JOURNAL OF
THE PALAEONTOLOGICAL SOCIETY OF INDIA
VOL. 15, 1970, *pp.* 32 to 41 (*Published in* 1972)

ON THE STRATIGRAPHY AND MICROPALAEONTOLOGY OF DALMIAPURAM FORMATION (LOWER CRETACEOUS)— A NEW ROCK-STRATIGRAPHIC UNIT OF SOUTH INDIA

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ABSTRACT—The occurrence of reef limestones near Dalmiapuram, Tamil Nadu, is known in the Indian geological literature for long. In this report, this limestone and associated rocks, exposed along the western crystalline margin, underlying the Uttatur Clays and overlying Gondwana boulder bed, have been given a new rock-stratigraphic status—*Dalmiapuram Formation.* The type section, geographic distribution, distinctive lithological characters, thickness and micro-fauna of this new formation are discussed. Two lithological members—Shale and Limestone, and two foraminiferal biostratigraphic zones—*Lenticulina macrodisca* and *Hedbergella planispira,* in an ascending order, are recognized. The planktonic foraminiferal assemblage indicates a Lower to Middle Albian age for this formation.

INTRODUCTION

The development of 'reef limestone' near Kallakkudi (new township—Dalmiapuram, 10° 58′ 30″: 78° 57′ 00″) and in the neighbourhood sedimentary areas of Tiruchirapalli area, Tamil Nadu, has been the subject of considerable interests to many leading geologists since its first elaborate description by Blanford in 1865. In recent years, the limestone has attained its economic importance and a big cement industry has grown up around Dalmiapuram. During the course of exploratory work by the Oil & Natural Gas Commission in this sedimentary area, known as the Cauvery Basin, very similar reef materials have been observed in few of the subsurface sections in the south of Cauvery-Coleroon rivers. There has been considerable controversy regarding the stratigraphic status and geologic age of the reef limestone, however, for all practical purposes, it was regarded as the basal part of Uttatur Formation

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(=Oottatur Group of Blanford, 1865). The Uttatur Formation was considered by earlier workers as the oldest marine rock-unit of this basin and belonged to the Cenomanian (Upper Cretaceous) in age. Recent stratigraphic work carried out by the Oil & Natural Gas Commission and others indicates that some rock-units which are marine in nature, are definitely older than the Upper Cretaceous in age and that the generally accepted system of stratigraphic nomenclature in this area, therefore, needs revision and modification.

Previous work. The limestone bodies were considered by Blanford (1865) as coral reef limestone of fringing type which had grown here and there along the shore line of Cretaceous sea soon after the first marine transgression, presumably during the Cenomanian. The formation of the reefs was marked by him as the commencement of Uttatur period. Later workers like Rama Rao (1956) and other made references to the Blanford's conclusions with little modifications. Krishnan (1960) in his book placed this limestone and coral rags as the lowermost unit of the Uttatur. Subbaraman (1966, 1968) has discussed in detail many interesting geological features observed while carrying out the prospecting work on the limestone deposits around Dalmiapuram. According to him the limestone, mostly of coralline in nature, is found at the base of the Uttatur Formation.

Regarding the palaeontology, the megafossils collected from the reef bodies were studied in detail by Stoliczka (1861-73). He distinguished large number of important species of corals pelecypods and echinoides etc. The Foraminifera from the limestone and associated rocks were studied by large number of palaeontologists as cited by Rama Rao (1956), Rasheed (1962), Gowda (1964), Ramanathan & Rao (1965) and Banerji 1968).

Regarding the geologic age, the limestones were considered to be the earliest deposited sedimentary rocks during the first marine transgression, presumably during the Cenomanian. Stoliczka (1861-73) concluded on the basis of palaeontology that the earliest fossil occurrences in the limestone had Middle - Upper Gault (Upper Albian) affinity. Kossmat (1897) correlated the limestone with the Valudavur Group (Senonian) of Pondicherry. Narayan Rao (1947) assigned an age as early as Jurassic (Lower to Middle Oolite), however, according to him some pebbly limestone at the base of reef limestone containing Jurassic algae, possibly were derived from the underlying Gondwana sequence. Recently Gowda (1964) referred the age of the limestone as Upper Albian to Cenomanian on the basis of his foraminiferal investigations.

