SECTION 3
SECTION 3
INFRA-TRAPPEAN BEDS

The Upper Condwana sequence in the vicinity of Pangadi in Andhra Pradesh is unconformably overlain by a 20 m thick set of sedimentary rocks which, in turn, is succeeded by Deccan Trap. These rocks, by virtue of their stratigraphic position, are commonly referred to as Infra-trappean beds (Table 1).

The Pangadi Infra-trappean beds were first scientifically described by Kin in 1880 and since then, they have remained a centre of great attraction to geologists in this country due to their strategic stratigraphic position. A study of these rocks serves a two-fold purpose: 1, it reveals the nature of Cretaceous-Tertiary boundary in the region, and 2, it illuminates the polemical age of the Deccan Trap with which they are closely associated in the area.

The first comprehensive study of the foraminifera from the Infra-trappean beds of the Pangadi area was made by the author (Bhalla, 1966). A rather meagre assemblage comprising eight species, including two new species, was found in these beds.

The paleoecology of the Infra-trappean beds was also studied for the first time by the author (Bhalla, 1966, 1968a) and it was observed that the foraminiferal fauna indicates a shallow marine, inner-neritic environment of deposition for them. In a subsequent publication, the author (Bhalla, 1968b) made a detailed petrographic study of the limestone belonging to the Infra-trappean beds in order to check the foraminiferal testimony. On combined evidence based on sediments and fossils, it was inferred that the Infra-trappean beds were deposited in a protected, rather warm, well-illuminated, inner-neritic environment which had open sea connections.
The Infra-trappean beds of the Pangadi area have yielded mega- and micro-fossils of marine nature providing clues to their age which remained controversial for a long time in spite of considerable attention paid to this aspect by paleontologists from time to time. It was pointed out by the author (Bhalla, 1966, 1968b) that the balance of foraminiferal evidence favoured a Paleocene age for them. It is now generally agreed that these beds mark the dawn of the Tertiary Era in this part of the country.

REFERENCES

BHALLA, S. K.


FORAMINIFERA FROM THE INFRA-TRAPPEAN BEDS OF THE PANGADI AREA, INDIA

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Abstract—The Infra-trappean beds of the Pangadi area have yielded eight species of foraminifera, including two new species, *Pseudopolymorphina devarapalleensis* and *Planulina bhattai*. The foraminiferal assemblage suggests a shallow marine, inner-neritic environment of deposition. The balance of foraminiferal evidence points to a Paleocene age for these beds.

**INTRODUCTION**

The nature of the Cretaceous-Eocene sequence has been one of the most controversial problems of geology and has engaged the attention of geologists almost all over the world. In India, the Cretaceous-Eocene rocks are widely distributed and are found associated together at several places. An interesting area of the Cretaceous-Eocene succession is found in the vicinity of Pangadi, Andhra Pradesh. In this locality outcrops of Upper Gondwana rocks, Infra-trappean beds, and Inter-trappean rocks are found in a small circumscribed area, and their association with the Deccan Traps make them even more interesting.

The marine Infra-trappean beds of the Pangadi area (Text-fig. 1) occupy an important place in Indian stratigraphy. Their age has been a subject of great controversy since they were first scientifically described (King, 1880). Although some megafossils from these beds have been described, their identifications need revision. The microfossils from these beds have been recorded by Rao & Rao (1935), but the present work deals for the first time with the foraminifera in detail.

Detailed sampling was done at different localities of the exposed Infra-trappean beds in this area with a view to make a comprehensive study of their microfauna, especially foraminifera.

In the present work, the reclassification proposed by Reiss (1963) has been followed for the perforate species of foraminifera, but Pokorny's (1963) classification has been adopted for porcelaneous foraminifera.

Synonymies are reduced to a minimum, arranged chronologically, and indicate only important shifts in the generic names. Further, in order to avoid repetition, the words *et syn.* follow those references in which complete or satisfactory synonymies have already appeared.

Holotypes and paratypes of the new species have been deposited in the museum of the Geology Department, Panjab University, Chandigarh, and their references are designated by a PUGD catalogue number in the text. Hypotypes of previously described species are also housed in the Geology Department of Panjab University.

**LABORATORY PROCEDURE AND TECHNIQUES**

The samples were crushed, boiled in detergents, disaggregated, and finally screened through a set of standard sieves. Microfossils were picked up from the picking tray with the help of a fine...
A sable-hair brush and arranged in squared slides for identification and study.

Particular attention was given to the structure of wall because in recent years a great deal of emphasis has been laid on this feature of calcareous foraminifera: the techniques described by Wood (1963) have been followed. The specimens were cleaned, immersed in absolute alcohol to remove moisture, and were placed in xylene contained in a glass slide having a central cavity.

The immersed specimen was examined under cross nicols. The black brushes in the keeled forms having a radially built wall were best seen at the periphery by rotating the stage of the microscope. However, in forms having globular chambers, as Vaginulina d'Orbigny, the black cross can well be seen in the centre of the chambers. Where conclusive results could not be obtained with the above-mentioned methods, thin sections were prepared.
The pores in the walls were studied by immersing the specimen in xylene for about two days in order to remove the air bubbles in the specimen and then crushing it in Canada balsam under a cover slip (Wood, personal communication, 1960).

In order to make the surface features distinct, specimens were stained following the silver nitrate method described by Levinson (1951).

PREVIOUS WORK

The Infra-trappean beds near Pangadi were first reported by King (1874, p. 199), who also King (1880, p. 233) gave a check-list of the fossils identified by Hinsho. He (King, 1880) gave a detailed account of the geology of the Rajahmundry area and made passing references to the studies of earlier workers. He (King) considered these Infra-trappean rocks to be of marine origin and to have Upper Cretaceous affinities.

Medlicott & Blanford (1879, p. 116), while discussing the fossil fauna and the age of the Infra-trappean beds of this area, observed, "Although the whole face is tertiary, there is a remarkable absence of characteristic genera, and the chief distinction from the cretaceous fauna of the upper beds in South India is simply the want of any marked cretaceous form. The fauna is distinctly marine." Discussing the evidence concerning the age of the Infra-trappean rocks of this region, these authors (ibid.) considered them to belong to "... cretaceous times than to tertiary. They may be of intermediate age." Their views were supported by Oldham (1891).

Das Gupta (1933) collected Surgeon's Notice of Achelela from the Infra-trappean rocks of Pangadi and suggested that these beds were of Late Cretaceous age.

Kao & Rao (1935) reported for the first time foraminifera, Rotalia Lamarck, Pseudolla Parker & Jones, Planulina, Brudy, Globigerina d'Orbigny and some millioids and radiolarians, from the Infra-trappean rocks of this region. They correlated these beds with the Utraturu (Cenomanian) of Trichinopoly on foraminiferal evidence. However, they did not give specific identifications, descriptions, or illustrations of these fossils. Except for some unidentifiable millioid muds, the author did not find any specimens which could be referred to any of the above-mentioned genera. Reliance cannot be placed on identifications made by Rao & Kao (1935).

