Late Permian *Albaillella* (Radiolaria) from a Bedded Chert Section in the Gujo-hachiman Area of the Mino Belt, Central Japan

—Preliminary Report on Morphometry and Cluster Analysis—

Kiyoko Kuwahara* and Masanori Sakamoto*

(With 4 Figures, 2 Tables and 3 Plates)

Abstract

Eight species of Late Permian *Albaillella* (*A. excelsa, A. flexa* n. sp., *A. lauta* n. sp., *A. levis, A. sp. aff. A. levis, A. triangularis, A. sp. A, and A. sp. B) were recognized from radiolarian assemblages in a bedded chert section in the Gujo-hachiman area of the Mino Belt, Central Japan. Quantitative features were measured for a total of 1000 specimens representing eight species of *Albaillella*. Their morphometry indicates morphological distinctions among species. From their stratigraphic distribution and resemblance of shell forms, *A. excelsa, A. flexa, A. lauta, A. sp. A, and A. sp. B* are considered to have closely phylogenetic relations.

Cluster analysis was attempted to well preserved specimens representing five species of *Albaillella*, in order to ascertain classification by visual inspection. Each clustered group generally corresponds to each species.

**Key Words:** Albaillella, Late Permian, morphometry, cluster analysis.

1. Introduction

Suborder Albaillellaria Deplandre is a characteristic and important taxon for Late Paleozoic radiolarian biostratigraphy. Ishiga _et al._ (1982) described three species of Late Permian *Albaillella* (*A. triangularis, A. excelsa and A. levis*) from bedded cherts which are distributed in the Mino-Tamba Belt, Southwest Japan. These species have short ranges which are limited to Late Permian age. There are many reports on these occurrences in Japan, e.g., from the Tamba Belt (e.g., Ishiga and Imoto, 1980; Takemura and Nakaseko, 1981); from the Mino Belt (e.g., Kojima, 1982; Wakita, 1983); from the Chichibu Belt (e.g., Nishizono _et al._, 1982; Miyamoto _et al._, 1985; Sashida and Tonishi, 1985); from the Maizuru Belt (e.g., Caridroit and De Wever, 1986). The report of occurrences for these Late Permian *Albaillella* has increased in other countries too, as for example, in Philippines (Cheng, 1989), in Yunnan, China (Wu and Li, 1989), and in California, America (Noble and Renne, 1990).

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Wakita (1983) recovered well preserved Late Permian radiolarians occurring in a chert block (G1709) in the Gujo-hachiman area of the Mino Belt, Central Japan. He recognized *Follicucullus scholasticus* ORMISTON and BABCOCK, *F. ventricosus* ORMISTON and BABCOCK, *Neoalbaillella optima* ISHIGA, KITO and IMOTO, *Albaillella levis* ISHIGA, KITO and IMOTO, and other many Albaillellids from this locality. In the present work, a stratigraphic section of bedded chert from the same locality was examined in order to clarify the morphology of *Albaillella*. Quantitative features were measured in order to distinguish *Albaillella* at species level, and cluster analysis using these quantitative features was attempted for some species.

We wish to express our thanks to Associate Professor A. Yao of Osaka City University for his many helpful suggestions during the course of this work.

### 2. Material and Method

The sampling site (136°51'07"E; 35°43'55"N), which is the same locality as G1709 in Wakita (1983) and Loc 62 in Wakita (1984), is located in the Gujo-hachiman area of the Mino Belt, Central Japan (Fig. 1).

Samples were continuously collected, bed by bed, from 155 horizons in a chert section of the allochthonous block (Fig. 2). This block belongs to the Nabigawa Formation, which is a part of the Paleozoic-Mesozoic sedimentary complex (Wakita, 1984). The total thickness of the studied section is 9.75 m. The section, which is bounded at the base and at the top by faults, is made up of greenish-gray bedded chert. The chert beds vary from 2 to 10 cm, and shale partings are less than several millimeters thick. The recrystallized part (lowermost 75 cm in the section) was not sampled.