Present work. During the years 1967 and 1969, large number of samples were collected from different quarries of the Dalmiapuram Cement Co. and nearby exposures of limestones and associated rocks like marls, shales and clays along the western margin of the Ariyalur area. In Dalmiapuram, the limestone occupies an area of about 8 sq. kms. Other important localities from where the samples were collected are--Agaram, Kallupadi, Karai, Kulligudi, Maruvattur, Melarasur, Naykulum, Terani, Tirupattur and Varagupadi. A number of systematic traverses were made especially in the quarry areas and the samples were collected at fairly close intervals, so as to study the section in every detail. The samples were processed and studied for their microfaunal contents at the Palaeontology Laboratory of

the Institute of Petroleum Exploration, Dehradun.

The purpose of this report is to examine the possible deficiencies of stratigraphic classification for this limestone and associated rocks now in use, to suggest modifications that are more reasonable in the light of the stratigraphic nomenclature and to illustrate how these modifications can affect the interpretation of the palaeogeography of that period. A detailed foraminiferal analysis of the rocks is also given.

The general geology of the area has been discussed in detail by several geologists in the past and more recently by Subbaraman (1966, 1968), it is not necessary to repeat them here.

DALMIAPURAM FORMATION

A new Rock-Stratigraphic Unit of South India. The reef limestone and its associated rocks like marls, shales and clays etc., exposed as isolaled bands, knolls and ridges at number of places along the western margin of the sedimentary Tiruchirapalli area near the contact with the Archaean crystallines, and underlying the Clay member of the Uttatur Formation and overlying the Gondwana sequence, have been given a new rock-stratigraphic nomenclature--'Dalmiapuram Formation', after the type locality near Dalmiapuram. This 'limestone' was not given so for any independent stratigraphic status and as stated earlier it was considered as the lowermost part of Uttatur Formation. The need for the independent formational status for the reef limestone can be discussed while considering:

(i) *Rock-stratigraphic relationship.* It (limestone and associated rocks) can be easily distinguished and mapped as an independent lithological unit wherever exposed, and is defind by distinct observable physical features. Its boundaries are placed as sharp contacts, lower–unconformable to boulder bed (equivalent to Upper Gondwana) or Archaean crystallines at places, and upper—unconformity followed by the Clay member of the Uttatur Formation or by the Garudamangalam Formation (*nom. correct.* Trichinopoly Group of Blanford, 1865) at places. This indicates *it* to be a distinct rock-stratigraphic unit. (Table-1).

(*ii*) *Unconformable relationship.* The reef limestones appear to have been frequently exposed to denudation before and during the deposition of Uttatur beds. Some of the fragments and pebbles of reef limestones are found within the conglomerate beds at the base of Uttatur Formation, indicating an unconformable relationship of the limestones with the overlying Uttatur Formation.

(*iii*) *Time-stratigraphic relationship.* The latest palaeontological researches (as discussed later) indicate that the reef limestone and associated rocks belong to the 'Lower Cretaceous Series', whereas the overlying Uttatur Clay member constitutes the lowermost part of the 'Upper Cretaceous Series', thus these two belong to two different major time-units.

iv) *Environmental set-up.* The reef limestone has been originated, more or less, from different types of environmental set-up (as discussed later) as compared to that of the overlying Clay and Sandstone members of Uttatur Formation. The limestones have grown at the flanks of the crystalline

TABLE – 1

STRATIGRAPHIC & GENETIC RELATIONSHIP OF DALMIAPURAM FORMATION (LOWER CRETACEOUS) WITH UNDERLYING & OVERLYING ROCK–STRATIGRAPHIC UNITS IN TIRUCHIRAPALLI AREA