Rao and others (1936), while discussing the age of the Decan Traps near Rajahmundry, concluded that the Infra-trappean beds are of very late Cretaceous age.

L. Rama Rao (1950, 1964), while discussing the problems pertaining to the Cretaceous-Eocene boundary, discouraged drawing a sharp boundary between the Cretaceous and the Eocene and suggested instead the use of the term "Crococene" for the transitional horizon separating the Cretaceous from the Eocene.

L. Rama Rao (1953) reviewed the problem of "Danian" with special reference to India, and on the evidence of Cardita bengalensis considered the Infra-trappean beds to be of "Danian" age. He observed (ibid., p. 361) that the "... Danian beds are best considered as occupying a part of the "passage" between the Cretaceous and Eocene without assigning to either of these systems". These views were maintained by him in a later publication (Rao, 1964).

The same author (L. Rama Rao, 1956, p. 230) considered the Infra-trappean beds, "... as belonging to the uppermost part of the Cretaceous, almost on the border line between that system and the Tertiary". He has further pointed out (ibid., p. 231) that "... the Rajahmundry Cretaceous beds below the Traps are of Danian age ...", thus by implication including the "Danian" in the Cretaceous. This is apparently in contradiction with his earlier view (L. Rama Rao, 1953).

Pascow (1959, p. 126) has given a comprehensive list of the fossils so far recorded from Infra-trappean rocks. The list includes the following: Turritella danaeensis Stoliczka, Navitha Line Cardita (Venericirica) testudin a d'Orbigny, Rostellum Lamarck, Escaluctus Lamarck, Pseudila Lamarck, Glycymeris Lamarck, Lacthe Lamarck (a chelostome bryozoan), and other fossils.

GEOLOGY OF THE AREA

Pangadi (Survey of India, Toposheet No. 65G, 12. 17° 1'-18° 39" 0'"") is a small village in the West Godavari district of Andhra Pradesh. The Pangadi area is of great geological interest because it is here that the trap rocks rest directly on the marine, fossiliferous Infra-trappean beds. The stratigraphic position of the Infra-trappean beds in this area follows:

<table>
<thead>
<tr>
<th>Rock unit</th>
<th>Rock type</th>
<th>Geologic age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decean Traps</td>
<td>Volcanic</td>
<td>Early Eocene</td>
</tr>
<tr>
<td>Infra-trappean</td>
<td>Marine</td>
<td>Eocene unconformity</td>
</tr>
<tr>
<td>beds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tirupati Sandstone</td>
<td>Fresh-water</td>
<td>Late Cretaceous</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Early</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cretaceous)</td>
</tr>
</tbody>
</table>

The Infra-trappean beds overlie the Tirupati sandstones and are in turn overlain by the Decan Traps. However, the exact contact of the
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Tirupati sandstones and the infra-trappean beds are not exposed in the area.

Two good exposures of the infra-trappean beds were noticed in the area: one, is about 0.5 mile southeast of Devarapalle in a small valley cutting near a pond on the Devarapalle-Lakshmiparam footpath (Locality P), and the other is 0.5 mile south of Duddukuru (Locality Q).

The outcrop at Devarapalle is small: the base of the section is not seen; and the succession at Locality P follows.

Sample number

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Thickness in feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trap rock: weathered, dirty green in color, fine-grained, friable</td>
<td>3</td>
</tr>
<tr>
<td>Infra-trappean rocks</td>
<td></td>
</tr>
<tr>
<td>Limestone: yellowish, hard, compact, and containing many specimens of Turritella (Turritella Zone)</td>
<td>0.5-2</td>
</tr>
<tr>
<td>Sand: green, soft, and fossiliferous</td>
<td>1.5</td>
</tr>
<tr>
<td>Trap rock: weathered, dirty green in color, fine-grained, friable</td>
<td>3</td>
</tr>
</tbody>
</table>

Bed Number 3 varies greatly in thickness. In places it is totally absent and thus allows the trap to overlie directly bed Number 2. This probably indicates an erosional unconformity between the infra-trappean beds and the traps.

The following sequence of infra-trappean rocks was observed about 0.5 mile south of Duddukuru (Locality Q), where the base of the section was not seen.

Sample number

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Thickness in feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trap rock: greenish, friable, weathered</td>
<td>3</td>
</tr>
<tr>
<td>Infra-trappean rocks</td>
<td></td>
</tr>
<tr>
<td>Limestone: yellowish, hard, compact, sandy, and containing many specimens of Turritella (Turritella Zone)</td>
<td>0.7-1</td>
</tr>
<tr>
<td>Sand: green, soft</td>
<td>2-3</td>
</tr>
<tr>
<td>Sandstone: calcareous</td>
<td>&gt;4.0</td>
</tr>
</tbody>
</table>

The basal sandstone (bed Number 1) can be seen extending from near the village Duddukuru to the junction between the traps and the limestone 0.5 mile south of the village.

A short note reporting new species of foraminifers from these infra-trappean beds has been sent for publication, but the detailed description of each species is given below.

SYSTEMATIC PALEONTOLOGY

Order Foraminifera d'Orbigny, 1826
Superfamily MILIOLIDEA Glaessner, 1945
Family MILIOLIDAE Ehrenberg, 1839
Genus QUINQUELOCULINA d'Orbigny, 1826
QUINQUELOCULINA SP. A
Pl. 40, fig. 1

Description.—Mold small, nearly oval, more or less triangular in end view, having a broadly rounded periphery; sutures more or less well marked, depressed; chambers distinct, slightly inflated, peripheral chambers nearly cylindrical, aperture end not protruded but somewhat truncated. Dimensions in mm.: length, 0.37; breadth, 0.30; and maximum thickness, 0.30.

Discussion.—A single internal mold, which may be unquestionably referred to Quinqueloculina brevidentata Le Calvez, 1947 from the Middle Eocene (Lutetian) of France, was found.

Occurrence.—Sample P/3.

QUINQUELOCULINA SP. B
Pl. 40, fig. 2

Description.—Mold elongate, nearly twice as long as broad, more or less oval in end view; chambers distinct, inflated, four visible on one side and three on the other side, peripheral chambers cylindrical; sutures distinct, somewhat depressed; aperture end slightly projecting; periphery broadly rounded. Dimensions in mm.: length, 0.48; breadth, 0.25; and maximum thickness, 0.25.

Discussion.—The solitary internal mold could not be assigned to any known species of Quinqueloculina.

Occurrence.—Sample P/3.

Superfamily Nodosariidae Ehrenberg, 1839
Family Nodosariidae Ehrenberg, 1839
Subfamily Nodosariinae Ehrenberg, 1839
Genus VAGINULINA d'Orbigny, 1826
emend. Marie, 1941
VAGINULINA cf. V. CENOMANA Perner, 1892
Pl. 40, fig. 3

Description.—Test free, elongate, flattened; dorsal margin more or less straight; ventral...
margin gently convex; periphery smooth and rounded; chambers five; proloculus spherical; sutures indistinct, slightly curved, somewhat thick; aperture small, radiate, at the dorsal angle. Dimensions in mm: length, 0.47; maximum breadth, 0.20; and maximum thickness, 0.12.

