Permian Tethyan Fusulinids From California

GEOLOGICAL SURVEY PROFESSIONAL PAPER 593-A

Permian Tethyan Fusulinids From California

By RAYMOND C. DOUGLASS

CONTRIBUTIONS TO PALEONTOLOGY

GEOLOGICAL SURVEY PROFESSIONAL PAPER 593-A

Faunal evidence for the existence of a shallow seaway from Japan to California during Early Permian time

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1967

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 40 cents (paper cover)

CONTENTS

ILLUSTRATIONS

[Plates at end of report]

TABLES

CONTRIBUTIONS TO PALEONTOLOGY

PERMIAN TETHYAN FUSULINIDS FROM CALIFORNIA

By Raymond C. Douglass

ABSTRACT

The Calaveras Formation of the California gold belt near Jackson, in Amador and Calaveras Counties, includes lenticular limestones, some of which contain fusulinid Foraminifera. The genera *Schubertella*, *Nagatoella*, *Parafusulina*, and *Misellina* have been recognized. *Nagatoella* had been described from Japan, but had not been found elsewhere until recently when it was recognized in California and Oregon. *Misellina* had been described from southeast Asia, the U.S.S.R., and Japan, and is now found in California, Oregon, and possibly in Washington. The other genera have a worldwide distribution.

The *Nagatoella* from California is similar to the type species from Akiyoshi, Japan. At Akiyoshi, *Nagatoella* is associated with *Misellina claudiae* near the top of the zone of *Pseudofusulina* or near the base of the zone of *Parafusulina kaerimizensis*. It is probably equivalent in age to late Wolfcamp or early Leonard. The *Misellina* from California is smaller in all dimensions than *M. claudiae* from Akiyoshi and more closely resembles forms reported from the *Pseudoschwagerina* zone in Japan. The species of *Schubertella* and *Parafusulina* from the California samples are more similar to forms described from Japan than they are to any reported from the Western Hemisphere.

W. R. Danner in 1965 suggested a eugeosynclinal origin for many of the deposits in Washington, Oregon, and British Columbia where limestones containing fusulinid faunas with Asiatic affinities commonly occur as isolated lenses in volcanic rocks, ribbon cherts, argillites, and graywacke. He also suggested that the Permian Tethyan seaway extending from the Mediterranean region through Japan continued to Yukon Territory, British Columbia, Washington, and Oregon. The California occurrence of Tethyan fusulinids in a similar lithic setting suggests that the seaway extended on to the south, at least as far as the Jackson area.

INTRODUCTION

PREVIOUS WORK AND GEOLOGIC SETTING

The Calaveras Formation in the western foothills of the Sierra Nevada contains many lenticular bodies of limestone, a few of which yield recognizable fossils. Turner (1894) mapped the Calaveras in the area near Jackson and noted many of the limestone outcrops. He did not indicate where fossils were found, but stated (p. 3) that

> at numerous points in this western belt of the Calaveras formation fossils have been found in the limestone lenses. These have been referred by Mr. C. D. Walcott to the Carboniferous, and are as follows: *Fusulina cylindrica*, *Zaphrentis* (?), *Lithostrotion* (?), and crinoid stems. According to Mr. Walcott, genus *Fusulina* does not occur lower than the Carboniferous or higher than the upper division of that system, usually called the Permian.

Clark (1964) remapped and redescribed the Calaveras Formation of this area and collected some Foraminifera which Henbest and Douglass reported to include the genera *Tetrataxis*, *Parafusulina*, *Nagatoella*, and *Misellina* of Permian age (Clark, 1964, p. 14).

The preservation of the material on which the report by Henbest and Douglass for Clark was based left some doubt about the identifications. The presence of the genera *Nagatoella* and *Misellina* had never been reported in the Western Hemisphere, and none of the Asiatic fusulinid faunas were known to occur south of Oregon in North America. A search of some of the limestone lenses for additional material was made by Douglass and Morikawa in September 1965, and two additional fossiliferous lenses were found in Amador County, Calif. This report is based primarily on the fauna found in one of these lenses.

The limestone lenses occur in a sequence of rocks that includes quartzose slate and chert, with minor amounts of volcanic rock in places. Black chert is interbedded with black phyllite in other places, and fine-grained volcanic breccia and some conglomerates are found. The limestone itself is variable in texture. Much of it is fragmental, with pieces of other limestone and pieces of fusulinids cemented in a microgranular to sparry groundmass. Many of the fusulinids show abrasion before deposition, and some show abrasion after having been imbedded in a microgranular matrix. Postdepositional fracturing and recementation is common.

Danner (1965, p. 120) has suggested a eugeosynclinal origin for many of the deposits in Washington, Oregon, and British Columbia where limestones commonly occur as isolated lenses in volcanic rocks, ribbon cherts, argillites, and graywacke. He also suggested that the Permian Tethyan seaway which extended from the Mediterranean region through Japan continued to the Yukon Territory, British Columbia, Washington, and Oregon. The California occurrence of Asiatic fusulinids in a similar lithic setting suggests that the seaway extended on to the south.

SIGNIFICANCE OF THE FUSULINID ASSEMBLAGE

Fusulinids have been known from California for many years, and Meek (1864), Staff (1912), Thompson and Wheeler (1946), Coogan (1960), and Skinner and Wilde (1965) have described many species from northern California. Thompson and Hazzard (1946) and Ross and Sabins (1966) have described species from southern California. In most of these studies, a similarity between the western American fusulinids and those of Asia has been noted. The similarities have not been, however, nearly so close as those between the faunas of Washington State and British Columbia and those of Japan. Neither *Misellina* nor *Nagatoella* had been found in northern or southern California.

The genus *Nagatoella* was described from the Permian of the Akiyoshi Plateau in southwest Japan where it occurs with *Misellina claudiae* above the zone of *Pseudofusulina vulgaris* and below the zone of *Parafusulina kaerimizensis*. It has also been described or recorded from the Atetsu Plateau, from the area near Gifu in central Japan, from the Kanto Mountainland, from Kozaki on Kyushu, and from Onogahara on Shikoku. The California occurrence was the first reported outside Japan. The close similarity, even at the specific level, between the specimens from Japan and the United States suggests a connecting environment between the two areas which would permit rapid migration.

The genus *Misellina* was described from southeast Asia in the area formerly called Indo-China. It has also been reported from the U.S.S.R. and from several places in Japan, including Kozaki on Kyushu, Onagahara and Kochi on Shikoku, the Akiyoshi Plateau and the Atetsu Plateau in southwest Honshu, near Gifu in central Japan, and in the Kanto Mountainland. The geologic range of *Misellina* appears to be greater than that of *Nagatoella*, as it is described from several horizons extending from the *Pseudoschwagerina* zone to the *Neoschwagerina* zone (Morikawa, 1965, p. 17–18). The California occurrence was the first reported in the Western Hemisphere. A recent discovery of *Nagatoella* and *Misellina* in Oregon was described by Bostwick and Nestell (oral commun. Geol. Soc. America Ann. Mtg., November, 1966).

