SMALLER FORAMINIFERA FROM THE AGATE-Conglomerates (Burdigalian) of the Surat-Broach Area, Western India

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ABSTRACT—Twenty-six foraminiferal species and varieties are illustrated and described from the Agate-conglomerates (Burdigalian) of the Surat-Broach area, Western India.

INTRODUCTION

The paper gives a systematic account of the smaller Foraminifera from the Agate-conglomerates (Burdigalian) of the Surat-Broach area, Western India. The work was undertaken primarily for the purpose of contributing to the knowledge of the occurrence and distribution of Tertiary Foraminifera of Western India. The study reveals the presence of a rich microfauna, consisting predominantly of Foraminifera, Ostracoda and calcareous algae. Twentysix foraminiferal species and varieties are described in this paper.

The material on which this study is based was collected by Prof. S. R. Narayana Rao during field investigations in the area between the years 1937–41. The authors are grateful to him, not only for the loan of the material but also for his critical reading of the manuscript.

STRATIGRAPHY AND PREVIOUS WORK

The marine Tertiary rocks exposed in the alluvial country between Surat and Broach have attracted great attention since they were first studied by Blanford in 1867. The Miocene (Burdigalian) beds consist predominantly of agate-bearing conglomerates and yellowish brown arenaceous marls. They unconformably overlie the ‘nummulitics’ (Eocene) and at some places even rest directly on the Deccan Traps.

The stratigraphy and palaeontology of these beds have already been described in detail by Blanford (1867), Rao (1939, 1941), Eames (1952) and Rao and Singh (1956).

From the agate-conglomerates, Rao (op. cit.) recognised the following Foraminifera: Lepidocyclina spp., Miogypsina spp., and Austrotrillina howchinii.

Recently, Rao and Singh (op. cit.) described two species of Lepidocyclina—Lepidocyclina (Nephrolepidina) tournouri (Lemoine and Douville) and L. (N.) sumatrensis (Brady) var. taptiensis Rao and Singh. Besides the lepidocyclines, they also recorded the presence of the following Foraminifera: Miogypsina irregularis (Michelotti), M. thecideaformis Rutten, Austrotrillina howchinii (Schlümberger), Nonion sp., Elphidium sp., and Rotalia sp. They considered the agate-conglomerates to be of Burdigalian age and to be equivalent to Upper Gaj of Sind and Baluchistan, Upper Pegu of Burma, and Tertiary ‘f1’ ‘f2’ stages of East Indies.

CHECK LIST OF FORAMINIFERA FROM THE AGATE-
CONGLOMERATES OF THE SURAT- BROACH
AREA

Textularia gramen d’Orbigny
Quinqueloculina lamarckiana d’Orbigny
Quinqueloculina seminulum (Linnaeus)
Triloculina tricarinata d’Orbigny
Triloculina trigonula (Lamarck)
Spiroloculina sp. indet.
Austrotroilina howchinii (Schlumberger)
Pyrgo subsphaerica (d’Orbigny)
Lagena sulcata (Walker and Jacob)
Lagena cf. L. apiopleura Loeblich and Tappan
Glandulina laevigata d’Orbigny
Nonion sp. indet.
Elphidium indicum Cushman
Elphidium minutum (Reuss)
Operculina sp. indet.
Operculinella sp. indet.
Entosolenia laevigata (Reuss)
Bolivina dilatata Reuss
Trifarina sp. indet.
Bucella? sp. indet.
Streblus annecensis (Parker and Jones)
Streblus papillosus (Brady)
Asterigerina dollfusi Cushman
Globigerina bulloides d’Orbigny
Cibicides lobatus (Walker and Jacob)
Cibicides tapanoelensisis Le Roy
Cibicides sp. indet.
Miogypsinia irregularis (Michelotti)
Miogypsinia thecaiformis Rutten
Lepidocyclina (Nephrolepidina) tournoueri (Lemoine and Douville)
Lepidocyclina (Nephrolepidina) sumatrensis Brady var. taptiensis Rao and Singh.

