

FORAMINIFERAL BIOSTRATIGRAPHY OF THE LOWER ARIYALUR STAGE (LATE CRETACEOUS) OF TIRUCHIRAPALLI AND ITS NEW LOWER GEOLOGICAL AGE LIMIT

RANJIT K. BANERJI*

Institute of Petroleum Exploration
Oil & Natural Gas Commission
Dehra Dun

ABSTRACT—The foraminiferal biostratigraphic study of the Lower Ariyalur Stage of Tiruchirapalli area, South India, has led to the recognition of three zones (in ascending order): (A) *Globotruncana concavata* Zone (Santonian), (B) *Globotruncana globigerinoides* Zone (Campanian) and (C) *Globotruncana linneiana tricarinata* Zone (Late Campanian—Early Maestrichtian). Thus the Lower Ariyalur Stage of Tiruchirapalli commenced during the Early Santonian instead of Campanian as was formerly believed, and its deposition was continued till Early Maestrichtian. The basis of assigning this new lower age limit, *i. e.* Santonian, is the record of Late Coniacian—Santonian restricted species—*Globotruncana concavata* (Brotzen) and *G. inornata* Bolli, for the first time from this area.

INTRODUCTION

While studying the microfaunal assemblage of the Lower Ariyalur Stage (Late Cretaceous) of Vridhachalam and Pondicherry areas of South India, a rich foraminiferal assemblage, represented by planktonic elements characteristic of Santonian—Early Maestrichtian age has been identified (Banerji, 1966a, b; 1968). One of the most characteristic planktonic foraminifera of Santonian, recorded throughout the Indo-Pacific regions

of the world is *Globotruncana concavata* (Brotzen) (= *Rotalia concavata* Brotzen); its presence in Vridhachalam and Pondicherry areas enables to recognise the *Globotruncana concavata* Zone for the first time in India. Similar biostratigraphic zone was earlier recognized in Naparima Hill Formation of Trinidad and was assigned a Late Coniacian—Early Santonian age (Bolli, 1957). This index fossil foraminifera and few others like *Globotruncana renzi* Gandolfi, *G. linneiana coronata* (Bolli), *G. cf. G.*

*Present Address : Marine Geology, Atlantic Oceanographic Laboratory, Bedford Institute, Dartmouth, Nova Scotia, Canada.

inornata Bolli and *G. vridhachalensis* Banerji, all of Coniacian—Santonian range, are recorded in good numbers from the above localities, however, no such record has so far been made from Tiruchirapalli area which is the type area for the exposed Cretaceous—Early Tertiary rocks of South India. The objects of this report are (i) to place on record the occurrence of typical Santonian and Early Campanian foraminifera in the Lower Ariyalur Stage (=Lower Ariyalur Group of Blanford, 1865; Sillakkudi Formation of Srivastava and Tewari, 1967) of Tiruchirapalli area; (ii) to work out the detailed biostratigraphic zonation scheme and (iii) to recognize certain evolutionary trends in the planktonic elements recorded from this area. The Lower Ariyalur Stage, according to earlier workers (Sastry *et al.*, 1965, Srivastava *et al.*, 1967) does not extend below the Campanian in Tiruchirapalli area. The results of this study will be helpful in delineating the boundaries between various recognized stratigraphical units in South India.

SAMPLE LOCALITIES

The samples were collected during the field season 1966-67 from a number of localities nearby Ariyalur town. Three sets of surface sampling were made from (i) Mel Mattur traverse—a nala section between Mel Mattur ($11^{\circ} 12'30'' : 79^{\circ}03'00''$) and Periyampalayam ($11^{\circ}12'00'' : 79^{\circ}02'00''$), (ii) Sadaiyakkampatti traverse—a nala section between Sadaiyakkampatti ($11^{\circ}10'00'' : 79^{\circ}04'00''$) and Kurinjipadi ($11^{\circ}10'00'' : 79^{\circ}04'30''$) and (iii) Sillakkudi traverse from Sillakkudi tank ($11^{\circ} 04'30'' : 79^{\circ}01'00''$) towards Kulattur ($11^{\circ}06'30'' : 79^{\circ}58'00''$). Few spot samples were also collected from the neighbourhood areas especially near the contact of the Ariyalur with the underlying Garudamangalam (former

Trichinopoly Group of Blanford, 1865) sediments. Except the nala cuttings, most of the samples were collected from the walls of the shallow wells, ditches and few outcrops. These samples have been examined for their microfaunal contents at the Palaeontology Laboratory, Institute of Petroleum Exploration, Oil & Natural Gas Commission, Dehra Dun.

