CHAPTER 7

AGE OF THE SOUTH INDIAN CRETACEOUS BEDS, AFFINITIES OF THE FAUNA AND PALAEOECOLOGY

AGE

Despite the fact that the marine Cretaceous beds of South India have yielded a very rich assemblage of fossils, opinions differ about the precise age limits of each of its four subdivisions. This is true not only of the Cretaceous beds of the Trichinopoly District, but also of the Vridhachalam and the Pondicherry Districts.

The views of earlier workers (Blanford, 1862; Stoliczka 1863, et seq.; Kossmat, 1897; and others) concerning the age of the South Indian Cretaceous beds were summarized by Pascoe (1959) as under:

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<th>Trichinopoly area</th>
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<th>Approximate European equivalent</th>
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<td>Ariyalur Formation</td>
<td>Trigonarca beds</td>
<td>Campanian - L. Maestrichtian</td>
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<td>Valudavur beds</td>
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<td>Trichinopoly</td>
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He (Pascoe, 1959, p. 1223) was, however, of the opinion that ".........until a revision of the ammonites and other fossils in the East Coast Cretaceous has been carried out, it would be unwise to attach too precise a value to the above approximate correlation with the Cretaceous of Europe." A somewhat similar view was expressed by Sahni (1960, p.4) who stated that "The conventional limits of the Cenomanian, Turonian and Senonian in India may need modification to fit them into the standard scale. The subdivisions in India were after all founded on a preliminary and general survey of an area where very little subsequent field investigation have been carried out by competent geologists."

The more recent views on the age of the Dalmiapuram, Uttatur, Trichinopoly and Ariyalur Formations, based mainly on the evidence furnished by ostracodes, planktonic foraminifers and ammonites are discussed in the sequel. It may be mentioned here that the ostracodes are rare and sporadic in occurrence in these formations, except for the upper part of the lower member of the Ariyalur Formation, where they are abundant both in the number of individuals as well as in the number of species.

Dalmiapuram Formation: The grey shales of the Dalmiapuram Formation, which underlie unconformably the Uttatur Formation,
were assigned a Neocomian-Albian age by Ramanathan (1968). Bhatia and Jain (1969), on the basis of the presence of *Pseudobythocythere* and *Acrocythere*, and also on stratigraphical grounds, assigned an Aptian-Albian (parts) age to the Dalmiapuram Formation. This view is further strengthened by the occurrence of "Bairdia" *pseudoseptentrionalis* (Mertens) (vide Jain, 1969a and present work) which was first reported from the Upper Albain of Germany (Mertens, 1956). Recently, Kaye (1965) has reported this species from the Middle and Upper Albian of England. The grey shales were assigned an Upper Hauterivian-Lower Barremian age by Gowda and Subbaraman (1970) on the basis of the ammonites, foraminifers and ostracodes. Since most of the identifications by Gowda and Subbaraman are either tentative, or else only up to the generic level (mostly long-ranging ones), not much reliance can be placed on them for the purpose of fixing a precise age. Moreover, as pointed out by Bhatia and Jain (1969), there are strong stratigraphical grounds (their occurrence below the Uttatur of Upper Albian-Lower Turonian age) which suggest that the grey shales of the Dalmiapuram Formation cannot be much older than the Aptian-Albian.

**Uttatur Formation:** As mentioned earlier, the Uttatur Formation comprises two lithological members - the 'Coral-
reef limestone' (and its equivalent, the Kallakudi Limestone) in the lower part, and shales, siltstones and gypseous clays in the upper. The age of these two members is discussed separately in the sequel.

The 'Coral-reef limestone' and its equivalent, the Kallakudi limestone, were considered by Blanford (1862) to be the basal part of the Uttatur Formation. This view was supported by Gowda (1964b) who, on the basis of several benthonic forms and two planktonic foraminifers - *Hedbergella portsdownensis* (Williams-Mitchell) and *H. planispira* (Tappan) - assigned them an Upper Albian - Cenomanian age. Recently, however, Banerji (1971a) on the basis of *H. planispira* assigned an Early to Middle Albian age to these limestones. Of the various ostracodes from the Kallakudi Limestone that are being described in the present work, "*Bairdia* pseudo septentrionalis" (Mertens) indicates a Middle to Upper Albian age. The remaining taxa are either new or else have been identified only up to generic level and hence are not of much use in fixing a precise age. The overall faunal evidence, however, suggests that the 'Coral-reef limestone' and the Kallakudi Limestone are of Albian (parts) - Cenomanian age.