SYSTEMATIC DESCRIPTION

Twenty-six foraminiferal species and varieties are described and illustrated in this paper, following in general Cushman’s classification (1948). Several forms are represented by very poorly preserved specimens of which even the generic identification is not possible; they have accordingly been omitted. The camera lucida sketches were drawn by the authors.

3a, b—Quinqueloculina seminulum (Linnaeus). a, side view: b, apertural view.
4—Spiroloculina sp. indet. side view.
5a, b—Triloculina tricarinata d’Orbigny. a, side view: b, apertural view.
6a, b—Triloculina trigonula (Lamarck). a, side view: b, apertural view.
7a, b—Pyrgo subsphaerica (d’Orbigny). a, side view: b, apertural view.
8—Lagena sulcata (Walker and Jacob). side view.
9—Lagena cf. apiopleura Loeblich and Tappan. side view.
10—Glandulina laevigata d’Orbigny. side view.
11—Elphidium indicum Cushman. side view.
12—Elphidium minutum (Reuss). side view.
13—Nonion sp. indet. side view. x100.
**Explanation of Text-fig. A**

All figures x60, unless otherwise stated.

- **Figs. 1a, b** — *Textularia gramen* d’Orbigny. a, side view; b, apertural view.
- **2a, b** — *Quinqueloculina lamarckiana* d’Orbigny. a, side view; b, apertural view.

(Contd., p. 164)
smooth, somewhat polished, imperforate; aperture oval, with an elongate tooth.

Length 0.30–0.72 mm.; breadth 0.23–0.54 mm.

Remarks: This is a cosmopolitan species—both in the fossil state and in the recent seas. Bhatia (1956) recorded the species from shore sands of various localities in Western India. Frequent in occurrence.

**QUINQUELOCULINA SEMINULUM** (Linnaeus)

Text-figs. A, 3a, b

*Serpula seminulum* Linnaeus, 1758, Systema Naturae, Edn. 10, p. 786.


**Description:** Test of medium size, about 1 1/2 times as long as broad, somewhat oval in outline, broadest and thickest in the middle, triangular in cross section with rounded angles; 5 chambers visible on the outside, arranged in a regular quinqueloculine series; three visible on one side, four on the others; sutures distinct, depressed; wall smooth, imperforate; aperture somewhat oval in shape, with a simple tooth.

Length 0.40 mm.; breadth 0.32 mm.

Remarks: Rare specimens of this cosmopolitan species occur in our material.

**Genus spiroloculina** d’Orbigny, 1826

**spiroloculina** sp. indet.

Text-fig. A, 4

A badly preserved specimen of this genus was found. The bad conservation renders exact determination impossible.

Length 0.45 mm.; breadth 0.32 mm.

**Genus triloculina** d’Orbigny, 1826

**TRILOCULINA TRIGONULA** (Lamarck)

Text-figs. A, 6 a, b


**Description:** Test about twice as long as broad; adult with three visible chambers, rounded-triangular in end view; periphery rounded, sides convex; sutures distinct; wall calcareous, imperforate; aperture with a short bifid tooth.

Length 0.32 mm.; breadth 0.20 mm.

Remarks: A few specimens referable to this species occur in our material. The species is known to range from Eocene to Recent.

**TRILOCULINA TRICARINATA** d’Orbigny

Text-fig. A, 5 a, b


**Description:** This species is similar to *T. trigonula* in all respects except that the periphery is carinate and the test elongate.

Length 0.32 mm.; breadth 0.18 mm.

Remarks: This is a widely distributed species and ranges from Eocene to Recent. It was recorded by Bhatia (1956, p. 19) from several shore samples from Western India. Rare in occurrence.