**Discussion.**—Only one specimen was found in the material which strongly resembles *Pseudopolymorphina devakapalleensis* n. sp., showing arrangement of chambers in a megasphere form. In B. Side views; 1c, basal view. ×125.

**Family Polymorphidae d'Orbigny, 1839**

**Subfamily Polymorphinae d'Orbigny, 1839**

**Genus Guttulina d'Orbigny, 1826**

*Guttulina lactea* (Walker & Jacob)

Pl. 40, fig. 6

*G. lactea* Walker & Jacob, 1798, p. 637, Pl. 14, fig. 2.

*Cushiania Cushnan & Ozawa, 1930*, p. 43, Pl. 10, figs. 1-4, et, syn., *Brotzen, 1948*, p. 49, figs. 6, 10; *Puri, 1953*, p. 107, Pl. 9, figs. 11, 12; *Haque, 1956*, p. 106, 107, Pl. 28, figs. 6A–C; *Haynes, 1958*, p. 38, Pl. 5, figs. 1, 2.

**Description.**—Test elongate, compressed, oval in end view; greatest width towards the base; apertural end slightly tapering; chambers five, not very distinct, elongate, embracing, reaching back to the base, arranged in a quinquelocular series; sutures distinct, very slightly depressed; wall thick, calcareous; aperture terminal, radiate; surface smooth. Dimensions in mm: length, 0.43; breadth, 0.23.

**Discussion.**—The specimens show close resemblance to the forms described and figured by *Hayes, 1958*. It is a well-known cosmopolitan species and ranges from Paleocene to Recent. From the Paleocene it has been recorded by *Hayes, 1958*, *Brotzen, 1948*, *Haque, 1956*, and others. This is its first record from India.

**Occurrence.**—Abundant in sample P. 9.

**Genus Pseudopolymorphina Cushnan & Ozawa, 1928**

*Pseudopolymorphina devakapalleensis* n. sp.

Pl. 40, figs. 4, 5. Text-figs. 2, 3.

**Description.**—Test elongate, somewhat compressed, ovate having blunt ends; periphery rounded; chambers seven, elongate, fairly well marked, slightly embracing, earlier chambers arranged in a quinquelocular series, later, be-
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TEXT-FIG. 2.—Paratype A of Pseudopolyomporina devarapallensis n. sp. showing arrangement of chambers in a microspheric form. 1a, 1b, Side views; 1c, basal view. X125.

Coming iserial; last chamber occupying nearly half of the test; sutures slightly impressed; aperture terminal, radiate; wall smooth and thick.

Demorphism and variation.—This species is apparently represented by two generations; the microspheric individuals have a small proloculus and as many as nine chambers (Text-figs. 3a-c), and megalospheric individuals have comparatively larger proloculus and as many as seven chambers (Text-figs. 2a-c). The chambers of the microspheric forms are more embracing, and the quadriloculine portion of the test is comparatively well developed compared with the megalospheric individuals. Tests belonging to the two generations do not differ markedly in size.

Variation has been observed in the size of the test as shown by the following measurements in millimeters.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Holotype</th>
<th>Paratype A-Other paratypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>0.73</td>
<td>0.67–0.72</td>
</tr>
<tr>
<td>Breadth</td>
<td>0.32</td>
<td>0.33–0.34</td>
</tr>
<tr>
<td>Thickness</td>
<td>0.33</td>
<td>0.33–0.35</td>
</tr>
<tr>
<td></td>
<td>0.38–0.33</td>
<td></td>
</tr>
</tbody>
</table>

Discussion.—This new species of Pseudopolyomorphina shows some resemblance to Pseudopolyomorphina decora (Reuss) (= Polymorphina decora Reuss, 1863) figured by Cushman and Ozawa (1930, Pl. 24, figs. 6, 8a,b), but differs from it in having an oval shape, comparatively more embracing chambers, a less developed biserial portion, and blunt apertural and basal ends.

Type horizon.—Infra-trappean beds; sample No. P/3; pale sandy limestone.

Type locality.—Infra-trappean beds exposed along the Devarapalle-Lakshmipuram footpath, about 0.5 mile southeast of the Devarapalle village, West Godavari District, Andhra Pradesh, India.

Geological age.—Paleocene.

Repository of type material.—Holotype, PUGD F1218; paratype A, PUGD F1219.

Etymology of trivial name.—This species is named after the village Devarapalle near which the Infra-trappean beds are exposed.

Superfamily BILAMELLIDEA Reis, 1957, emend. 1958
Family CIBICIDAE Cushman, 1927
Subfamily CIBICINAE Cushman, 1927
Genus CIBICIDES Montfort, 1808

Taxonomic notes.—Several publications dealing with the microstructure of the wall of Cibicides have appeared since 1949, but the microstructure of the wall of this genus is still not clearly understood.

Wood (1949), in his significant work on the wall structure of foraminifers, erroneously placed the type species of Cibicides Cibicides refugens (Montfort), 1808, in the Perforate
FORAMINIFERA FROM PANGADI AREA, INDIA 349

Granulate' group, but later Wood & Haynes (1957, p. 46) modified the earlier views of Wood (1940) and stated, "The results appear to show that both radial and granular species are included in Cibicides as at present understood." However, they (Wood & Haynes, 1957) considered that the microstructure of the wall, as well as pore character, are of value in classification.

Groves (1951, p. 10) placed great stress on the "...place and the structure of the pores," and considered this character to be "...of high systematic importance.

Reiss (1959, p. 355) has also recorded "granular-calcareous structure" in some species of Cibicides.

Loeblich & Tappan (1961, p. 248) considered, "test wall composition and structure" as the criteria for the separation of superfamilies and included the family Cibicididae in the superfamily Cassidulinacea, which has a granular wall. In a later publication, Loeblich & Tappan (1962, p. 71) restricted the genus Cibicides to include "radially built bimembrilid wall."

Cifelli (1962, p. 125) in his studies on Ammonites has shown that in this species the test wall is radial but the septa are of granular microstructure and concluded, "Clearly, the nature of the wall at least as it is presently understood, cannot alone provide a natural basis for classifying the hyaline Foraminifera." A similar opinion was expressed by Wood and Haynes (1957), "The evidence as to the value of the wall structure in classification is yet inconclusive."

Although all species of Cibicides in the present work have a radial wall, the author, in view of the foregoing discussion, believes that the genus Cibicides should include forms that may have either a radial or a granular wall.

Cibicides mensilla (Schwager) Pi. 40, fig. 10

Discorbina mensilla Schwager, 1883, p. 123, Pl. 28(5), figs. 1a-c.

Cibicides manifestus Bandy, (non Nuttal), 1944, p. 375, Pl. 62, figs. 1a-c.