The upper member of the Uttatur Formation was assigned an Upper Albian - Lower Turonian age by the earlier workers.
(vide Pascoe, 1959). The lower age limit was fixed on the basis of *Schloenbachia inflata* Sowerby, *Turrilites bergeri* Brongniart, *Hamites armatus* Sowerby, etc., and the upper on the basis of *Hamites conciliatum* (Stoliczka), *Nautilus huxleyanus* Blanford, etc. Das and Chatterji (1963), who studied a few smaller foraminifers, however, concluded that these beds are as young as Senonian. The views of these two authors do not find any support by the latter workers, namely Gowda (1964b), who on the basis of smaller foraminifers, assigned a Cenomanian age and Sastry et al. (1968), who on the basis of the revision of the ammonites from the Uttatur Formation, assigned an Upper Albian - Lower Turonian age. The upper member has yielded only two ostracode taxa - *Cytherella* sp. E and Indet. Genus A - both of which are of little significance in fixing a precise age. However, the overall faunal evidence favours an Upper Albian - Lower Turonian age for the upper member of the Uttatur Formation.

Trichinopoly Formation: The third member of the Trichinopoly Cretaceous, the Trichinopoly Formation, has been assigned a Turonian - Santonian age mainly on the basis of the ammonites (vide Pascoe, 1959; Sastry et al. 1968). Some of these are *Lewesiceras vaju* (Stoliczka), *Kossmaticeras theobaldianum*, *Placenticeras tamulicum* (Blanford).
The microfossils are exceedingly rare in the Trichinopoly Formation and the few foraminifers and ostracodes that do occur do not throw much light on the age of the beds concerned.

Ariyalur Formation: The upper member of the South Indian Cretaceous is well developed in all the three districts namely, Trichinopoly, Vridhachalam and Pondicherry. In the Trichinopoly District it is known as the Ariyalur Formation. The equivalent of the Ariyalur Formation in Vridhachalam have been named by Rasheed and Govindan (1966) as the Patti and Palakkollai Members and in Pondicherry as the Valudavur and Mettuveli Members by Rajagopalan (1965). All these beds were assigned a Campanian - Maestrichtian age by the earlier workers (vide Pascoe, 1959). This view has been supported by Sastry et al. (1968) on the basis of the revision of the ammonite fauna from the Ariyalur Formation of Trichinopoly District. Some of the more important ammonite species reported by these workers are Karapadites karapadense (Kossmat), Pachydiscus eggertonianus (Forbes), Mauriceras rembda (Forbes), Eubaculites vagina (Forbes), Pachydiscus otacodensis (Stoliczka) and Desmophyllites diphylloides (Forbes). The Upper Cretaceous beds of Pondicherry were assigned an Upper Campanian - Maestrichtian age by Rajagopalan (1965) on the basis of Globotruncanana tricarinata (Qureau) and G. gangseri Bolli. Rao et al.
(1963), on the basis of the presence of *Globotruncana linneiana* (d'Orbigny), *G. ventricosa* White, *G. contusa* (Cushman) and *G. ganzi* Bolli, etc., assigned a Campanian - Maastrichtian age to the Ariyalur Formation of Trichinopoly District.

Benerji (1968, et seq.) in a series of papers on the planktonic foraminifers and biostratigraphy of the Ariyalur Formation of Trichinopoly, Vridhachalam and Pondicherry Districts concluded that the placement of the lower part of this formation in the Campanian, is incorrect. In Vridhachalam, for example, the basal beds of this formation have yielded *Globotruncana linneiana coronata* (Bolli) and *G. renzi* Gandolfi on the basis of which Benerji (1968) assigned them a Late Turonian - Coniacian to early Maastrichtian age. The basal part of the Ariyalur Formation in Pondicherry has, however, not yielded the above two species. Instead, it is characterized by the presence of *G. concavata* (Grotzen), a characteristic Santonian species, on the basis of which Benerji (1968a) fixed the lower age limit of these beds as Santonian. Similarly, Benerji (1971b) on the basis of *G. concavata* assigned a Santonian age to the basal members of the Ariyalur Formation of Trichinopoly. In view of the fact that *G. linneiana coronata* is absent in the basal beds of the Ariyalur Formation of Trichinopoly, the type area, and of Pondicherry it is likely that the
G. linneiana coronata bearing Coniacian beds of Vridhachalam belong to the Trichinopoly Formation. This view, however, will have to be substantiated by detailed field work.