Samples were immersed in a 5% solution of hydrofluoric acid for 24 hours. Residues, including fossils, were obtained by using 35 to 200 mesh sieves. Radiolarians were picked up under a binocular microscope and mounted on glass slides using a mounting medium, "ENTELLAN neu". Specimens were measured under the microscope with an ocular micrometer at mainly ×200 magnification. Both a mechanical stage and a turning stage were attached to the microscope.

Seven quantitative features (Fig. 3) were measured in a total of 1000 specimens representing eight species. The number of specimens of each species varied from several specimens to several hundred specimens.

### 3. Radiolarian Assemblage

The Late Permian radiolarian assemblages from the Gujo-hachiman area are composed of Albaillellarians, stauraxon polycystines and spherical polycystines. Albaillellarian abundance in the total samples was less than several percent. Four genera belonging to Albaillellaria were obtained, namely, *Albaillella Defflandre*, *Neoalbaillella Takemura* and Nakaseko, *Follicucullus* ORMISTON and BABCOCK, and *Pseudoalbaillella Holsworth* and JONES. Judging from occurrences of each species of Albaillellaria, the studied
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Late Permian Albaillella in the Gujo-hachiman Area

Fig. 1 a: Index map of the Gujo-hachiman area. Abbreviations: M.T.L., Median Tectonic Line; I.S.T.L., Itoigawa-Shizuoka Tectonic Line.

b: Geographical map showing the sampling site. The sampling site is the same locality as G1709 in WAKITA (1983), and Loc. 62 in WAKITA (1984) (a part of 1:50,000 map of “Hachiman” published by the Geographical Survey Institute of Japan).

Chert section corresponds to the Upper Permian Neoalbaillella optima and N. ornithofor­mis Assemblage-zones of ISHIGA (1986).

Eight species of Albaillella were recognized. Among them, two species are described as new species in chapter 4. The stratigraphic distribution of Albaillella is shown in Fig. 2.

Rarely encountered specimens of A. asymmetrica ISHIGA and IMOTO, and A. sinuata ISHIGA and WATASE occurred in a few horizons in this section. These two species have been regarded as Early to Middle Permian radiolaria. There are two possibilities to explain these occurrences from the Upper Permian section. One possibility is that the fossils were reworked from lower horizons; the other is that they have rather longer ranges than
Fig. 2 Stratigraphic distribution of *Albaillella* from a Late Periman bedded chert section in the Gujo-hachiman area of the Mino Belt. Frequency of occurrence is qualitatively shown: black circle, abundant; gray circle, common; cross, rare. Gj-number shows sampling number.
Late Permian Albaillella in the Gujo-hachiman Area

Fig. 3 Sketch of Albaillella excelsa, showing measured features in Albaillella. Abbreviations: HS, height of shell excluding H-frame; LA, length of apical part from shell apex to the proximal part of wing; LW, length from proximal part of wing to aperture; W1, width of shell on the proximal part of wing; W2, width of shell under proximal part of wing; W3, width of shell near aperture; AA, bending angle of apical part.

previously known. As the present data are little, it is hard to solve this problem. These two species are ignored in this study.

Late Permian Albaillella shows closely related shell forms at the species level. They all have one strong ventral wing and a curved apical part. They are distinguishable by their shell height, the position of the wing, the presence of transverse bands (surface construction), the curvature of the apical part, and the proportion of height to width, generally. There are a few specimens that have forms intermediate between species.

Measured features, mean values, number of specimens and standard deviations are shown in Table 1. These mean values and standard deviations show both intraspecific variations and interspecific distinctions.

