до конијака указује на честе појаве максимума и минимума нивоа мора, који се могу објаснити доминирањем циклуса вишег ранга. Током периода конијак–дански кат, постепена издизања и спуштања нивоа мора су у равнотежи са мањом учесталошћу циклуса вишег реда. Ниво мора током периода сантон–доњи кампан је у сталном порасту, што се поклапа са периодом редукције тектонске активности у овом басену. Састав басена и топографија приобаља условили су да максимуми нивоа мора резултују у повећаној депозицији карбоната, док минимуми нивоа мора омогућавају депозицију силицикластичних седимената. Анализа тренда криве нивоа мора указује на постепени пораст нивоа мора од барема до конијака, а постепени пад од конијака до данског ката. Оваква постојана кретања нивоа мора утицала су на начин седиментације, као и на одлике присутних фација. Претпоставља се да је дубина депозиционе средине одржавана на умерено плитком нивоу пре свега последица недостатка значајнијег таложења током еволуције басена. Истраживања су показала да више преовлађују једноставни процеси запуњавања басена, односно механизми који су условљавали промене нивоа мора, него тектонски покрети.