SECTION 7
Like other coastal regions of the Peninsular India, Andhra Pradesh was invaded by sea off and on during different periods of earth's history. The marine formations present there narrate the story of various advances and retreats of the sea in this region from Early Cretaceous to Eocene times (Bhalla, 1970).

**Marine Invasions:** The first marine transgression occurred towards the closing phase of the Gondwana sedimentation in Early Cretaceous times and the Raghavapura shale and its equivalents, i.e., the Middle formation of the Upper Gondwana of the east coast, were deposited. Then the sea regressed from most of the region resulting in the accumulation of the Tirupati sandstone of the Upper Gondwana under fresh-water conditions. However, in the Rajahmundry-Vishakhapatnam sector, a few small marine outcrops, probably marine equivalents of the fresh-water Tirupati sandstone, suggest the presence of the sea there for a brief period. Then there was a pause in sedimentation as inferred from an unconformity between the Tirupati sandstone and the overlying Infra-trappean beds.

The second marine invasion took place at the dawn of the Paleocene Epoch, synchronising with the world-wide re-distribution of land and sea, and the Infra-trappean beds were laid down during this transgression. Thereafter, the region started getting the impulses of one of the major activities affecting the Indian Peninsula which triggered the withdrawal of the Paleocene sea and outburst of the Deccan Trap lava flows. A slight unconformity exists between the Infra-trappean beds and the overlying flows which suggests exposure of the Infra-trappean beds for a brief period before the commencement of igneous activity.
The third and the last major invasion of the sea in Andhra Pradesh took place at the beginning of the Eocene Epoch and the Inter-trappean beds were deposited. The paleoecological study of these beds indicates minor fluctuations of the shore-line during the entire period of their deposition.

The sea finally regressed from Andhra Pradesh and the region witnessed the outpouring of an immense volume of lava now forming magnificent Deccan Trap. Gradually, the fresh-water conditions advanced towards the east and Rajahmundry sandstone was deposited under fresh-water (brackish-water) conditions during Neogene times.

It is important to note that of all the regions of Andhra Pradesh, the sea invaded only the Kakinada-Rajahmundry-Masulipatnam region off and on. In all probability, broad structural pattern of this and connected regions were responsible for it. The Godavari graben in Peninsular India is a major structural feature stretching from near Nagpur in Central India to the Godavari delta on the east coast and the Kakinada-Rajahmundry-Masulipatnam region is the southeastern extremity of this graben. Oscillations of the shore-line, bordering this region, was most probably due to the movements along the faults of the Godavari graben synchronising with the unstable conditions of the earth as a whole and the east coast of India in particular. Also, that the sea always followed the same passage each time, lends credence to this contention of the author (Bhalla, 1970).

It is equally fascinating to know that the different marine formations in Andhra Pradesh are mainly confined to the southeastern extremity of the Godavari graben although it extends up to Nagpur—a distance of about 1000 km. Recent geophysical investigations of the Godavari graben have revealed the presence of a buried ridge northwest of Rajahmundry, lying at right angles to the main trend.
of the graben. Taking clue from its presence, it is the surmise of
the author that this ridge acted as a hinge and only the region
southeast to this ridge, including Kakinada-Rajahmundry-Masulipatnam,
moved with the earth's disturbances while the region northwest to it
remained practically unaffected.

**Oil Possibilities:** The different marine and nonmarine formations and
their contemporaries ranging from Early Cretaceous to Recent are
present in the coastal region of Andhra Pradesh and in the adjacent
Bay of Bengal. In India, oil and gas possibilities have been explored
mainly in Tertiary rocks so far. The Mesozoics have proved to be the
major producers of oil and gas in several countries of the world and
they hold promise in India also. If detailed geological and
geophysical investigations are made, there are reasons to expect
oil and gas in the Kakinada-Rajahmundry-Masulipatnam region of
Andhra Pradesh and also in the adjacent shelf of the Bay of Bengal
(Bhalla, 1970).

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MARINE INVASIONS AND OIL POSSIBILITIES IN ANDHRA PRADESH, INDIA

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SUMMARY

The different marine formations in Andhra Pradesh narrate the story of various advances and retreats of the sea in this region from Early Cretaceous to Eocene times. The occurrence of various marine invasions in this region alone is of considerable interest and the broad structural pattern of the whole region appears to be the chief controlling factor for such occurrences. Probable extension of different marine and continental formations and their contemporaries, has been visualized. In the light of these, the possibility of finding oil and gas in this region as well as in the adjacent shelf of the Bay of Bengal, has also been discussed.

