CHAPTER I

INTRODUCTION
INTRODUCTION

1.1 Prelude

The carbonate rocks of sedimentary origin (of which the present study relates to) are essentially formed due to chemical and biological processes and are composed predominantly (> 50%) of carbonate minerals. These carbonate rocks are the most abundantly found among the non-terrigenous sedimentary rocks and they roughly constitute about one tenth of the earth’s sedimentary shell (Prothero and Schwab, 1996). These rocks have gained importance owing to their ability to serve as good reservoir rocks for petroleum and natural gas; as a host of for a variety of ore minerals; as a building material; as a soil acid neutralizing agent and as a flux for smelting iron and steel. Further, the study of these rocks enables to understand the palaeo-environment conditions of deposition. In view of such varied and wide applications, these rocks have received the attention of geo scientists and have been thoroughly studied. In the present study the carbonate rocks formed during the Upper Cretaceous period in the composite Tiruchirappalli District of Tamil Nadu State, India, have been studied to understand their various geological, petrological and geochemical characteristics. The inputs from these studies have been used to decipher the depositional and post-depositional environments.
1.2 Carbonate rocks

Since the present study concerns with the carbonate rocks of upper Cretaceous period, it is necessary to have a thorough knowledge about their mineralogy, chemistry, texture, factors controlling their deposition, depositional environment and diagenesis. In the following sections a detailed account of these characteristics are given.

1.2.1 Chemistry

Carbonates are composed largely of both calcium and magnesium carbonate minerals as well as carbon dioxide. In most carbonate rocks, the silica composition is low. The common sedimentary carbonate minerals are aragonite, calcite and dolomite. In most of the carbonates the composition lies somewhere between calcite (CaCO₃) and dolomite (CaMg(CO₃)₂). For example, most contain some amount of magnesium but not as much as pure dolomite. The carbonate minerals contain trace elements also and they do not readily substitute into carbonate minerals. As a result their values are quite low. However, other cations (besides Ca²⁺ and Mg²⁺) may be found in carbonate minerals. Cations such as Fe²⁺, Mn²⁺, Sr²⁺ may substitute calcium in carbonate minerals. Sodium may also be present, in the form of fluid which fills vacuoles.
1.2.2 Texture

Calcite and aragonite are primarily found in three forms:

a. Grains: silt size or larger aggregates of crystals
b. Mud: 1 – 5 size crystals – texturally analogous to siliceous muds. This size class is commonly called micrite
c. Spar: Coarser grained crystals which appear translucent in plane light (clear or white), 0.02-0.1 mm range. Crystals fill pore spaces, often due to recrystallisation.

1.2.3 Factors controlling deposition

The important conditions that favour the deposition of carbonate rocks are:

i) increase in the temperature or reduction in the pressure of sea water
ii) shallow water depth
iii) greater degree of agitation and
iv) higher degree of organic activity

1.2.4 Depositional environment and diagenesis

The depositional sedimentary environment primarily concerns about the hydrodynamics, biological and chemical conditions under which the rocks were deposited. It is characterized by a unique set of physical, biological and chemical processes operating at a specified rate and intensity imparting sufficient imprint on the sediment
producing characteristic deposit. The character of a sediment so produced is determined both by the intensity of the formative processes operating on it and by the duration through which such action has continued (Pettijohn, 1957).

**a. Study of depositional environment**

The study of depositional environment of geologically ancient sediment is essentially the study of geomorphology which can be preserved in ancient sediment. The geomorphic processes, which leave a lasting record in ancient sediments, are useful in the recognition of environment of deposition. The geomorphic processes may be physical, chemical or biological (Reineck and Singh, 1973).