As regards the evidence furnished by the ostracodes from this formation, it may be mentioned that most of the taxa have come from the orbitoid bearing bed exposed in and around Ariyalur (viz., localities 11, 12, 13) and near Brumaur (locality 15). As stated earlier, this bed occurs towards the top of the lower member of the Ariyalur Formation and has been assigned a Lower Maestrichtian age on the basis of Lepidorbitoides inornata Narayan Rao, L. blanfordi Narayan Rao, Globotruncana linneiana tricarinata, G. gansseri and G. contusa (Cushman). Some of the more important ostracodes from this bed are Bairdia ex gr. B. cretacea, "B." ex gr. B. dentifera, "B." ex gr. B. limburgensis, "B." ex gr. B. pentagonalis, "B." sp. cf. B. pseudocreates, Clithrocytheridea bosqueti, Veenidea limburgensis, Krithe kritheformis, Curfina sp. aff. G. reginae-astrig, etc. These were, until the present work, known only from the Maestrichtian of Holland. Besides these, many of the new species from South India are closely related to the Maestrichtian forms described from Europe. Some of these are Bythocypris arivalurensis which appears to be closely related to B. limburgensis; Kikliocythere szczechurae to K. pseudofavrodiana; Kingmaina arivalurensis
to *K. hagenowi*; *Limburgina ariyalurensis* to *L. calciporaceae*; *L. bhatiai* to *L. pseudosemicancellata* (see also subsequent discussion under the head Affinities, p. 251). It is thus evident that the ostracodes from the orbitoid bearing bed also strongly suggest a Maestrichtian age.

In the Vridhachalam District, ostracodes were found near Patti (locality 14) at the base of the *Globotruncanana linneiana coronata* zone (Coniacian) of Banerji (1965) and near Erumanur (locality 15). The ostracodes from the latter have already been discussed. From the former locality, only *Cytherella* sp. A, *Cytherella* sp. B, *Brachycythere* sp. cf. *B. epko*, *Curfchina thuatiensis* n.sp. and *Dumontina hazeli* n.sp. were found. Of these, *Cytherella* sp. A appears to be related to *C. ovoides*, first described from the Maestrichtian of U.S.A.; *Cytherella* sp. B shows some resemblance to *C. meijeri*, reported from the Danian of Tunisia; *Brachycythere* sp. cf. *B. epko* was first described from the Coniacian - Lower Santonian of Nigeria; *Curfchina thuatiensis* occurs in the Coniacian of the Bagh beds (present work); and *Dumontina hazeli* in the Lower Maestrichtian of Trichinopoly (present work). It is thus evident that the ostracodes from Patti show an admixture of fauna ranging from Coniacian to Danian, and that they do not throw much light on the age of these beds.
In the Pondicherry District, the ostracode fauna is very poorly represented. At locality 16, *Brachycythere angulata* was found from the *Globotruncan margarita* subzone (Upper Santonian - Campanian) of Banerji (1968a) and *Cytherelloidea* sp. B and *Brachycythere sedarapattuensis* n. sp. from the *Globotruncan linneiana tricarinata* zone (Late Campanian - Early Maestrichtian) (locality 16) of Banerji (1968a). Of these, *Brachycythere angulata* ranges in age from Coniacian to Lower Maestrichtian (Grekoff, 1951; Rement, 1960; Bold, 1964); *Brachycythere sedarapattuensis* n. sp. appears to be closely related to *B. ledaforma*, first reported from the Maestrichtian of U.S.A. (Israelsky, 1929) and to *B. ledaforma porosa* (Crane, 1965). The stratigraphic ranges of both these species are in conformity with the age as deduced from the foraminiferal evidence.

In conclusion, it may be stated that the evidence furnished by the ostracodes from the upper part of the lower member of the Ariyalur Formation is quite in conformity with the evidence furnished by foraminifers and ammonites. However, as discussed elsewhere, there is considerable difference of opinion regarding the lower age limit of the lower part of the lower member, particularly in the Vridhachalam District. A solution to this problem may well depend upon further detailed biostratigraphic work in the area.
AFFINITIES OF THE FAUNA

The Cretaceous beds of South India were considered by Kossmat (1895) to represent the type of the Pacific Cretaceous. He also recognized elements of both the eastern and western hemispheres in the fauna and a connecting link between the two. Recent work on the revision of the ammonites, foraminifers and ostracodes from these beds lends further support to the above contention.