LITHOSTRATIGRAPHY AND FORAMINIFERAL ASSEMBLAGE

In most of the above localities, the exposed uppermost lithological unit is hard yellowish brown calcareous to argillaceous sandstone with minor greyish white to yellowish marl and clay, containing a rich foraminiferal assemblage, which Sastry *et al.* (1965) and Tewari *et al.* (1965) have assigned a Campanian age. This unit is underlain in general by relatively less compact and soft greyish to brownish yellow, fine to medium grained, calcareous sandstone with minor shale or clay bands, also rich in foraminifera. These two lithological units can be recognised in wells and ditches of the above mentioned localities; though the paucity of their exposures on the surface and practical difficulty in tracing their lateral continuity has made it almost impossible to plot each unit successfully in the field. These two units may tentatively correspond to the Sillakkudi Formation and a part of Kallankurchchi Formation (excluding the hard arenaceous limestone) of Srivastava and Tewari (1967). It is interesting to note that these two units though essentially belonging to sandy facies, differ considerably in faunal assemblage, as recorded from the samples of different localities. The samples of Mel Mattur and Sillakkudi resemble to each other in respect to their microfauna but differ to a large extent

from those of Sadaiyakkanpatti. Their foraminiferal assemblages are described separately and differences are recorded in detail.

A. Samples from Mel Mattur and Sillakkudi

I. *Lower unit.* Highly fossiliferous, planktonic foraminifera is about 25-30% of the total assemblage.

Important planktonic foraminifera are—*Globotruncana concavata* (Brotzen), *G. fornicata* Plummer, *G. linneiana* (d'Orbigny), *G. cf. G. inornata* Bolli, *Globotruncana* sp. *indet.*, *Heterohelix globulosa* (Ehrenberg), *H. moremani* (Cushman), *Rugoglobigerina* sp. *indet.*, *Hedbergella* sp. *indet.* Out of all these, *G. linneiana* (d'Orbigny) is quite abundant in occurrence, whereas species of *Heterohelix* and *Hedbergella* are rare.

Among benthos, the more important species are—*Anomalina complanata* Reuss, *A. vridhachalensis* Banerji, *Cibicides stephensoni* Cushman, *C. subcarinatus* Cushman and Deaderick, *Dorothia oxycona* (Reuss), *Gyroidina globosa* (Hagenow), *Hoeglundina supracretacea* (ten Dam), *Lenticulina munsteri* (Roemer), *Pleurostomella subnodosa* Reuss, *Raphanulina lacrima* (Reuss), *Saraceneria triangularis* (d'Orbigny) and *Tritaxia tricarinata* (Reuss). Members of the families Anomaliniidae and Nodosariidae predominate over others among which the specimens of *Lenticulina*, *Anomalina* and *Cibicides* are very common. Arenaceous forms as listed above are, however, rare.

II. *Upper unit.* Rich in foraminifera; planktonic foraminiferal frequency has reduced to 15-20% of the total assemblage.

Important planktonic foraminifera are—*Globotruncana ventricosa* White, *G. marginata* Reuss, *G. fornicata* Plummer, *G. linneiana*

(d'Orbigny), *Heterohelix striata* (Ehrenberg), *G. globulosa* (Ehrenberg), *Rugoglobigerina rugosa* Plummer. No *G. concavata* (Brotzen) is recorded. *G. linneiana* (d'Orbigny) continues to predominate in the total planktonic assemblage. Amongst the new elements, *G. ventricosa* White is more common in occurrence than *G. marginata* Reuss. Benthos are very similar to the lower unit, but an increase in the frequency of the arenaceous forms is well pronounced. Species of *Dorothia*, *Gaudryina*, *Textularia* and *Tritaxia* (not in order of abundance) are quite common.

B. Samples from Sadaiyakkanpatti

I. *Lower unit.* Foraminiferal assemblage is very similar to the lower unit (A-I) of Mel Mattur and Sillakkudi, however, the total frequency of occurrence in per sample is relatively very low. Almost all the planktonic species of A-I, except *G. fornicata* Plummer are present in this unit. *G. linneiana* (d'Orbigny) continues to predominate in the assemblage. Specimens of *G. concavata* (Brotzen) are not as well developed and well preserved as in the samples A-I and hence it is sometimes difficult to distinguish these specimens from those *G. ventricosa* White (recorded from unit A-II) as these two species look morphologically very similar. There are number of specimens recorded from the Lower Ariyalur Stage of Vridhachalam showing the continuous gradation in their morphological characters between these two species, and *Globotruncana vridhachalensis* Banerji is definitely an intermediate form (Banerji, 1966, 1968), however, these intermediate forms are not well represented in this unit.

Most of the benthonic foraminiferal species of A-I are also recorded from this unit. Some of the important ones are: *Anomalina madraszi* Banerji, *Apiopterina cylindroides* (Roemer),

Cibicides blanfordi Banerji, *Glandulina manifesta* Reuss, *Gyroidina depressa* (Alth), *Hoeglundina supraretacea* (ten Dam), *Lenticulina pondi* (Cushman), *Textularia ripleysensis* W. Berry, *T. subconica* (Franke), *Tritaxia tricarinata* (Reuss) etc.

