Mem. Fac. Integrated Arts and Sci., Hiroshima Univ., Ser. IV, Vol. 21, 19−32, Dec. 1995

# Endothyroid foraminifers of the Hina Limestone in Okayama Prefecture, western Japan

Mutsumi FUJIMOTO* and Kimiyoshi SADA

*Faculty of Integrated Arts and Sciences,*
*Hiroshima University, Higashi-Hiroshima 739, Japan*

**Abstract** : The Carboniferous Hina Limestone is divided into three fusulinacean-endothyracean zones which are in ascending order *Endothyra-Mediocris* Zone, *Eostaffella-Millerella* Zone and *Pseudostaffella-Profusulinella* Zone and the primitive fusulinacea had already been reported and described in our preceding papers (Fujimoto and Sada, 1994a, b). This paper treats of the descriptions and the illustrations of the endothyracean species belonging to *Planoendothyra*, *Granuliferelloides*, *Endostaffella*, *Endothyra*, *Zellerinella*, *Endothyranopsis* and *Eoendothyranopsis*.

**Key words** : Carboniferous, endothyracean species, descriptions, Hina Limestone, Okayama Prefecture.

## I. Introduction

The studies of the Carboniferous Hina Limestone distributed in the northern part of Yoshii Town, Shitsuki County, about 50 km to the west of Okayama City, have been carried out by many workers: Kobayashi (1950) studied the regional geology of this area, Nakano (1952) the stratigraphy of the Triassic Nariwa Formation and the Hina Limestone, Hase and Yokoyama (1975) the geologic structure of this limestone, Kobayashi and Hamada (1978) some species of Lower Carboniferous trilobites, Sada et al. (1979) and Sada et al. (1985) the geologic structure and microfossils of this area, Otoh (1985) the geologic structure of the Oga area, Mizuno (1993) the conodont faunas of this limestone.

However, many problems concerning the stratigraphy and structure of this limestone have remained unsolved. We have been studying the fusulinacean faunas which play an important role for the age determination and the analysis of the structure of this limestone and also divided the Hina limestone into three fusulinacean zones, *Endothyra-Mediocris* Zone, *Eostaffella-Millerella* Zone and *Pseudostaffella-Profusulinella* Zone in ascending order (Fujimoto and Sada, 1994a, b). In this paper we described and illustrated endothyracean species from the *Endothyra-Mediocris* Zone and a fusulinacean species, *Rectomillerella* sp. A, from the *Eostaffella-Millerella* Zone of the Hina Limestone.

*Acknowledgments*: We wish to express our hearty thanks to Dr. Paul L. Brenckle of

Received August 25, 1995; Accepted October 9, 1995

* Permanent address: Fukken Co., Ltd., Hikarimachi, Higashiku, Hiroshima 732, Japan