The ammonite zones established by Sastri et al. (1968) and enumerated earlier have been correlated with similar biostratigraphic zones established in the Cretaceous of Japan, New Zealand and Vancouver Islands.

Banerji (1968a, 1971b) established several foraminiferal zones in the lower member of the Ariyalur Formation of Trichinopoly, Vridhachalam and Pondicherry Districts and correlated them with similar zones established in Europe by Rowe (1908) and in Gulf Coast and Trinidad by Bolli (1957). According to Rasheed and Govindan (1968), the foraminiferal fauna from Vridhachalam has affinities with that of North America, Europe, Egypt, Iran and Trinidad.

As regards the ostracode fauna, of the one hundred and twenty taxa from the South Indian Cretaceous that are being described herein, thirty-two (including one new subspecies)
are new, twenty-two are also known to occur outside India, and sixty-six have been left under open nomenclature. The taxa which are known to occur outside India and which also occur in the Cretaceous beds of South India are as follows:


Most of the taxa listed above, with the exception of

*Cytherelloidea addisonensis*, "Bairdia" ex gr. *B. magna*, "B". *pseudo septentrionalis*, *Pontocyprilla recurva*, *Brachycythere angulata*, and *B*. sp. cf. *B. epko* were reported from Holland (vide Boonema, 1940-1941; Veen, 1932 et seq.; Deroo, 1966). The taxa listed above have also been reported from North America, Africa and Europe (vide Hazel, 1968; Alexander, 1927; Mertens, 1956; Esker, 1963, Grekoff, 1951; Reyment, 1960).
Of the new species being described from the Cretaceous of South India, *Cytherelloidea vimali* appears to be related to *C. reticulata* described from U.S.A.; "Bairdia" tendonii to *B. limburgensis* from Holland; *Bythocypris arivalurensis* to *B. limburgensis* from Holland; *Brachycythere sedapattu-ensis* to *B. ledaforma* and *B. ledaforma porosa*, both from U.S.A.; *Kikliocythere szzechuriae* to *K. pseudofavrodiana* from Holland; *Kingsmaina arivalurensis* to *K. hagenowi* from Holland; *Cushmanidea pandei* to *Cushmanidea* sp. from U.S.A.; *Eucytherura whatleyi* is closely related to *E. hyonensis* from Belgium and also to *E. aff. dentata* from Belgium; *E. tumida* from Holland, and to *E. columbiaensis* from U.S.A.; *Sphaeroleberis ? howei* somewhat resembles *S. gambiensis* from Senegal; *Amphicytherura arivalurensis* to *A. limburgensis* from Holland; *Curfsina thuatiensis* to *C. kafkai kafkai* from Bohemia; *Echinocythereis apostolescui* to *E.? variolata* from Holland; *Limburgina arivalurensis* to *L. calciporacea* from Holland; *L. hatalai* to *L. pseudosemicancellata* from Holland; *Phacorhabdotus dalroiapuramensis* to *P. pokornyi* from U.S.A., to *P. semiplicatus* from Bohemia, and to *P. filicosta* from Ruegen Island.

It is evident from the foregoing that most of the new species described from the Cretaceous of South India have affinities with the European species.
Of the fifteen taxa reported by Sastry and Rao (1963) from the Ariyalur Formation, Cytherella ubaghsi Veen, Cytherelloidea cf. dubia Veen, Bairdoppilata acuticauda (Veen), B. cf. limburgensis (Veen) were first reported from Holland, while Bairdoppilata pondera Jennings, Loxoconcha cf. cretacea Alexander, Cythereis dentonensis Alexander and C. vacuitatis (Schmidt) were first reported from U.S.A.

Gowda (1966) figured twelve ostracode taxa from the Uttatur and Ariyalur Formations. Of these, Bairdia ex gr. pentagonalis Veen, and Murrayina montensis (Marliere) are known to occur in Holland; Bairdia cf. comanchensis Alexander in U.S.A. and Cythereis cf. lurnannae Triebel in Germany and France.

Of the eighteen ostracode taxa reported by Govindan (1969) from the Upper Cretaceous of Vridhachalam, Bythocypris windhami Butler and Jones, Cytheropteron harrisi Skinner, Cythereis costatana Israelsky, Loxoconcha fletcheri Israelsky, Xestoleberis seminulata Crane, Cytherella tuberculifera Alexander, Cytherelloidea ozanana Sexton, and C. bicosta Crane, are all known from U.S.A. while Xestoleberis ovata Bonnema, is known from Holland.

Banerji (1970) described twenty-five ostracode taxa from the Upper Cretaceous of Vridhachalam, including thirteen
new species. The species which are found in the Vridhachalam area and are also known from outside India are Cytherella pyriformis (Cornuel), from France, Buntonia delta Marianos and Valentine, from U.S.A., Haplocytheridea kummi Triebel, from Germany, Lowconcha wagneri Bold, from Trinidad, Cytherura sp. cf. C. vistabellensis Bold, from Trinidad, Kestoleberis sp. cf. K. moriakensis Bold, from Trinidad, and Schuleridea bilobata (Triebel) from Germany. Of the new species described by Banerji, Cytherella renzi is close to C. serpentiensis Bold, from Trinidad, while Krithe ashoki is close to K. saunderi Bold, also from Trinidad.

It is evident from the foregoing that the ostracode fauna from the South Indian Cretaceous is more closely related to the Cretaceous ostracode faunas of Western Europe though some elements of the North American and Trinidad fauna are also present.

Further, it is interesting to note that the ostracode fauna from South Indian Cretaceous is characterized by the presence of a number of genera which, until the present work, were known either from the Tertiary or from Tertiary and Recent. These are Propontocypris, Hulingsina, Cushmanidea, Cytheridea, Neocytherideis, Leguminocythereis and Leniocythere (fide, Swain, Howe and Sylvester-Bradley
in Moore, 1961; Morkhoven, 1963). The present record of these genera from the Cretaceous beds of Peninsular India would obviously necessitate a revision of the views on the stratigraphic distribution of these genera and also perhaps on their evolution and migration.

PALAEOLOGY

It is a well known fact that the marine Cretaceous beds of South India were laid down in a transgressing sea during Aptian (parts) - Lower Maestrichtian times. An excellent account of the oscillatory movements along the present east coast which were responsible for down-warping the Peninsular shield along with its continental Jurassic sediments has been given by Venkataraman and Rangaraju (1968). According to these authors the downwarping was initiated in Neocomian times as evidenced by the marine intercalations found in the east coast Gondwanas and main rejuvenation took place during the beginning of Upper Cretaceous preceded by frequent and violent oscillations in the nature of pulses. They are also of the view that the absence of Upper Gondwana, Uttatur and Trichinopoly Formations in the north of Trichinopoly, that is, in Vridhachalam and probably in Pondicherry was due to erosion consequent to the uplift of these beds in post-Trichinopoly times. They also postulated that during the Ariyalur times the northern part of the basin was undergoing a continuous
uplift resulting in continuous regression as indicated by
the gradual coarsening of the sediments and presence of
land vertebrates towards the top of the Ariyalur Formation
and that there was a consequent subsidence and transgression
in the central part of the area covered by the Ariyalur
Formation. A brief account of the palaeoecology of the
marine Cretaceous beds namely, Dalmiapuram, Uttatur,
Trichinopoly and Ariyalur Formations is given in the sequel.

The Dalmiapuram Formation (Aptian - Albian) comprises grey
shales which are rich in Pyrite crystals. This formation
has yielded only a few taxa each of ostracodes, ammonites,
smaller foraminifers and plant fossils. The occurrence of
pyrite in the grey shales indicates deposition in a closed
basin under reducing environments. Under such environments,
the normal marine fauna of the open seas, is generally not
found. The few indigenous forms which may occur are generally
stunted (Hallam, 1965). The occurrence in these shales of
normal-sized ammonites, e.g. Eunoceratites, of planktonic
foraminifers Hedbergella and of several ostracode genera
like "Bairdia", Cytherella, Acrocythere, Pseudobithocythere,
Bythocypris, Paracypris, Cytherelloidea and Limburgina which
in general indicate an open epi-neritic environment, suggests
that these marine organisms must have drifted from the open
sea into the partially restricted basin. The environments
of deposition of the grey shales have been ably surmised by
Subbaraman (1968, p.97), who states:

"It is likely that the area around Dalmiapuram was a broad and a shallow basin during pre-Uttatur times. Into this basin an arm of the present Bay of Bengal must have encroached for a very brief period; and due to some unknown cause the sea must have receded temporarily without filling the basin fully. Thus a land locked basin was brought into existence. The topographical conditions perhaps did not permit the circulation of the bottom waters in this basin, as a consequence of which the bottom waters were deprived of oxygen either wholly or partially. This resulted in the absence of any benthonic life. Into such waters, the waters from sea and land must have continued to gain entrance through narrow channels which brought some marine and terrestrial organisms into these basins. Introduction of such marine and terrestrial organisms into these polluted waters must have resulted in their immediate death and they must have been entombed in the grey muds."

The presence of an unconformity between the Dalmiapuram and the overlying Uttatur Formation (vide Subbaraman, 1968; Bhatia and Jain, 1969) indicates a time gap between the two. That there was a complete change in the environmental conditions during the deposition of the basal member of the Uttatur Formation is indicated by the
occurrence in this member of massive coral reefs, which as is well known, thrive only in clear and shallow warm tropical waters. This view is further substantiated by the occurrence of ostracode genera Cytherella, "Bairdia" and Hemicytherura which are found in shallow marine environments (fide Morkhoven, 1963, and others). The other ostracode genera of the Kallakudi Limestone are "Cytheropteron", Amphicytherura and Phacornabdatus. Of these, "Cytheropteron" has a wide range of ecological tolerance (fide Morkhoven, 1963). Not much is known about the palaeoecological significance of Amphicytherura and Phacornabdatus as they do not survive to the present day. However, they may be considered as indicating shallow marine conditions in view of their heavy ornamentation and well-developed eye spots, which according to Morkhoven (1962), are characteristically developed in forms inhabiting littoral to shallow marine environments. The Kallakudi Limestone has also yielded a very rich assemblage of smaller foraminifers. A large majority of these belong to the families Lagenidae, Rotaliidae, Anomalinidae. The arenaceous genus Textularia and the planktonic Hedbergella, also occur, though in smaller numbers. The highly diverse population of foraminifers with many families and genera and locally dominated by Lagenidae, Buliminidae and Rotaliidae is found between a depth range of 120 to 300 ft.
(fide Lowman, 1949). *Textularia* is found in Recent seas at depths of about 20 fathoms (fide Burnaby, 1962), whereas the presence of planktonic forms like *Hedbergella* indicates open sea conditions.

It may, therefore, be safely concluded that the basal member of the Uttatur Formation was laid down in clear, warm neritic environment.

The upper member of the Uttatur Formation comprises argillaceous and arenaceous beds with gypsum and phosphatic nodules. These beds have yielded a prolific fauna consisting of molluscs, brachiopods, echinoids, corals, smaller foraminifers, fishes and fossil wood. The ostracodes are, however, represented by only two taxa namely, *Cytherella* and *Indet. Genus A*. Of the various groups of fossils, the gastropods and pelecypods are mostly littoral (fide Pascoe, 1959). Abundant echinoid remains according to Cooke (in Hedgpeth, 1957) indicate clear, shallow water conditions. The presence of tenuous involute, weakly ornamented ammonites like *Placenticeras* indicates an epi-neritic environment; uncoiled forms like *Turrilites, Baculites* and *Hamites* an infra-neritic; and smooth ovate types like *Desmoceras, Fuzosia* indicate an epi-bathyal environment (vide Scott, 1940).
The smaller foraminifers are abundantly represented in the clays of the Uttatur Formation. A large majority of these are benthonic, though a few planktonic forms are also present. The overall composition of the foraminiferal fauna is similar to that of the underlying Kallakudi Limestone with the exception of the presence of *Ammonia* and *Lenticulina* which according to Lowman (1949) indicate near-shore brackish-water environment. More recently, Bhatla (1968) recorded a similar foraminiferal assemblage from the Raghavapuram Shales (Neocomian) which according to him were laid down in a shallow, brackish-water environment. From the foregoing it can be concluded that the deposition of the bulk of the upper member of the Uttatur Formation took place in a very shallow, brackish-water to marine environment. The presence of thick silts and clays indicates that the area of deposition was probably part of an estuary, or an open bay. That there were periodic fluctuations of the sea level, which at times resulted in a partially cut off marine basin, is evidenced by the presence of gypsum and phosphatic nodules (vide Venkatakrishnan and Rangaraju, 1968).

The overlying Trichinopoly Formation comprises irregularly bedded sands and clays, coquina limestone, calcareous grits and conglomerates. Like the Uttatur Formation, it has also yielded a large number of invertebrate fossils and large
The youngest unit of the South Indian Cretaceous - the Ariyalur Formation - is found exposed not only in Trichinopoly District (like the three older formations) but also in Vridhachalam and Pondicherry Districts. The Ariyalur Formation comprises two members - a lower, marine member and an upper, fresh-water, terrestrial member. Both these members are largely arenaceous. Calcareous grits, conglomerates, nodular calcareous shales and limestones also occur in the lower member.

The lower member of the Ariyalur Formation in Trichinopoly and its equivalent in Vridhachalam and Pondicherry has...
yielded a very rich fossil invertebrate fauna including ostracodes, foraminifers, molluscs, echinoids, brachiopods, corals and bryozoans.

The presence of coarse clastics in the Ariyalur Formation indicates deposition along the shore in turbulent zone. This supposition is further supported by the occurrence of large number of pelocypods and gastropods, which according to Hopkins (in Hedgpeth, 1967) require an abundant supply of planktons and which in turn thrive in agitated waters.

The upper part of the lower member of the Ariyalur Formation, the orbitoid bearing bed, has yielded a very rich ostracode fauna. The ostracodes occur mostly in association with bryozo, ophiuroid ossicles, larger and smaller foraminifers and thick shelled pelocypods like *Gryphaea* and *Mactryonias*. The rock type is generally an argillaceous limestone with intervening thin bands of calcareous, gritty to pebbly sandstone.

Of the various ostracode genera found in the orbitoid bearing bed, *Cythereella*, *Cytherelloides*, "Bairdia", *Propontocypris*, *Cytherides*, *Chamnoides*, *Hulingsina*, "Cytherura", *Neocytherideis*, *Hemicytherura*, Paracytherides and *Kestoleberis* are known to occur in the Recent seas in a near-shore environment (fide Benson, 1959; Kornicker, 1961, 1963; Korkhoven, 1963; Ascoli, 1964; Puri et al., 1964;
Sohn, 1964; Deroo, 1966; Maddricks, 1969b; and others). The genera *Bythocypris*, *Macrocypris*, *Echinocythereis* and *Bythoceratina* inhabit deeper waters (fide Morkhoven, 1963). There is some difference of opinion as regards the palaeoecological significance of *Krithe* and *Paracypris*. According to Sohn (1951), *Krithe* occurs in brackish to marine environment; according to Bold (1960) in both near shore as well as open shore facies; according to Morkhoven (1963) it is most common in infra-neritic to bathyal environments; according to Rome (1964) it occurs commonly at depths between 130 to 360 ft. and according to Puri et al. (1964) in an off-shore environment. According to Keij (1957), *Leguminocythereis - Krithe* association indicates a shallow marine environment. The genus *Paracypris*, according to Lozo (1943), is found in warm, shallow waters. According to Morkhoven (1963), the genus is restricted to a marine environment. Oertli (1967) opined that it may also be found in brackish-water environment. The genus *Eucytherura* is known to have a wide ecological tolerance (fide Morkhoven, 1963). The remaining ostracode genera are not found in the Recent seas and hence are of little palaeoecological significance.

It can, therefore, be concluded that the ostracodes as a whole indicate that the orbitoid bearing bed was laid down
in a shallow sea, close to the shore. The presence of such a large number of genera and species in the Lower Maastrichtian of South India has its parallel in the Maastrichtian of Holland from where Derov (1966) described an equally rich ostracode fauna and which according to him also thrived in a tropical epicontinental environment.

As stated earlier, the ostracodes are absent in the remaining part of the lower member of the Ariyalur Formation of Trichinopoly. However, the occurrence of foraminifers belonging to the families Lagenidae and Miliolidae, and of a number of species of the planktonic genus Globotruncan, suggest fluctuations in the environmental conditions from brackish-estuarine to normal marine. The ammonite genera namely, Desmoceras and Puzosia indicate a maximum depth up to 100 fathoms.

The upper member of the Ariyalur Formation is devoid of any marine fossils and has yielded vertebrate fossils of terrestrial reptiles which indicate that by this time the sea had regressed and land conditions had been established in the area.

The Cretaceous beds of Vridhachalam have been subdivided by Banerji (1965) into five biostratigraphic zones. Of these, the lowest zone (? Upper Turonian) is unfossiliferous indicating thereby that during the deposition of beds of
this zone the environmental conditions were perhaps not conducive to the growth of fauna. The basal part of the *Globotruncanina linneiana coronata* zone (Coniacian) has yielded *Cytherella*, *Brachycythere*, *Curfsina*, *Dumontina*, "*Cytheropteron*", *Eucytherura*, *Haplocytheridea* and *Schuleridea*. The palaeoecology of most of these, with the exception of *Haplocytheridea* and *Schuleridea*, has already been discussed. The ostracode fauna as a whole points towards a shallow marine environment. This conclusion is supported by the evidence furnished by foraminifers. According to Banerji (1968b, 1969) the lower part of this zone is characterized by the abundance of arenaceous forms and the upper by *Anomaliniidae*, indicating thereby that initially estuarine to very shallow water conditions (with depth between 20-50 m.) prevailed, followed by somewhat deeper conditions. The ostracodes from the *G. concavata* zone (Santonian) do not throw much light on the ecological conditions prevalent at that time as "*Bairdia*" and *Cytherella* indicate shallow water conditions, while *Buntonia* (*fide* Morkhoven, 1963) has a wide ecological tolerance. As stated earlier there is some difference of opinion regarding the ecology of the genus *Krithe*. The foraminiferal fauna from this zone is characterized by the dominance of *Nodosariidae* and an increase in the percentage of planktonic forms from base upwards. These facts led
Banerji (1968b, 1969) to conclude that normal marine conditions had been established in the area by this time and the depth of the basin varied between 10 and 20 m. The overall composition of the ostracode fauna from the *G. globigerinoides* zone (Campanian) comprising "Bairdia", *Cytherella*, *Krithe*, *Schuleridea* and *Xestoleberis* indicates a shallow water environment. The foraminifers from this zone, however, indicate a much greater depth (from 120 to 150 m.) for the basin as evidenced by the dominance of the families *Nodosariidae*, *Anomaliniidae* and *Rotaliidae* as well as a much larger percentage (20-35%) of the planktonic forms (vide Banerji, 1968b, 1969). The uppermost zone, the *G. linneiana tricarinata* zone (Lower Maastrichtian), has yielded the following ostracode genera: *Kikliocythere*, *Schuleridea*? (*Aequocytheridea*?), *Veenidea*, *Krithe*, *Cushmanidea*, *Leguminocythereis*, *Murrayina*, *Actinocythereis*, *Eucythere*, *Loxoconcha* and *Trachyleberis*. Of these, *Trachyleberis* and *Actinocythereis* are commonly found in a neritic environment, *Loxoconcha* in a mesohaline to littoral, and *Eucythere* in varying depths (vide Morkhoven, 1963). The palaeoecology of the remaining genera has already been discussed elsewhere. From the evidence at hand it may be concluded that the ostracodes on the whole indicate a shallow marine environment for the deposition of the beds of the uppermost zone. This is substantiated
by the evidence furnished by the foraminifers. According to Banerji (1968b, 1969) the dominance of planktonic forms in the lower part of this zone and of miliolids in the upper indicates a gradual shallowing up of the basin.

From the foregoing, it may be concluded that in the Vridhachalam area shallow water conditions prevailed during the Upper Turonian - Santonian times, deep water conditions during Campanian, and shallow water during the Lower Maestrichtian. The absence of any Middle - Upper Maestrichtian foraminifers in the Palakkollai Member indicates its deposition in fluvial/terrestrial conditions.

The Cretaceous beds of Pondicherry District have also been subjected to a detailed biostratigraphic study, particularly by Rajagopalan (1965) and Banerji (1968a). These beds have yielded only two ostracode genera namely, *Cyttherelloidea* and *Brachycythere*, on the basis of which no definite conclusions regarding the palaeoecology can be drawn. However, a more precise picture is available based on the evidence furnished by the foraminifers from these beds. According to Banerji (1968a) the sedimentation in the area commenced during the ? Coniacian - Santonian times. The basal beds are arenaceous and unfossiliferous, passing through shaly to calcareous one. The *Globotruncana concavata* zone (Santonian) is characterized by the dominance
of benthonic and arenaceous forms. The planktonic forms are rare indicating thereby that the deposition of this zone and of the unfossiliferous basal beds probably took place in estuarine to inner shelf environment (depth from 20 to 50 m.). The maximum depth (100 to 120 m.) was reached during the G. marginata and G. ventricosa sub zones (Campanian) as evidenced by an increase in the percentage of the planktonic forms and a decrease in the number of arenaceous forms (vide Banerji, 1968a). The fauna during the G. linneiana tricarinata zone (Lower Maestrichtian) is characterized by the abundance of benthonic forms of the families Nodosariidae, Miliolidae, Anomaliniidae and Textulariidae which according to Banerji (1968a) indicate estuarine to semi-deltaic conditions. Almost similar views on the palaeoecology of the Upper Cretaceous beds of Pondicherry were expressed by Rajagopalan (1965).