**Genus pyrgo** Defrance, 1824

**PYRGO SUBSPHÆRICA** d’Orbigny

Text-fig. A, 7a, b


**Pyrgo subsphaerica** (d’Orbigny) Petri, 1954, *Universidade de Sao Paulo, Brazil, Bull. no. 176, Geol. no. 11*, p. 57, pl. 2, figs. 17–19.

**Description:** Test small, inflated, slightly longer than broad; adult with two visible chambers; periphery rounded; sutures distinct, depressed; wall smooth, imperforate aperture oval, with a short bifid tooth partially filling the aperture.

Length 0.47 mm.; breadth 0.41 mm.; thickness 0.41 mm

Remarks: A few specimens referable to this species were found in our material. It has been widely recorded and ranges from Oligocene to Recent.
Family **Lagenidae**

Subfamily **Lagenininae**

Genus *Lagen* Walker and Jacob, 1798

*Lagen sulcata* (Walker and Jacob)

Text-fig. A, 8

*Serpula* (Lagen) *striata sulcata rotundata* Walker and Boys, 1784, Testacea minuta rariors, p. 2, pl. 1, fig. 6.

*Serpula* (Lagen) *sulcata* Walker and Jacob, 1798, Adam's Essays, Kammerer's Edn., p. 634, pl. 14, fig. 5.

*Lagen sulcata* (W. and J.) Parker and Jones, 1865, Philos. Trans., vol. 155, p. 351; Cushman, 1913, *U.S. Nat. Mus.*, Bull. 71, pt. 3, p. 27, pl. 9, fig. 2 (et syn.).

**Description:** Test unilocular, flask shaped with a short neck; wall calcareous, perforate, ornamented with numerous longitudinal costae running the length of the test.

Length 0.34–0.41 mm.; diameter 0.27–0.29 mm.

**Remarks:** This is a cosmopolitan species and ranges from Eocene to Recent. Rare in occurrence.

*Lagen* cf. *L. apiopleura* Loeblich and Tappan

Text-fig. A, 9


**Description:** Test unilocular, pyriform in outline with rounded base; wall calcareous, perforate, ornamented with several longitudinal costae which extend upward from the base and merge into a smooth collar below the neck; aperture terminal.

Length 0.31 mm.; diameter 0.23 mm.

**Remarks:** A single specimen which may be questionably referred to this species was found in our material. It belongs to *L. acuticosta* group.

Family **A polymorphinidae**

Subfamily **Polymorphininae**

Genus *Glandulina* d'Orbigny, 1826

*Glandulina laevigata* d'Orbigny

Text-fig. A, 10


**Description:** Test somewhat fusiform in shape, circular in transverse section; chambers biserial in the early stages, later uniserial; sutures straight; wall smooth, finely perforate; aperture terminal, radiate.

Length 0.34–0.55 mm.; breadth 0.27–0.29 mm.

**Remarks:** This is a cosmopolitan species and ranges from Eocene to Recent. Rare in occurrence.

Family **Nonioeidae**

Genus *Nonio* Montfort, 1808

*Nonio* sp. indet.

Text-fig. A, 13

A solitary specimen of this genus occurs in our material. More specimens are required for specific identification.

Diameter 0.18 mm.; thickness 0.09 mm.

Genus *Elphidium* Montfort, 1808

*Elphidium indicum* Cushman

Text-fig. A, 11


**Description:** Test planispiral, biconvex, somewhat rhomboidal in peripheral view; periphery entire, rounded; chambers numerous, 12–15 in the adult, slightly inflated; sutures indistinct in the earlier portion, later distinct, depressed, gently curved; retrace processes numerous; early portion of
the test with continuous costae parallel to the periphery; aperture numerous at the base of the apertural face.

Diameter 0.52–0.78 mm., thickness 0.25–0.55 mm.

Remarks: The types of this species were from the Recent shore sand at Bombay. Bhatia (loc. cit.) recorded it from Juhu and Chowpatty beach sand, Bombay, and Bhogat beach sand, Saurashtra. The species has not so far been reported in the fossil state. Our specimens are identical with the topotype specimens. Rare in occurrence.