The genus *Parafusulina* has a wide distribution around the world. The species in the California assemblage, however, is not similar to other species described from North America. It is most similar to *Parafusulina edoensis* (Ozawa) which was described from the Akiyoshi Plateau in Japan. The genus *Schubertella* is also known from many areas around the world. The species represented in California was first described from southeast Asia and is also known from several places in Japan. The entire assemblage, then, suggests a close affinity to the faunas of southeast Asia and Japan.

CORRELATION

There remains the problem of the relationship between the Calaveras Formation and the Permian deposits to the north and south in California. The age suggested is within the range of zones G to H of the McCloud Limestone (Skinner and Wilde, 1965, pl. 4), and yet the assemblage is completely different. The Calaveras Formation would also seem to correlate with the middle part of the Owens Valley Formation from which fusulinids were cited but not described (Merriam and Hall, 1957, p. 11–12). Again, the fusulinid faunas cannot be compared directly as they have no species in common. The faunas reported by Ross and Sabins (1966, p. 155–157) from the El Paso Mountains, Calif., are of approximately the same time interval yet do not contain overlapping taxa. For the first two areas mentioned above, one might assume that the depositional environment might have been the controlling influence, as the Owens Valley Formation and the McCloud Limestone may represent a shelf environment. Skinner and Wilde (1965, p. 15) have suggested the shelf environment for the McCloud Limestone. The common occurrence of the crossbedding in the sandy limestones of the Owens Valley Formation and the interbeds of brick-red, greenish-gray, and yellowish-brown shales and siltstones suggest a fluctuating marginal environment. The sequence in the El Paso Mountains, however, is more similar to that of the Calaveras Formation and contains metasedimentary rocks including chloritic shale and siltstone, chert, chert conglomerates, various kinds of basaltic rocks, and some recrystallized limestone and conglomeratic limestone (Ross and Sabins, 1966, p. 155). I would expect that, if the seaway was continuous this far south, Asiatic faunas may yet be found in some of the limestone bodies.

LOCALITIES

The fossil localities are indicated in figure 1.

f9594 Calaveras County, Calif. Block of limestone about 5 ft in diameter exposed in the north wall of a railroad cut in sec. 10, T. 4 N., R. 11 E., at the west boundary

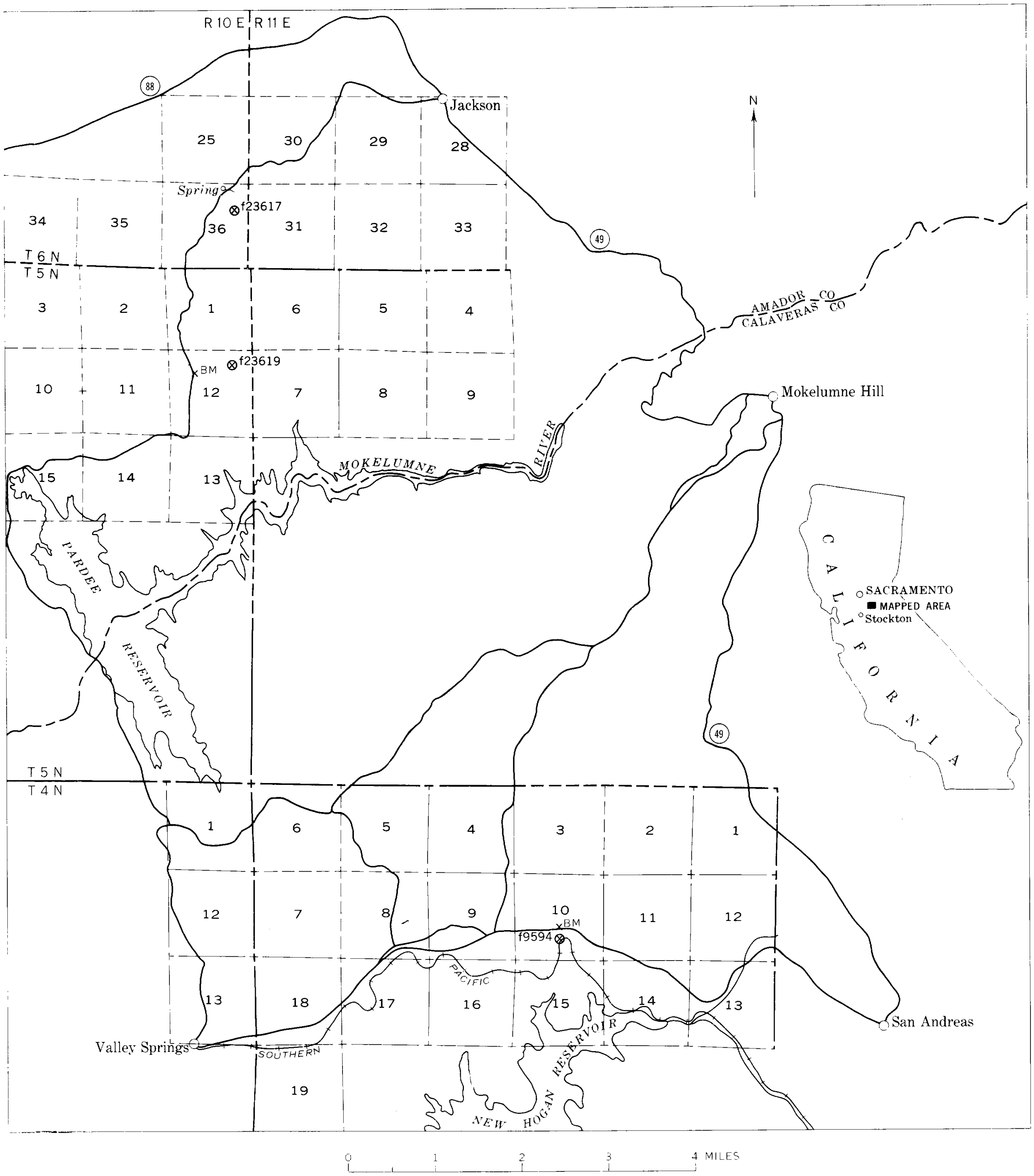


FIGURE 1.—Index to fossil localities in Amador and Calaveras Counties, Calif. ⊗f23617, fossil locality.

of the San Andreas quad. The limestone block is surrounded by conglomerate, tuff, and slate belonging to the Mariposa Formation of Jurassic age and is interpreted as a boulder derived from the Calaveras Formation of the western belt (Clark, 1964, p. 14). L. D. Clark and D. B. Tatlock colln. LC–52–256.

f23617 Amador County, Calif. Lens in Calaveras Formation in NE¼ sec. 36, T. 6 N., R. 10 E. Sutter Creek quad. The limestone forms a low hill with fair-to-good exposure through a light cover of grass. Douglass and Morikawa colln. MC–1, Sept. 5, 1965.

f23619 Amador County, Calif. Lens in Calaveras Formation in NW¼,NE¼ sec. 12, T. 5 N., R. 10 E. Sutter Creek quad. The limestone is exposed through a light cover of poison oak, grass, and small bushes on the north side of a small ranch road. Douglass and Morikawa colln. MC–3, Sept. 5, 1965.

DISPOSITION OF MATERIAL

The specimens used in this study are deposited in the collections of the U.S. National Museum and are entered in catalog 130 under the numbers 643466 through 643509.