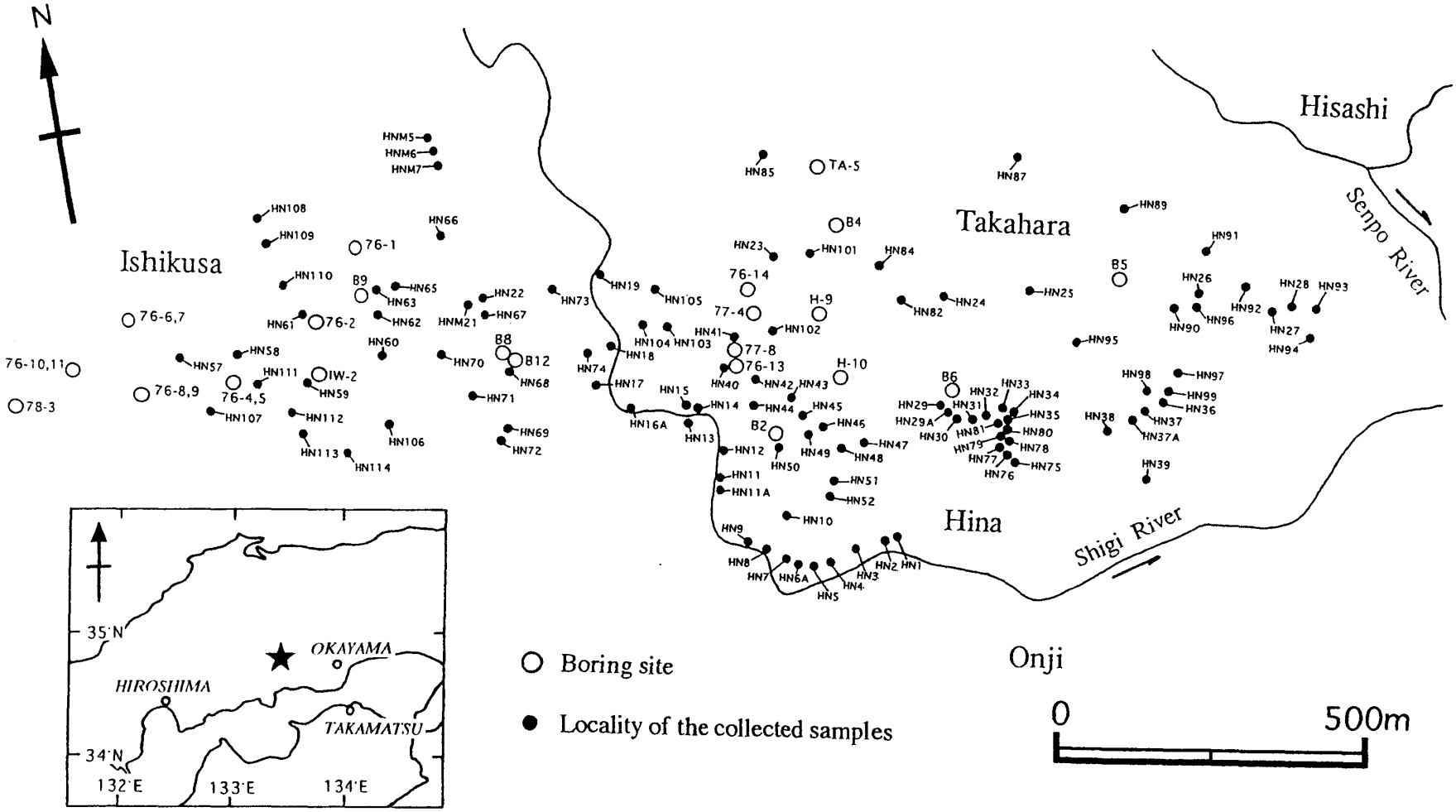



**Figure 1.** Map showing the location of the studied area, the microfossil localities and the bore hole sites in the Hina Limestone upland.

Amoco Production Company in Houston, Texas, who has given us the useful advice for some of the endothyracean species herein. We are deeply indebted to Directors T. Itoh and K. Kobukai of the Yoshii Mining station of Kokan Kogyo Co., Ltd. for their having offered us the core samples of boring in the studied area. Thanks are also due to Prof. Y. Oho, A. Prof. M. Fukuoka, A. Prof. M. Kaibori, Dr. S. Niko and Dr. Y. Hirayama of Hiroshima University for their helps in various ways. This work was carried out under the auspices of the Grants-in-Aid for Scientific Research from Japanese Government Ministry of Education.

## II. Brief summary of the *Endothyra-Mediocris* Zone

The *Endothyra-Mediocris* Zone of the Hina Limestone is characterized by the following species: *Endothyra similis* Rauzer-Chernousova and Reitlinger, *Endothyra exilis* Rauzer-Chernousova, *E.* sp., *Eoendothyranopsis* sp., *Planoendothyra sigma* Solov'eva, *Endothyranopsis compressa* Rauzer-Chernousova and Reitlinger, *Granuliferelloides* sp., *Endostaffella* sp. A, *Mediocris mediocris* (Vissarionova), and *M. adducta* Durkina.

Of these species, *Endothyranopsis* is a marker of Lower Carboniferous (Lower Visean) in Russia, USA and Canada. *Endostaffella* is an indicator of Lower Carboniferous (Upper Tournaisian to Visean) in USA, Great Britain and Belgium. *Granuliferelloides* is known from Upper Tournaisian in Canada and USA. These three genera are found out in the lower part of *Endothyra-Mediocris* Zone of the Hina Limestone. Kobayashi and Hamada (1978) described Lower Carboniferous trilobites from the lower part of the Hina Limestone without the description of the fossil locality. Therefore the exact locality has been unknown yet. And they defined that the lower part of this limestone is of Kinderhookian to Lower Osagean or Tournaisian to Lower Visean. Taking all these considerations into account, the lower part of the *Endothyra-Mediocris* Zone may be

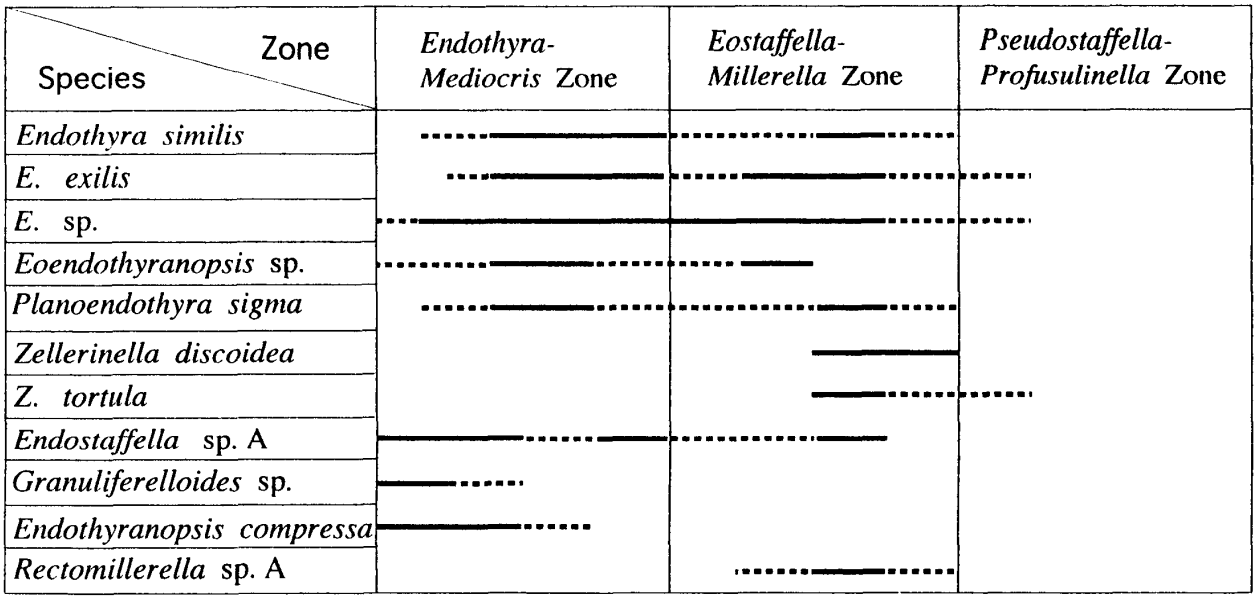



Figure 2. Stratigraphic ranges of microfossils in the Hina Limestone.

considered to be of Late Osagean to Early Meramecian or Early Visean.

## Ⅲ. Systematic Description

Superfamily Endothyracea Brady, 1884
Family Endothyridae Brady, 1884
Subfamily Endostaffellinae Loeblich and Tappan, 1984
Genus *Granuliferelloides* Mckay and Green, 1963

*Type species.*—*Granuliferelloides jasperensis*, 1963

*Granuliferelloides* sp.
Fig. 4-1

*Descriptive remarks.* — Shell of *Granuliferelloides* sp. illustrated in Figure 4-1 is elongate. Shell is streptspirally enrolled at the early stage and is planispiral at the later stage. Finally it is becoming uncoiled and rectilinear, having short cylindrical chambers and nearly horizontal septa.

Shell is 1132 $\mu$m in length and 473 $\mu$m in width. Outside diameter of proloculus is 40 $\mu$m. Spirotheca is calcareous and coarsely granular and consists of thick single layer. Its thickness measures 14 to 27 $\mu$m.

The present species differs from *Granuliferelloides jasperensis* Mckay and Green (1963) from Alberta, Canada in its larger width and fewer number of septa. This species could be a new species. The final identification, however, is postponed until more information is obtained.

*Localities.*—HN65 and others.

*Microfossil zone.*—*Endothyra-Mediocris* Zone.

Genus *Endostaffella* Rozovskaya, 1961

*Type species.*—*Endothyra parva* von Moller, 1879

*Endostaffella* sp. A
Figs. 3-1–4

*Descriptive remarks.*—Shell of *Endostaffella* sp. A is small and discoidal in shape. Inner volutions are involute but outer ones are evolute to partially involute. Coiling of the juvenarium is slightly rotated and in the last volution it becomes planispiral.

The illustrated specimen (Figure 3-3) is 134 $\mu$m in length and 435 $\mu$m in width, giving a form ratio of 0. 31. Outside diameter of proloculus is 34 $\mu$m. Diameters of whorls of the 1st to the 3rd volution are 93, 200 and 435 $\mu$m, respectively. Spirotheca is composed of calcareous, microgranular and undifferentiated layer. Spirothecal thickness of the 1st to the 3rd volution is 9, 11 and 19 $\mu$m, respectively.

The present species somewhat resembles *Zellerinella tortula* Zeller (1953) in general outline of shell. However, the former species differs from the latter in having calcareous,

microgranular undifferentiated layer.

*Localities.*—HN65, HN98 and others.

*Microfossil zone.*—*Endothyra-Mediocris* Zone to *Eostaffella-Millerella* Zone.

Subfamily Endothyrinae Brady, 1884

Genus *Endothyra* Phillips, 1846

emend. Brady, 1876

*Type species.*—*Endothyra bowmani* Phillips, 1846 emend. Brady, 1876

*Endothyra exilis* Rauzer-Chernousova

Figs. 4-2–3

*Endothyra exilis* Rauzer-Chernousova, 1948, p. 178-179, pl. 5, figs. 11-13.
*Endothyra exilis*, Golubtsov, 1957, p. 110-111, pl. 2, figs. 15-16.
*Plectogyra exilis*, Ivanova, 1973, pl. 5, fig. 8, pl. 14, fig. 11.
*Omphlotis? exilis*, Armstrong and Mamet, 1977, p. 65.
*Endothyra exilis*, Rich, 1980, p. 21, pl. 6, fig. 6; pl. 7, figs. 1, 2, 16.

*Descriptive remarks.* — Shell of *Endothyra exilis* Rauzer-Chernousova is enrolled throughout growth and the last volution is evolute. Periphery of the last volution is rounded and coiling is changing abruptly in inner volutions.

Shell illustrated in Figure 4-2 measures 202 $\mu$m in length and 540 $\mu$m in width. Form ratio is 0. 37. Proloculus is spherical and its outside diameter is 33 $\mu$m. Spirotheca is calcareous and microgranular and it consists of a tectum, a thicker fibrous layer and outer tectorium. Secondary deposits are composed of nodes and hooks on the chamber floor. Spirothecal thickness measures 13 to 29 $\mu$m. Septa are straight in inner volutions but bend anteriorly in the last one.

The present species is quite similar to *Endothyra exilis* by Rich (1980) in shell shape, internal modes and measured values and can be ascribed to *Endothyra exilis* Rauzer-Chernousova.

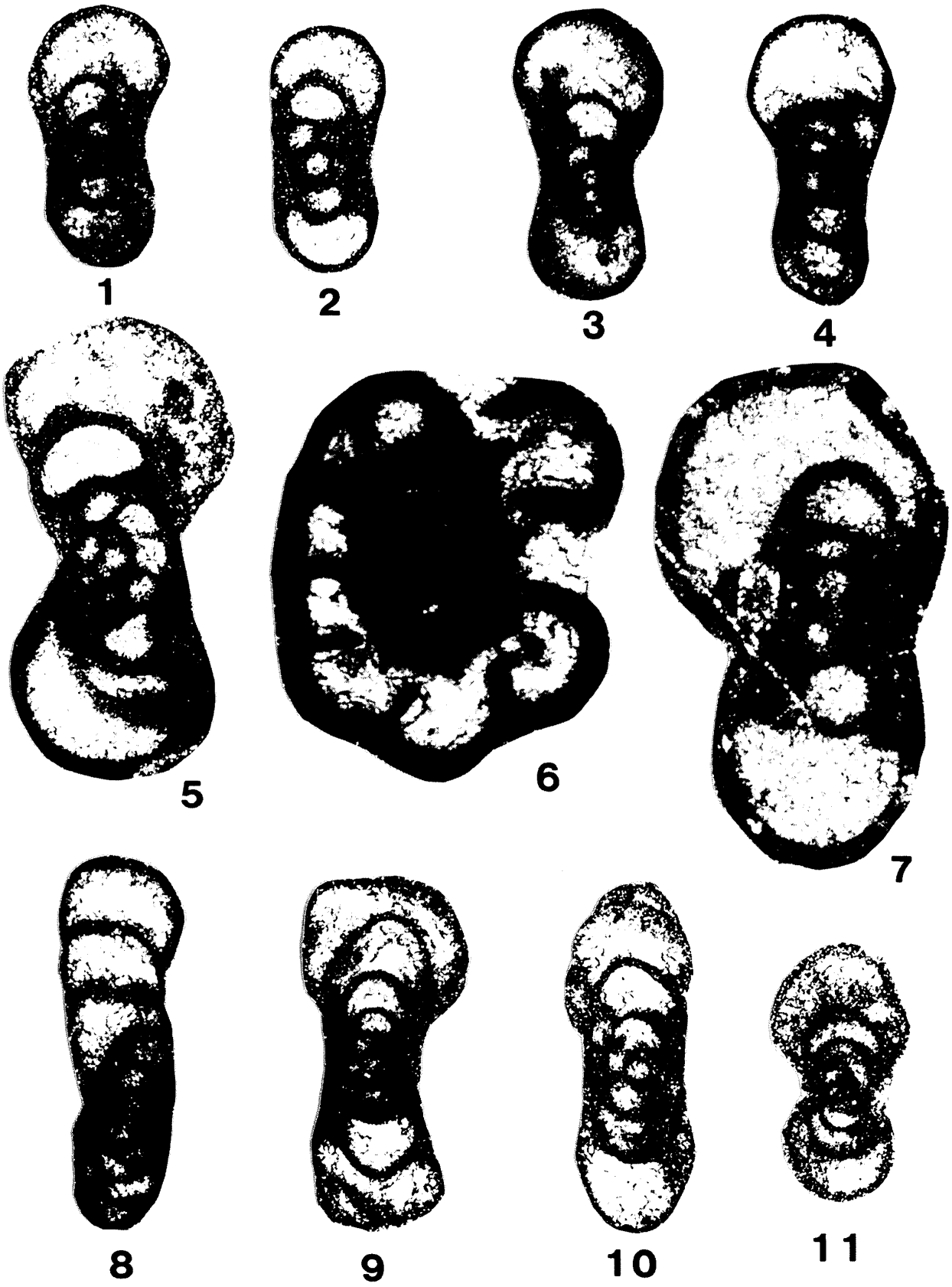
*Localities.*—HN25, HN42, HN82 and others.

*Microfossil zone.*—*Endothyra-Mediocris* Zone to *Eostaffella-Millerella* Zone.

*Endothyra similis* Rauzer-Chernousova and Reitlinger

Figs. 4-4–5

*Endothyra similis* Rauzer-Chernousova and Reitlinger, in Rauzer-Chernousova et al., 1936, p. 211-212, pl. 6, figs. 5-6.
*Endothyra similis*, Grozdilova and Lebedeba, 1954, p. 103-104, pl. 13, fig. 2.
*Endothyra similis*, Brazhnikova, in Brazhnikova et al., 1956, pl. 4, figs. 4-6.
*Plectogyra similis*, Bogush and Yuferev, 1962, p. 136-140, pl. 4, fig. 12.
*Endothyra similis*, Bogush and Yuferev, 1966, p. 118-119, pl. 6, fig. 12.
*Endothyra* of the group *E. similis*, Mamet, 1970, pl. 6, figs. 6, 8.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*Plectogyra similis*, Malakhova, 1972, pl. 4, figs. 2, 3.
*Endothyra* of the group *E. similis*, Mamet, 1973, pl. 6, fig. 12.
*Endothyra* of the group *E. similis*, Armstrong and Mamet, 1977, p. 69, pl. 32, figs. 2, 3.
*Endothyra similis*, Aizenberg et al., 1983, p. 133, pl. 5, fig. 15-16.
*Endothyra similis*, Rich, 1980, p. 25, pl. 10, figs. 3, 4, 9, 11, 13; pl. 11, figs. 1-3, 11.
*Endothyra* ex gr. *similis*, Matsusue, 1986, pl. 3, fig. 1.
*Endothyra* ex gr. *similis*, Matsusue, 1992, p. 384, Figure 3-3.

*Descriptive remarks.*- Shell of *Endothyra similis* Rauzer-Chernousova and Reitlinger is small in size, discoidal and evolute to partially evolute. Coiling is rotated throughout growth and the last volution is planispiral and evolute to partially evolute. Periphery of the last volution is rounded.

Shell illustrated in Figure 4-4 is 201 $\mu$m in length and 449 $\mu$m in width, having a form ratio of 0.45. Outside diameter of spherical proloculus measures 29 $\mu$m. Spirotheca consists of a tectum, outer tectorium and inner thicker dark granular layer. Thickness of spirotheca measures 12 to 25 $\mu$m. Septa are straight in inner volutions but bend anteriorly in the last volution. Low nodes exist on the chamber floor.

Shell shape, internal modes and measured values of the present species are agreeable to those of *Endothyra similis* described by many authors and may be ascribable to *Endothyra similis* Rauzer-Cherunousova.

*Localities.*—HN65, HN113 and others.
*Microfossil zone.*—*Endothyra-Mediocris* Zone to *Eostaffella-Millerella* Zone.

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**Figure 3. 1-4.** *Endostaffella* sp. A, 1-4, axial sections, Rg. No. HN65-1b, HN65-11a, HN65-8b and HN98-a, respectively. **5-6.** *Planoendothyra sigma* Soloveva, 5, axial section, Rg. No. HN44-32h1, 6, sagittal section, Rg.No. HN44-28e. **7.** *Eoendothyranopsis.* sp., axial section, Rg. No. HN65-8d. **8.** *Rectomillerella* sp. A, axial section, Rg. No. HN42-21b. **9-10.** *Zellerinella discoidea* (Girty), 9-10, axial sections, Rg. No.HN113-10c and HN113-8c, respectively. **11.** *Zellerinella tortula* (Nordine Zeller), axial section, Rg. No. HN33-35b. (All × 100)

Genus *Zellerinella* Mamet, 1981

*Type species.*—*Endothyra discoidea* (Girty, 1915)

*Zellerinella discoidea* (Girty)

Figs. 3-9–10

*Endothyra discoidea* Girty, 1915, p. 27, pl. 10, figs.11-16.
*"Eostaffella"* discoidea, Mamet, in Sando et al., 1969, p. E15-E16.
*Zellerina discoidea*, Mamet and Skipp, 1970, p. 336.
*Zellerina discoidea*, Armstrong and Mamet, 1977, p. 88, pl. 34, fig. 11.
*Zellerina discoidea*, Rich, 1980, p. 32, pl. 14, figs.10-12, 15-22.

*Descriptive remaks.* — Shell of *Zellerinella discoidea* (Girty) is small and discoidal in shape. The last volution is evolute but inner volutions are involute to partially evolute. Coiling of the juvenarium is slightly streptospiral and in outer volutions it becomes planispiral .

Shell of the present specimen illustrated in Figure 3-9 is 142 $\mu$m in length and 520 $\mu$m in width, giving a form ratio of 0.27. Outside diameter of spherical proloculus is 29 $\mu$m. Diameters of whorls of the 1st to the 4th volution are 122, 221, 382 and 520 $\mu$m, respectively. Spirotheca consists of a tectum and inner and outer tectoria. Its thickness is 10 to 15 $\mu$m.

The present species can be referred to *Zellerinella discoidea* (Girty) in shell shape, internal biocharacters and measured values.

*Localities.*—HN16A, HN113 and others.

*Microfossil zone.*—Upper part of *Eostaffella-Millerella* Zone.

*Zellerinella tortula* (Nodine-Zeller)

Figs. 3-11

*Millerella tortula* Zeller, 1953, p. 192-194, pl. 26, figs. 7-8, 10, 12, 13-18, 19-21, 23-26.
*Paramillerella tortula*, Zeller, 1957, p. 703, pl. 75, figs. 4-8, 10-12.
*Paramillerella tortula*, Skipp, 1961, p. C242-243, fig. 236. 3.
*Paramillerella tortula*, Anisgard and Campau, 1963, p.102.
*Millerella tortula*, Rozovskaya, 1963, p. 33.
*Eostaffella tortula*, Brenckle, 1973, p. 75.
*Zellerina tortula*, Armstrong and Mamet, 1977, p. 87.
*Zellerina tortula*, Rich, 1980, p. 32, pl. 14, figs. 23-31.

*Descriptive remarks.* — Shell of *Zellerinella tortula* is discoidal, small and highly umbilicate. Inner volutions are involute and outer ones are evolute with broadly rounded periphery. Coiling of juvenarium is slightly rotated and in most volutions coiling is planispiral. Length of shell illustrated in Figure 3-11 is 101 $\mu$m and width is 383 $\mu$m, giving a form ratio of 0.26. Proloculus is very small and its outside diameter is 25 $\mu$m.

Diameters of whorls of the 1st to the 3rd volution are 135, 220 and 383 $\mu$m, respectively. Spirotheca is thin and is composed of a tectum and inner and outer tectoria. Its thickness of the 1st to the 4th volution is 9 to 20 $\mu$m.

The present species closely resembles *Zellerinella tortula* described by Zeller (1953) from the Chesterian section of Glen Dean Limestone of Illinois in shell shape, internal biocharacteristics and measured values. They may be considered to be of conspecific.

*Localities.*—HN33, HN44 and others.

*Microfossil zone.*—Upper part of *Eostaffella-Millerella* Zone.

Subfamily Endothyranopsinae Reitlinger, 1958

Genus *Endothyranopsis* Cummings, 1955

*Type species.*—*Involutina crassa* Brady, in Moore, 1870

*Endothyranopsis compressa* (Rauzer-Chernousova and Reitlinger)

Fig. 4-9

*Endothyra crassa* var. *compressa* Rauzer-Chernousova and Reitlinger, in Rauzer-Chernousova et al., 1936, p. 209, pl. 6, figs. 1-2.

*Endothyra crassa* var. *compressa*, Rauzer-Chernousova, 1948, p. 166-167, pl. 4, figs. 8-9.

*Endothyra compressa*, Grozdilova and Lebedeva, 1954, p. 93-94, pl. 11, fig. 4.

*Endothyra compressa*, Durkina, 1959, p. 185-186, pl. 14, figs. 2-3.

*Endothyranopsis compressa*, Rozovskaya, 1963, p. 57-58, pl. 10, figs. 3-9; pl. 11, figs. 1-2.

*Endothyranopsis compressa*, Okimura, 1965, p. 250-251, pl. 21, figs. 5-7.

*Endothyranopsis* cf. *compressa*, Brenckle, 1973, p. 54-55, pl. 8, figs. 3-6.

*Endothyranopsis compressa*, Matsusue, 1986, pl. 3, fig. 3.

*Endothyranopsis compressa*, Matsusue, 1992, p. 384, Figure 3-15.

*Descriptive remarks.* — Shell of *Endothyranopsis compressa* (Rauzer-Chernousova and Reitlinger) is large for the genus, and discoidal, planispiral and involute, but the last volution is evolute. Chomata are primitive and axial filling is fairly thick.

Length of shell is 195 $\mu$m and width measures 614 $\mu$m, showing a form ratio of 0.32. Proloculus is large and its outside diameter is 72 $\mu$m. Diameters of whorls of the 1st to the 2nd-and-a-half volution are 221, 432 and 614 $\mu$m, respectively. Thickness of spirotheca of the 1st to the 2nd-and-a-half volution is 21, 28 and 17 $\mu$m, respectively.

The species described herein is quite similar to *Endothyranopsis compressa* originally described by Rauzer-Chernousova and Reitlinger (in Rauzer-Chernousova et al., 1936, p. 209, pl. 6, figs. 1-2) and recently reported and illustrated by Matsusue (1986) from Akiyoshi in its shell shape, internal modes and measured values. Proloculus of the present species is rather larger than those of the species by Matsusue (1986). Such a difference may be considered to be within a specific variation. The present species is referable to *Endothyranopsis compressa* (Rauzer-Chernousova and Reitlinger).

*Localities.*—HN42, HN65 and others.

*Microfossil zone.*—*Endothyra-Mediocris* Zone.

Superfamily Fusulinacea von Moller, 1878
Family Ozawainellidae Thompson and Foster, 1937
Subfamily Ozawainellinae Thompson and Foster, 1937
Genus *Rectomillerella* Liem, 1974

*Type species.*—*Rectomillerella texasensis* Liem, 1974

*Rectomillerella* sp. A
Fig. 3-8

*Descriptive Remarks.*—Shell of *Rectomillerella* sp. A is small. It consists of two parts, the planispiral and lenticular part and the rectilinear part. Periphery is subrounded in the planispiral and lenticular part and involute to partially evolute in the rectilinear part.

Length of shell is 134 $\mu$m and width including the rectilinear part of shell is 554 $\mu$m. Outside diameter of proloculus is 40 $\mu$m. Diameters of whorls of the 1st to the 3rd volution in the planispiral and lenticular part of shell are 132, 232 and 314 $\mu$m, respectively. The rectilinear part is uniserial and cylindrical. Spirotheca is thin and consists of a tectum, diaphanotheca and outer tectorium.

*Rectomillerella* sp. A somewhat resembles *R. tekisasensis* Liem, in Loeblich and Tappan 1988, (syn. *Millerella marblensis*, variant by Moore, 1964, p. 301-305, pl. 48, figs. 1-14, 19-21) from Big Saline Formation in McCullock County, Texas. However, the former species has a larger length of shell and more rapid expansion of cylindrical chambers. *Rectomillerella* sp. A differs from *Rectomillerella okubensis* described by Matsusue (1988) from Akiyoshi in having smaller shell in the planispiral and lenticular part.

*Localities.*—HN4, HN42 and others.

*Microfossil zone.*—*Eostaffella-Millerella* Zone.


Figure 4. 1. *Granuliferelloides* sp., longitudinal section across axis of coiling, Rg. No. HN65-18a. 2-3. *Endothyra exilis* Rauzer-Chernousova, 2, axial section, Rg. No.HN25-1d, 3, sagittal tangential section, Rg. No. HN42-18f. 4-5. *Endothyra similis* Rauzer-Chernousova and Reitlinger, 4, axial section, Rg. No. HN65-5c, 5, sagittal section, Rg. No.HN113-10e,. 6-8. *Endothyra* sp., 6-7, oblique axial sections, Rg. No. HN65-34a and HN65-1a, respectively. 8, sagittal section, Rg. No. HN113-9f. 9. *Endothyranopsis compressa* (Rauzer-Chernousova and Reitlinger), axial section, Rg. No. HN65-4b. (All ×100)

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