

ABSTRACT: The first known occurrence of foraminifera in the Upper Carboniferous marine bed near Manendragarh, central India, is reported. Nine species are recorded, including one new species. The fauna is characterized by the exclusive occurrence of arenaceous forms, which show affinity with contemporaneous faunas from the Pennsylvanian of North America.

Carboniferous (Uralian) foraminifera from Manendragarh, central India

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INTRODUCTION

Until recently, the only known occurrence of marine Paleozoic beds in Peninsular India was that at Umaria, which was discovered by K. P. Sinor in 1921 (*vide* Fermor, 1923). The brachiopod and molluscan fauna was described in detail by Reed (1928), who assigned a Permo-Carboniferous age to the bed. Bhatia and Saxena (1957) reported the first known occurrence of the foraminiferal genus *Hyperammina* (represented by *Hyperammina gracilis* and *Hyperammina* aff. *H. elongata* var. *clavatula*) from this bed.

In a recent publication, Ghosh (1954) reported the occurrence of a small patch of a marine boulder bed at the base of the Talchir series, on the right bank of the River Hasdo, about two and one-half miles northeast of Manendragarh railway station (80° 12' E., 23° 13' N.). The fossil content however, was not described. Datta (1957*a, b*) reported the occurrence of another small patch of a marine boulder bed about one and one-half furlongs upstream from the first outcrop. The fossils recorded by him from this locality are *Eurydesma?* *cordatum*, *Eurydesma?* *globosum*, *Aviculopecten* sp., and *Pleurotomaria nuda*.

According to Datta (1957*b*, p. 6), the marine bed was deposited in the "shallow waters of a transgressive sea which penetrated into central India (South Rewa) during Uralian time." He further suggested that the "*Eurydesma*-*Aviculopecten*-*Pleurotomaria* (*P. nuda*) association favourably, though tentatively, leads to the correlation of the marine boulder bed with the basal part of the lower Speckled Sandstone group, especially of the *Eurydesma* horizon of the Salt Range area." A similar faunal association although not of identical species has also been reported from the late Carboniferous beds of the Salt Range, Kashmir, Australia, and South Africa.

The discovery of this *Eurydesma* horizon in the heart of Peninsular India is of great paleontological, stratigraphic and paleogeographic significance. It not only extends the limits of the previously known Permo-Carboniferous sea in central India, but it also suggests that the marine transgression commenced during Upper Carboniferous (Uralian) time and continued up to the Lower Permian (Artinskian). It is hoped that further discoveries of a similar nature in other parts of central India will help in deciphering the paleogeography of the area, particularly during the Carboniferous and Permian periods.

The authors have made a paleontological collection from the *Eurydesma* bed near Manendragarh, and the present paper deals with the foraminiferal fauna of this bed. The samples were collected during the 1957-1958 field season. The assistance given by their colleague Mr. K. S. Valdiya is gratefully acknowledged. Thanks are also due to Professor S. R. N. Rao for his kind perusal of the manuscript.

LOCATION OF SAMPLES AND STRATIGRAPHY

In all, five samples (M1-M5) were collected from the marine bed exposed at the base of the Talchir series at the locality first discovered by Ghosh, reference to which was made earlier. The stratigraphic section exposed at this locality is given in Table 1.

COMPOSITION AND AFFINITIES OF THE FAUNA

The foraminifera described in the present paper were obtained from sample M3 (green sandy shale) immediately underlying the boulder bed. Although foraminifera were noted also in the overlying beds, they are too fragmentary to be identified specifically. Their description, therefore, has been omitted from this paper.

TABLE 1

	Sample number	Lithology	Thickness	Fossils
Talchir series	M5	Yellowish-green sandstone	5'-15'	<i>Aviculopecten</i> sp., <i>Spirifer</i> sp., <i>Pterinea</i> sp., small gastropods, and fragmentary foraminifera.
	M4	Boulder bed	2'-2'6"	<i>Aviculopecten</i> sp., <i>Eurydesma</i> spp., <i>Pleurotomaria</i> sp., and fragmentary foraminifera.
	M3	Green sandy shales	6"-9"	No macrofossils, but abundant arenaceous foraminifera.
	M2	Green shale	1'	Unfossiliferous, (?)marine.
	M1	Grey limestone	6"-1'6"	Unfossiliferous, (?)marine.
Archean	Granites and gneisses			

In all, nine species are described and illustrated. These include one new species. A check list is given below.