ACKNOWLEDGMENTS

I should like to acknowledge the help of all who have assisted in this study. I am especially grateful to Prof. Rokuro Morikawa, of Saitama University, and Mr. Masamich Ota, of the Akiyoshi Science Museum for taking me to, and helping me to collect from, Kaerimizu sinkhole on the Akiyoshi Plateau in Japan. I also appreciate the help of Mr. Donald A. Dean, of the U.S. National Museum, who prepared some of the thin sections. Funds for the collecting in Japan were provided by the United States-Japan Cooperative Science Program through the National Science Foundation.

SYSTEMATIC DESCRIPTIONS

Genus TETRATAXIS Ehrenberg, 1854

Tetrataxis sp.
Plate 1, figures 7–9

A rather high-coned form of this genus is present in several of the samples from the Calaveras Formation. The larger specimens are about 1 mm high with a diameter near 2 mm at the base.

Genus SCHUBERTELLA Staff and Wedekind, 1910

Schubertella giraudi (Deprat)
Plate 1, figures 1–6

Neofusulinella giraudi Deprat, 1915, p. 11–12, pl. 1, figs. 6–11, text fig. 5.
Ozawa, 1927, p. 150–151, pl. 38, figs. 3–6, 9, 16c; pl. 39, figs. 4–6.
Schubertella giraudi (Deprat) Kobayashi, 1957, p. 263–264, pl. 1, figs. 1–5.
Kanmera, 1963, p. 88–89, pl. 12, figs. 8–12.

Description.—Shell minute, fusiform about 1.2 mm long by 0.8 mm wide at five volutions. The juvenarium of approximately one and a half volutions is generally coiled at a large angle to the axis of the adult. One specimen (pl. 1, fig. 6) was found with an unusually large proloculus (about 106 microns) and with regular coiling throughout. The adult chambers have an almost constant height from center to pole with only a slight poleward increase. The proloculus is generally close to 40 microns in maximum outer diameter. The spirotheca is thin and shows little structure (pl. 1, figs. 1b, 2b). Where the chomata are in contact with the wall, an impression of layering is given (pl. 1, fig. 1b, next to last volution), but in equatorial section only a thin tectum and lighter inner layer could be recognized (pl. 1, fig. 2b). The septa are plane throughout and closely spaced, numbering 18–20 in the outer volutions. The chomata are well developed in the middle volutions but variable in size and shape, extending one-fourth to one-half the chamber height. The tunnel is about 30° in the outer volutions.

Comparison and remarks.—The specimens from California agree closely with those described by Deprat, Ozawa, and Kanmera listed above. They appear to be similar to those of Kobayashi, but his specimens seem to be consistently more ellipsoidal in shape and less regular in their coiling.

Specimens studied.—The specimens illustrated are from locality f23617 in the Calaveras Formation of Amador County, Calif., where they are associated with *Misellina*, *Nagatoella*, and *Parafusulina.*

Genus NAGATOELLA Thompson, 1936

Nagatoella orientis (Ozawa)
Plate 2, figures 1–5; plate 3, figures 1–10; plate 4, figures 1–3

Schellwienia ellipsoidalis Staff var. *orientis* Ozawa, 1925, p. 22–23, pl. 6, fig. 1a; pl. 8, figs. 3, 5.
Nagatoella orientis (Ozawa) Thompson, 1936, p. 198–200, pl. 12, figs. 1, 2.
Ishizaki, 1962, p. 159, 160, pl. 9, figs. 9–11.
Nagatoella kobayashii Thompson, 1936, p. 200–202, pl. 12, figs. 4–6.
Toriyama, 1958, p. 162–163, pl. 20, figs. 6–9.
Nogami, 1961, p. 205, 206, pl. 10, figs. 9–11.

Description.—The shell is ellipsoidal, mature specimens being about 7 mm in length and about 4 mm in width at about 11 volutions. Form ratios vary between 1.4 and 3.1 but are generally about 2. (See fig. 2 and table 1.) The shell tends to elongate less rapidly in the outer volutions, becoming a little more inflated. Slightly oblique axial sections, such as that of the holotype and the specimens figured as plate 2, figure 4, and plate 3, figure 9, appear to have rounded ends and heavy axial filling. The proloculus is variable in size, ranging from

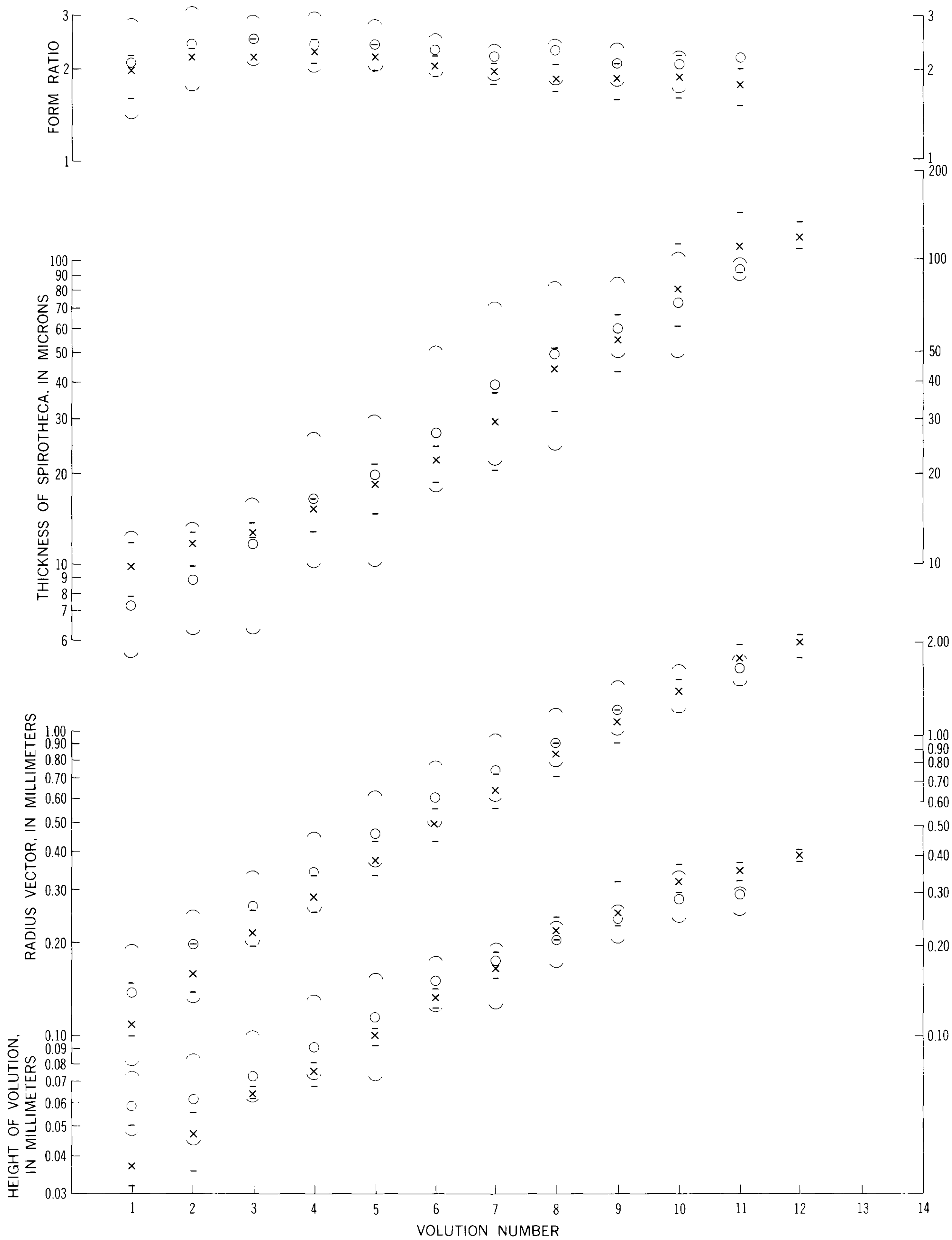


FIGURE 2.—Summary graphs for *Nagatoella orientis* (Ozawa) 1925. The observed limits and mean for the topotypes shown by "(0)"; for California specimens, by "| × |."