**Elphidium minutum** (Reuss)

Text-fig. A, 12


Description: Test planispiral, involute, periphery rounded, entire; chambers distinct, slightly inflated, 10 in the outer whorl, gradually increasing in size with growth; sutures distinct, depressed, curved; retrol processes distinct, 8–10 in the adult chamber; wall thin, calcareous perforate; aperture a series of pores at the base of the apertural face.

Diameter 0.35 mm.; thickness 0.19 mm.

Remarks: A single specimen referable to this species occurs in our material. It comes within the range of variation of the species. It is known to range from Oligocene to Miocene.

**Family Camerinidae**

**Subfamily Camerininae**

Genus Perculinella Yabe, 1918

**Perculinella sp. indet.**

Text-fig. B, 2a, b

A few indeterminate specimens referable to this genus were found. They appear to be closely related to *O. venosa* (Fichtel & Moll) figured by Jacob and Sastri (1952, p. 343, pl. 14, fig. 1; pl. 16, figs. 18, 19).

Diameter 0.40 mm.; thickness 0.15 mm.

**Family Buliminidae**

**Subfamily Bulimininae**

Genus Entosolenia Ehrenberg, 1848

**Entosolenia laevigata** (Reuss)

Text-fig. B, 3


Description: Test minute, single chambered, bilaterally symmetrical, somewhat pyriform in shape, compressed, tapering towards the apertural end, base broadly rounded, the two sides convex, periphery subacute; wall smooth, somewhat translucent, finely perforate; apertural end slightly drawn out, aperture fissurine, terminal, a narrow elongate slit in the median line.

Length 0.23 mm.; breadth 0.20 mm.

Remarks: This is a cosmopolitan species and ranges from Eocene to Recent. Rare in occurrence.

**Subfamily Virgulininae**

Genus Bolivina d’Orbigny, 1839

**Bolivina dilatata** Reuss

Text-fig. B, 5


Description: Test elongate, about twice as long as broad, compressed, tapering towards the initial end; periphery acute; chambers numerous, biserially arranged; sutures distinct, limbate, oblique, with a
distinct lobe towards the inner angle; wall smooth, finely perforate; aperture narrow, elongate, loop-shaped.

Length 0.28–0.36 mm.; breadth 0.14–0.18 mm.

Remarks: Our specimens are fairly typical of the species. It is known to range from the Upper Oligocene to the Pliocene. Frequent in occurrence.

Subfamily UVIGERININAE
Genus TRIFARINA Cushman, 1923
TRIFARINA sp. indet.
Text-fig. B, 4

A few indeterminate specimens belonging to this genus were found and one of them is figured here. The species somewhat obscurely resembles T. bradyi Cushman.

Length 0.51 mm.; breadth 0.24 mm.

Family ROTALIIDAE
Genus BUCELLA Andersen, 1952
BUCELLA ? sp. indet.
Text-figs. B, 6a–c

Description: Test large, trochoid, dorsal side convex, ventral concave; periphery subacute, lobulate; 7 chambers in the final whorl, rapidly increasing in size with growth, last chamber large and strongly inflated as compared to earlier ones; sutures gently curved on the dorsal side, indistinct in the earlier portion, later distinct, strongly depressed; ventral umbilicus and sutures filled with fine-grained shell material; aperture indistinct, probably at the base of the apertural face; wall calcareous, coarsely perforate.

Diameter 0.60 mm.; thickness 0.20 mm.

Remarks: A single specimen which may be questionably referred to the genus Bucella Andersen occurs in our material. The genus is characterised by the “development of pustules on the ventral side of the test, which conceal the sutures, umbilicus, and basal, anterior margin of the adult chamber” (Andersen, 1952). In our specimen there are no definite pustules, although there is a ‘filling’ of shell material on the ventral side. More specimens are required for a definite identification.