Hyperammina gracilis Waters

Hyperammina aff. *H. bulbosa* Cushman and Waters

Hyperammina aff. *H. clavatula* (Howchin)

Hyperammina sp. indet.

Glomospira articulosa Plummer

Glomospirella umbilicata (Cushman and Waters)

Lituotuba? sp. indet.

Tolypammina polyverta Ireland

Trochammina hasdoensis Bhatia and Singh, n. sp.

The foraminiferal fauna, which is composed exclusively of arenaceous forms, shows a general similarity to those described from the Pennsylvanian rocks of various localities in North America (Cushman and Waters, 1927a, b; 1928; Plummer, 1944; Miller and Swineford, 1957). Four species - *Hyperammina gracilis*, *Glomospira articulosa*, *Glomospirella umbilicata*, and *Tolypammina polyverta* - have been recorded so far only from Pennsylvanian rocks. The remainder of the species also have affinities with related Pennsylvanian forms.

PALEOECOLOGY OF THE SANDY SHALES

As already remarked, the most notable feature of the fauna from the sandy shales is the occurrence, in great abundance, of arenaceous foraminifera, to the exclusion of all other faunal groups. Although arenaceous foraminifera are known to adapt themselves to a wide range of environmental conditions, varying from shallow, brackish water to typical deep marine waters, the presence of numerous coarsely arenaceous forms in an assemblage is generally indicative of a shallow-water depositional environment. None of the species recorded here, however, occurs in present-day seas.

The most abundant species in the present assemblage is the new species *Trochammina hasdoensis*. Although it presumably does not occur in present-day seas, it shows morphological resemblance (deflated chambers and contorted specimens) to certain Recent species whose ecology is known.

Ronai (1955, p. 140) recorded arenaceous forms, consisting of species of the genera *Trochammina* and *Ammoastuta* and finer-grained forms of *Miliammina*, from a warm, turbid, brackish-water environment (11,000-14,000 ppm. chloride ion content). Concerning *Trochammina macrescens* Brady, he noted (*op. cit.*, p. 144) that the deflated tests of this species were similar to the convex tests of other species of *Trochammina*, and that it still remained a problem "as to why certain species of *Trochammina* in a given sample would deflate while others retained their convexity."

This feature was also noted by Parker, Phleger and Peirson (1953, p. 15), who stated that specimens with collapsed chambers occur frequently when specimens are dried. They reported *Trochammina macrescens* and other species of *Trochammina* from brackish-water and near-shore areas in San Antonio Bay. Warren (1957) reported the occurrence of *Trochammina macrescens*, *T. comprimata*, *T. inflata*, and *T. lobata* from marshy or brackish-water areas in the Buras Scofield Bayou region, Louisiana. Said (1953, p. 13) recorded a similar *Trochammina* assemblage from the Great Pond Embayment, Falmouth, a sandy to very shallow area subjected to less fluctuation in salinity.

Similarly, Bolin (1956, p. 289) reported *Trochammina minnesotensis* with deflated tests in subsurface Cretaceous sediments from Aitkin and Crow Wing

Counties, Minnesota. On the basis of the evidence furnished by the predominantly arenaceous foraminiferal assemblage and by the nature of the enclosing sediments, Bolin deduced a near-shore, probably cold, brackish-water depositional environment for the assemblage.

A large number of specimens of *Trochammina hasdoensis* show similar morphologic features (i.e., tests with deflated chambers). It is therefore probable that *Trochammina hasdoensis* had the same ecology as *Trochammina macrescens* in the present-day seas and as *Trochammina minnesotensis* during Cretaceous time.

Another peculiar morphologic feature of *Trochammina hasdoensis* is the presence of a number of contorted specimens along with the normal, undeformed tests (see pl. 2, fig. 10a-c). Contortions in foraminiferal tests are generally produced either by variations in salinity or, in the case of attached specimens, by varying modes of attachment.

Arnold (1954), while studying the variation shown by *Discorinopsis aguayoi* (Bermudez) in laboratory cultures, noted that between 10 and 15 per cent of the specimens of that species show noticeable contortion of the test—either along the B-B' or C-C' axes (Arnold, *op. cit.*, pl. 2). Although no apparent reason for this contortion was given, it may well have been due to changes in salinity (20 to 57 parts per thousand) to which the living foraminifera were subjected in the laboratory cultures. *Discorinopsis aguayoi* has been recorded from brackish-water areas in San Antonio Bay (Parker, Phleger and Peirson, 1953, where variations in salinity would be marked).