GEOCHRONOLOGICAL UNITS			ROCK-STRATIGRAPHIC UNITS		ENVIRONMENTAL SET-UP	TRANSGRESSIVE PHASES
			FORMATIONS	MEMBERS		
CRETACEOUS	UPPER	CENOMANIAN	UTTATUR	SANDSTONE CLAY	EPINERITIC TO LITTORAL NERITIC	REGRESSIVE IInd. MARINE TRANSGRESSION
	LOWER	ALBIAN	DALMIAPURAM	LIMESTONE SHALE	REEFOIDAL EUXINIC	STABLE PHASE Ist. MARINE TRANSGRESSION
		NECCOMIAN TO PORTLANDIAN	UPPER GONDWANA		INFRA-LITTORAL TO CONTINENTAL	TRANSGRESSION ON MINOR SCALE
JURASSIC	UPPER					
PRE-CAMBRIAN			ARCHAEAN CRYSTALLINES			

margins during the very first marine transgression of an arm of the southern sea to the on-shore areas resulting in a, more or less, restricted basin. The succeeding Uttatur Clays on the other hand resulted during the later phases of a much prolonged transgressive sea. The limestone and associated rocks of Dalmiapuram were deposited in this restricted shallow basin, whereas Uttatur Clays represent an inner to outer neritic type of environment.

It is thus emphasized that the 'reef limestone and associated rocks', underlying the Uttatur Clay member, constitute a single entity and may be accounted for a formational status. As per the definition of a formation (American Comm. Stratigr. Nomencl., 1961), this limestone (of Dalmiapuram) is a body of rock characterized by lithological homogeneity (as discussed later) and is mappable at the earth's surface (in the exposed areas of Tiruchirapalli) or traceable in the sub-surface (near Pattukottai). The limits of this formation are the boundaries of sharp lithologic change, the lower—boulder bed, and upper—clay bed. These features give the greatest practical aspects of its individual constitution. As per the definition, a formation may represent a long or short time interval, may be composed of materials from one or several sources, and may include breaks in the time-stratigraphic sequence.

SYSTEMATIC STRATIGRAPHY

DALMIAPURAM FORMATION

(Lower Cretaceous Marine Rock-stratigraphic Unit)

Author. Proposed name after Dalmiapuram, near Kallakkudi, on the Tiruchirapalli—Vridhachalam road, Tamil Nadu. First proposed in Baneji (1968).

Type Section. Northern face of Dalmiapuram limestone quarry No. 2.

Geographic distribution. It is mainly localized in nearby Dalmiapuram, where the patch is extensively mined. Some other isolated patches are found to be scattered in Tiruchirapalli area around Agaram, Kallupadi, Karai, Kulligudi, Maruvattur, Melarasur, Naykulum, Terani, Tirupattur and Veragupadi. Some of the well sections near east of Uttatur village have exposed the limestones just below the Uttatur Formation. In the sub-surface section near Pattukottai, a thick sequence of reef limestone is also noted. This formation has not so far been recorded from other exposed parts of South India.

Lithostratigraphy. Lithologically, this formation is sub-divided into two distinct parts, lower—Shale member, and upper—Limestone member.

Shale member. At the base of the type section, there is a good development of greyish to dark coloured laminated to fissile shale which appears to be rich in organic matter. The shale band shows some sort of irregular fractures and movements and may represent a type of fault gouge material. A prominent fault plane is also recognized. The shale forms a persistent band just below the limestone, however, it has not yet been discovered in the surface eutcrops, except in quarries and few wells drilled in further northwest near Alandalippur and Garudamangalam villages.

Limestone member. It is, more or less, a crystalline type of limestone with very little portion of siliceous, ferruginous and other clastic materials, which indicate the relative paucity in the supply of terrigenous materials from neighbourhood areas. The limestone on the flanks is massively bedded, hard, compact, brittle, verigated with pink to flesh red colours, thus giving it a mottled appearance. Petrographically the rocks are biosparites and biomicrites (personal communication with Dr. C. Gundu Rao). The bedding planes are in general low dipping all along from the margins towards the central part of the quarry. In the southern quarry, the dips may be as high as 25° due south. Alongwith the stratified limestones, yellowish brown to pinkish marls of varying thicknesses are also seen. They generally alternate with the limestone bands and are relatively less hard, compact and fine grained in nature. Small lenticular bodies of grey shales having few centimetres in thickness and about one metre length are seen at few places within the massive limestone bodies.