Cibicides mensilla (Schwager) Haque, 1956, p. 203, Pl. 20, figs. 1a-c.

Description.—Test small, trochospiral, plano-convex, nearly circular in outline; dorsal side evolute, flat, ventral side convex having moderately developed umbilical plug; some specimens also having an umbilical boss of clear shell material on dorsal side; chambers non-inflated, distinct, increasing gradually in size with growth, 7 to 10 in last coil; sutures clearly marked, poreless, backward curving, limbate; dorsal sutures flush with surface, ventral sutures in some specimens very slightly depressed in last two or three chambers, spiral suture clearly visible; dorsal pores coarse having very fine ones in between, ventral pores very fine having a few coarse ones scattered on the last three or four chambers; periphery subacute showing poreless keel, very slightly lobulate in last three or four chambers, in some forms entire; aperture interiomarginal, peripheral, extending a short distance along the spiral suture on the dorsal side; wall calcareous displaying radial microscopic nature.

Discussion.—Two groups of protoloculus are observed; one possibly represents microspheric individuals and has a diameter of 16μ and the other possibly represents megasospheric forms and has a diameter ranging from 30μ to 33μ. The development of chambers in the two groups does not differ markedly. The microspheric forms generally have 10 chambers in the first whorl followed by eight in the second whorl, while the megaspheric forms have nine chambers in the first whorl and eight chambers in the second whorl.

Both sinistral and dextral tests have been found and their ratio of occurrence is nearly equal. Average diameter of coarse pores on the dorsal side is 5μ. Other dimensions in millimeters are given below.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Adult specimens</th>
<th>Juvenile specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major diameter</td>
<td>0.18 to 0.33</td>
<td>0.13</td>
</tr>
<tr>
<td>Minor diameter</td>
<td>0.17 to 0.28</td>
<td>0.12</td>
</tr>
<tr>
<td>Thickness</td>
<td>0.10 to 0.15</td>
<td>0.08</td>
</tr>
<tr>
<td>Diameter of proloculus</td>
<td>16μ to 33μ</td>
<td></td>
</tr>
</tbody>
</table>

Discussion.—The specimens strongly resemble Cibicides mensilla (Schwager), first described from the "Eocene" of the Libyan desert. Recently, Haque (1956) recorded it from the lowermost Laki beds (upper Paleocene) of Namal gorge, West Pakistan. The Indian specimens are apparently similar to those described by Haque (1956) from Pakistan and probably come within the range of variation of the species. In the present forms, however, the dorsal sutures are not depressed, and the dorsal convexity is not as developed as shown in Haque's figure (1956, Pl. 20, fig. 11c). The degree of convexity, however, is not considered to be of much significance in Cibicides because it is generally an attached form and shows considerable range of variation (Bhatia, 1956; Nyhalm, 1961).

Cibicides castelliformi Haynes, 1957, described from the Thanet Beds (Paleocene) of East Kent, England, differs from the present form in being much larger, in having nonliminate ventral pu-
I: Dorsal view of a megalospheric form of *Pianulina hatiai* n. sp. X80.

**Dorsal view of a microspheric form of *Pianulina hatiai* n. sp. X80.**

Texture showing lappets at the aperture, and granular microstructure of the test wall. From *Cenidices casserellanus* var. *buxtorff* Haynes, 1927, also described from the Thanet Beds, the present species differs in having noninflated chambers, subacute periphery, aperture without lip, limbate ventrai sutures, and radial wall.

**Occurrence.**—Abundant in samples P/3 and Q/3.

**Cenidices sp. indet.**

**Pl. 40 fig. 9**

**Description.**—Test concavo-convex, nearly circular in outline, dorsal side evolute, somewhat convex, ventral side involute and slightly concave, ventral plug not well developed; periphery lobulate, rounded, slightly keeled; chambers, including proloculus, nine in the first coil and eight in the second coil, distinct, slightly inflated, enlarging gradually with growth; last chamber broken; dorsal sutures curved, well marked, slightly depressed, nonlimbate; ventral sutures curved; both sides of test finely perforate, radial, smooth. Dimensions in mm.: maximum diameter, 0.30; thickness, 0.13; proloculus diameter, 26u.

**Discussion.**—A solitary, broken specimen was found in the material. It may be questionably referred to *Cenidices pharaoa* described by LeRoy (1923) from the Eocene of Egypt. Occurrence.—Sample P/3.

**Genus Planulina d'Orbigny, 1926**

**Planulina hatiai** n. sp.

**Pl. 40 figs. 7,8; Text-figs. 4,5**

**Description.**—Test discoidal, trochospiral, bi-evolute, dorsal side more so than the ventral; test consisting of two whorls, the first having ten chambers (including the proloculus), the second having seven chambers; chambers distinct, increasing fairly rapidly in size; sutures well marked, limbate, slightly depressed, curved, especially in the second volution; periphery entire, except for slight lobation in the last two chambers; keel faint, imperforate; umbilical side slightly depressed; aperture equatorial, interiromarginal, and arch-shaped having slight lip, extending on to the umbilical side; wall calcareous, moderately perforate on both sides, radial, smooth.

**Dimorphism and variation.**—About one hundred specimens of this new species were examined to trace out the dimorphic generations. The average diameter of megalospheric proloculus is 26u, but the average diameter of the proloculus in microspheric forms is 12u. The periphery is generally entire in microspheric forms but in megalospheric individuals it is lobulate. Slight variation has been observed in the lobulation of the periphery and the prominence of the keel. The periphery of the last two or three chambers is generally lobulate, and the poreless keel is normally not very well marked.

**Average diameter of the pores is 2u. Other dimensions in millimeters are given below.**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Holotype</th>
<th>Paratype A</th>
<th>Paratype B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major diameter</td>
<td>0.30</td>
<td>0.31</td>
<td>0.18 to 0.37</td>
</tr>
<tr>
<td>Minor diameter</td>
<td>0.25</td>
<td>0.25</td>
<td>0.13 to 0.29</td>
</tr>
<tr>
<td>Thickness</td>
<td>0.08</td>
<td>0.10</td>
<td>0.07 to 0.12</td>
</tr>
<tr>
<td>Diameter of proloculus</td>
<td>26u</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Discussion.**—This distinctive new species of *Planulina* shows some resemblance to *Planulina caribana* described by Cushman (1931) from the Montego Bay, Jamaica, West Indies but differs in being smaller, less compressed, and having moderately sized perforations on both sides. From *Planulina heterotropha* Ehrenberg, 1854, described from the Cretaceous of Egypt, this new species differs in having gently curved sutures and comparatively coarsely punctate test. Definite comparisons cannot be made with *P.*
FORAMINIFERA FROM PANGADI AREA, INDIA

The Infra-trappean beds contain a meagre microfossil fauna comprised of molds of miilolids, *Vaginalina*, *Guttulina*, *Pseudopoliomorpha*, *Cibicides*, *Planulina*, and ophiuroid ossicles. In this assemblage, only *Planulina* is abundant, and the other forms are either rare or common. Of these, two species, *Pseudopoliomorpha devrapaliensis* and *Guttulina bhatiai*, are new, and the others, except *Guttulina lactea* (Walker & Jacob), are extinct. The microfossil assemblage is associated with *Turritella* (abundant), *Destria*, *Nautilus*, *chelae* of crabs, and other megafossils. Because of the limited number of species and the lack of forms having definite ecological significance, environment under which these beds were deposited cannot be deduced precisely. The new species cannot be taken into consideration for paleoecological deductions. Some broad generalizations, however, regarding the paleoecology of the area, can be made.