TABLE 1.—*Measurements for* Nagatoella orientis (*Ozawa*) *from Akiyoshi, Japan, and loc. f23617 in California*

Half length (millimeters)

Specimen	Shown on— Pl.	Fig.	Diameter of Proloculus (microns)	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13
Akiyoshi, Japan																
1	----	----	263	0.36	0.53	0.72	0.92	1.19	1.45	1.75	2.08	2.44	2.87	----	----	----
2	----	----	200	.43	.73	.89	1.16	1.49	1.75	2.15	2.58	2.97	----	----	----	----
3	----	----	244	.33	.44	.63	.85	.99	1.38	1.60	2.10	2.50	3.00	----	----	----
4	3	8	219	.18	.31	.52	.72	1.03	1.34	1.55	2.05	2.54	3.07	3.46	----	----
5	3	5	----	.19	.34	.49	.65	.90	1.07	1.34	2.05	2.54	2.97	3.40	----	----
6	3	6		.19	.41	.59	.81	1.06	1.22	1.47	1.88	2.31	2.87	3.17	----	----
7	----	----	200	----	----	----	----	----	----	----	----	----	----	----	----	----
8	----	----	194	----	----	----	----	----	----	----	----	----	----	----	----	----
9	----	----	206	----	----	----	----	----	----	----	----	----	----	----	----	----
10	----	----	269	----	----	----	----	----	----	----	----	----	----	----	----	----
Mean			225	.28	.46	.64	.85	1.11	1.37	1.64	2.12	2.55	2.96	3.34	----	----
Standard deviation			30	.11	.15	.15	.18	.21	.23	.28	.23	.22	.09	.15	----	----
Amador County, Calif.																
1	2	1	270	0.24	0.41	0.55	----	----	----	----	----	----	----	----	----	----
2	2	4	----	----	----	----	----	----	----	----	----	----	----	----	----	----
3	----	----	----	.24	.31	.41	0.55	0.67	0.85	1.04	1.27	1.55	1.91	2.24	2.64	3.23
4	2	5	200	.24	.37	.57	.73	.93	1.11	1.42	1.82	2.34	2.91	3.40	----	----
5	2	2	----	----	----	----	----	----	----	----	----	----	----	----	----	----

Radius vector (millimeters)

Specimen	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13
Akiyoshi, Japan													
1	0.20	0.26	0.35	0.46	0.59	0.75	0.92	1.15	1.38	1.72	----	----	----
2	.15	.23	.34	.47	.64	.81	.99	1.22	1.48	----	----	----	----
3	.16	.21	.28	.36	.45	.57	.73	.92	1.11	1.35	----	----	----
4	.13	.18	.24	.33	.39	.52	.64	.83	----	----	----	----	----
5	.08	.13	.20	.28	.37	.50	.67	.83	1.08	1.38	1.64	----	----
6	.10	.15	.20	.26	.37	.50	.64	.81	1.03	1.25	1.47	----	----
7	.11	.16	.24	.33	.41	.57	.73	.93	1.16	1.41	1.64	----	----
8	.11	.16	.23	.31	.44	.57	.75	.91	1.11	1.42	1.67	----	----
9	.18	.24	.31	.41	.52	.67	.83	1.07	1.30	1.56	1.79	----	----
10	.18	.23	.31	.39	.49	.62	.80	----	----	----	----	----	----
Mean	.14	.20	.27	.36	.47	.61	.77	.96	1.21	1.44	1.64	----	----
Standard deviation	.04	.04	.06	.07	.09	.11	.12	.15	.16	.15	.11	----	----
Amador County, Calif.													
1	0.15	0.20	0.26	0.34	0.44	0.57	0.75	0.94	1.19	1.47	1.75	2.14	----
2	.10	.14	.20	.26	.37	.49	.67	.88	1.14	1.47	1.98	----	----
3	.10	.15	.20	.26	.34	.44	.57	.73	.94	1.19	1.47	1.78	2.08
4	.11	.16	.23	.29	.39	.50	.67	.85	1.09	1.33	1.68	2.11	----
5	.10	.15	.20	.28	.36	.48	.65	.90	1.20	1.51	1.95	----	----

Form ratio

Specimen	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
Akiyoshi, Japan											
1	1.8	2.0	2.1	2.0	2.0	1.9	1.9	1.8	1.8	1.7	----
2	2.9	3.2	2.6	2.5	2.3	2.2	2.2	2.1	2.0	----	----
3	2.1	2.1	2.3	2.4	2.2	2.4	2.2	2.5	----	----	----
4	1.4	1.7	2.2	2.2	2.6	2.6	2.4	2.5	----	----	----
5	2.4	2.6	2.5	2.3	2.4	2.1	2.0	2.5	2.4	2.2	2.1
6	1.9	2.7	3.0	3.1	2.9	2.4	2.3	2.3	2.2	2.3	2.2
7	----	----	----	----	----	----	----	----	----	----	----
8	----	----	----	----	----	----	----	----	----	----	----
9	----	----	----	----	----	----	----	----	----	----	----
10	----	----	----	----	----	----	----	----	----	----	----
Mean	2.1	2.4	2.5	2.4	2.4	2.3	2.2	2.3	2.1	2.1	2.2
Standard deviation	.5	.5	.3	.4	.3	.3	.2	.3	.3	.3	.1
Amador County, Calif.											
1	1.6	2.1	2.1	----	----	----	----	----	----	----	----
2	----	----	----	----	----	----	----	----	----	----	----
3	2.1	2.3	2.1	2.1	2.0	1.9	1.8	1.7	1.6	1.6	1.5
4	2.2	2.3	2.5	2.5	2.4	2.2	2.1	2.1	2.1	2.2	2.0
5	----	----	----	----	----	----	----	----	----	----	----

Tunnel angle (degrees)