II. *Upper unit.* Moderately fossiliferous, planktons are represented by new elements like *Globotruncana linneiana tricarinata* (Quereau), *G. arca* (Cushman), *G. contusa* (Cushman), and *G. stuarti stuartiformis* Dalbiez. Other long ranging species are *G. linneiana* (d'Orbigny). *G. fornicata* Plummer *Heterohelix striata* (Ehrenberg), *H. carinata* (Cushman), *Rugoglobigerina rugosa* Plummer, etc. The assemblage is dominated the *G. linneiana* (d'Orbigny), whereas among the new elements *G. linneiana tricarinata* (Quereau) is relatively more common in occurrence. The assemblage as reported by Sastry *et al.* (1965) probably belongs to this unit.

Benthonic assemblage includes also some new elements like- *Anomalina henbesti* Plummer, *A. submadraszi* Banerji, *Anomalinoidea pinguis* (Jennings), *Cibicides beaumontianus* (d'Orbigny), *C. harperi* (Sandidge), *C. purobi* Banerji, *Heterolepa pondi* Banerji *Lenticulina navarroensis* (Plummer), *L. spisso-costatus* (Cushman), and *Planulina spisso-costata* Cushman. A number of the species of genera- *Bolivina*, *Bolivinoidea*, *Bulimina*, *Dentalina*, *Dorothia*, *Ellipsoglandulina*, *Frondicularia*, *Gaudryina*, *Gavelinella*, *Gyroidina*, *Hoeglundina*, *Lenticulina*, *Lagena*, *Marginulina*, *Nodosaria*, *Planulina*, *Quinqueloculina*, *Raphanulina*, *Saraceneria*, *Spiroplectammina*, *Textularia*, *Tritaxia*, *Vaginulina*, *Valvulineria*, *Verneuilina* etc. also are recorded.

BIOSTRATIGRAPHY

Globotruncana concavata (Brotzen) is recorded from the samples of the litho-units A-I and B-I.

This species was earlier recorded from *Globotruncana concavata* Zone (Early Santonian), Naparima Hill Formation, Trinidad (Bolli, 1957) and also from *Micraster cor-anguinum* and *Micraster costudinarium* Zones (Coniacian) of Isle of Wight, England (Barr, 1961). It has been found to be restricted to Santonian horizons of Vridhachalam and Pondicherry (Banerji, 1968). Recently, Bolli (1966) has also established its range as within the Santonian. *G. inornata* Bolli, which is also associated with *G. concavata* (Brotzen) in this area, was originally described from the Coniacian of Naparima Hill Formation, Trinidad, by Bolli (1957), and has its stratigraphic range from the uppermost part of Coniacian to throughout Santonian in Vridhachalam (Banerji, 1966). Similar record of this species from Coniacian to Santonian is known from other parts of world. Other species of *Globotruncana* like *G. linneiana* (d'Orbigny) and *G. fornicata* Plummer, recorded from these two litho-units (A-I and B-I) have longer stratigraphical range from Santonian to Early Maestrichtian; all these forms are also known from the *G. concavata* Zone of Pondicherry. The planktonic assemblage as such can be compared well with those of Santonian horizon of Vridhachalam and Pondicherry. A similar zone name—*Globotruncana concavata* Zone is proposed for these two lower units and is assigned to a Santonian age. This zone was first proposed by Sigal (1955) for the Santonian horizon of North Africa and later on it has been recognised from many tropical and sub-tropical parts of the world including Central America and Australia.

It is interesting to note that *Globotruncana fornicata* Plummer, which is a long ranging form (Santonian to Early Maestrichtian, Bolli, 1957; Cita, 1948; Subbotina 1953), is recorded from the lower unit (A-I) of Mel Mattur and Sillak-

TABLE—1

SUBZONES OF *Globotruncana concavata* ZONE

ZONE	SUB-ZONES	LITHO-UNITS	GEOLOGIC AGE
<i>Globotruncana concavata</i> Zone	<i>Globotruncana fornicata</i> Sub-Zone	A — I	Late Santonian
	Devoid of <i>Globotruncana fornicata</i> Sub-Zone	B — I	Early Santonian

TABLE—2

BIOSTRATIGRAPHIC ZONES OF LOWER ARIYALUR STAGE OF TIRUCHIRAPALLI AND ITS CORRELATION WITH VRIDHACHALAM

Standard Biostratigraphic Zones of Lower Ariyalur Stage of Vridhachalam (Banerji, R. K., 1964)	Recognized Biostratigraphic Zones in Tiruchirapalli	Sample Areas		Geologic Age
		Mel-Mattur & Sillakkudi	Sadaiyakkapatti	
<i>Globotruncana linneiana tricarinata</i> Zone	<i>Globotruncana linneiana tricarinata</i> Zone		B-II	Early Maestrichtian to Late Campanian
<i>Globotruncana globigerinoides</i> Zone	<i>Globotruncana globigerinoides</i> Zone	A-II		Campanian
<i>Globotruncana concavata</i> Zone	<i>Globotruncana fornicata</i> Sub-Zone	A-I	B-I	Late Santonian
	Devoid of <i>Globotruncana fornicata</i> Sub-Zone			Early Santonian
<i>Globotruncana linneiana coronata</i> Zone	Absent	—	—	Coniacian