INTRODUCTION

Due to its proximity to the sea even in the geologic past, Andhra Pradesh, like several other coastal regions of the Indian Peninsula, was an open ground for marine transgressions and regressions. The Kakinada–Rajahmundry–Masulipatam region of Andhra Pradesh (Fig 1) deserves careful attention because the rocks of this region bear testimony to several cycles of advancements and retreats of the sea ranging from Early Cretaceous to Eocene times. The thick pile of sediments which accumulated here is a repository of the marine life flourishing along the east coast of India during this span of time and the study of these rocks helps in solving some important problems of Indian geology including the evolution of the eastern coast-line of the Indian subcontinent. In addition, the sediments are promising from the point of view of oil exploration also. Keeping these advantages in view, the Kakinada–Rajahmundry–Masulipatam region of Andhra Pradesh was selected for the present study. The different rock units along with their paleoecology, met within the region, have been summarized in Fig 2. They all lie at low angles towards east and southeast.

MARINE INVASIONS

The first marine transgression in the region took place during Early Creta-
ceous (Neocomian) times—towards the closing phase of the Gondwana Era. The sea transgressed from the east and southeast and occupied, perhaps, an isolated depression, e.g., the Raghavapuram Basin in the Eluru area. The sediments deposited under the influence of this marine invasion, now constitute the Raghavapuram Stage—a middle division of the Upper Gondwanas of the east coast. The trend of Raghavapuram outcrops indicates that the basin was probably crescentic and surrounded by land on three sides—north, northwest and west. Recently, the author (BHALLA, 1969a) made a comprehensive study of the Foraminifera from this stage and observed that the Raghavapuram Basin was a shallow water-body. The faunal evidence suggests that out of a total thickness of 160 ft. of the Raghavapuram Shales, the lower 60–70 ft. of the sediments were deposited in a truly marine conditions marking the transgressive phase of the sea. Thereafter, the sea regressed towards the east and southeast and the basin became land-locked resulting in the

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Fig. 2. Record of marine transgressions in Andhra Pradesh through geological time.

development of a serene, marine marsh in which the rest of the Raghavapuram column was laid down (BHALLA, 1969b). The change-over from a truly marine to marsh environment is marked by the presence of glauconite-bearing mudstone, about 2 ft. thick, and occurring at a level 60-70 ft. from the base of the shale sequence (BHALLA, 1969c).

With further regression of the Early Cretaceous sea towards the east and southeast, fresh-water conditions advanced from the west and under its influence, the sandstones of Tirupati Stage—the topmost stage of the Upper Gondwanas on the east coast—were deposited. However, the presence of a series of about six small but isolated Gondwana outcrops, some of which showing marine fossils, in the trans-Godavari region lying between Rajahmundry and Vishakapatnam, suggests that they are probably the marine equivalents of fresh-water Tirupati Sandstones of the Eluru area. This would, then, suggest that the Early Cretaceous sea regressed from the Eluru area and migrated to the Rajahmundry–Vishakapatnam area.

After the deposition of the Tirupati Sandstones, there was a hiatus in the depositional history of the region under description. This is inferred from the presence of a suspected break between the Tirupati Stage and the overlying Infra-trappean Beds (RAJU et al., 1965). This gap in sedimentation marks the change from Mesozoic to the Tertiary Era.

At the dawn of the Paleocene Epoch, marine invasion took place in Andhra Pradesh for the second time synchronizing with the world-wide re-distribution of land and sea. The Paleocene sea advanced over a wide area near Pangadi from east and southeast but its western limit was markedly lesser than that of the Early Cretaceous sea. In the Paleocene sea, the Infra-trappean Beds were laid down. BHALLA (1966a) described Foraminifera from the Infra-trappean Beds of the Pangadi area near Kovvur and concluded that the deposition of the limestones—the top beds of the sequence yielding Foraminifera—took place in a shallow marine, rather warm, inner-neritic environment, facing an open sea. The petrographic studies of the limestones (BHALLA, 1966b) show that the rock is a sandy packed biomicrudite with a large amount of terrigenous material and corroborate the environmental conditions visualized by the author earlier on the foraminiferal evidence. The presence of abundant terrigenous material further indicates unstable conditions in the provenance.

After the deposition of the Infra-trappean Beds, the region started getting the impulses of one of the major tectonic activities affecting the Indian Peninsula which triggered the withdrawal of the Paleocene sea and outburst of the Deccan trap lava flows. The Infra-trappean Beds were exposed to the agents of weathering for a rather short duration as is evidenced by the presence of a slight erosional unconformity between them and the overlying trap rock. During this episode, about 40–50 ft. of the lava flows piled up in the area.

At the beginning of the Eocene Epoch, the sea again appeared on the scene.
marking the third and the last major invasion in the region. This transgression was comparatively of feeble nature and was rather limited in extent. During the tenure of this sea, the Inter-trappean Beds were deposited. From the location of the Inter-trappean outcrops, it appears that the venue for the Early Eocene sea shifted slightly northeastwards with relation to that of the Early Cretaceous sea. Bhalla (1967) studied Foraminifera from the Inter-trappean Beds of the Pangadi area in detail. The Foraminifera, supported by Ostracoda, reflect two marine, alternating with two brackish-water, conditions of deposition starting with the latter one. This suggests that first the sea influenced the marginal basin by slight advancement resulting in the development of brackish-water environment. Soon after, it completely advanced and truly marine conditions were established. Then, the sea withdrew from the scene to appear again after a brief pause, marking the end of marine transgressions in the region. The foraminiferal studies by the author (Bhalla, 1967) suggest that the Inter-trappean sedimentation took place either at the mouth of a big river or in some coastal depression which was influenced by the nearby sea off and on.