Study of physical environments relates to determination of hydrodynamic conditions under which certain sediments were deposited. These conditions include depositional medium, current and wave intensity, velocity, water depth, etc. Information about these conditions is best obtained by detailed and careful study of primary sedimentary structures - both inorganic and organic, size distribution parameters and type of sediment particles. Deposits of a geomorphic unit are also strongly influenced by the climate, size and shape of the basin of deposition. Details about general climatic conditions may be provided by faunal and floral studies and to a certain extent by mineralogical and chemical parameters. Study of sedimentary tectonics is also considered in the reconstruction of ancient environments. Details of lateral and vertical facies changes, knowledge of rate of deposition and palaeogeography provide
information about sedimentary tectonics. Sedimentary tectonics has a strong control over the thickness of sedimentary deposits and the nature of juxtaposition of various facies in space and time. Similarly syn-depositional tectonics can be significant in affecting the nature of sediments in a given environment. Recognition of minerals originally precipitated in the environment of deposition provides details about the pH and salinity of depositing medium. Biological criteria, i.e., palaeo ecological information can provide valuable information about water depth, salinity, temperature, turbulence, rate of sedimentation and re-sedimentation etc. The study of physical factors, in conjunction with the study of biological and chemical factors provide a complete picture of the sedimentary depositional environment.

The importance of environmental reconstruction had been recognized from the very beginning of the study of sediments. Leo Nardo Da Vinci undertook environmental interpretation in fifteenth century, when he recognized fossils as preserved animals. He had concluded that the presence of corals and oysters, on the rocks of Monte Ferrato/Lombardei were indicators of marine deposits and the presence of sea at that place. Since then, geologists have been engaged in interpretation of depositional environments of ancient environments (Reineck and Singh 1973).

Study of present-day environments has provided considerable information, on the basis of which environmental models can be proposed. Such models can be based on actual informations obtained from the study conducted. Information on investigation in different
geographic areas of a given environment can be considered and may be put together to build up a generalized model. These models should be considered no more than “Models”, because many variations in the deposits of similar environments are possible. However, despite their deposition in varying conditions, certain basic patterns are always similar in deposits of a given environment. This enables the recognition of depositional environments, even in old geological records.

b. Diagenesis

Diagenesis refers to the processes that are involved in post-depositional alteration of freshly deposited sediments. They do not operate with complete uniformity and regularity. These processes may include compaction, cementation, recrystallisation and mineral transformation or replacement. Diagenesis includes all the processes that took place during the time interval between deposition and metamorphism (Flugel, 1982; Tucker and Wright, 1990).

Three major diagenetic environments are recognized. They are the marine, near-surface meteoric and burial environments (Tucker and Wright 1990). Diagenetic processes that have taken place in a specific environment leave behind their specific imprints in the rocks on which they have acted. These imprints can be studied in terms of structural (micro and macro), textural, chemical (major, minor trace, and rare earth elements) and mineralogical characteristics. As proposed by Brand (1991), multi-method approach is needed to
precisely delineate the diagenetic processes acted and environment of
diagenesis. Diagenetic models can be drawn on the basis of this
information.

Recognition of ancient depositional environment and post
depositional changes are helpful in the understanding of sedimentary
and lithification processes in the history of the earth. They are also
useful in the exploration of natural resources like petroleum, coal,
limestone, dolomite, phosphate, placer deposits etc., as these deposits
are found in association with certain specific depositional
environments.

1.3 The Upper Cretaceous Sedimentary Sequence

The Upper Cretaceous has been a remarkable Period in the
history of the earth for it experienced major marine transgressions in
several parts of the globe. Such transgressions brought the marine
sediments inside the cratons of the drifting continents. The
epicontinental basins of the cratons accommodated these shallow
marine sediments and have recorded the history of events that took
place during the stratification. During this Period, in the Indian
subcontinent, a number of such epicontinental basins accommodated
the shallow marine sediments which were later transformed into
sedimentary rocks (fig.1.1). One such important epicontinental basin
is the Cauvery basin, located in the south eastern portion of the Indian
coast. In this area, a thick, continuous sequence of marine
sedimentary rocks belonging to Aptian – Albian to Maastrichitan age
SKETCH - MAP OF THE INDIAN SUBCONTINENT
SHOWING THE POSITION OF VARIOUS CRETACEOUS BASINS

LEGEND
1. Andaman-Nicobar
2. Assam-Arakan
3. South Shillong
4. Lesser Himalaya
5. Tethyan Himalaya
6. Cauvery-Palar
7. Krishna-Godavari
8. Narmada
9. Kutch-Saurashtra
10. Jaisalmer

DECCAN TRAP
GONDWANA

FIG. 1.1
is exposed in an area of about 470 sq.km. and this sequence has been recognized. This is considered as a reference sequence for the Upper Cretaceous Period. The area chosen for the present study forms a part of this sequence. A detailed account of the evolutionary history, tectonic setting, stratigraphy of the Cauvery basin are given in chapter 2.