Paleoecology

The Infra-trappean beds of the Pangadi area contain a meagre microfossil assemblage. In all, eight species of foraminifera (Text-fig. 6) were found, of which one belongs to the family *Nodosariidae*, two each to the families *Polymorphidae* and *Miliolidae*, and three to the family *Cibicides*. The foraminifera on the whole are rare, except *Cibicides mensilla* and *Planulina bhatiai* n. sp. which are found abundantly.

The miliolids are represented only as molds. *Quinqueloculina* sp. A. may actually belong to *Q. tremodesmis* an Eocene species but, because actual foraminiferal tests were not found, no specific comments can be made on this. Only one specimen of *Vaginalina* has been found which shows some resemblance to *V. cenomanica*, which was described originally from the Cenomanian of Czechoslovakia.

The occurrence of *Guttulina lactea* and *Cibicides mensilla* is significant. The former species is cosmopolitan and ranges from Paleocene to Recent. The Indian specimens show close resemblance to the Paleocene forms figured and described by Haynes (1958) from the Thanet beds of England and by Haque (1956) from the Paleocene of West Pakistan. *Cibicides mensilla*, which is found abundantly in this material, was abundant; *Turritella* associate with...
first described from the "Eocene" of the Libyan desert. Bandy (1944) recorded it from the Eocene of Cape Blanco, Oregon. U.S.A. Recently, Bandy (1956) reported it from the lowermost part of the Upper Paleocene of Nambal gorge, West Pakistan.

The megafossiliferous beds in the infra-trappean beds have not been studied in detail. It is not certain whether the majority of the species belong to Cretaceous or to Tertiary. Das Gupta (1933) on the basis of Cardita bennisi from these beds, considered them to belong to the upper part of the Upper Cretaceous. Detailed investigation by Kutsch (1936, non radii), however, on the so-called "C. bennisi" from different parts of the world shows that "C. bennisi" exhibits a wide range of variation and ranges from Maastrichtian to Middle Eocene. Unless the "C. bennisi" from the infra-trappean beds is thoroughly restudied, little reliance can be placed on this species for ascertaining the age of these sediments.

Many workers consider these beds to be of Damian age, but in recent years, Damian is favoured to be included in the Paleocene rather than in the Cretaceous.

The infra-trappean beds are separated from the Inter-trappean rocks by a definite early Eocene age by 40 feet to 50 feet of Traps and a slight unconformity. On this basis, the infra-trappean beds are not likely to be older than Paleocene. Although the balance of foraminiferal evidence indicates a Paleocene age for the infra-trappean strata, the faunas are too meagre to suggest any definite age for these beds. The conclusive evidence must come from the megafossils which are abundant but need a detailed and thorough revision.

Acknowledgements

The author is grateful to Professor M. R. Sahni, formerly Head of the Geology Department, Panjab University, Chandigarh, and now Honorary Professor of Geology, Panjab University, for his constant encouragement and constructive comments. I am indebted to Dr. S. P. Bhatia of the Panjab University Geology Department for his guidance and help. To Dr. V. K. Srivastava, Geology Department, Aligarh Muslim University, I am grateful for his helpful criticism and useful suggestions. I am...
A NOTE ON FORAMINIFERA FROM THE INFRA- AND INTER-TRAPPEAN BEDS OF THE PANGADI AREA

S. N. BHALLA
A NOTE ON FORAMINIFERA FROM THE INFRA- AND INTER-TRAPPEAN BEDS OF THE PANGAD1 AREA

S. N. BHALLA *

A detailed investigation of the Foraminifera from the infra- and the inter-trappean beds of the Pangadi (17° 1' : 81° 39' 02") area was undertaken by the author. This area was chosen particularly because the outcrops of the infra-trappeans, the inter-trappeans, and the Deccan traps were found closely associated within a comparatively small area, and it was felt that a detailed study of these rocks would help in solving some important riddles of Indian geology, namely, (1) the nature of the Cretaceous-Tertiary sequence in this region, and (2) the age of Deccan traps in this part of India. The present note gives a concise account of the author's main findings.

The general sequence of various rock units in the area is as follows:

<table>
<thead>
<tr>
<th>Geologic age</th>
<th>Rock unit</th>
<th>Rock Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Eocene</td>
<td>Inter-trappean beds</td>
<td>Estuarine to shallow epineritic</td>
</tr>
<tr>
<td></td>
<td>unconformity</td>
<td>Volcanic</td>
</tr>
<tr>
<td>Paleocene</td>
<td>Infra-trappean beds</td>
<td>Marine</td>
</tr>
<tr>
<td></td>
<td>unconformity</td>
<td>Fresh-water and paralic</td>
</tr>
<tr>
<td>Lower Cretaceous</td>
<td>Upper Gondwanas</td>
<td></td>
</tr>
</tbody>
</table>

I. Infra-trappean beds: The infra-trappean beds of the Pangadi area are marine in nature and overlie the Tirupati sandstones (Upper Gondwanas) with an unconformity. The infra-trappean band extends for about six miles and consists mainly of sandstones and fossiliferous limestones.

The study reveals the presence of eight species of Foraminifera in these infra-trappean beds. The species are: *Quinqueloculina* sp. A, *Quinqueloculina* sp. B, *Vaginulina* cf. *V. cenomana* Perner, *Guttulina lactea* (Walker & Jacob), *Pseudopolyplorhina devarapalleensis* Bhalla, *Cibicides mensilla* (Schwager), *Cibicides* sp. indet., and *Planulina bhatiai* Bhalla.

The foraminiferal fauna indicates a warm, marine, and inner neritic environment of deposition. The assemblage, on the whole, favours a Paleocene age for the infra-trappean beds.

The Pangadi area affords a good site for the demarcation of Creta-
ceous-Tertiary boundary in this part of the Deccan. The infra-trappeans are Paleocene in age and overlie the Tirupati sandstones of the Upper Gondwanas with an unconformity. The age of the Tirupati sandstones is considered to be Lower Cretaceous on the basis of plant fossils and stratigraphical considerations. Thus, it becomes evident that the Tirupati sandstones are of Lower Cretaceous age whereas the infra-trappean beds are of Paleocene age; and the unconformity between the two marks the Cretaceous-Tertiary boundary in the area.