The isolated outcrops near Tirupattur, Karai and other areas in the west of Uttatur village comprise of hard compact greyish to little pinkish limestones.

Thickness. The thickness of Dalmiapuram Formation varies considerable from few metres to as much as 150 metres at different places; the maximum thickness of the Shale member has been estimated to be about 50 metres.

Palaeontology. Foraminifera—The marls and shales have yielded a rich assemblage of

Foraminifera. The limestone is not in general rich in Foraminifera, however, in their thin sections few forms are seen. In all about 40 genera of smaller Foraminifera belonging to 14 families are recorded. The total number of species may be above 150. Most abundant forms are the members of the family Nodosariidae; other well represented families are—Anomaliniidae, Rotaliidae, Polymorphinidae and Buliminidae. Most of the species are calcareou sperforate benthonic type; planktons are represented by less number of species. Arenaceous and imperforate calcareous forms are however meagre. The frequency distribution of planktonic forms increases from below to the top in the stratigraphic sequence, however, the total frequency suddenly decreases near the top of the Limestone member. The forms are well developed and their preservations are generally excellent especially those recorded from the Shale member.

The important planktonic foraminiferal species recorded are—*Praeglobotruncana infracretacea, P. stephani* (Gandolfi), *Hedbergella planispira* (Tappan), *H. postdownensis* (William—Mitchell), *Globorotaloides micheliana* (D'Orbigny) etc. Few planktons are recorded from the Shale member, which on the other hand is very rich in benthos like *Lenticulina macrodisca* (Reuss), *L. nodosa* (D'Orbigny), *L. ovalis* (Reuss), *L. grata* (Reuss), *L. rotulata* Lamarck, *L. crassa* D'Orbigny, *L. alexanderi* (Sandidge), *L. discrepans* (Reuss), *L. isidis* (Schwager), *L. incurvata* (Reuss), *Marginulina cretacea* Cushman, *Pleurostomella subnodosa* Reuss, *Spirillina minima* Schacko etc. Some of the benthonic species not observed in the Shale member, but are common in marls of the Limestone member these are—*Arenobulimina chapmani* Cushman, *Astacolus incurvata* (Reuss), *Dentalina bullata* Schwager, *D. wimani* Brotzen, *D. cylindrica* Schwager, *Frondicularia simplicissima* Ten Dam, *Glandulina pygmeae* (Reuss), *Lagena globosa* (Montagu), *Marginulina glabra* D'Orbigny, *M. compressa* D'Orbigny, *M. jonesi* Reuss, *Nodosaria glabra* D'Orbigny, *Planularia richteri* Brotzen, *Pleurostomella obtusa* Berthelin, *P. reussi* Berthelin, *Ramulina arkadelphiana* Cushman, *Raphanulina prisca* (Reuss), *Rotalia umbonella* Reuss, *Saraceneria triangularis* (D'Orbigny) and *Vaginulina kochii* Roemer. Arenaceous forms recorded from this formation include *Ammobaculites parvisipra* Ten Dam, *Gaudryina rugosa* D'Orbigny, *Haplophragmoides aequale* (Roemer), *Textularia chapmani* Lalicker, *Tritaxia pyramidata* Reuss, *T. tricarinata* (Reuss) and many others. Rasheed (1962) and Gowda (1964) have listed a large number of foraminiferal species from this formation.