Contorted specimens of *Trochammina hasdoensis*, similar to those of *Discorinopsis aguayoi*, occur frequently in our material. It would perhaps be presumptuous to extend the analogy to *Trochammina hasdoensis*, as the resemblance between the two is purely superficial. The ecologic factor governing the production of contorted tests in *Trochammina* is not definitely known; however, it could well have been compatible with a near-shore, brackish-water environment where changes in salinity are generally marked and frequent. Verification of this hypothesis will have to await detailed studies on the ecology of Recent species of *Trochammina*.

Examination of the data concerning the distribution of other genera, such as *Tolypammina*, *Hyperammina*, *Glomospira*, and *Glomospirella*, in present-day seas suggests that they are frequent at depths between 27 and 3800 fathoms (see Galloway, 1933). However, Ronai (1955, p. 140) recorded species of *Ammobaculites* and *Hyperammina* and coarse-grained

forms of *Miliammina* in brackish-water environments, in cool, slightly turbid waters of low chloride ion content (1.800 ppm.).

Conkin (1954, p. 167), in discussing the paleoecology of the Floyds Knob formation (Pennsylvanian), concluded that "*Hyperammina kentuckyensis* was an inhabitant of an offshore shallow sea." Miller and Swineford (1957, p. 2028) recorded a foraminiferal assemblage consisting predominantly of arenaceous forms, from the basal 6 inches of Robbins shale (Pennsylvanian) in Douglas County, Texas. The following species were noted by them: *Ammodiscus semiconstrictus*, *Hyperammina* sp. cf. *H. clavacoidea*, *Hyperammina* sp. cf. *H. bulbosa*, *Thuraminoides* sp. cf. *T. sphaeroidalis*, *Glomospira articulosa*, and *Reophax* sp. Discussing the paleoecology of these shales, they state (*op. cit.*, p. 2034): "The presence of arenaceous foraminifera (the most abundant faunal element in this zone), a few ostracodes and a few conodonts indicates a near-shore marine or brackish-water environment..." They further report: "No macrofossils, with the exception of a small embryonic shell of a productid (?) brachiopod, were found in this shale. The lack of typical marine invertebrates and the brackish-water aspect of the foraminiferal fauna indicate a near-shore, low-salinity environment of deposition."

The absence of typical marine macrofossils, the presence of an exclusively arenaceous foraminiferal assemblage, and the occurrence of contorted and deflated specimens of *Trochammina hasdoensis* indicate that the sandy shales under consideration were deposited in a near-shore, probably cold, brackish-water environment, with access to the open sea. This is also in accordance with the views of Datta (1957b, p. 6), who suggested that this marine bed was deposited in the shallow waters of a transgressive sea.

SYSTEMATIC DESCRIPTIONS

Family HYPERAMMINIDAE

Subfamily HYPERAMMININAE

Genus HYPERAMMINA Brady, 1878, emend.
Conkin, 1954

Hyperammina gracilis Waters

Plate 1, figures 1-2

Hyperammina gracilis WATERS, 1927, Jour. Pal., vol. 1, p. 130, pl. 22, figs. 4-5. — BHATIA AND SAXENA, 1957, Cushman Found. Foram. Res., Contr., vol. 8, pt. 4, pp. 146-147, pl. 21, figs. 5-7.

This species is fairly common in the present material, and the specimens are identical with those described

from the Umaria marine bed by Bhatia and Saxena (1957). The wall appears white, with siliceous cement. This may be due to secondary silicification (see Cummings, 1955, p. 234).

Dimensions: Length up to 1.40 mm.; diameter up to 0.35 mm.

Hyperammina sp. aff. *H. bulbosa* Cushman and Waters
Plate 1, figure 3

Hyperammina bulbosa CUSHMAN AND WATERS, 1927, Cushman Lab. Foram. Res., Contr., vol. 3, pt. 2, p. 109, pl. 22, fig. 7.

A single attached specimen that may be questionably referred to this species occurs in our material. The proloculus is large, globular, and somewhat compressed. This specimen probably represents the megalospheric form of *Hyperammina gracilis*.

Dimensions: Length 0.85 mm.; diameter of the proloculus 0.25 mm.; diameter of the tubular chamber 0.15 mm.