II. Inter-trappean beds: The inter-trappean band of the Pangadi area is sandwiched between the flows of the Deccan traps and is mainly composed of limestones with some shale partings. The inter-trappeans contain a prolific and interesting assemblage of both plant and animal fossils.

A fairly rich assemblage of Foraminifera comprising of eighteen species, was recovered from these inter-trappean beds. The species are: Bathysiphon eocenicus Cushman & Hanna, Quinqueloculina sp., Triloculina decipiens Reuss, Vaginulina icenii Haynes, Fissurina laevigata Reuss, Globulina inaequalis Reuss, Virgulina cf. V. dubia Haque, Epistominella dubia Haque, Protelphidium adamsi Bhalla, Protelphidium dudhakuraense Bhalla, Rosalina sp. cf. R. depressa d’Orbigny, Rosalina siburlareboana (Rzebak) Nonion kingi Bhalla, Rosalina sphereuligera (Schwager). Discorbis toddae Bhalla, Globorotalia (Globorotalia) sp., Globorotalia (Turborotalia) sp. cf. G. (T.) centralis Cushman and Bermúdez, and Cibicides reinholdi ten Dam.

The foraminiferal fauna, supported by ostracode fauna, indicates the prevalence of alternating marine and brackish-water conditions of deposition for the inter-trappean beds of the Pangadi area. There are two brackish-water units; the sedimentation commenced with a brackish-water environment.

The foraminiferal assemblage of the inter-trappean beds of this area consists of species which have been recorded from various Tertiary horizons of the world. However, the overall predominance of Eocene species, supported by other microfossils, indicate a Lower Eocene age for the inter-trappean beds of the Pangadi area. The present study supports the views of Rao et al. (1936) that the Pangadi inter-trappeans are of Eocene age. Due to the absence of marker species of Foraminifera, it has not been possible to fix precisely the age of these beds within the Lower Eocene.

Age of the Deccan Traps: The early flows of the Deccan traps of the Pangadi area lie in between the infra-trappean and the inter-trappean beds. The infra-trappeans are of Paleocene age whereas the inter-trappeans have been assigned a Lower Eocene age. This indicates that the lava of the lower flows of the Deccan traps started pouring out during early Eocene times in this part of the country. Rao et al. (1936) discussed in detail the relationship of the outlier of the Deccan traps at Pangadi with the main body of the traps in Central India and concluded that the Pangadi traps are homotaxial with the lowest traps in Central
India. The Pangadi traps are of early Eocene age which would, then, suggest that the igneous activity of the Deccan traps in the Indian subcontinent started at the dawn of the Eocene epoch.

REFERENCE

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CRETAESSUS-TERTIARY BOUNDARY IN THE PANGADI AREA, WEST GODAVARI DISTRICT, ANDHRA PRADESH

S. N. BHALLA
Department of Geology, Aligarh Muslim University, Aligarh

ABSTRACT

The Cretaceous-Tertiary boundary in the Pangadi area, Andhra Pradesh, is discussed in the light of the foraminiferal evidence obtained from the infra-trappean beds exposed in the region. The Foraminifera, though poor in number and frequency of species, indicate the prevalence of a shallow marine, inner-neritic condition of sedimentation. The assemblage favours a Palaeocene age for the infra-trappean beds. On this basis, the overlying flows of the Deccan Traps are regarded to be of early Eocene age.

INTRODUCTION

The demarcation of boundaries, whether political or natural, has always been a ticklish problem. Of all the boundaries in the geological column, the one between the Cretaceous and the Tertiary or, to be more precise, that between the Cretaceous and the Palaeocene, is, perhaps, the most controversial and at the same time a very interesting problem of world stratigraphy. The problem of the Cretaceous-Tertiary boundary has attracted the attention of not only the palaeontologists who are considered to be at the helm of the affair, but also of sedimentologists, geochronologists, and petrologists from different parts of the world. However, it is interesting to note that in spite of different criteria employed and detailed work done throughout the world, no amicable agreement regarding the Cretaceous-Tertiary boundary has yet emerged.

In southern India, a few good exposures of marine Cretaceous-Tertiary sequence containing attractive fossil assemblages are present. In the vicinity of Pangadi in the West Godavari district of Andhra Pradesh, an interesting set of sedimentary rocks, underlying the Deccan Traps, is present which is commonly referred to as the infra-trappeans. These infra-trappeans are important from the stratigraphical point of view because a detailed study of these rocks serves a two-fold purpose: (1) it reveals the nature of the Cretaceous-Tertiary sequence in this region, and (2) it throws considerable light on the age of the Deccan Traps with which they are closely associated in the area.

The age of the infra-trappean beds of the Pangadi area has been a subject of controversy ever since these were brought to the attention of Indian geologists by William King in 1874. The majority of workers consider it to be of topmost Cretaceous age. The rocks contain abundant marine fossils and it is rather unfortunate that except for one or two reports on the fossils from these beds, no detailed work on the fossil fauna has yet been made.

The recent advances in our knowledge of Foraminifera, especially the planktonic group, have proved that they are the best tools in local as well as long distance correlations. Parker (1965) pointed out certain irregularities in the distribution of planktonic Foraminifera but, maintained that in spite of the irregularities, they are
excellent for stratigraphic correlations. Since the last decade, an intense micro-
palaeontological activity has been generated by the workers on Foraminifera to
demarcate the Cretaceous-Tertiary boundary. The most interesting point arising
out of their studies is the inclusion of the Danian in the Paleocene. Not only the
Foraminifera, but other groups of microfossils also, including calcareous nanoplankton, support this view. However, it is beyond the scope of the present paper
to discuss the position of Danian in the geological time scale, especially when the
whole problem of the Cretaceous-Tertiary boundary, including that of the Danian,
has been critically reviewed in a recent publication by Rama Rao (1964). The
author agrees with the view that the Danian marks the basal stage of the Paleocene.

It was therefore, considered that a detailed study of the Foraminifera, from the
infra-trappean beds of the Pangadi area would greatly advance our knowledge
regarding the age and palaeoecology of these beds which, in turn, would throw light
on the nature of the Cretaceous-Tertiary boundary, and also on the age of the overlying flows of the Deccan Traps in this area. With this end in view, detailed
sampling of these infra-trappean beds was done to make a comprehensive study of
the Foraminifera entombed in these sediments.

HISTORICAL RESUME

The infra-trappean beds of the Pangadi area occupy an important place in Indian
stratigraphy. The beds were discovered by King in 1874 and their fossil content was
studied by Rev. Hislop. King (1880) in his monumental work on the geology of the
Rajahmundry region, dealt with the infra-trappean beds in detail and suggested an
Upper Cretaceous age for them. According to him, these beds were deposited in a
marine environment.

Medlicott and Blanford (1879) opined that the fauna of the Pangadi infra-
trappean beds show Tertiary affinities and that they are of marine origin. However,
they failed to arrive at any definite conclusion as regards the age of these beds.