Specimen	Shown on— Pl.	Fig.	Diameter of Proloculus (microns)	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13
Akiyoshi, Japan—Continued																
1	----	----	----	35	35	30	30	21	25	25	25	28	----	----	----	----
2	----	----	----	40	43	33	35	30	29	35	39	----	----	----	----	----
3	----	----	----	30	35	36	33	35	26	25	35	----	----	----	----	----
4	3	8	----	35	34	35	30	35	35	34	----	----	----	----	----	----
5	3	5	----	58	45	38	43	35	40	34	28	32	----	----	----	----
6	3	6	----	----	----	----	----	40	40	37	35	35	----	----	----	----
7	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
8	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
9	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
10	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Mean			----	40	38	34	34	33	33	32	32	32	----	----	----	----
Standard deviation			----	11	5	3	5	7	7	5	6	4	----	----	----	----
Amador County, Calif.—Continued																
1	2	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----
2	2	4	----	----	----	----	----	----	----	----	----	----	----	----	----	----
3	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
4	2	5	----	45	50	----	39	35	28	25	----	----	----	----	----	----
5	2	2	----	----	----	----	----	----	----	----	----	----	----	----	----	----

Thickness of spirotheca (microns)

Specimen	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13
Akiyoshi, Japan—Continued													
1	5	10	13	15	15	19	44	63	88	109	----	----	----
2	13	10	17	28	32	53	75	88	81	----	----	----	----
3	7	14	16	13	19	18	25	38	63	69	----	----	----
4	8	10	15	19	20	25	32	50	----	----	----	----	----
5	6	----	----	13	15	19	22	34	53	88	94	----	----
6	----	----	----	19	19	25	32	44	65	81	94	----	----
7	6	6	6	10	10	22	32	55	50	75	----	----	----
8	5	6	8	10	21	30	30	25	50	49	97	----	----
9	10	9	10	15	25	32	50	69	69	75	100	----	----
10	----	----	----	25	25	32	56	----	----	----	----	----	----
Mean	7	9	12	17	20	28	40	52	65	78	96	----	----
Standard deviation	3	3	4	6	6	10	16	19	14	26	8	----	----
Amador County, Calif.—Continued													
1	10	13	----	17	22	23	26	44	44	63	94	----	----
2	10	10	14	16	19	25	30	50	60	119	----	----	----
3	----	11	13	13	22	25	38	48	50	69	113	----	----
4	12	12	13	15	15	19	21	33	60	70	113	----	----
5	8	13	13	17	15	21	38	53	69	106	150	----	----

Height of volution (millimeters)

Specimen	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
Akiyoshi, Japan—Continued											
1	0.063	0.075	0.081	0.103	0.156	0.170	0.185	0.231	0.256	0.345	----
2	.069	.088	.106	.138	.163	.181	.200	.236	.269	----	----
3	.075	.069	.069	.088	.097	.138	.194	.169	.250	.250	----
4	.050	.053	.072	.081	.069	.125	.128	.188	----	----	----
5	.050	.053	.069	.088	.110	.140	.175	.194	.265	.275	.300
6	.050	.044	.063	.075	.113	.138	.156	.188	.238	.238	.250
7	.050	.050	.069	.081	.094	.163	.181	.206	.250	.282	.300
8	.048	.044	.063	.088	.119	.156	.169	.181	.200	.306	.300
9	.069	.056	.072	.088	.125	.150	.181	.225	.250	.256	.282
10	.063	.075	.088	.100	.119	.138	.200	----	----	----	----
Mean	.059	.061	.075	.093	.117	.150	.177	.202	.247	.279	.286
Standard deviation	.010	.015	.013	.018	.028	.017	.022	.024	.021	.037	.021
Amador County, Calif.—Continued											
1	0.032	0.050	0.063	0.081	0.106	0.131	0.171	0.206	0.256	0.300	0.357
2	.032	.036	.059	.075	.103	.144	.181	.250	.282	.369	----
3	.032	.056	.069	.081	.100	.138	.169	.221	.260	.313	.326
4	.050	.044	.069	.069	.094	.124	.156	.206	.231	.313	.315
5	.044	.044	.063	.081	.094	.131	.181	.250	.326	.351	.351

a low of about 90 microns, measured by Toriyama on one of Ozawa's specimens, to 270 microns in specimens from California and Akiyoshi, Japan. The proloculus of most specimens is not round, and the measurements recorded in the table are all maximum outer diameters. The spirotheca is relatively thin in the inner volutions but thickens gradually through about the first six volutions and then more rapidly in the outer volutions. (See table 1 and fig. 2.) The inner volutions show little structure (pl. 4, fig. 2), but coarse keriotheca can be seen in the outer volutions (pl. 4, figs. 1, 3). The keriotheca generally extends down along the septa, giving them a wedge shape in places in the inner volutions and thickening them throughout most of the shell. Secondary deposits related to the chomata tend to coat both forward and trailing edges of the septa, especially in the vicinity of the tunnel (pl. 3, fig. 2b; pl. 4, fig. 3), the coating commonly extending all the way to the roof of the chamber. The septa are tightly fluted at their base, with cuniculi formed in parts of some specimens. The upper parts of the septa are nearly plane. The number of septa per volution increases from about eight in the first volution to about 30 in the outer volutions. The tunnel is well developed, the angle averaging in the thirties throughout most of the shell. In the inner volutions it is bordered by small asymmetrical chomata. In the outer volutions the chomata become discontinuous or absent. The tunnel increases in height in the outer volutions, commonly attaining half the chamber height. Axial filling is developed in the early volutions but is generally lacking beyond the sixth or seventh volution.

Comparison and remarks.—Thompson (1936, p. 196) established the genus *Nagatoella* based on specimens originally described by Ozawa (1925, p. 22–23). He pointed out that Ozawa's three specimens were from three localities. He selected the specimen prepared as an oblique axial section to be the holotype of *N. orientis* (Ozawa) and assigned the parallel and oblique equatorial sections to a new species *N. kobayashii* Thompson. *N. orientis* was designated the type species "(genotype)" for *Nagatoella*. The holotype (only specimen) was from the *Misellina claudiae* bed at Kaerimizu doline (sinkhole) on the Akiyoshi Plateau. In the vicinity of the sinkhole the *Misellina* bed is a continuous zone 10–100 cm thick. Other specimens from this bed were later (Toriyama, 1958, p. 163) assigned to *Nagatoella kobayashii* Thompson. I have studied samples from this bed and found that the specimens cover a range of variability which includes *N. orientis* and *N. kobayashii* and intermediate forms (pl. 3). They are all, therefore, assigned to *N. orientis*. The specimens described by Nogami (1961, p. 205) from the Atetsu Plateau and from Ibukiyama also fall within this range and are here included in *N. orientis*. The specimens from California are poorly preserved, but they show many features in common with those from Kaerimizu at the type locality. The measurable features follow each other closely (fig. 2). The distribution of axial filling, the tunnel and chomata, the development of septal fluting, and the wall structure all seem to be similar.

Distribution—*Nagatoella orientis* is now known from southwest and central Honshu and central Shikoku in Japan and from central California. In California it has been found at three localities: f9594 in Calaveras County where it was reported by Henbest and Douglass (in Clark, 1964, p. 14); f23617 in Amador County, from which the specimens illustrated in this report were derived; and f23619 in Amador County. In Japan, *N. orientis* is generally associated with *Misellina claudiae* near the top of the zone of *Pseudofusulina* or near the base of the zone of *Parafusulina*. In California it is in the Calaveras Formation associated with *Misellina*, *Parafusulina*, and *Schubertella* in isolated limestones which are not in a well-dated sequence. Neither *Nagatoella* nor *Misellina* has been found in the more continuous fossiliferous sections of the Permian to the north and south in California.