kudi areas and not from the lower unit (B-I) of Sadaiyakkanpatti. If we consider that *G. fornicata* Plummer has its evolution after the first appearance of *G. concavata* (Brotzen), it may indicate that the unit B-I belongs to the lower part and unit A-I corresponds to the upper part of *Globotruncana concavata* Zone. The boundaries between these two parts of the Zone is demarcated by the first appearance of *G. fornicata* Plummer. Two sub-zones (Table 1) are thus recognised for the first time.

The assemblage of upper unit A-II is very similar to that of *Globotruncana globigerinoides* Zone of Vridhachalam and Pondicherry (Bannerji, 1968). It may be noted that no typical specimens of *G. globigerinoides* Brotzen are however recorded from this unit; this may be due to the fact that the tests of this species is very minute in size and fragile in nature and gets easily destroyed while processing the samples. The presence of restricted Early-Middle Campanian species like *Globotruncana ventricosa* White and *G. marginata* Reuss, which

TIRUCHIRAPALLI AREA		PLANKTONIC FORAMINIFERA												GEOLOGIC AGE					
STAGE	RECOGNIZED BIO-STRATIGRAPHIC ZONES	LITHO-UNITS IN																	
		Met Mattur	Sillakkudi	Sadaiyakkanpatti	<i>Globotruncana</i> cf. <i>G. inornata</i>	<i>Globotruncana concavata</i>	<i>Globotruncana linneliana</i>	<i>Globotruncana fornicata</i>	<i>Globotruncana marginata</i>	<i>Globotruncana ventricosa</i>	<i>Globotruncana arca</i>	<i>Globotruncana l. tricarinata</i>	<i>Globotruncana confusa</i>	<i>Globotruncana stuarti-stuarti-formis</i>	<i>Heterohelix globulosa</i>	<i>Heterohelix stricta</i>	<i>Rugoglobigerina rugosa</i>		
LOWER ARIYALUR	<i>Globotruncana linneliana</i> <i>tricarinata</i> Zone		B-II															EARLY MAESTRICHTIAN TO LATE CAMPANIAN	
	<i>Globotruncana globigerinoides</i> Zone		A-II															CAMPANIAN	
	<i>Globotruncana concavata</i> Zone	<i>Globotruncana fornicata</i> Sub-Zone		A-I															LATE SANTONIAN
		Devoid of <i>Globotruncana fornicata</i> Sub-Zone		B-I															EARLY SANTONIAN

Text Fig. 1.—Stratigraphic range chart of *Globotruncana* spp. and other planktons in the Lower Ariyalur stage of Tiruchirapalli area.

are generally associated with *G. globigerinoides* Brotzen in Vridhachalam may help in such correlations. The absence of *G. concavata* (Brotzen) and *G. inornata* Bolli in this unit encourages in recognizing it as a separate and independent biostratigraphic zone. A similar zone—*Globotruncana globigerinoides* Zone (first proposed by Banerji, 1964 for the hard grey limestone unit of Patti Nala section of Vridhachalam) is proposed for the unit A-II. In Vridhachalam and Pondicherry areas, this zone is further sub-divided into, lower—*Globotruncana marginata* Sub-Zone and upper—*Globotruncana ventricosa* Sub-Zone; however, in the present study such classification seems to be difficult.

Globotruncana lapparenti bulloides Vogler as reported by Sastry *et al.* (1965) and Srivastava *et al.* (1967) from the Ariyalur Stage of Tiruchirapalli, is regarded as a junior synonym of *G. marginata* (Banerji, 1968). Similarly *G. lapparenti lapparenti* Brotzen also recorded by the above authors, is conspecific to the *G. linneiana* (d'Orbigny) and is regarded as the junior synonym of the latter (Banerji, 1968). Both these species are known to occur in unit A-II.

The assemblage of the upper B-II bears close resemblance with those reported by Sastry *et al.* (1965) and from Kallankurchchi by Srivastava *et al.* (1967). The species like *Globotruncana linneiana tricarinata* (Quereau), *G. arca* (Cushman), *G. contusa* (Cushman) and few others of this unit are also known to occur in *Globotruncana linneiana tricarinata* Zone of Pondicherry (Banerji, 1968) and a similar zone name is proposed for this unit (Table 2). *Globotruncana linneiana tricarinata* Zone (*Globotruncana lapparenti tricarinata* Zone) was first proposed by Bolli (1957) for the Trinidad Early Maestrichtian section. The stratigraphic ranges of plank-

tonic species in Tiruchirapalli area are shown in Text Fig. 1.