A. excelsa, A. flexa, and A. lauta have relatively high shell height, and show successive stratigraphic distribution. A. flexa is distinguished from A. lauta by having a strongly bent apical part. Some specimens occurred in Gj-50-9 (upper horizon of stratigraphic range of A. flexa) show a less curved apical part, thus being similar to A. lauta (Pl. 1, Fig. 7). Two peculiar morphotypes, tentatively named A. sp. A and A. sp. B, have moderate shell height, and occur in the same horizon (Gj-47) as that of the last occurrence of A. excelsa. Their morphological features and stratigraphic distributions suggest that they are phylogenetic relations. A. flexa evolved from A. excelsa, and A. flexa gave rise to A. lauta. A. sp. A and A. sp. B seem to be evolutionally transitional forms.

4. Systematic Paleontology

Authorship of two new taxa described in the systematic section of this paper is as-
Table 1  List of measurements for each species. Each column shows: total number of measured specimens (N.S.); mean value (mean); number of specimens (N); and standard deviations (S.D.). See Fig. 3 for abbreviations of features.

<table>
<thead>
<tr>
<th>N.S.</th>
<th>HS</th>
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<th>LW</th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>AA</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>N</td>
<td>S.D.</td>
<td>mean</td>
<td>N</td>
<td>S.D.</td>
<td>mean</td>
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<td>10.6</td>
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<td>4</td>
<td>15.2</td>
<td>81.9</td>
<td>4</td>
<td>5.6</td>
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<tr>
<td>A. sp. B</td>
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<td>181.8</td>
<td>8</td>
<td>14.7</td>
<td>87.7</td>
<td>9</td>
<td>7.2</td>
</tr>
</tbody>
</table>
Late Permian Albaillella in the Gujo-hachiman Area

cribed to KUWAHARA. Type and figured specimens are registered in the Department of Geosciences, Osaka City University, under numbers OCU PR 0001 to OCU PR 0033.

Subclass Radiolaria MÜLLER, 1858

Order Polycystina EHRENBERG, 1838, emend. RIEDEL, 1967

Suborder Albaillellaria DEFLANDRE, 1953, emend. HOLDSWORTH, 1969

Family Albaillellidae DEFLANDRE, 1952

Genus Albaillella DEFLANDRE, 1952

Type species: Albaillella paradoxa DEFLANDRE, 1952

Albaillella excelsa ISHIGA, KITO and IMOTO

(Pl. 1, Fig. 8; Pl. 3, Figs. 1–3)

Measurements (based on 522 specimens from Gj-11, Gj-17, Gj-24, Gj-27, Gj-32, Gj-35 and Gj-41): See Table 1.

Remarks: This species is distinguished from the other Late Permian Albaillella by its large shell height and the proportion of the protruding ventral wing. Shell height (HS) is more than 3 times (mean 3.5 times) that of width (W2). Position of the small aperture under the ventral wing is different from other Late Permian Albaillella. A few specimens show remarkable transverse bands (Pl. 3, Fig. 2).

Albaillella flexa KUWAHARA, n. sp.

(Pl. 1, Figs. 1–3; Pl. 2, Figs. 1–7)

Description: Imperforate, slightly flattened conical shell having a ventral wing. Shell height (HS) is less than 3 times width (W2). Upper part of shell is curved strongly to the ventral side. Curved angle (AA) is more than 30 degrees, and the mean value is 45 degrees. Curvature maximized in the middle of shell apex and base of wing. Weak transverse bands on the surface of the shell. Large hollow wing protrudes from nearly lower one third of the shell. A small aperture under ventral wing. Two small apertures on distal dorsal side near main aperture. Two internal rods are observed in transmitted light. Dorsal internal rod stronger than ventral one. Dorsal internal rod and outer shell are connected indirectly. H-frame is incompletely preserved. Small blade like spines on H-frame.

Measurements (based on 151 specimens from Gj-50–7 and Gj-50–9): See Table 1.

Remarks: This species is distinguished from the other Late Permian Albaillella by having diagnostic bending at the apical part. Shell curvature is variable.

Etymology: Named from Latin flexus, -a, -um, meaning bend.

Type specimens: Holotype, OCU PR 0001 (Pl. 1, Fig. 1); Palatype, OCU PR 0003 (Pl. 1, Fig. 3). Holotype and paratype from Gj-50–9.