Hyperammina sp. aff. *H. clavatula* Howchin
Plate 1, figure 4

Hyperammina elongata Brady var. *clavatula* HOWCHIN, 1888, Roy. Micr. Soc. London, Jour., p. 533, pl. 8, figs. 1-2.

Hyperammina clavatula Howchin. — CUMMINGS, 1955, Micro-palaeontology, vol. 1, no. 3, p. 234.

A few specimens which may be questionably referred to this British Carboniferous species were found in our material. The wall is arenaceous with siliceous cement. It was erroneously referred to as a variety of *Hyperammina elongata* Brady by Bhatia and Saxena (1957). According to Cummings (1955, and personal communication), Howchin's variety should be raised to specific rank.

Dimensions: Length up to 1.75 mm.; diameter up to 0.40 mm.

Hyperammina sp. indet.

Plate 1, figures 5-6

Two fragments, which are illustrated here, apparently belong to this genus, but the absence of a proloculus precludes specific determination. The tubular chamber has numerous irregular depressions over the surface.

Dimensions: Length up to 0.95 mm.; diameter up to 0.30 mm.

Family TOLYPAMMINIDAE

Subfamily INVOLUTININAE

Genus GLOMOSPIRA Rzehak, 1888

Glomospira articulosa Plummer

Plate 1, figures 7-9

Glomospira articulosa PLUMMER, 1944, Texas, Univ., Publ., no. 4401, p. 233, pl. 16, figs. 21-25.

This is a very distinctive species, but it shows considerable range of variation. Its characters were adequately described by Plummer (1944), who noted: "It apparently follows no formal plan of coiling, but twists and turns about itself haphazardly, winding itself into a compact body of no definite shape."

The species was originally described from the Strawn of central Texas. It has also been recorded by Miller and Swineford (1957, p. 2028) from the basal Robbins shale of Texas and by Ireland (1956, p. 847) from the Virgilian series, Upper Pennsylvanian, of Kansas.

Dimensions: Diameter of the tubular chamber up to 0.35 mm.

Genus GLOMOSPIRELLA Plummer, 1944

Glomospirella umbilicata (Cushman and Waters)