Das Gupta (1933) described Cardita beaumonti d'Archiac from the Pangadi
infra-trappeans and on this basis assigned these beds to the topmost Cretaceous age.

Rao & Rao (1935) discovered Foraminifera and Radiolaria from the infra-
trappean beds, but neither descriptions nor illustrations were given. On the basis
of the foraminiferal assemblage, they correlated the infra-trappean beds with the
Utattur (Cenomanian) rocks of Trichinopoly area.

Rao et al. (1936) while dealing with the age of the Deccan Traps of the Pangadi
area, considered the infra-trappean rocks to be of Upper Cretaceous age.

Rama Rao (1950) did not consider it desirable to draw a sharp boundary
between the Cretaceous and the Eocene and, therefore, suggested the use of the term
‘Creocene’ for the transition beds which intervene between the undisputed Cretaceous
and the Eocene strata.

On the basis of Das Gupta’s (1933) find of C. beaumonti from the Pangadi infra-
trappeans, he (1953) considered these beds to be of Danian age. As regards the
position of the Danian, he maintained his earlier views (Rama Rao, 1950). In
1956 he considered the infra-trappean rocks of Pangadi to be of Danian age and the
overlying flows of the Deccan Traps, including the inter-trappean beds, to be of early
Eocene age.
Sarkar (1964) revised *Venericardia beaumonti* and allied forms from the Indian sub-continent. He made some taxonomic shifts in certain forms of *V. beaumonti* but retained the form from the Pangadi infra-trappeans, described by Das Gupta (1933), as such.

Mathur & Evans (1964) considered the infra-trappean beds of the Pangadi area to be either of late Cretaceous or of Paleocene age.

Raju *et al.* (1965) suggested an unconformity between the infra-trappean and the underlying Tirupati sandstones on the basis of heavy mineral data. These authors (*op. cit.*) considered the Pangadi infra-trappean beds to be of late Cretaceous age.

Baksi (1965) while discussing the palaeoecology of the infra-trappean beds of Pangadi, considered the lower part of the sequence to be of fluvial deltaic nature, and the upper part to be of estuarine origin.

Bhalla (1966) made a comprehensive study of the Foraminifera from the infra-trappean beds of the Pangadi area and concluded that the assemblage suggested a shallow, marine, inner-neritic environment of deposition. According to him (*op. cit.*), the balance of foraminiferal evidence favoured a Paleocene age for these beds. Besides the Foraminifera, some ostracodes were also found by the author in these beds and are being reported here for the first time. However, due to imperfect state of preservation and paucity of specimens, no systematic work on these could be carried out.

**STRATIGRAPHY**

The stratigraphical succession of the infra-trappean beds of the Pangadi area was worked out by the author at two localities: Locality-A (Pl. I. fig. 1), about half a mile southeast of Devarapalle village; and Locality-B (Pl. I. fig. 2), about half a mile south of Duddukuru village. The sequence is as follows:

- **Deccan Traps (Volcanic)**
- **Lower Eocene**
  - **Locality-A**
    - 3. Compact, yellowish limestone full of *Turritella* 6" to 2'
  - **Locality-B**
    - 3. Compact, yellowish limestone with abundant *Turritella* 8" to 1'
- **Infra-trappeans (Marine)**
  - **Locality-A**
    - 2. Sandy limestone (fossiliferous) 1' 6"
  - **Locality-B**
    - 2. Soft sands 2' to 3'
  - **Paleocene**
    - 1. Greenish sands (fossiliferous) 3'
    - 1. Calcareous sandstones 40'
  - **Unconformity**
  - **Tirupati sandstones**
  - **Fresh-water**
  - **Lower Cretaceous**

The top bed (Bed No. 3) of the infra-trappeans at both the localities, is a yellowish, compact limestone. It is interesting from the palaeontological point of view because it is crowded with *Turritella* and other invertebrate shells (Plate 2) and
CRETACEOUS-TERTIARY BOUNDARY IN PANGADI AREA

has yielded the maximum number of foraminiferal species (Bhalla, 1966). It varies considerably in thickness; at some places it is up to 2 feet thick whereas at others, it is completely missing with the result that the Traps come in direct contact with Bed No. 2. This feature of the limestone suggests a possible erosional unconformity between the infra-trappeans and the overlying traps.

Structurally, the area is practically undisturbed. The infra-trappean beds dip with an angle of 6° to 10° towards southeast and overlie the Tirupati sandstones; however, the contact between the two is concealed below the alluvium and is not seen in the area. On the basis of the heavy mineral characteristics of the two formations, Raju et al. (1965) suggested an unconformity between the Tirupati sandstones and the infra-trappean beds. A slight erosional unconformity between the infra-trappeans and overlying flows of the Deccan Traps exists and is indicated by a considerable variation in the thickness of the top bed of the infra-trappean sequence.

PALAEOECOLOGY OF THE INFRA-TRAPPEAN BEDS

The infra-trappean beds of the Pangadi area have not been subjected to detailed palaeoecological investigations in the past. Baksi (1965, p. 145) in a short note on the environment of deposition of the infra-trappean sequence mentioned, "... a definite estuarine condition (from faunal evidence) in its upper part, the lower beds being deposited under fluvial deltaic conditions. ... The nature and volume of the detritus in this formation suggest a slight uplift in the source area ...". However, no faunal evidence for the estuarine nature of the upper part of the infra-trappean beds was given in support of his conclusions.

Bhalla (1966) described eight species of Foraminifera from the Pangadi infra-trappean beds. The foraminiferal assemblage comprise abundant Planulina and Cibicides, and rare to frequent forms of Guttulina, Pseudopolymorphina, Vaginulina, and miliolid moulds. Except for Guttulina lactea (Walker & Jacob), other species are either new or do not live in the modern seas. He (Bhalla, op. cit.) suggested that these beds were deposited in a shallow, marine, rather warm, inner neritic environment having open-sea connections.

Further ecological information is furnished by the presence of abundant ophiuroid ossicles in the topmost bed of the infra-trappean sequence (Bhalla, 1966). The ophiuroids are exclusively stenohaline organisms and most of them favour a near shore, shallow water environment. Thus it corroborates the contention that these beds were deposited under truly marine conditions.

Another evidence supporting the marine nature of the beds is obtained from the work of Rao & Rao (1935) who reported the occurrence of Radiolaria besides the Foraminifera from the infra-trappean beds. The Radiolaria are exclusively marine protozoa and their presence in these beds does not, naturally, support the estuarine origin as postulated by Baksi (1965).

In association with the microfossils, megafossils are also found in the infra-trappean beds. A check-list of the megafossil fauna is given by Pascoe (1959, p.1262). It includes Turritella, Cardita (Venericardia) beaumonti, Volutilithes, Glycimeris, Natica, Rostellaria, Lamulites, Nautilus, Dentalium, Meretrix, chelae of a crab, etc. Of these Turritella is most abundant. The studies of Gardner (1957) show that Turritella is an exclusively marine genus. It is abundant in warm and shallow waters.
of modern seas (Easton, 1960) and favours a near shore, sandy bottom condition (Plummer, 1933). Dentalium is a marine, bentonic genus and prefers a shallow water environment (Ladd et al., 1957). Similarly, Natica is also a marine genus but is found from neritic to abyssal depths (Clarke, 1962; Jung, 1965). The occurrence of chelae of crab suggests a shallow water environment as the modern marine crabs inhabit an approximately 10 to 30 metre depth range.