Range and Occurrences: Late Permian. This species occurs abundantly in Gj-50–7 and Gj-50–9 of the Gujo-hachiman bedded chert section in the Mino Belt (see Fig.
2). It occurs in the Upper Permian, lower part of the *Neoalbaillella ornithoformis* Assemblage-zone of Ishiga (1986).

*Albaillella lauta* Kuwahara, n. sp.

(Pl. 1, Figs. 4–6; Pl. 2, Figs. 8–12)

Description: Imperforate, flattened conical shell having a ventral wing. Shell height (HS) is about 3 times width (W2). Upper part of shell curved to ventral side gradually. Shell surface smooth. Two or three dimple-like depressions on dorsal surface. Large, hollow ventral wing originating from lower two-fifths of the shell. A small aperture under ventral wing. Two small apertures on distal dorsal side near main aperture. Internal structure is not clear; only two internal rods are preserved in some specimens. Internal rod of dorsal side and outer shell are connected indirectly. H-frame is not completely preserved. Small blade like spines on H-frame.

Measurements (based on 40 specimens from Gj-55 and Gj-60): See Table 1.

Remarks: This species resembles *Albaillella levis*, but differs by having large shell height and protruding portion of wing protruded.

Etymology: Named from Latin *latus, -a, -um*, meaning neat, elegant.

Type specimen: Holotype OCU PR 0004 (Pl. 1, Fig. 4); Paratype OCU PR 0005 (Pl. 1, Fig. 5). Holotype and paratype from Gj-60.

Range and occurrences: Late Permian. This species occurs from Gj-55 to Gj-87 of the bedded chert section in the Gujo-hachiman area of the Mino belt (see Fig. 2). It occurs in the Upper Permian, *Neoalbaillella ornithoformis* Assemblage-zone of Ishiga (1986).

*Albaillella levis* Ishiga, Kito and Imoto

(Pl. 3, Figs. 8–9, 12)

Measurements (based on 98 specimens from Gj-47, Gj-50–9, Gj-55, Gj-60, Gj-67 and Gj-75): See Table 1.

Remarks: This species resembles *A. sp. aff. A. levis* but differs by having slender shell width (W2) and higher shell height (HS).

*Albaillella* sp. aff. *A. levis* Ishiga, Kito and Imoto

(Pl. 3, Figs. 10–11)

Measurements (based on 54 specimens from the Gj-47, Gj-50–9, Gj-67, Gj-75, Gj-136 and Gj-140): See Table 1.

Remarks: This species closely resembles *Albaillella levis*, but differs in the shape of curve and proportion of height and width. Shell shape of this species resembles *A. triangularis*, except for structure of shell surface.

Occurrences: This species occurs abundantly in Gj-136 and Gj-140 (see Fig. 2). First occurrence was not clear.
**Late Permian Albailllella in the Gujo-hachiman Area**

**Albaillella triangularis** ISHIGA, KITO and IMOTO
(Pl. 3, Figs. 5–6)

*Measurements* (based on 117 specimens from the Gj-7, Gj-9, Gj-11 and Gj-27): See Table 1.

*Remarks:* This species resembles *A. levis* and *A.* sp. aff. *A. levis*, but differs by having diagnostic transverse bands.

**Albaillella sp. A**
(Pl. 1, Fig. 9)

*Measurements* (based on 7 specimens from Gj-47): See Table 1.

*Remarks:* Small *Albaillella* with transverse bands. Ventral wing protrudes from middle part of the shell. Shell width is narrow. This species resembles *Albaillella triangularis* in its remarkable transverse bands, but differs in shell proportion.

*Occurrence:* This species commonly occurs from Gj-47 (see Fig. 2).

**Albaillella sp. B**
(Pl. 1, Fig. 10; Pl. 3, Figs. 4, 7)

*Measurements* (based on 11 specimens from Gj-47): See Table 1.