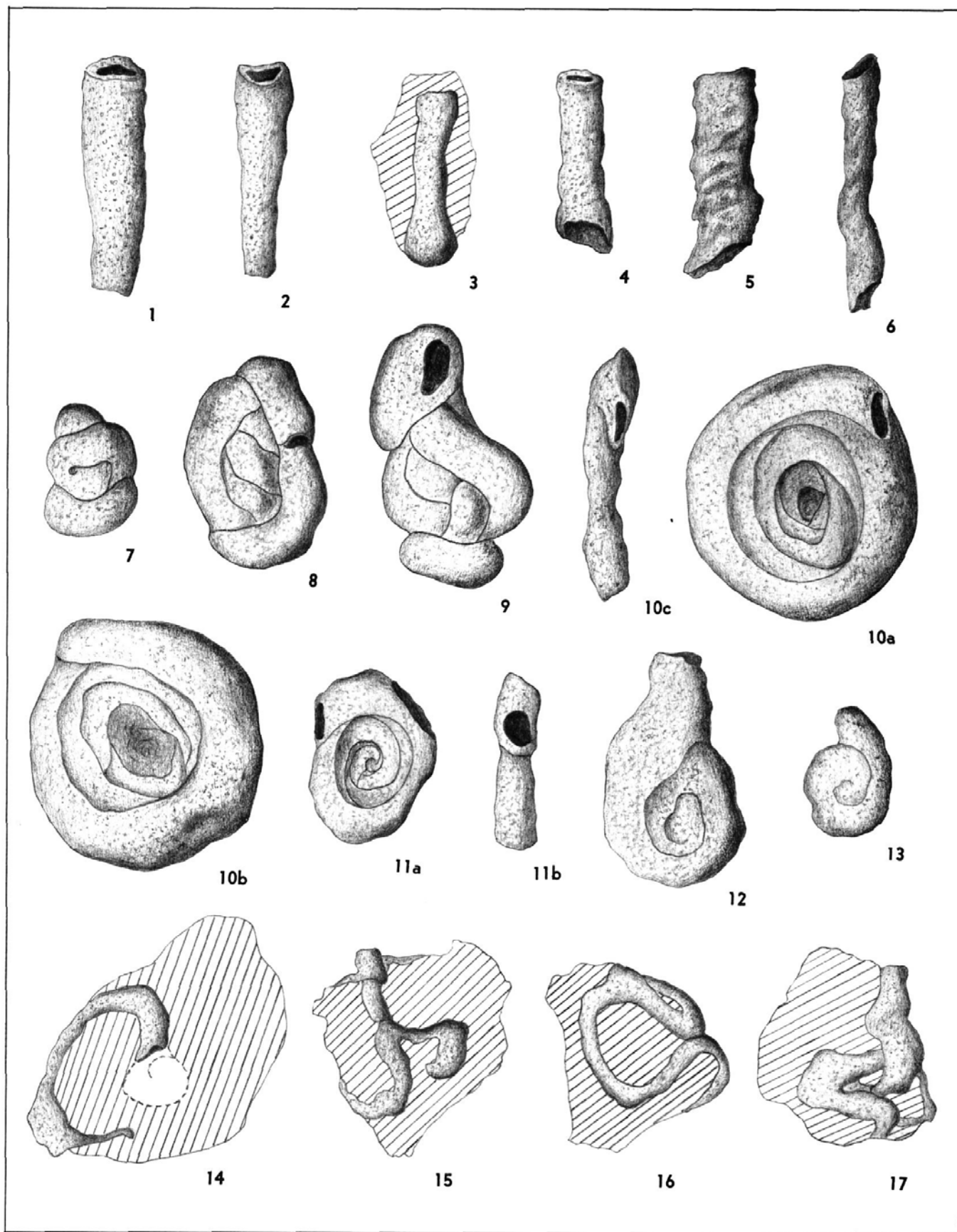
Plate 1, figures 10a-c, 11a-b

Glomospira umbilicata CUSHMAN AND WATERS, 1927, Cushman Lab. Foram. Res., Contr., vol. 3, p. 148, pl. 26, figs. 7-8.

PLATE 1

All figures $\times 42$, unless otherwise stated.

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|------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1-2 <i>Hyperammina gracilis</i> Waters
Lateral views. | 10-11 <i>Glomospirella umbilicata</i> (Cushman and Waters)
10, microspheric form, $\times 54$: a-b, opposite sides;
c, peripheral view; 11, megalospheric form:
a, side view; b, peripheral view. |
| 3 <i>Hyperammina</i> aff. <i>H. bulbosa</i> Cushman and Waters
Attached specimen, lateral view. | |
| 4 <i>Hyperammina</i> aff. <i>H. clavatula</i> (Howchin)
Specimen with damaged proloculus; lateral view. | 12-13 <i>Lituotuba?</i> sp. indet.
Lateral views. |
| 5-6 <i>Hyperammina</i> sp. indet.
Lateral views. | |
| 7-9 <i>Glomospira articulosa</i> Plummer.
Specimens showing varying modes of coiling. | 14-17 <i>Tolypammina polyverta</i> Ireland
Top views; lined areas represent the object of
attachment. |



Glomospirella umbilicata (Cushman and Waters). — PLUMMER, 1944, Texas, Univ., Publ., no. 4401, p. 233.

The species is frequent to common in occurrence. The triangular outline does not seem to be a constant character. This is also apparent from the figures given by Cushman (1948, pl. 42, fig. 25) and by Ireland (1956, text-fig. 4, no. 21), which show specimens with a nearly rounded outline. Our specimens also have a rounded outline, and thus come within the range of variation of the species.

Both the microspheric and the megalospheric generations were recognised. In the former the test is large, rounded in outline, and with about five whorls; in the latter the test is small, somewhat oval in outline, and with fewer whorls.

The species was originally described from the Southwick shale (Pennsylvanian) of Algerita, Texas. Plummer (1944) reported it from the Smithwick, Marble Falls, and lower Strawn beds of central Texas. Ireland (1956) found the species in the Virgilian series of Kansas.

Dimensions: Diameter up to 0.95 mm.; thickness up to 0.15 mm.

Genus LITUOTUBA Rhumbler, 1895

Lituotuba? sp. indet.

Plate 1, figures 12–13

A few specimens that appear to belong to this genus occur in our material. It is possible that the specimens are variants of *Tolypammina polyverta*, which occurs commonly in the present material. If the object, to which it is attached is small, the tubular chamber covers it completely, and the test appears to be free.