Genus PARAFUSULINA Dunbar and Skinner, 1931

Discussion.—The description of this genus was based on the type species *P. wordensis*, described at the same time, which is now considered to be an advanced representative of the genus. Many forms have since been assigned to *Parafusulina*, and there has been a tendency, at least in America, to assign any large schwagerinid with a single tunnel and cuniculi to this genus. More recently, the genera *Monodiexodina*, *Eoparafusulina*, and *Cuniculinella* have been recognized with cuniculi. The genus *Parafusulina* has thus been restricted to some extent, but a problem still remains in the assignment of forms apparently intermediate between *Schwagerina* and *Parafusulina*. Several forms develop low or beaded cuniculi, especially in their outer volutions, while retaining otherwise the characters of *Schwagerina*. For many advanced forms described as *Schwagerina*, no tangential sections are illustrated that would show the intensity of the fluting and possible development of cuniculi. The form hereunder assigned to *Parafusulina* is one of these intermediate forms. It has definite cuniculi, but they are not developed throughout, and they are not straight sided as in the type species. The presence of phrenothecae may be considered unusual in a *Parafusulina* also. They are more common in this species than in others that I have seen, but they do occur in *P. rothi* Dunbar and Skinner, 1937, *P. bösei* Dunbar and Skinner, 1937, and its variety *attenuata* Dunbar and Skinner, 1937, *P. sapperi* (Staff) of Dunbar, 1939, *P. deltoides* Ross, 1960, P. *vidriensis* Ross, 1960, and P. *laudoni* Skinner and Wilde, 1966.

Parafusulina impensa n. sp.

Plate 4, figure 4; plate 5, figures 1–10

Description.—The shell is large and subcylindrical to elongate fusiform attaining a length of as much as 15 mm in seven to eight volutions. The early volutions are generally fusiform, but the chamber height increases rapidly toward the poles of the outer volutions, developing a more cylindrical shape. The proloculus is large, with a range from about 300 to more than 500 microns and a mean of about 430 microns. (See fig. 3 and table 2). It tends to be spherical, but is commonly flattened on one side. The spirotheca is composed of a tectum and well-defined keriotheca (pl. 4, fig. 4) which have finer divisions near the tectum in the outer volutions. The wall thickens rapidly from about 30 microns in the inner volution to about 150 microns in the outer volution (fig. 3). Phrenothecae are irregularly developed (pl. 5, figs. 7, 10). The septa are tightly fluted throughout the shell, with narrow beaded cuniculi at the base of the chambers (pl. 5, figs. 5, 10). There are more than 20 septa in the second volution and as many as 30 in the outer volutions. The tunnel is slightly irregular, and its width is difficult to observe in places. It averages 30°–36° in the inner volutions. Chomata were detected on the proloculus, but they do not seem to be developed elsewhere, though the base of the septa appear thickened where they touch the floor of the chamber in some places (pl. 5, figs. 1, 2). Axial filling is developed from an early stage and tends to spread away from the axis to some extent (pl. 5, figs. 7–9).

Comparisons and remarks.—Parafusulina impensa bears a slight resemblance to *P. diabloensis* Dunbar and Skinner (1937, p. 674), but it is larger, has fewer chambers in each volution, and has a larger form ratio throughout. It more closely resembles *P. endoensis* (*Ozawa*), as redescribed from topotypes by Toriyama (1958, p. 197), but *P. impensa* has a consistently thicker spirotheca, a smaller proloclus, and the shell elongates more rapidly in the outer volutions (fig. 3).

Material studied.—The description and illustrations are based on samples from locality f23617 in Amador County, Calif., where the *Parafusulina* is associated with *Misellina*, *Nagatoella*, and *Schubertella*. Twenty-one oriented and many oblique sections were studied in addition to etched and lacquered slices of the limestone.

Designation of types.—The specimen illustrated on plate 5, as figure 8, is designated the holotype. The other specimens studied are paratypes.

Genus MISELLINA Schenck and Thompson, 1940

Misellina californica n. sp.

Plate 1, figures 10–12; plate 6, figures 1–16

The shell is small and variable in shape from elongate ellipsoidal (pl. 6, fig. 1) to nearly rounded (pl. 6, figs. 6–8). The juvenarium is endothyroid, and the earliest subsequent volutions tend to be spherical. Later volutions tend to elongate along the axis, attaining form ratios of about 1.4 (See fig. 4 and table 3.) The axis of coiling in the juvenarium is not precisely at 90° to the later coiling, and coiling in the adult form is not necessarily regular (pl. 6, figs. 5, 6, 8). Mature specimens develop six to seven volutions, and some reach nearly 1.5 mm in length, but most are smaller. The proloculus is small and nearly spherical, with an outer diameter commonly about 60 microns. One was found to measure as much as 75 microns in maximum outer diameter. The spirotheca is composed of a tectum and well-defined keriotheca. The thickness of the wall varies greatly from place to place in a volution. It thickens in the vicinity of each septum to eight or more times the thickness between septa (pl. 1, figs. 10, 11). In places the wall seems to be represented only by tectum at the highest part of the chamber, between septa as in figure 11, next to last volution on right. Measurements of the wall, therefore, are difficult to interpret. The wall seems to increase in thickness from about 6 microns in the early volutions to about 20 microns in the outer volution. The Keriotheca tends to extend the entire length of the septa, and the septa are commonly covered at their lower ends with the parachomatal deposits.

The septa increase in number gradually from about 10 in the second volution to about 16 in the outer volution. The septa are nearly straight along their length and have a tendency to be pitched forward. The parachomata are low, rarely reaching half the chamber height. Between septa they tend to be rounded to slightly pyramidal (pl. 6, figs. 3, 7). At the septa they tend to spread out, sometimes extending along the lower edge of the keriotheca for some distance between septa and generally extending along the septa, leaving only low openings between chambers (pl. 6, fig. 9; pl. 1, fig. 10). About 10 parachomata are developed in the outer volutions.