The petrography of the limestone occurring in the upper part of the infra-trappean beds provides an altogether independent palaeoecological evidence and supports the conclusions of this author drawn on faunal evidences. The limestone is a sandy, packed, biomicrodite (often passing into sandy biomicrocrite) in the terminology of Folk (1962). An important feature of this rock is the presence of large quantities (15% to 35%) of terrigenous material in the sand-grade size which is intimately mixed up with the organic debris (Pl. 2). The land-derived detritus comprise angular grains of quartz and fresh felspars (perthite and acid plagioclase) with minor amounts of red and colourless garnet and actinolite.

Such limestones originate essentially in calm, turbulence-free environments which could be established both in shallow, protected, basins as well as in deep waters. However, the large quantities of sand sized terrigenous material and lack of even small amounts of clay and silt in the rock and, above all, the fauna itself, rule out the possibility of deep sea sedimentation and suggests rather the proximity of land in relation to the basin of deposition. It is obvious that the rock originated in an inner neritic environment, in a somewhat protected basin having open sea connections, where the currents were not strong enough or persistent enough to winnow away the calcite ooze which subsequently got deposited with the shells of the sedentary organisms living in the basin. Estuaries and lagoons, though providing conditions similar to those in protected seas, would not yield the type of sediment described above by virtue of a large contribution of clay and silt which is unavoidable in these environments.

It is indeed possible that the large quantity of sandy material in limestone is due to uplift in the source area which must have consisted of crystalline schists and gneisses. This uplift, perhaps, was contemporaneous with limestone sedimentation or might have been slightly later and was responsible for creating conditions unfavourable to carbonate sedimentation. This, then, may explain the limited distribution of this limestone both in space and time and also the presence of such abnormally high amounts of land-derived debris in the rock.

From the foregoing discussion based on fossil as well as sedimentological evidences, it is concluded that these beds were deposited in a protected, rather warm, well illuminated, inner neritic environment which had open sea connection, like the one now existing in parts of the Gulf of Mexico.

EXPLANATION OF PLATE I

1. Infra-trappean beds with the overlying traps, in a nala cutting at locality A, about half a mile southeast of Devarapalle village.

2. Infra-trappean calcareous sandstone (Bed No. 1) at locality B, half a mile south of Duddukuru village.
Bhalla: Cretaceous-Tertiary boundary in Pangadi area
CRETACEOUS-TERTIARY BOUNDARY IN PANGADI AREA

In the Pangadi area both Cretaceous and Paleocene strata are present and an attempt has been made to demarcate the boundary between the two. The lowermost stratigraphic unit in the area is the Tirupati sandstones. The sandstone has been assigned an early Cretaceous age by various workers on the basis of plant fossils as well as on stratigraphic considerations.

The age of the overlying infra-trappean beds has been a matter of controversy ever since they were discovered by King in 1874. As has been stated elsewhere, the majority of workers favour a late Cretaceous age for these beds. They found support from the occurrence of *Cardita beaumonti* which was reported by Das Gupta in 1933, and, thus assigned a Danian age to these beds. In the past, palaeontologists invariably regarded *Cardita beaumonti* as a Danian marker and the Danian was considered as the topmost stage of the Cretaceous. However, the investigations of Rutsch (1936) revealed that *Cardita beaumonti* was not confined exclusively to the Danian but, was a variable form and ranged from Maestrichtian to Middle Eocene. As such, it is hardly of any value as an age marker. In recent years, a majority of foraminifero-ologists consider that the Danian marks the basal stage of the Paleocene.

The typical genera and species of Foraminifera which have been extensively used in demarcating the Cretaceous-Tertiary boundary, are not present in the Pangadi infra-trappeans. However, the foraminiferal assemblage of these beds includes a well known species (Bhalla, 1966) which have been recorded either from the Eocene or from the Eocene of different parts of the world. Among these, *Cibicides mensilla* (abundant), *Guttulina lactea* (frequent), and a mould of *Quinqueloculina* closely resembling *Q. brevidentata*, are of significant value in dating the infra-trappean beds. *Cibicides mensilla* was originally described by Schwager (1883) from the Eocene of Libya and has subsequently been recorded from the Eocene of England by Bandy (1944) and from the late Paleocene of Pakistan by Haque (1956). *Guttulina lactea* is a well known polymorphinid and has been reported from various Tertiary strata of the world. The species of *G. lactea* from the Infra-trappean beds show close similarities with the ones described and illustrated by Haque (1956) from the Paleocene of Pakistan and by Haynes (1958) from the Paleocene of England. The mould of *Quinqueloculina* closely resembles *brevidentata* Le Calvez, described from the Lutetian of France.

The megafossils, ostracodes, radiolaria, and ophiuroid ossicles also occur in the Pangadi infra-trappean beds but need detailed studies before they can be used for dating these strata.

The foraminiferal assemblage, on the whole, favours a Paleocene age for the infra-trappean beds, but due to paucity of forms having precise age records, it is not possible to assign these beds to any particular stage within the Paleocene. However,

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EXPLANATION OF PLATE II

Photomicrograph of the infra-trappean limestone (Bed No. 3) showing ill sorted shell debris in calcite-mud matrix. Note the abundant quantity of terrigenous quartz grains in the sand-grade size and the articulate nature of the shells. The rock is a sandy biomicrudite.
it is certain that the infra-trappean beds represent the dawn of the Tertiary era in this part of India.

The contact between the Tirupati sandstone and the overlying infra-trappean beds is concealed below a vast stretch of alluvium and is nowhere seen in the area. However, Raju et al (1965) on the basis of heavy mineral characteristics of the Tirupati sandstones and the infra-trappean beds, suggested an unconformity between the two.

From the foregoing discussion, it is clear that the Tirupati sandstones are of early Cretaceous age whereas the overlying infra-trappean beds are Paleocene in age; and the unconformity between the two marks the Cretaceous-Tertiary boundary in the area.

The infra-trappeans are unconformably overlain by the flows of Deccan Traps which, in turn, contain the fossiliferous inter-trappean beds. As discussed earlier, the infra-trappean beds are of Paleocene age while the inter-trappeans have been assigned a definite Eocene age by various workers on the basis of fossil evidences. Thus, the flows of the Deccan Traps are sandwiched between the Paleocene infra-trappeans and the Eocene inter-trappean beds. On this basis, it is inferred that the outpouring of the lava of Deccan Traps started in early Eocene times. This conclusion is in harmony with the view expressed by Rama Rao (1956) that the traps, including the inter-trappeans, are of Lower Eocene age.

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