Environment. The environment of depositional basin during the Santonian and Early Campanian times appears to be of inner to central neritic zone type. Considering the more restricted and less abundant types of planktonic forms present in Vridhachalam and Pondicherry areas, the site of deposition of Ariyalur sediments in Tiruchirapalli area was little further away from the main Cretaceous southern sea. There must have been more fluctuations in the depth of the basin especially towards the upper part of this studied sequence as marked by the variations in the planktonic foraminiferal frequencies in different zones.

Evolutionary Trend in *Globotruncana*

This study further helps to delineate different evolutionary trends amongst the different species of *Globotruncana*. In continuation to the earlier studies on this aspect (Banerji, 1966 a, b,) *Globotruncana concavata* (Brotzen) and *G. fornicata* Plummer have been shown to belong to two different sub-stocks of evolution; the present study establishes that the evolution of *G. fornicata* Plummer was definitely little later than *G. concavata* (Brotzen). The latter probably originated from *G. inornata* Bolli, was earlier considered to have given rise to *G. marginata* Reuss through *G. vridhachalensis* Banerji. The present study, as well study conducted in Pondicherry area (Banerji, 1968), the evolution of *G. fornicata* Plummer to *G. marginata* Reuss, *G. ventricosa* White, *G. arca* (Cushman) in one hand and *G. contusa* on the other, are well recognised. *G. contusa* is recorded from the Upper Ariyalur Stage of Tiruchirapalli and Pondicherry. *G. linneiana* (d'Orbigny) and *G. linneiana tricarinata* (Quereau) constitute third evolutionary substock in this sequence.

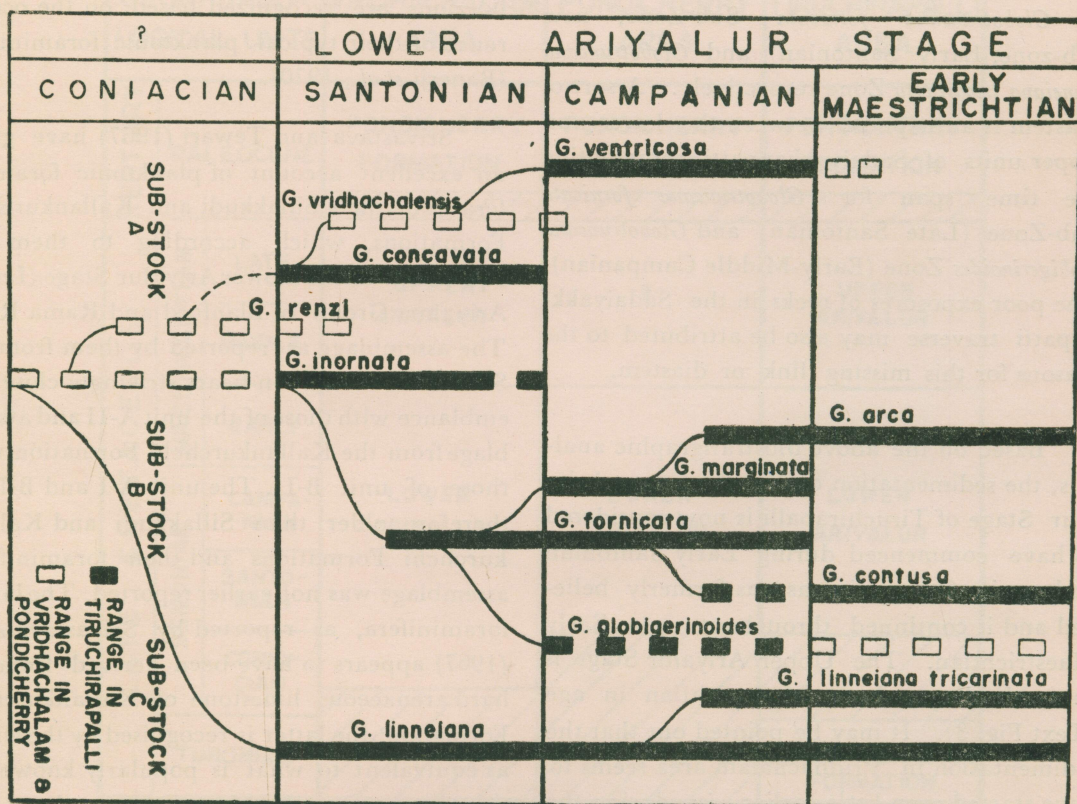
(Text Fig. 2). The morphological relationship amongst all these planktonic species are discussed elsewhere (Banerji, 1966, 1968).

DISCUSSION

As stated, the Lower Ariyalur Stage of Tiruchirapalli is rich in foraminifera including the planktonic elements. Arenaceous and calcareous imperforate foraminifera are relatively rare in occurrence. In all about 38 genera and 72 species of foraminifera are recorded from this Stage in contrast to 32 genera and 110 species from Vridhachalam and Pondicherry areas. Thus an influx of new elements

in Tiruchirapalli area is visualized, however, further speciation in this area was restricted. Most of these species are well known from many parts of the world including South India. The new forms from the present area of study will be described and illustrated elsewhere.

The planktonic foraminiferal biostratigraphic zones thus established in these four lithological units of Tiruchirapalli area corroborate well with the biostratigraphy of the Lower Ariyalur Stage of Vridhachalam and Pondicherry, however, with little exceptions. In Vridhachalam, *Globotruncana linneiana coronata* (Coniacian),



Text Fig. 2.—Evolutionary trends in different species of *Globotruncana*.

Globotruncana concavata (Santonian), *Globotruncana globigerinoides* (with two sub-zones, Campanian) and *Globotruncana linneiana tricarinata* (Late Campanian-Early Maestrichtian) Zones are established in an ascending order, whereas, the biostratigraphy of Pondicherry first begins with *Globotruncana concavata* Zone and all the succeeding zones are represented (Banerji, 1966). In Tiruchirapalli, the lower and upper units (A-I and A-II) of Mel Mattur and Sillakkudi are equivalent to *Globotruncana concavata* Zone and *Globotruncana globigerinoides* Zone respectively, whereas, those (B-I and B-II) of Sadaiyakkannpatti belong to the lower part of *Globotruncana concavata* Zone (here designated as 'Devoid of *Globotruncana fornicata* Sub-Zone, new sub-zone, Early Santonian) and *Globotruncana linneiana tricarinata* Zone respectively. A sort of diastem is anticipated between the lower and upper units of Sadaiyakkannpatti representing the time span for *Globotruncana fornicata* Sub-Zone (Late Santonian) and *Globotruncana globigerinoides* Zone (Early-Middle Campanian). The poor exposures of rocks in the Sadaiyakkannpatti traverse may also be attributed to the reasons for this missing link or diastem.

Based on the above biostratigraphic analysis, the sedimentation during the Lower Ariyalur Stage of Tiruchirapalli is now considered to have commenced during Early Santonian and not in Campanian as was formerly believed and it continued throughout upto Early Maestrichtian. The Upper Ariyalur Stage is thus Middle to Late Maestrichtian in age (Text Fig. 3). It may be pointed out that the sedimentation in Vridhachalam area seems to have started even little earlier, i.e. during the Early Coniacian (represented by *Globotruncana linneiana coronata* Zone). Based on the available literature till 1966, it was pointed out that

'the lower age limit of the Lower Ariyalur Stage as exposed in Tiruchirapalli area may be shifted as early as Late Coniacian—Santonian, and it would be improper to state that this stage does not extend below Campanian'. (Banerji, 1968). The present study has thus established this lower age limit of the Lower Ariyalur Stage of Tiruchirapalli.

It would be worth mentioning here that almost similar zonation scheme has been worked out in the Late Cretaceous sub-crop sequence drilled near Thanjavur and Pattukottai in the south of Coleroon river. In this sub-crop sequence, the Coniacian-Santonian horizons are recognized based on the occurrence of their typical planktonic foraminifera (Banerji *et al.*, 1970).

Srivastava and Tewari (1967) have given an excellent account of planktonic foraminifera from their Sillakkudi and Kallankurchchi Formations, which according to them are equivalent to the Lower Ariyalur Stage (Lower Ariyalur Group of Blanford and Rama Rao). The assemblage as reported by them from the Sillakkudi Formation bears strikingly close resemblance with those of the unit A-II and assemblage from the Kallankurchchi Formation with those of unit B-II. The unit A-I and B-I are therefore older than Sillakkudi and Kallankurchchi Formations and their foraminiferal assemblage was not earlier reported. The larger foraminifera, as reported by Srivastava *et al.* (1967) appears to have been derived from the hard arenaceous limestone of Kallankurchchi Formation; the latter is recognised by the writer as equivalent to what is popularly known in the literature as 'Maestrichtian limestone band' or 'Gryphaea bed'. The field observations made by the writer indicates that this limestone is definitely younger than the B-II and

the contact is marked by an angular unconformity. The limestone is rich in *Orbitoides* and other larger shallow water forms and is considered by Sastri *et al.* (1968) as a type of bank deposit in a regressive sea, whereas the unit B-II is rich in planktonic foraminifera and other deeper water forms and was deposited during the transgressive phase of the southern sea. The limestone is conformably overlain by fine sands and clays (Cullmood Formation of Srivastava *et al.*, 1967) which is practically devoid of invertebrate fossils

except few dinosaurian remains. The sandstone unit is the result of the continued regressive phase of sedimentation which has started during the deposition of the orbitoidal limestone. These two lithologies - limestone and sandstone in fact constitute one major stratigraphic unit, deposited under a continued regressive phase, designated here as Kallankurchchi Formation (not of Srivastava and Tewari, 1967) with two members, lower-Chokanadapuram Limestone member (named after village Chokanadapuram) and upper-

GEOCHRONOLOGICAL UNITS		VRIDHACHALAM AREA	PONDICHERRY AREA	TIRUCHIRAPALLI AREA	
TERTIARY	PALEOCENE	PONDICHERRY FORMATION	PONDICHERRY FORMATION	PONDICHERRY FORMATION	
		/ / / / /			
LATE CRETACEOUS	MAESTRICHTIAN	LATE	?	UPPER ARIYALUR	
		MIDDLE		UPPER ARIYALUR	
	EARLY	LOWER ARIYALUR	LOWER ARIYALUR		
	SENONIAN			CAMPANIAN	LOWER ARIYALUR
				SANTONIAN	LOWER ARIYALUR
	CONIACIAN	/ / / / /	/ / / / /	GARUDAMANGALAM FORMATION	
	TURONIAN				

Text. Fig. 3—Lower and Upper boundaries of Lower Ariyalur Stage in different areas.

Cullmood Sandstone member (named after village Cullmood). The sequence lying immediately below the Kallankurchchi Formation, comprising mainly of calcareous and argillaceous sandstones, is designated as Ariyalur Formation (equivalent to the Lower Ariyalur Stage of Banerji, 1966). Based on the recommendations of the American Commission on Stratigraphic Nomenclature, a new rock stratigraphic classification of these sediments of Tiruchirapalli area is proposed (Text-Fig. 4). The details of these proposed units will be discussed elsewhere.

SYSTEMATIC BIOSTRATIGRAPHY

ARIYALUR FORMATION

Lower Ariyalur Group of Blanford, 1865, Rama Rao, 1956; Lower Ariyalur Stage of Vridhachalam of Banerji, 1964, 1966; Sillakkudi Formation and Kallankurchchi Formation (in part) of Srivastava and Tewari, 1967.

SANTONIAN

I. *Globotruncana concavata* Zone

Author: Sigal, J., 1955, North Africa.

Typical Section: Patti Nala Section, Vridhachalam.

Litho-units: Units A-I and B-I.

Definition: Range of zonal marker.

Sub-Zones: (i) Devoid of *Globotruncana fornicata* Sub-Zone.

Author: Banerji, R. K., proposed name, Tiruchirapalli.

Typical Section: Sadaiyakkanpatti section, Tiruchirapalli.

Litho-unit: B-I.

Definition: Interval between the first appearance of *Globotruncana concavata* (Brotzen) and *G. fornicata* Plummer.

Age: Early Santonian.

(ii) *Globotruncana fornicata* Sub-Zone

Author: Bolli, H. M., 1957, *Globotruncana fornicata* Zone, Naparima Hill Formation, Trinidad.

Typical Section: Mel Mattur section, Tiruchirapalli.

Litho-unit: A-I.

Definition: Interval between the first appearance of *Globotruncana fornicata* Plummer and the extinction of *G. concavata* (Brotzen).

Age: Late Santonian.

EARLY-MIDDLE CAMPANIAN

II. *Globotruncana globigerinoides* Zone

Author: Banerji, R. K., 1964, Patti Nala Section, Vridhachalam.

Typical Section: Sillakkudi section, Tiruchirapalli.

Litho-unit: A-II.

Definition: Interval between the last occurrence of *Globotruncana concavata* (Brotzen) and the first appearance of *G. linneiana tricarinata* (Quereau).

LATE CAMPANIAN-EARLY MAESTRICHTIAN

III. *Globotruncana linneiana tricarinata* Zone.

Author: Bolli, H.M., 1957, Naparima Hill Formation, Trinidad.

Typical Section: Patti Nala Section, Vridhachalam.

Litho-unit: B-II.

Definition: Interval between the zonal marker's first and last occurrence.

BLANFORD 1865		RAMA RAO 1956		BANERJI 1964		SRIVASTAVA & TEWARI 1967		PRESENT PROPOSED ROCK STRATIGRAPHIC CLASSIFICATION		GEOCHRONO- LOGICAL UNITS		
ARIALLOOR GROUP	?	ARIYALUR	UPPER	ARIYALUR STAGE	UPPER	CULLMOOD	KALLANKUR- CHCHI	CULLMOOD SANDSTONE	LATE	MAESTRICHTIAN	LATE CRETACEOUS	
	UPPER							LOWER	LOWER			KALLANKUR- CHCHI
	MIDDLE		UPPER		UPPER	UPPER	CULLMOOD	EARLY				
	LOWER	LOWER	LOWER	LOWER	SILLAKKUDI	CAMPA- NIAN	SENONIAN					
	?					SANTO- NIAN		CONIA- CIAN				
							TURONIAN					

Text Fig. 4—Nomenclature of Stratigraphical units as used by various authors.

CONCLUSIONS

This study is thus useful for recognising the biostratigraphic zones and sub-zones of Santonian age for the first time in the Lower Ariyalur Stage (Ariyalur Formation, proposed nomenclature) of Tiruchirapalli and their correlation with the zones of Vrindhachalam and Pondicherry. This (Ariyalur Formation) Stage in Tiruchirapalli area commenced as early as in Santonian and not in Campanian as was formerly considered and its deposition was continued up to the Early Maestrichtian. (Text Fig. 4).

ACKNOWLEDGEMENTS

The author is grateful to Shri V. V. Sastri,

Additional Director, Shri L. L. Bhandari, Joint Director, and Dr. A. K. Datta, Senior Scientific Officer, Institute of Petroleum Exploration, Oil & Natural Gas Commission, for their encouragement and reviewing the work. For the study conducted in the field and laboratory, thanks are due to Shri P. K. Sharma, who accompanied the author to the field.

The views expressed in the paper are those of the author and not of the Oil & Natural Gas Commission. The paper is published with the kind permission of the Additional Director, Institute of Petroleum Exploration, Oil and Natural Gas Commission, Dehradun.

REFERENCES

- BANERJI, R. K., 1964. Biostratigraphic study of Upper Cretaceous Lower Ariyalur Stage foraminifera from Vrindhachalam and Pondicherry areas, South India. (Ph. D. Dissert., Ind. Inst. Technology, Kharagpur, India).
- IDEM, 1965. The genus *Glandulina* in the Upper Cretaceous of Vrindhachalam and Pondicherry, South India. *Cushman Found. Foram. Res. Contr.* **16** (4) : 141-143.
- IDEM, 1966a. The genus *Globotruncana* and biostratigraphy of the Lower Ariyalur Stage (Upper Cretaceous) of Vrindhachalam, South India. *J. geol. Soc. India* **7** : 51-69.
- IDEM, 1966b. Foraminiferal biostratigraphy of the Lower Ariyalur Stage of Pondicherry and Vrindhachalam areas. Abstract, Sem. Cret. Tert. Form. South India. *Bull. geol. Soc. India* : 21.
- IDEM, 1968. Late Cretaceous foraminiferal biostratigraphy of Pondicherry area, South India. *Mem. geol. Soc. India* **2** : 30-49.
- IDEM, 1971. Foraminiferal biostratigraphy of the Lower Ariyalur Stage (Upper Cretaceous) of Tiruchirapalli and its new lower age limit. Abstract, 58th Indian Sci. Congr., Bangalore.
- BANERJI, R. K. AND MOHAN, R., 1970. Foraminiferal biostratigraphy of Meso-Cenozoic sequence of the Cauvery Basin, South India. *J. Geol. Soc. India* **11** ; 348-357.
- BARR, F. T. 1961. Upper Cretaceous planktonic foraminifera from the Isle of Wight, England. *Palaeontology* **4** : 552-580.
- BLANFORD, H. F., 1865. On the Cretaceous and other rocks of the South Arcot and Trichinopoly districts. *Mem. geol. Surv. India* **4** (1).
- BOLLI, H. M., 1957. The genera *Praeglobotruncana*, *Rotalipora*, *Globotruncana* and *Abathomphalus* in the Upper Cretaceous of Trinidad, B. W. I. *Bull. U. S. Nat. Mus.* **215** : 51-60.
- IDEM, 1966. Zonation of the Cretaceous to Pliocene marine sediments based on planktonic foraminifera. *Bol. Inform. Assoc. Venezolana du Geol. Min. y Petrole* **9** (1) : 3-32.
- CITA, M. B., 1948. Recherche stratigraphiche e micropaleontologiche sul Cretacico e sull' Eocene di Tignale (Lago di Garda). *Riv. Ital. Pal.* **54** (2) : 49-74 ; (3) : 117-133 ; (4) : 143-168.
- RAMA RAO, L., 1956. Recent contributions to our knowledge of the Cretaceous rocks of South India. *Proc. Indian Acad. Sci. Sec. B.* **44**.
- SASTRY, M. V. A., MAMGAIN, V. D. AND RAO, B. R. J., 1965. Campanian horizon in Ariyalur stage of Trichinopoly Cretaceous. *Bull. geol. Soc. India* **2** (4) : 88-90.
- SASTRY, V. V. AND RAIVERMAN, V., 1968. On the Basin study of Cretaceous-Tertiary sediments of the Cauvery Basin. *Mem. geol. Soc. India* **2** : 143-152.
- SIGAL, J., 1955. Notes micropaleontologiques nord-africaines. *Soc. Geol. France, Compte Rendu Somm. Seances* : 157-160.
- SRIVASTAVA, R. P. AND TEWARI, B. S., 1967. Biostratigraphy of the Ariyalur Stage, Cretaceous of Trichinopoly. *J. Palaeont. Soc. India* **12** : 48-54.
- SUBBOTINA, N. N., 1953. Fossil foraminifera of U. S. S. R. *VNIGRI, Trudy*, N. S. (76) : 1-794.
- TEWARI, B. S. AND SRIVASTAVA, R. P., 1965. On the occurrence of *Globotruncana* in Ariyalur Stage of Trichinopoly Cretaceous, South India. *Curr. Sci.* **34** (51) : 150-151.