*Remarks:* Small *Albaillella* without transverse bands. This species is closely related to *Albaillella excelsa*, but differs in having short shell height. Intermediate forms of *A. excelsa* and *A.* sp. B exist.

*Occurrences:* This species commonly occurs from Gj-47 (see Fig. 2). First occurrence was not clear.

5. **Cluster Analysis**

5.1. **Method**

Cluster analysis is the method of numerical classification by similarity (or dissimilarity) between specimens. Clusters are represented in a dendrogram which is made by connecting specimens or groups of specimens on the basis of the similarity. The application of cluster analysis in micropaleontology has developed considerably in recent years. For example, Wei (1987) reported the differentiation of chronospecies in the foraminiferal lineage by multivariate morphometrics, and used cluster analysis in an attempt to reveal possible groupings in a sequence of analyses.

In this study, cluster analysis was applied to Late Permian *Albaillella* which have similar shell forms, in order to ascertain their classification by visual inspection. *A. triangularis*, *A. levis*, and *A.* sp. aff. *A. levis* were excluded from the analysis because they are easy to distinguish from other *Albaillella* by their relatively small shell height. Cluster analysis was, therefore, applied to five species (*Albaillella excelsa*, *A. flexa*, *A. lauta*, *A.* sp. A and *A.* sp. B). Well preserved specimens numbering 51 from 12 horizons were selected (Table 2). These specimens had already been identified by visual
Table 2  Data of specimens relating to cluster analysis. See Fig. 3 for abbreviations of features.

<table>
<thead>
<tr>
<th>species</th>
<th>level</th>
<th>LW</th>
<th>AA</th>
<th>HS/W2</th>
<th>HS</th>
<th>W2</th>
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<td>4.000</td>
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Cluster analysis was attempted to two measured values and one derived ratio, which represent characters of species. The values used were:

1. LW: length from proximal part of wing to aperture.
2. AA: bending angle of apical part.
3. HS/W2: ratio as an indicator of shell proportion.

The dissimilarities between specimens were calculated on the standardized squared Euclidean distance, and the clustering method applied was the group-average method. Cluster analysis was carried out using the statistical program of Tanaka et al. (1984).

5.2 Results

Figure 4 shows the result of analysis. A large Cluster A designates *A. excelsa.*

Fig. 4 Dendrogram of cluster analysis showing distinctive clusters. Asterisk shows outlier.
Cluster B is referable to *A. sp. A* and *A. sp. B*. Cluster C reveals *A. lauta*, and Cluster D corresponds to *A. flexa*. The resulting clusters correspond to each species, generally. This result indicates that the method of cluster analysis is applicable to the classification of Late Permian *Albaillella* in general, and that these quantitative features could express species distinctions by visual inspection.

5.3 Discussion

Some outliers exist on the dendrogram in this study, and they may be caused by the following differences between the visual inspection and cluster analysis. The morphometric features used in cluster analysis may be insufficient and/or inadequate to express the shell form. In visual inspection, non-measurable diagnostic features (e.g., the presence of transverse bands) and the difficulty of measuring some parts (e.g., the form of curvature) could be considered as such features. However, the cluster analysis in this study excluded those factors.

For further study, some multivariate analyses will be applied to the classification. Principal-component analysis is another means of classification. Using this method, the scatter-plot of scores of first and second principal components in 51 specimens showed the same grouping as the result of the cluster analysis. Methods of multivariate analysis can be an effective technique to find out discriminating features.

6. Conclusions

(1) Eight *Albaillella*, which included two newly proposed species were distinguished from the bedded chert section in the Gujo-hachiman area of the Mino Belt, Central Japan.

(2) Species distinctions were clarified by means of measurement of quantitative features.

(3) Cluster analysis using well preserved specimens could support classification by visual inspection.

References


Late Permian Albaillella in the Gujo-hachiman Area


Explanation of Plate 1

(All figures × 225)

All figures are transmitted light photomicrographs of Late Permian *Albaillella* (Radiolaria) from a bedded chert section in the Gujo-hachiman area of the Mino Belt, Central Japan.