Comparisons and remarks.—Misellina californica is one of possibly several species that are closely similar morphologically. It is difficult to determine how close a taxonomic relationship exists between it and the following forms:

Misellina aliciae (Deprat), 1912
M. termieri (Deprat), 1915
M. minor (Deprat), 1915

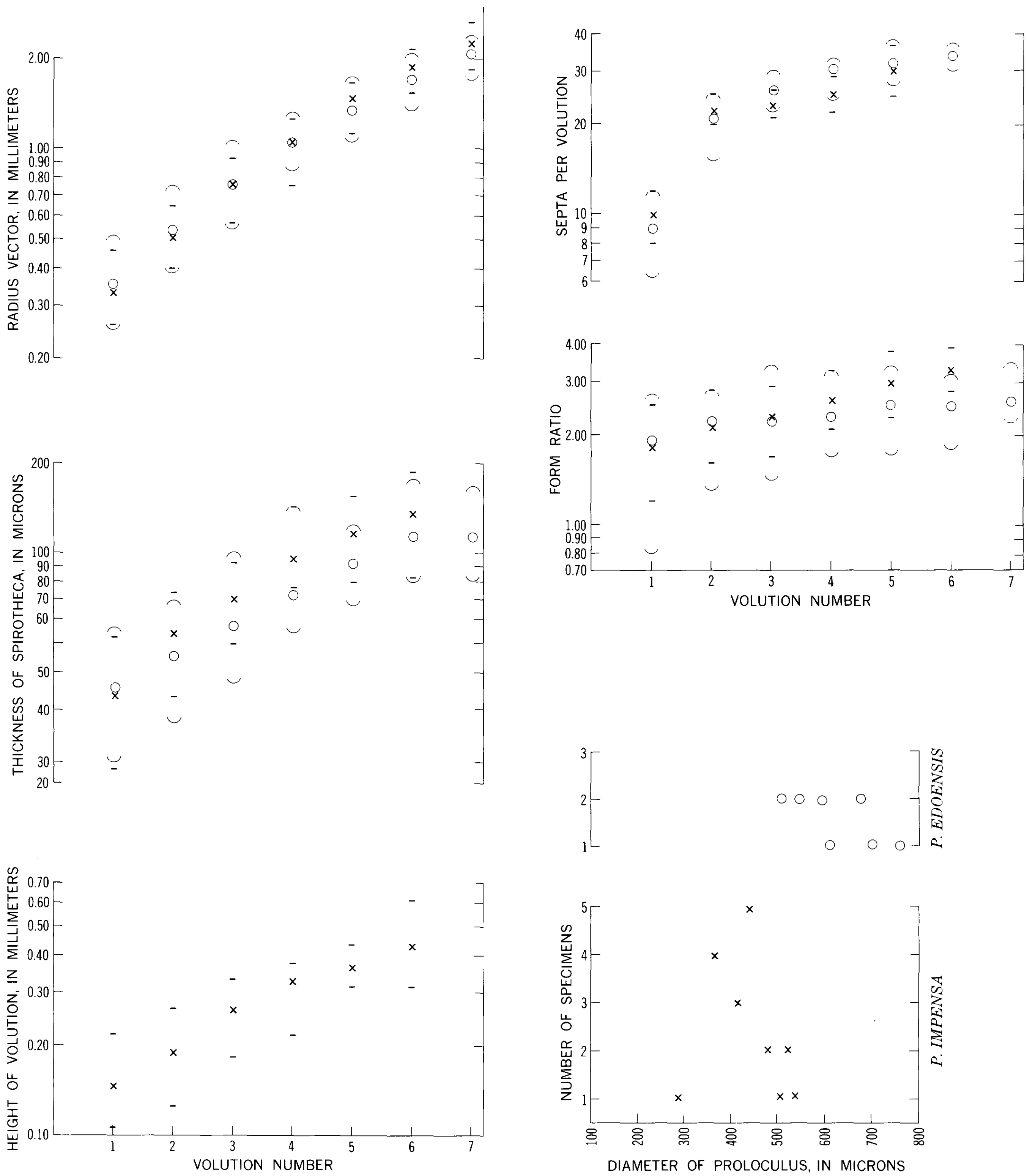


FIGURE 3.—Summary graphs for *Parafusulina impensa* n. sp., with comparative data for *P. edoensis* from Toriyama (1958, table 74). Data for *Parafusulina impensa* indicated by "| × |"; data for *P. edoensis* indicated by "(O)."

TABLE 2.—*Measurements of* Parafusulina impensa *n. sp. from loc. f23617*

Specimen	Shown on— Pl.	Shown on— Fig.	Diameter of proloculus (microns)	Half length (millimeters) V1	V2	V3	V4	V5	V6	V7
1	5	7	500	0.56	0.93	1.77	2.80	3.81	5.12	6.32
2	5	8	476	.50	.99	1.91	3.04	4.37	6.23	7.44
3	----	----	519	.69	1.05	1.85	2.81	----	----	----
4	----	----	357	.59	.99	1.72	2.81	4.10	5.30	----
5	----	----	407	.83	1.55	2.21	3.14	----	----	----
6	----	----	438	.66	.89	1.49	2.18	3.30	4.93	----
7	5	9	519	.49	.99	1.85	3.17	4.65	6.23	----
8	5	3	369	.43	.79	1.25	2.28	4.25	5.67	----
9	5	4	288	.41	.81	1.30	1.63	----	----	----
10	5	6	413	.36	.73	1.25	2.08	----	----	----
11	----	----	438	.43	1.19	1.58	3.14	3.91	6.05	----
12	5	1	482	----	----	----	----	----	----	----
13	5	2	407	----	----	----	----	----	----	----
14	----	----	438	----	----	----	----	----	----	----
Mean			429	.42	.90	1.45	2.46	4.27	5.98	6.88
Standard deviation			62	.05	.19	.26	.68	.37	.29	----

Specimen	Radius vector (millimeters) V1	V2	V3	V4	V5	V6	V7	Form ratio (millimeters) V1	V2	V3	V4	V5	V6	V7
1	0.30	0.46	0.79	1.12	1.45	1.82	2.21	1.9	2.0	2.2	2.5	2.6	2.8	2.9
2	.30	.43	.66	.92	1.29	----	----	1.7	2.3	2.9	3.3	3.4	----	----
3	.33	.49	.69	1.00	----	----	----	2.1	2.1	2.5	2.8	----	----	----
4	.26	.46	.73	1.06	1.45	----	----	2.3	2.2	2.4	2.7	2.8	----	----
5	.43	.63	.92	1.25	----	----	----	2.5	2.5	2.4	2.5	----	----	----
6	.36	.53	.83	1.06	1.45	----	----	1.8	1.7	1.8	2.1	2.3	----	----
7	.36	.59	.92	1.25	1.68	2.15	2.64	1.4	1.7	2.0	2.5	2.8	2.9	----
8	.30	.40	.59	.83	1.13	1.55	1.82	1.4	2.0	2.1	2.7	3.8	3.7	----
9	.26	.41	.57	.75	----	----	----	1.6	2.0	2.3	2.2	----	----	----
10	.30	.46	.73	1.00	----	----	----	1.2	1.6	1.7	2.1	----	----	----
11	.30	.43	.63	.99	1.25	1.55	----	1.4	2.8	2.5	3.2	3.1	3.9	----
12	.46	.65	.90	1.22	1.65	1.98	----	----	----	----	----	----	----	----
13	.36	.56	.86	1.22	1.58	20.1	----	----	----	----	----	----	----	----
14	.33	.52	.80	1.11	----	----	----	----	----	----	----	----	----	----
Mean	.33	.50	.75	1.05	1.44	1.85	2.23	1.8	2.1	2.3	2.6	3.0	3.3	----
Standard deviation	.06	.08	.12	.15	.19	.25	.41	.4	.4	.3	.4	.5	.6	----

Specimen	Pl.	Fig.		Tunnel angle (degrees) V1	V2	V3	V4	V5	V6	V7
1	5	7	----	38	45	34	34	30	48	----
2	5	8	----	40	30	32	39	----	----	----
3	----	----	----	26	30	----	----	----	----	----
4	----	----	----	25	36	36	36	----	----	----
5	----	----	----	37	29	28	----	----	----	----
6	----	----	----	----	----	----	----	----	----	----
7	5	9	----	22	44	25	30	----	----	----
8	5	3	----	----	----	----	----	----	----	----
9	5	4	----	----	----	----	----	----	----	----
10	5	6	----	32	35	45	----	----	----	----
11	----	----	----	----	----	----	----	----	----	----
12	5	1	----	----	----	----	----	----	----	----
13	5	2	----	----	----	----	----	----	----	----
14	----	----	----	----	----	----	----	----	----	----
Mean			----	31	36	33	35	----	----	----
Standard deviation			----	7	7	7	17	----	----	----

Specimen	Thickness of spirotheca (microns) V1	V2	V3	V4	V5	V6	V7	Height of volution (millimeters) V1	V2	V3	V4	V5	V6	V7
1	----	----	65	80	81	94	94	----	0.188	0.270	0.340	0.332	0.375	0.451
2	19	33	81	88	125	125	----	.113	.125	.250	.282	.407	.381	----
3	19	63	69	81	----	----	----	.113	.175	.238	.345	----	----	----
4	38	63	69	100	131	131	----	.113	.200	.306	.357	.438	.616	----
5	35	65	78	106	----	----	----	.219	.238	.313	.313	----	----	----
6	38	44	69	78	125	125	----	.168	.263	.300	.294	.400	.438	----
7	53	75	94	144	153	188	----	.131	.234	.332	.375	.425	.482	.470
8	27	32	63	81	95	169	----	.188	.125	.194	.282	.319	.438	----
9	35	46	53	77	----	----	----	.125	.156	.181	.213	----	----	----
10	44	38	75	88	----	----	----	.131	.181	.263	.313	----	----	----
11	25	----	50	106	81	81	----	.106	.163	.250	.363	.338	.313	----
12	28	52	75	113	156	156	----	.156	.181	.269	.375	.326	.375	----
13	40	70	70	106	106	156	----	.188	.238	.313	.375	.394	.500	----
14	38	63	88	94	----	----	----	.144	.206	.282	.338	----	----	----
Mean	34	54	71	96	117	136	----	.146	.191	.269	.326	.375	.435	.460
Standard deviation	10	15	12	19	28	35	----	.036	.042	.044	.047	.046	.090	.013

Specimen	Septa per volution V1	V2	V3	V4	V5	V6
1	----	----	----	----	----	----
2	----	----	----	----	----	----
3	----	----	----	----	----	----
4	----	----	----	----	----	----
5	----	----	----	----	----	----
6	----	----	----	----	----	----
7	----	----	----	----	----	----
8	----	----	----	----	----	----
9	----	----	----	----	----	----
10	----	----	----	----	----	----
11	----	----	----	----	----	----
12	8	21	21	22	25	30
13	9	20	26	29	37	----
14	12	25	22	----	----	----
Mean	----	----	----	----	----	----
Standard deviation	----	----	----	----	----	----

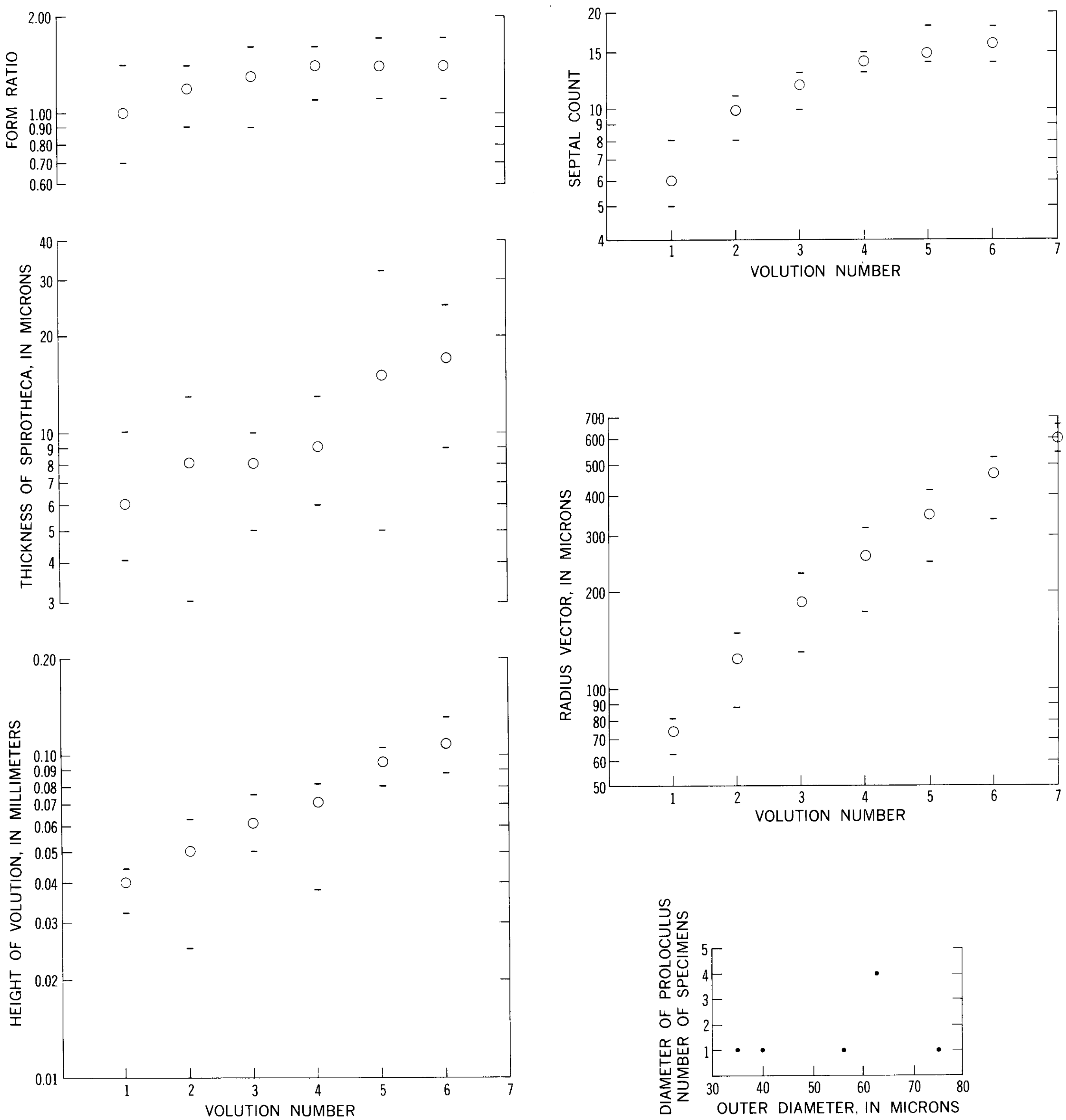


FIGURE 4.—Summary graphs for *Misellina californica* n. sp. showing observed limits of variation and the mean at each volution.

TABLE 3.—*Measurements of* Misellina californica *n. sp. from loc. f23617*

Specimen	Shown on— Pl.	Shown on— