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

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Abstract: The Carboniferous Hina Limestone is divided into three fusulinacean-endothyrian 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 endothyrian species belonging to Planendothyra, Granuliferelloides, Endostaffella, Endothyra, Zellerinella, Endothyranopsis and Eendothyranopsis.

Key words: Carboniferous, endothyrian 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, Otos (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 endothyrian species from the Endothyra-Mediocris Zone and a fusulinacean species, Rectomillerella sp. A, from the Eostaffella-Millerella Zone of the Hina Limestone.

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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 endothyroidean 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-Chernysova and Reitlinger, Endothyra exilis Rauzer-Chernysova, E. sp., Eoendothyranopsis sp., Planoendothyra sigma Solov’eva, Endothyranopsis compressa Rauzer-Chernysova 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 Viséan) in Russia, USA and Canada. Endostaffella is an indicator of Lower Carboniferous (Upper Tournaisian to Viséan) 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 Viséan. Taking all these considerations into account, the lower part of the Endothyra-Mediocris Zone may be

<table>
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<th>Species</th>
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<th>Eostaffella-Millerella Zone</th>
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<td>Endothyra similis</td>
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<td>E. exilis</td>
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<td>Zellerinella discoidea</td>
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<td>Z. tortula</td>
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<td>Endostaffella sp. A</td>
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<td>Granuliferelloides sp.</td>
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<td>Endothyranopsis compressa</td>
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<td>Rectomillerella sp. A</td>
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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 *Granuliferelloydoides* Mckay and Green, 1963
*Type species.* — *Granuliferelloydoides jasperensis*, 1963

*Granuliferelloydoides* sp.
Fig. 4.1

*Descriptive remarks.* — Shell of *Granuliferelloydoides* 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 μm in length and 473 μm in width. Outside diameter of proloculus is 40 μm. Spirotheca is calcareous and coarsely granular and consists of thick single layer. Its thickness measures 14 to 27 μm.

The present species differs from *Granuliferelloydoides 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 μm in length and 435 μm in width, giving a form ratio of 0.31. Outside diameter of proloculus is 34 μm. Diameters of whorls of the 1st to the 3rd volution are 93, 200 and 435 μm, respectively. Spirotheca is composed of calcareous, microgranular and undifferentiated layer. Spirothecal thickness of the 1st to the 3rd volution is 9, 11 and 19 μm, 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 exulis Rauzer-Chernousova
Figs. 4-2–3

Endothyra exulis, Golubtsov, 1957, p. 110-111, pl. 2, figs. 15-16.
Plectogyra exulis, Ivanova, 1973, pl. 5, fig. 8, pl. 14, fig. 11.
Endothyra exulis, Rich, 1980, p. 21, pl. 6, fig. 6; pl. 7, figs. 1, 2, 16.

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

Shell illustrated in Figure 4-2 measures 202 μm in length and 540 μm in width. Form ratio is 0.37. Proloculus is spherical and its outside diameter is 33 μm. Spirotheca is calcareous and microgranular and it consists of a tectum, a thicker fibrous layer and outer tecton. Secondary deposits are composed of nodes and hooks on the chamber floor. Spirothecal thickness measures 13 to 29 μm. Septa are straight in inner volutions but bend anteriorly in the last one.

The present species is quite similar to Endothyra exulis by Rich (1980) in shell shape, internal modes and measured values and can be ascribed to Endothyra exulis 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 Lebedeva, 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.
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 μm in length and 449 μm in width, having a form ratio of 0.45. Outside diameter of spherical proloculus measures 29 μm. Spirotheca consists of a tectum, outer tectorium and inner thicker dark granular layer. Thickness of spongotheca measures 12 to 25 μm. 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-Chernousova.

Localities.—HN65, HN113 and others.

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

Figure 3-4. Endostaffella sp. A, 1-4, axial sections, Rd. No. HN65-1b, HN65-11a, HN65-8b and HN98-a, respectively. 5-6. Panoendothyra sigma Soloveva, 5, axial section, Rd. No. HN44:32b1, 6, sagittal section, Rd.No. HN44-28e. 7. Eoendothyranopsis sp., axial section, Rd. No. HN65-8d. 8. Rectomillerella sp. A, axial section, Rd. No. HN42-21b. 9-10. Zellerinella discoidea (Girty), 9-10, axial sections, Rd. No.HN113-10c and HN113-8c, respectively. 11. Zellerinella tortula (Nordine Zeller), axial section, Rd. No. HN33-35b. (All X 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.


*Zellerina discoidea*, Armstrong and Mamet, 1977, p. 88, pl. 34, fig. 11.


*Descriptive remarks.* — 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 μm in length and 520 μm in width, giving a form ratio of 0.27. Outside diameter of spherical proloculus is 29 μm. Diameters of whorls of the 1st to the 4th volution are 122, 221, 382 and 520 μm, respectively. Spireotheca consists of a tectum and inner and outer tectoria. Its thickness is 10 to 15 μm.

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


*Paramillerella tortula*, Zeller, 1957, p. 703, pl. 75, figs. 4-8, 10-12.


*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 μm and width is 383 μm, giving a form ratio of 0.26. Proloculus is very small and its outside diameter is 25 μm.
Diameters of whorls of the 1st to the 3rd volition are 135, 220 and 383 μm, respectively. Spirotheca is thin and is composed of a tectum and inner and outer tectoria. Its thickness of the 1st to the 4th volition is 9 to 20 μm.

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 biocharactersitics 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 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*, Brenkle, 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 μm and width measures 614 μm, showing a form ratio of 0.32. Proloculus is large and its outside diameter is 72 μm. Diameters of whorls of the 1st to the 2nd-and-a-half volution are 221, 432 and 614 μm, respectively. Thickness of spirotheca of the 1st to the 2nd-and-a-half volution is 21, 28 and 17 μm, 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 μm and width including the rectilinear part of shell is 554 μm. Outside diameter of proloculus is 40 μm. Diameters of whorls of the 1st to the 3rd volutions in the planispiral and lenticular part of shell are 132, 232 and 314 μm, 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 McCulloch 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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