Genus TOLYPAMMINA Rhumbler, 1895

Tolypammina polyverta Ireland

Plate 1, figures 14–17; plate 2, figures 1–2

Tolypammina polyverta IRELAND, 1956, Jour. Pal., vol. 30, no. 4, pp. 850–851, text-fig. 4, nos. 30–35.

Next to *Trochammina hasdoensis*, this is the most common species in the present material. The specimens are generally attached to large quartz grains. In some speci-

mens the test is coiled in the early stages, later increasing rapidly in diameter and coiling randomly in many directions. The wall is finely arenaceous, with siliceous cement.

A few specimens (pl. 2, figs. 1–2) resembling *Glomospira monogranula* Ireland (1956, p. 847) were also found. The authors found it difficult to separate them from typical specimens of *Tolypammina polyverta*, as the only difference between the two is in the size of the objects to which they are attached. The species was originally described from the Virgilian series (Upper Pennsylvanian) of Kansas.

Dimensions: Maximum diameter of the tubular chamber 0.25 mm.; length variable.

Family TROCHAMMINIDAE

Subfamily TROCHAMMININAE

Genus TROCHAMMINA Parker and Jones, 1859

Trochammina hasdoensis Bhatia and Singh,
new species

Plate 2, figures 3–10

Diagnosis: Test compressed, trochospirally coiled, dorsal side slightly convex, ventral side concave, umbilicate; periphery rounded, somewhat lobulate; two and one-half to three whorls visible on the dorsal side, only the last one visible on the ventral side; five to seven chambers in the final whorl, rapidly increasing in size with growth, the last one being nearly one-third of the size of the test, chambers occasionally collapsed or deflated, resulting in raised margins; sutures rather indistinct, strongly curved on both the dorsal and the ventral side, intersecting the periphery at an acute angle; wall arenaceous, medium to fine grained, with insoluble cement; aperture indistinct, probably at the base of the last chamber.

Dimorphism and variation: Both the megalospheric and the microspheric generations were recognised. In the former (pl. 2, figs. 3–6), the test is strongly compressed, with two and one-half to three whorls on the dorsal side. The last chamber is about one-third of the size of the test. In the latter (pl. 2, figs. 8–9), the test is somewhat inflated, and the last chamber is nearly half the size of the test. The sutures are strongly curved and arched backward.

PLATE 2

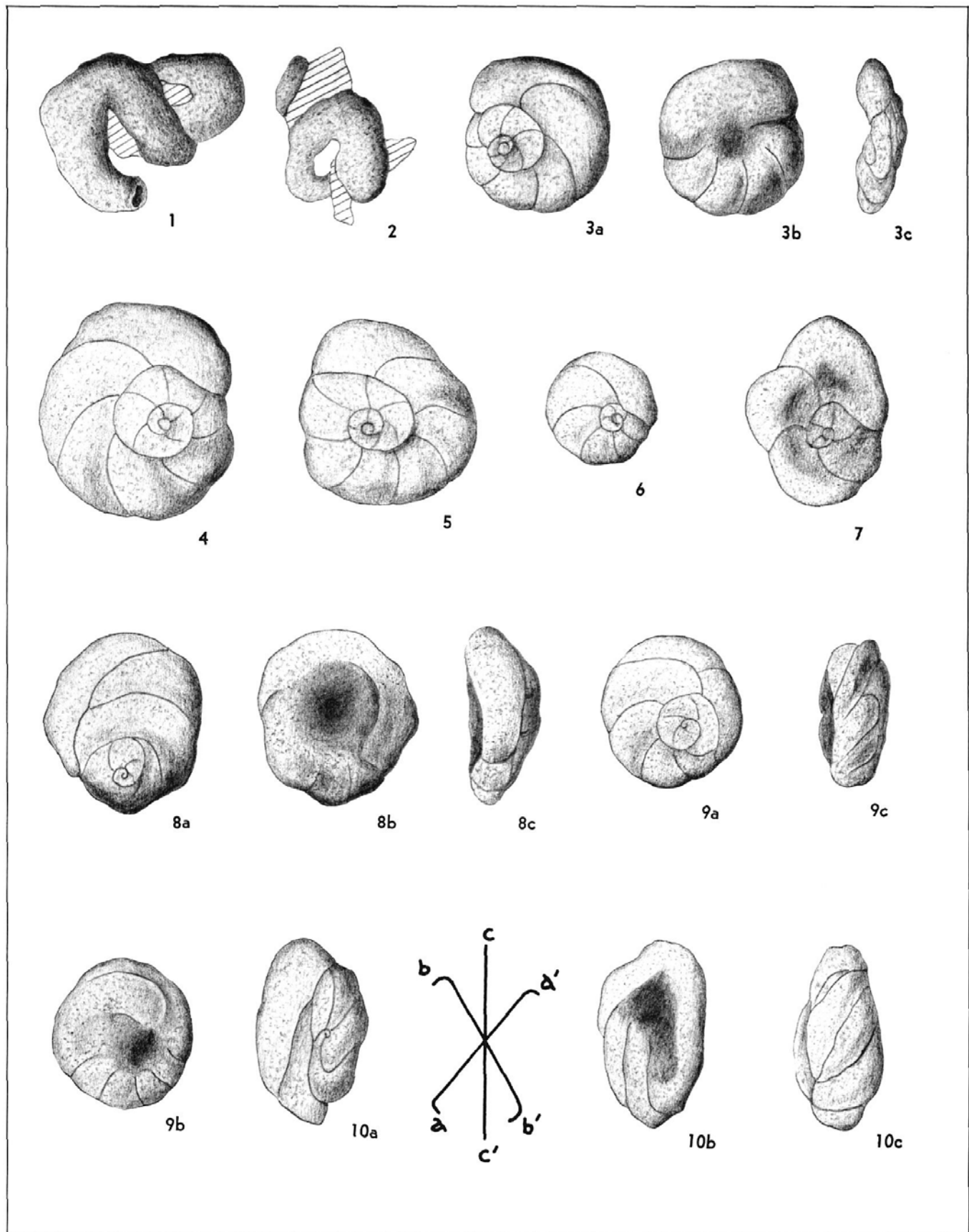
All figures $\times 42$.