The sea finally withdrew and the region witnessed the outpouring of an immense volume of lava which now constitute the magnificent Deccan traps in the region. The Inter-trappean Beds were slightly eroded before they started receiving the lava flows and an unconformity marks the junction between the two. About 100–150 ft of trap rock accumulated during this igneous episode. Gradually, the fresh-water conditions advanced towards the east resulting in the deposition of brackish-water (‘fresh-water) Rajahmundry Sandstones during the Neogene times.

**DISCUSSION**

An important question which stems from the present study is that of all the regions in Andhra Pradesh, why the Kakinada-Rajahmundry-Masulipatam region alone was so prone to different marine invasions? The answer would, perhaps, come from the broad structural pattern of this and the connected regions and, therefore, it is necessary in the present context to mention them in brief.

In peninsular India, the coalfields belonging to the Gondwana Era occur along certain well defined tracts which coincide with the trend of main tectonic troughs (grabens) in the region. In fact, all the important coalfields of India owe their preservation mainly to these narrow, long troughs. There are three such major tracts, viz., Damodar–Son, Mahanadi, and Godavari valleys, all having been named after the respective rivers which flow through them. The Godavari graben stretches from near Nagpur to the Godavari delta and contains a chain of Lower Gondwana coalfields, commonly referred to as the Godavari Valley coalfields. Its boundaries are straight, parallel to each other, and trend in northwest–southeast direction. Like other grabens, the Godavari graben has also been an
important sedimentary basin of peninsular India and witnessed intense sedimenta-
tion since Late Carboniferous times.

The Kakinada–Rajahmundry–Masulipatnam region of Andhra Pradesh is
the southeastern extremity of the Godavari graben and the oscillations of the
shore-line bordering this region during different periods in the history of the earth,
ranging from Early Cretaceous to Eocene, was probably due to the movements
along the faults of this graben. This is, perhaps, one of the reasons why in other
coastal parts of Andhra Pradesh, no such fluctuations of the shore-line occurred
in the geologic past. It would, then, imply that the different marine invasions
in the region were tectonically induced and gets further corroboration from the
synchronous advancements of the sea and the unstable conditions of the earth as
a whole and the east coast of India in particular. The sea started occupying the
Bay of Bengal region probably during the Late Jurassic and the eastern coast-line
of the Indian Peninsula assumed its present configuration possibly during the
Early Cretaceous times.

The history of marine sedimentation in Andhra Pradesh is a chapter of
accidents. When the sea transgressed, it stamped its presence by laying the marine
deposits but, at times, when it was not there, its absence was marked either by
a gap in sedimentation or by a piling up of fresh-water beds. The above discussion
reveals that the sea was present along the coast of Andhra Pradesh since at least
Early Cretaceous when the first marine deposit in the form of Raghavapuram
Shales were laid down. The various marine formations in the region do not re-
present the complete sequence of marine strata since the advent of the Early
Cretaceous sea but are the result of sporadic invasions of the sea, stationed nearby.
At times, when fresh-water conditions prevailed in the region, i.e., during Tirupati
and Rajahmundry times, it is evident that marine sedimentation must have taken
place in the adjacent sea and, therefore, the marine facies of Tirupati and Rajah-
mundry Beds are expected to be found towards east and southeast of the region.
Moreover, the sea was constantly present along the coast of Andhra Pradesh since
Early Cretaceous and a complete set of marine beds, ranging from Early Cretaceous
to Recent, should exist in this region as well as in the shelf of the Bay of Bengal,
lying next to it. What we see today as outcrops of different marine formations
is only a fringe of vast stretch of strata deposited under marine environment since
Early Cretaceous. The major part of each formation, whether marine or non-
marine and its contemporary, should lie hidden under the blanket of younger
formations, including alluvium, and might extend in the shelf region of the Bay of
Bengal. A thorough search, surface as well as subsurface, should reveal the presence
of these beds which will provide additional data for solving some important
problems of Indian geology, viz., the upper age limit of the Gondwanas, precise
age determination of the Infra- and the Inter-trappean Beds and the associated
Deccan traps, the nature of the Cretaceous–Tertiary boundary, paleogeographic
reconstructions, etc.
OIL POSSIBILITIES

The Kakinada-Rajahmundry-Masulipatam region of Andhra Pradesh is quite attractive from the economic point also. In India, the oil and gas possibilities have been explored mainly in the Tertiary rocks so far. The Mesozoic rocks have proved to be the major producers of oil and gas in several countries of the world and they hold promise in India also. Unfortunately, they have not received due attention here. The region under consideration is such where Mesozoic-Cainozoic, marine as well as continental, deposits are present. If detailed geological and geophysical investigations are made, there are reasons to expect oil and gas in this region as well as in the adjacent shelf of the Bay of Bengal.

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