There is an interesting observation while recording the variations in the frequency of (a) total planktonic forms and (b) all species of the genus *Lenticulina* in different samples arranged in stratigraphical order. The Shale member and the lowermost part of Limestone member comprising also the marls, have a high frequency of *Lenticulina* spp. and low in planktons, whereas the planktons become abundant at the cost of *Lenticulina* in the upper part of the Limestone member. These planktons/*Lenticulina* spp. abundance ratios are shown in Table-II. Two biostratigraphic zones thus can be delineated based on the frequency numbers of these two parameters. *Lenticulina macrodisca* (Reuss) and *Hedbergella planispira* (Tappan) are quite common in occurrence and are easily identifiable, they are considered as the representatives of two biostratigraphic zones, lower—*Lenticulina macrodisca* Zone and upper—*Hedbergella planispira* Zone respectively.

Geologic age. The planktonic Foraminifera listed above have strong Albian (Lower Cre-

TABLE II

BIOSTRATIGRAPHIC ZONES OF DALMIAPURAM FORMATION

FORMATION	MEMBERS	BIOSTRATIGRAPHIC ZONES	FREQUENCY NUMBERS		GEOLOGIC AGE
			As. I	As. II	
DALMIAPURAM FORMATION	LIMESTONE	*Hedbergella planispira* Zone	8	4	Middle to Lower Albian
	SHALE	*Lenticulina macrodisca* Zone	2	6	

As. I—all planktons

As. II—all species of *Lenticulina*

taceous) affinity. Similar assemblage has also been recorded from Upper Moridale Formation (Albian) of Trinidad, Albian of England, Germany, Rumania, Russian platform, Mediterranean regions and Africa. The '*Hedbergella* sp. bearing Zone' (equivalent to *Hedbergella planispira* Zone of the present study) in different parts of the Southern Europe like Switzerland (Klaus 1959, Mohler 1966) and many other places in Mediterranean and Pacific tropical regions (Van Hinte 1965) is considered to be equivalent to the Lower—Middle Albian. Bolli's (1966) *Praeglobotruncana rohri* Zone of Albian age in Trinidad and elsewhere is equivalent to '*Hedbergella* sp. bearing Zone' of above authors (Table-III). *P. rohri* as such is not recorded from the present studied samples of Dalmiapuram Formation, however, a number of other species of the genus is identified (see p. 37). The absence of *Globotruncana* in this formation may also indicate its Lower Cretaceous affinity instead of Upper Cretaceous (Cenomanian) as considered by previous authors. The benthonic assemblage recorded during this study has much similarity with the Albian assemblage of many parts of Europe, Mediterranean and Caribbean regions. Excellent similarity can be recorded with the Albian Foraminifera of Rumanian Plains recently published by Neagu (1965).

Previously this limestone was assigned Jurassic age by Narayan Rao (1947) and Turonian to Early Senonian by Rama Rao (1956). Kossmat in 1897 correlated this limestone with Valudavur group (Senonian) of Pondicherry. On the basis of foraminiferal study, Gowda (1964) assigned an Upper Albian to Cenomanian age. The present study clearly indicates the age of this limestone and associated rocks to be Lower to

TABLE III

CORRELATION OF LOWER CRETACEOUS ZONAL SUBDIVISIONS BASED ON FORAMINIFERA

GEOLOGIC AGE		SOUTHERN TRINIDAD (Bolli, 1957, 1959, 1966)	PREALPES, MEDIANES OF GRUYERE SWITZERLAND (Klaus, 1959)	CENTRAL SWISS ALPS (Mohler, 1966)	OTHER AREAS (Van Hinte, 1965)	CAUVERY BASIN (This report)
LOWER CRETACEOUS	ALBIAN	Rotalipora ticinensis ticinensis Zone	Zone 2 Inferieure a Thalmaninella.	Rotalipora ticinensis Zone	Ticinella roberti – Rotalipora ticinensis	
			Zone 1	Ticinella roberti Zone		
		Praeglobotruncana rohri Zone	a Hedbergella	Hedbergella Zone	Hedbergella	Hedbergella planispira / Lenticulina macrodisca
	APTIAN	Biglobigerinella barri				
		Leupoldina protuberans				

Middle Albian. The Dalmiapuram Formation may be considered as the only Lower Cretaceous marine stratigraphic unit in Tiruchirapalli area. Equivalent horizon in nearby areas may be the Sriperumbudur beds of Palar basin (near Madras) which have been referred as Lower Cretaceous in age by Murthy and Sastri (1962),