1.4 Previous Studies

The Cretaceous system, having nearly 80 million years of earth’s record has been one of the well-reported systems in different parts of world. A number of geoscientists have conducted various studies on the Cretaceous sequence of the Cauvery basin, of which the area chosen for the present study forms a part. The Cretaceous sequence exposed has been recognized as being of global significance as a reference sequence for the Upper Cretaceous system for well over a century. Palaeontological collections were made from the area by French expeditioners in 1856 and perhaps earlier (Kennedy and Anderson 1992). The first published report from the study undertaken in the area relates to the fossils by Kaye (1840). Egerton (1845 and 1846) and Forbes (1846) undertook similar studies. Blanford (1862) carried out a detailed study on the Cretaceous rocks of the Cauvery basin. Systematic surveying, geological mapping, fossil studies in the area resulted in the publication of monographic series (Blanford and Stoliczka, 1863-66; Stolizka, 1870-71). These studies revealed a very rich and diverse composite fauna, rivalling the Upper Cretaceous system of the Western Europe. Later, Kosmat (1895-98) revised the
systematics of the ammonites established by Stoliczka and correlated with the ammonites of the other parts of the world.

Pascoe (1959), Srivatsava and Tiwari (1967) conducted studies with regard to biostratigraphic zonation of the Upper Cretaceous rocks of the area. Krishnan (1968) carried out studies with relates to the Cretaceous sequences of the Cauvery basin. Ramarao (1968) has studied the Cretaceous-Tertiary rocks of the basin. Nair (1974), conducted a study on the carbonate rocks of the Cauvery basin. This was followed by a detailed investigation of the coral reefs of the Cauvery basin by Banerji (1979). Sastry et al., (1981) have studied the stratigraphy and tectonics of the Cauvery basin. Sundaram and Rao (1986) have given a detailed account on the structure, tectonics and evolution of Cauvery basin. They proposed a new lithostratigraphic classification of the Cretaceous and Palaeocene sequence of the composite Tiruchirappalli District.

Ayyasamy (1990) has proposed biostratigraphy of the Tiruchirappalli-Cretaceous and correlated with the European Cretaceous formations. Ramasamy and Banerji (1991) have conducted studies relating to geology, petrography and stratigraphy of the pre-Ariyalur sequence in the Tiruchirappalli District. Systematics and biostratigraphic studies of the Pondicherry area, which lies in the northern part of the area chosen for the present study, have been conducted by Forbes (1846) which was subsequently revised by Henderson (1992 a and b). Chandrasekaran and Ramkumar (1994a) made an attempt to understand the diagenetic environments of
Kallankurichchi formation of Ariyalur group, South India with the help of geologic and petrographic studies. Martin-Chivlet (1995) has documented sequence stratigraphic interpretation by field observations in mixed carbonate-siliciclastic sedimentary systems in a tectonically active setting of the Upper Cretaceous formations of Betic Continental margin of Spain.

Raju and Mishra (1996) have reviewed the Cretaceous stratigraphy of India and have recognized seventeen biozones, eight chronostratigraphic units of the rank of stage and 57 lithounits of formation rank in the surface and subsurface succession of the Cretaceous of Indian basins.

Okada (1996) has given a detailed account on the distribution and characteristic lithologic features of Cretaceous sediments in the Japanese Islands and has discussed their tectonic significance. Jafar (1996) has provided a coherent account of the evolution of marine Cretaceous basins of India in the light of deep sea data and with special reference to global nannofossil zones established in various basins.

Govindan et al. (1996) have studied the stratigraphy of Tiruchirappalli Cretaceous by synthesizing information obtained from detailed geological mapping, data from bore holes and deep wells in the outcrop and micropalaeontological findings. Cant (1996) has summarized the stratigraphic organization and sedimentology of an intensively studied clastic wedge in the Western Canada foreland.
basin. Certain aspects of regional geology and Cretaceous stratigraphy have been dealt by Sahni (1996) and a year later, Sahu and Zutshi (1997) have brought out in detail the role of tectonics in the evolution of Cretaceous sedimentary package of the basin.

Nandi and Desai (1997) have examined the diagenetic aspects of exposed Mesozoic carbonates of Jhurio and Jumara formations of the Kutch region of India through petrographic and geochemical analysis. The study reveals complex diagenetic features indicating the depositional and post-depositional changes that took place under the phreatic conditions in marine as well as fresh water environments. Further the trace element analysis has revealed that the study area has been subjected to meteoric diagenetic environment. The isotope analysis suggests diagenesis of the Jhurio formation in shallow marine environment and that for the Jumara formation in marine, meteoric and burial environments. Lal and Gupte (1998) have reviewed the petrography and other relevant data in order to understand the process responsible for the formation of secondary porosity in the carbonate reservoir rocks of Bombay offshore basin in India.

Alam and Akhtar (1998) have discussed the diagenesis and porosity evolution of the sandstones, which form the basal part of the otherwise carbonate sequence of the Jaisalmer Formation and have found from their study that the Jaisalmer Formation was deposited in shallow marine condition which favoured the development of the carbonate buildup with associated fluvial to shallow marine clastic
facies. Rogers (1998) has provided outcrop documentation of the Upper Cretaceous of Judith river Formations, Montana, United States. The results of the study have important implications on the sequence analysis in foreland basin settings.

Madhavaraju and Ramasamy (1999) studied the depositional history of the Ariyalur Group of the composite Tiruchirappalli District based on the analysis of the different micro textures of the quartz grains. The multivariate analysis conducted for deducing controls of carbonate deposition reveal that the deposition of carbonate rocks of the Kallankurichchi formation was controlled by the amount of terrigeneous influx.

Govindan (2000) has summarized the criteria for redefining the stage / substage boundaries in the Cretaceous of Tiruchirappalli. The sections in India were correlated with European stages. Tiruchirappalli Cretaceous, could be demarcated with standard biomarkers like ammonites, planktonic foraminifera and nannofossils. Tripathy and Lahiri (2000) studied the Bagh basin of Madhya Pradesh based on the analysis of hard ground. Radulovic and Ramamoorthy (2000) have made taxonomic revision of brachiopods from the Ariyalur Group of the Cauvery basin.

Hart et al., (2000) have reassessed the three major sedimentary Groups of Upper Cretaceous of the Cauvery basin. The various characteristic features and responses to eustatic sea level have been dealt to bring out a comprehensive picture on the lithostratigraphy of
the Upper Cretaceous of the Cauvery basin. Kale et al. (2000) have conducted a study relating to the calcareous nannofossils of the Uttatur Group of Tiruchirappalli Cretaceous. In his work he has discussed the palaeogeographic and palaeoecologic aspects of these nannofossils. From the study of the distribution of these nannofossils they have found that the Uttatur Group shows a high latitude austral setting in Late Aptian and middle to low latitude austral setting in the Turonian time. They have found that the nannoflora of the Kallakudi grey shale is ecologically controlled and is deposited in a quite basin with periodic influx of nutrient rich waters from the adjoining open parts of the basin. Further the nannoflora of the Group on the whole shows an open marine setting.

Steinhoff and Bandel (2000) have studied the Middle Cretaceous bioherm sequences of the Tiruchirappalli District in order to understand the palaeoenvironmental condition. From the study they have found that during the Middle Aptian to Cenomanian age, shallow water sediments were deposited on a tectonically active coastline, which was influenced by the Bay of Bengal. The bioherms represented by flat, incrusting sponge-coral-algae association were developed in a clear shallow water environment.

Sundaram et al., (2001) on the basis of intensive regional mapping have revised the lithostratigraphy of the Cretaceous shelf succession of the Cauvery Basin. Further, they have given a detailed account on the palaeoenvironmental conditions of the area. Mineralogic, petrographic and geochemical analyses of sediments by
Malone et al., (2001) have been used to characterise the early marine diagenesis of the shallow-water, periplatform carbonates of the western slope of Great Bahama Bank.

Samankassou (2002) in his study has observed the unusual occurrence of high-diversity bryozoans, brachiopods, crinoids, red algae, sponge spicules and ostracods in the cooler regions of Carnic Alps of Austria-Italy. He is of the opinion that water-temperature changes linked with nutrient supply and coastal upwellings are the most convincing causes for the unusual associations. Bralower et al., (2002) from the study of the sediments recovered from the northwest Pacific has found abrupt climate events that took place during the Cretaceous. Nagendra et al., (2002) have studied the complete succession of the Kallakudi Quarry – II (of Lower Uttatur) of Kallakudi composite Tiruchirappalli District and have developed a sequence stratigraphic framework for the area.

Murkute (2003) has brought to light the depositional environment of the Lameta Formation formed during the Cretaceous Period on the basis of petrography, sedimentary structures, fossil remains and geochemistry. From the analysis he has found that the rocks of the area have been formed under shallow marine environment.
1.4 The Present Study

1.4.1 Need for the present study

Recognition of ancient depositional environments and post-depositional changes are helpful in the understanding of sedimentary and lithification processes in the history of earth. Further, they are helpful in the exploration of the sedimentary carbonate rocks like limestone, dolomite etc. Apart from this, they provide valuable information regarding the palaeo water depth, temperature, intensity of waves and currents. A study of these physical factors in conjunction with the palaeo environmental factors provides a complete picture of the depositional environment. A comprehensive study on these aspects have not been carried out so far for the Lower Uttatur Group, the present study has been undertaken to understand the environment of deposition.

1.4.2 Aim and Objectives

The aim of the study is to decipher the depositional and post-depositional environments of carbonate rocks of Lower Uttatur Group of the Upper Cretaceous sequence of Tiruchirapalli District, Tamil Nadu, India.

The objectives of the study are

a. To conduct a detailed geological study.
b. To analyse physical, chemical and biological parameters which have influenced the deposition/precipitation of calcium carbonate.

c. To study post-depositional processes, its products and the environment and those that have brought the conversion of these sediments into a carbonate rock.

1.4.3 Methodology

The methodology adopted for the present study is shown in the Flow chart 1.1 and the same is described in detail in the following section.

Literature relating to the present study were carefully studied in order to have a thorough understanding of the subject under study and the study area. For the present study, geological, petrological and geochemical investigations were carried out. By integrating the results from these investigations, the depositional and post-depositional environments were deciphered.

For the study of the geology of the area, both regional geology and the geology the present study area were considered. The regional geology of the area was studied with help of literature relating to the geology of the region. For understanding the geology of the area under present study, the various rock types, geological structure and fossils were studied. Intensive field work was undertaken for this purpose. Suitable samples were taken from the various parts of the study area. Thin sections were prepared from these samples in order to identify
Flowchart 1.1: GENERALISED METHODOLOGY ADOPTED FOR THE PRESENT STUDY
the minerals that constituted the rock samples. The geological structure was studied from the field investigations and the fossils were identified from their morphological characters.

For the study of petrology of the study area, the rock constituents such as skeletal components, non-skeletal grains, matrix and cement in each sample were studied in detail. Based on the classification procedure suggested by Folk and Dunham the carbonate rocks were classified. Further, details regarding porosity, cementation, micritization, compaction and neomorphism were also obtained.

For geochemical investigations, the concentrations of elements in each sample was found out. The data obtained for each sample were compared with one another. Further, interpretations were made based on molar ratios, total CO₃ in terms of CaCO₃ and X-ray diffraction studies.

By integrating the results obtained from the geological, petrological and geochemical investigations, inferences were made regarding diagenesis, depositional environment and post-depositional environments.

1.5 The study area

1.5.1 Location

The area chosen for the present study forms a part of the Cauvery basin (Fig 1.2). It lies between 10°58’ – 11° 25’ north
DISTRIBUTION OF SEDIMENTARY ROCKS
IN PART OF CAUVERY BASIN

LEGEND
- Alluvium
- Cuddalore Sandstone Formation
- Niniyur Formation
- Ariyalur Group.
- Tiruchirappalli Formation
- Uttatur Formation
- Terani Formation
- Archeans

FIG 1.2

Modified after Krishnan, (1982)
latitudes and 78°45' – 79°10' east longitudes (Fig. 1.3). It forms part of the Survey of India topographic sheets, viz., 58 I/16, 58 J/13 and 58 M/3 of 1:50,000 scale. Within this area the carbonate rocks of Lower Uttatur Group of Upper Cretaceous sequence, found in and around the villages of Kovandakurichi, Kallakudi, Melarasur, Tirupattur, Neykulam, Verugupadi, Maruvattur, Olapadi and Govindarajapattinam were taken up for the present study. A geological map showing sample sites is shown in Fig.1.4.

1.5.2 Climate

The area experiences hot and dry climate for most part of the year with the temperatures ranging between 35° to 40°C. The average annual rainfall is about 850 mm and in general, the average annual rainfall decreases from east to west. Though, the area receives most of the rainfall during south west monsoon (June to September) and northeast monsoon (October to December), the rainfall during northeast monsoon is substantially higher.

1.5.3 Physiography and Drainage

The study area in general is a gently undulating terrain ranging in altitude from 75 to 100m above mean sea level. The altitude of the area gradually decreases towards the eastern part of the study area. The Marudhaiyar and Chinnar are the two main rivers that flow through in the study area. While the Marudhaiyar river flows through the central part of the study area in a north west – south east direction
before debouching into the Coleroon river in the southeastern part, the Chinnar river and its tributaries which drain the northern part of the study area, flows in a south west - north east direction. These rivers are dry for most part of the year and the water flow is restricted to monsoon seasons.

1.5.3 Land use

In the study area, most of the area are under cultivation, especially for raising dry crops. Though lakes and tanks serve as an important source of irrigation, their distribution is very much limited. Next to the agricultural lands, the area is occupied by scrubs. The saline nature of the soil and poor water availability does not facilitate luxuriant growth of natural vegetation. Hence, the vegetation in the study area is restricted to salt tolerant species. Apart from the agricultural lands, water bodies in the form of streams, lakes and ponds are also found in various parts of the study area. The wastelands are generally characterized by gully erosion. Wastelands, in the form of gully-eroded lands are found in various parts of the area.

1.5.4 Accessibility

The study area is well connected with road and rail. The National Highway No. 45 which connects Chennai and Dindigul passes very near to the western boundary of the study area. This National Highway is connected to a number of State Highways and
other road networks which passes through various parts of the study area. The Chennai – Tiruchirappalli broad gauge railway track passes through the study area connecting the important towns of the study area, such as Dalmiapuram, Ariyalur, etc.

1.6 Organization of the thesis

The present thesis has been organized by into six chapters where in the first chapter deals with mineralogy, texture, factors controlling their deposition, depositional environment and diagenesis, a brief account of the upper cretaceous rocks, aim and objectives and the methodology adopted for the present study. Further, a detailed review of the previous works relevant to the present study has been made. These apart, a detailed brief description of the study area has also been made.

In the second chapter, a detailed account of the geology of the area has been made. In the first part, the regional geology of the Cauvery basin has been elaborated and in the second part, the geology of the study area has been discussed which includes the methodology adopted, lithology, structure and fossils.

The third chapter describes in detail the petrology of the study area. The methodology adopted and the results obtained have been discussed elaborately. The fourth chapter describes in detail the geochemistry of the study area. The methodology adopted for the analysis of concentration of elements such as calcium, magnesium, iron, aluminium, sodium, potassium, manganese, strontium and
barium and the interpretation made from them have been described. Also, interpretations have been made by comparing the concentration of elements with one another, analyzing their molar ratios and total carbonate content. Further, the methodology adopted and the inferences drawn from the x-ray diffraction study has also been presented.

In the fifth chapter, the depositional environment of the carbonate rocks of the study area, the diagenesis and their modules have been presented. Inferences drawn from correlation and factor analysis have been presented.

The sixth chapter, which is the final chapter, summarizes the results obtained and the conclusions from the study. Recommendations for further research have also been described.