Genus STREBLUS Fischer, 1817
STREBLUS ANNECTENS (Parker and Jones)
Text-fig. B, 7 a, b; 8 a, b

Rotalia beccarii (Linnaeus) var. annectens Parker and Jones, 1855, Philos. Trans., vol. 155, pp. 387, 422, pl. 19, figs. 11a–c.

Description: Test trochoid, biconvex, dorsal and ventral sides equally so; periphery subacute with a distinct keel; chambers numerous, 10–12 in the final whorl, gradually increasing in size with growth; sutures limbate dorsally, slightly raised, gently curved; ventral sutures depressed; ventral umbilicus filled with an umbo or star-shaped shell material; wall thin, calcareous, perforate; aperture consisting of a protoforamen and a deuteroforamen, but usually covered with rock matrix.

Diameter 0.30–0.70 mm.; thickness 0.15–0.38 mm.

Remarks: Both the megalospheric (Text-fig. B, 8) and the microspheric (Text-fig. B, 7) generations were recognised, exhibiting similar characters as those illustrated and described by Bhatia (loc. cit.) in the recent specimens from shore sands of Western India. The Miocene specimens are identical with the recent specimens. It has not previously been recorded in the fossil state.

STREBLUS PAPILLOUS (Brady)
Text-fig. B, 9a, b; Text-fig. C, 1a, b

Rotalia papillosa Brady, 1884, Challenger Rept., Zool., vol. 9, p. 708, pl. 106, fig. 9.

Description: S. papillosus is allied to S. annectens but differs from it in possessing sculptured and beaded dorsal sutures and a double row of beading along the sutures on the ventral side.
EXPLANATION OF TEXT-FIG. B

All figures x60

Figs. 1a, b—O perceptina sp. indet. a, side view; b, peripheral view.
2a, b—O perceptinella sp. indet. a, side view; b, peripheral view.
3—Entosolenia laevigata (Ruess). side view.

(Contd., p. 171)
Diameter 0.32–1.10 mm.; thickness 0.16–0.50 mm.

Remarks: This is a characteristic Indo-Pacific species and our specimens are similar to the recent specimens described by Bhatia (loc. cit.) from shore sands of Western India. The two dimorphic generations were also recognised and are figured here. The species has not previously been recorded in the fossil state.

Family **Amphisteginidae**

Genus *asterigerina* d’Orbigny, 1839

*asterigerina dollfusi* Cushman

Text-fig. C, 2a–c


Description: Test trochoid, circular in outline, plano-convex, dorsal side flat or slightly convex, ventral side strongly convex; periphery subacute, keeled; 2–2½ whorls visible dorsally; chambers numerous, about 8 in the final coil; sutures limbate and oblique on the dorsal side, meeting the periphery at an acute angle, indistinct in the earlier whorls; ventral side with a prominent umbo, flush with the supplementary chambers, sutures rather indistinct; wall calcareous, finely perforate, somewhat polished; aperture ventral, a low arched opening at the base of the aperture face.

Diameter 0.24–0.36 mm.; thickness 0.13–0.16 mm.

Remarks: The types of this species were from the Oligocene (Stampian) of Jeure, Paris Basin. It has also been recorded from the Miocene of various localities in Europe. Our specimens closely resemble those figured by Cushman (loc. cit.). Abundant in occurrence.

Family **Globigerinidae**

Subfamily **Globigerininae**

Genus *globigerina* d’Orbigny, 1826

*globigerina bulloides* d’Orbigny

Text-fig. C, 3


Description: Test subtrochoid, consisting of 1½ to 2 whorls, the last one occupying almost the whole of the test; chambers globular, inflated; wall calcareous, coarsely perforate; aperture large, rounded, in the umbilical region.

Diameter 0.24 mm.

Remarks: This is a cosmopolitan species and has been recorded from Cretaceous to Recent. A single specimen was found in our material.

Family **Anomalinidae**

Subfamily **Cibicidinae**

Genus *cibicides* Montfort, 1808

*Cibicides lobatus* (Walker and Jacob)

Text-fig. C, 4a–c

*Nautilus lobatus* Walker and Jacob, 1798, Adam’s Essays, Kammacher’s Edn., p. 642, pl. 14, fig. 36.

*Cibicides lobatus* (W. and J.) Cushman, 1931, *U.S. Nat. Mus., Bull.* 104, pt. 8, p. 118, pl. 21, figs. 3a–c (et syn.).

Description: Test trochoid, compressed, ventral side convex, dorsal side flattened to concave, 2–2½ whorls visible on the dorsal side; periphery subacute, keeled; 7–9 chambers in the final whorl, fairly rapidly increasing in size with growth; dorsal sutures depressed, curved, somewhat limbate; ventral sutures strongly depressed, curved; umbilicus

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4—Trifarina sp. indet. side view.
5—Bolivina dilatata Reuss. side view.
6a–c—Buccella ? sp. indet. a, dorsal view: b, ventral view: c, peripheral view.
7a, b—Strebulus annectens (Parker and Jones). Microspheric form. a, dorsal view: b, ventral view.
8a, b—Strebulus annectens (Parker and Jones). Megalospheric form. a, dorsal view: b, ventral view.
9a, b—Strebulus papillosus (Brady). Megalospheric form. a, dorsal view: b, ventral view.
EXPLANATION OF TEXT-FIG. C

All figures x60

Figs. 1a, b—Streblus papillosus (Brady). Microospheric form. a, dorsal view; b, ventral view. (Specimen partially covered with rock matrix).

(Contd., p. 173)
hollow; wall calcareous, coarsely perforate; aperture peripheral, extending dorsally along the base of the chambers.

Diameter 0.20–0.40 mm.; thickness 0.12–0.15 mm.

Remarks: It is a cosmopolitan species and shows considerable variation in morphological characters. In our material it appeared impossible to make a separation between *C. lobatulus* and its related species *C. refulgens* and *C. aknerianus*. Both these species appear to be variants of *C. lobatulus*. It is known to range from Eocene to Recent. Frequent in occurrence.

**Cibicides tapanoeliensis** Le Roy

Text-fig. C, 5 a–c


Description: Test of medium size, trochoid, circular in outline, ventral side more convex than the dorsal; periphery subacute, somewhat lobulate in the last few chambers; chambers distinct, 9–12 in the final whorl, gradually increasing in size with growth; sutures distinct, limbate, curved; dorsal side with raised spiral suture, central region filled with clear shell material; ventral side with a distinct umbo; wall smooth, finely perforate; aperture peripheral, extending dorsally along the spiral suture for several chambers.

Diameter 0.24–0.26 mm.; thickness 0.09–0.10 mm.

Remarks: The types of the species were from the Miocene of Central Sumatra. Our specimens are typical of the species and are frequent in occurrence.

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**Cibicides** sp. indet.

Text-fig. C, 6a–c

A few specimens of this diminutive *Cibicides* were found. They have a strongly convex ventral side with a prominent umbo. They might be the juvenile forms of *C. tapanoeliensis*.

Diameter 0.25 mm.; thickness 0.10 mm.

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**References**


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2a–c—*Asterigerina dollfusi* Cushman. a, dorsal view; b, ventral view; c, peripheral view.

3—*Globigerina bulloides* d’Orbigny. Ventral view.

4a–c—*Cibicides lobatulus* (Walker and Jacob). a, dorsal view; b, ventral view; c, peripheral view.

5a–c—*Cibicides tapanoeliensis* Le Roy. a, dorsal view; b, ventral view; c, peripheral view.

6a–c—*Cibicides* sp. indet. a, dorsal view; b, ventral view; c, peripheral view.