Figs. 1–3. *Albaillella flexa* Kuwahara, n. sp.
1. OCU PR 0001, Gj–50–9, holotype
2. OCU PR 0002, Gj–50–7
3. OCU PR 0003, Gj–50–9, paratype

Figs. 4–6. *Albaillella lanta* Kuwahara, n. sp.
4. OCU PR 0004, Gj–60, holotype
5. OCU PR 0005, Gj–60, paratype
6. OCU PR 0006, Gj–60

Fig. 7. *Albaillella* sp.
OCU PR 0007, Gj–50–9

Fig. 8. *Albaillella excelsa*
OCU PR 0008, Gj–41

Fig. 9. *Albaillella* sp. A
OCU PR 0009, Gj–47

Fig. 10. *Albaillella* sp. B
OCU PR 0010, Gj–47
Explanation of Plate 2

All figures are scanning electron micrographs of Late Permian *Albaillella* (Radiolaria) from a bedded chert section in the Gujo-hachiman area of the Mino Belt, Central Japan.

Figs. 1–7. *Albaillella flexa* Kuwahara, n. sp.
1. OCU PR 0011, Gj–50–7, × 250
2. OCU PR 0012, Gj–47, × 250
3. OCU PR 0013, Gj–24, × 225
4. OCU PR 0014, Gj–50–7, × 375
5. OCU PR 0015, Gj–50–9, × 375
6. OCU PR 0016, Gj–50–7, × 250
7. OCU PR 0017, Gj–50–7, × 250

Figs. 8–12. *Albaillella lauta* Kuwahara, n. sp.
8. OCU PR 0018, Gj–60, × 175
9. OCU PR 0019, Gj–60, × 250
10. OCU PR 0020, Gj–60, × 175
11. OCU PR 0021, Gj–60, × 175
12. OCU PR 0022, Gj–60, × 175
Explanation of Plate 3

All figures are scanning electron micrographs of Late Permian Albaillella (Radiolaria) from a bedded chert section in the Gujo-hachiman area of the Mino Belt, Central Japan.

Figs. 1–3. Albaillella excelsa Ishiga, Kito and Imoto
1. OCU PR 0023, Gj–32, ×250
2. OCU PR 0024, Gj–32, ×250
3. OCU PR 0025, Gj–32, ×175

Fig. 4. Albaillella sp. B
OCU PR 0026, Gj–47, ×250

Figs. 5–6. Albaillella triangularis Ishiga, Kito and Imoto
5. OCU PR 0027, Gj–24, ×300
6. OCU PR 0028, Gj–14, ×225

Fig. 7. Albaillella sp. B
OCU PR 0029, Gj–47, ×250

Figs. 8–9. Albaillella levis Ishiga, Kito and Imoto
8. OCU PR 0030, Gj–50–9, ×250
9. OCU PR 0031, Gj–60, ×225

Figs. 10–11. Albaillella sp. aff. A. levis Ishiga, Kito and Imoto
10. OCU PR 0032, Gj–106, ×175
11. OCU PR 0033, Gj–106, ×175

Fig. 12. Albaillella levis Ishiga, Kito and Imoto
×750, The same specimen as Fig. 8, showing internal dorsal rod.
NOTES FOR CONTRIBUTORS

Contributions: Contributions for publication should be addressed to the Editorial Committee, Department of Geosciences, Faculty of Science, Osaka City University, Sugimoto 3–3–138, Sumiyoshi-ku, Osaka 558, Japan. Submission implies that the manuscript has not been published previously nor currently submitted for publication elsewhere.

All contributions should be written in English, must be sent in triplicate and typed on one side of A4 size paper, with wide margins and double-lined spacing throughout. Contributions should follow the general style of papers in the recent issue of the Journal. No limitation on the length of the manuscript is generally specified. The authors are required to nominate one or two possible referees, although their services need not necessarily be sought.

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