1–2 *Tolypammina polyverta* Ireland

Top views; specimens attached to small quartz grains, represented by lined areas.

3–10 *Trochammina hasdoensis* Bhatia and Singh, n. sp.

3, Holotype, megalospheric form: a, dorsal view; b, ventral view; c, peripheral view; 4–6, megalospheric forms, dorsal views; 7, specimen with deflated chambers, dorsal view; 8–9, microspheric forms: a, dorsal view; b, ventral view; c, peripheral view; 10, contorted specimen: a, dorsal view; b, ventral view; c, peripheral view.



A few contorted specimens (pl. 2, fig. 10a-c) were also noticed, the contortion being along the B-B' and A-A' axes (according to Arnold's terminology, 1954). They appear to be ecological variants of normal specimens.

Another notable feature of the species is the presence of a number of tests with deflated chambers (see pl. 2, fig. 7). As already pointed out, this feature is also common in other species of *Trochammina*, for example, *T. macrescens* and *T. minnesotensis*. These specimens also appear to be ecological variants of typical members of the species.

Dimensions: Maximum diameter up to 1.05 mm.; thickness up to 0.28 mm.

Type material: The specimen illustrated in plate 2, figure 3, is the holotype. It is our intention to deposit the holotype and a few paratypes in the paleontological collection of the Geological Survey of India, Calcutta, at a later date.

Type horizon: Bed no. M3, green sandy shale 6 to 9 inches in thickness, underlying the boulder bed containing *Eurydesma* sp., *Aviculopecten* sp., *Pleurotomaria nuda*, and other macrofossils.

Type locality: On the right bank of the River Hasdo, below the railway bridge, about two and one-half miles northeast of Manendragarh railway station.

Age: Upper Carboniferous, Uralian.

Discussion: The species is very distinctive but shows considerable variation, as noted above. It is characterized by having: a) a low trochoid spire; b) five to seven chambers in the final whorl, which rapidly increase in size with growth; and c) strongly curved and backwardly arched sutures, both dorsally and ventrally.

The species somewhat resembles *Trochammina squamiformis* Cushman and McCulloch, from off Milwaukee Pier, Port Angeles, Washington, but differs from it in having strongly curved sutures and in the large, distinctive final chamber. The contorted specimens resemble those of *Trochammina constricta* Haeussler, from the Upper Jurassic of Switzerland, but the resemblance is superficial.

Remarks: The specific name is derived from the River Hasdo, on the right bank of which the marine bed was first discovered.

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