Apart from the Foraminifera, some occurrences of Ostracoda like species of *Acrocythere Cytheridea*, *Cytherella*, *Cythereis Bairdia*, *Luxoconcha*, *Xestoleberis*, bryozoan and crinoid remains are also noted. Fragmentary pieces of pelecypods and gastropods shells are seen. Algae are also the most important constituents of the rocks and belong to Corallinaceae and Solenopraceae types. Sponges are otherwise rare. Excellent account on the occurrence of other mega—fossils like corals, ammonoides, pelecypods, gastropods, echnoides, crinoides, etc. is available in Stoliczka (1861-73) The Shale member has not yielded any well preserved mega-fossils except few broken shells of pelecypods and rare ammonoides.

Palaeoecology. As stated, reefs were developed along the margin of the sea; the latter had transgressed into the land area somewhere from the northeast or east of the present area during the Lower Albian times. Whether the reef growth was a continuous process or was interrupted by the periods of reef erosion, is not definitely known.The growth of the reef was both upwards and basinwards depending upon the fluctuations of the relative sea level. Gundu Rao (personal commnication) is of the opinion that these exposed reefs are more bank like bioherms and biostromes than true reefal elements. It is beyond the scope of this paper to discuss their true nature. The occurrence of greyish black shale occurring at the base marine transgression of a minor scale, which was later followed by open sea conditions favourable for the development of the reef. The abundance of organic matter in the reef including the algae, corals, pelecypods, foraminifers indicates normal warm marine conditions of environment. Reef growth along the margins, restricted the marine circulation

over the platform and the resulting euxinic conditions lead to the accumulation of the argillaceous limestones and grey shales found intercalated within the reef limestones. Optimum supplies of the oxygen nutrients and organic food needed by the lime-secreting bottom organisms, evidently were limited to a belt along the edges of the shelf and thus the basin became progressively more restricted and unfavourable for faunal growth. This phase of reef development was soon over at the time of second major marine transgression all over the area on a much wider scale during the Lower Cenomanian and resulted in the deposition of Uttatur Clay member.

Foraminiferal trends. The close study of variations in the planktonic foraminiferal frequencies from its lower magnitude observed in the Shale member and to higher in the Limestone member exemplify that the original limited and unhealthy living conditions for this faunule in the Shale member was later approached to more open and favourable conditions. This also indicates that the depositional basin maintained a good connection with the open Lower Cretaceous sea during the deposition of middle and upper parts of the Limestone member. However, the sudden decrease in faunal frequency at the uppermost part of the sequence indicates a reversible of the unfavourable conditions.

Palaeogeography and Marine Transgression. At about the commencement of the Deccan trap activity during the Lower Cretaceous times, the eastern coast of India was invaded gradually by a southern sea, as early as during the Neocomian-Albian, as indicated by the existence of marine Lower Cretaceous rocks (Sriperumbudur beds) near Madras. The first well defined transgression of still low magnitude occured during the early parts of Albian resulting the Dalmiapuram Formation in the Cauvery Basin. The ancient shore line during that period existed as far on shore near Tirupattur. This on-shore sea got encroached from all sides by the reef development. During early Cenomanian, further subsidence was experienced followed by widespread marine transgression resulting in series of well developed Upper Cretaceous formations in Cauvery Basin. The embayment formed during the later transgression might have acted as venue for further reef growth along the margins. This is evidenced by the presence of reef like materials at the top of Uttatur Sandstone and Clay members near Maruvattur. Some of the reefs observed in other parts of the Cauvery Basin may belong to stratigraphically higher levels.

ACKNOWLEDGEMENTS

The authors are thankful to Shri V. V. Sastri, Additional Director and Shri L. L. Bhandari, Joint Director, Institute of Petroleum Exploration, Oil and Natural Gas Commission, for their permission, encouragement and suggestions in preparation of this note.

The views expressed in this paper are those of the author and not of the Oil and Natural Gas Commission.

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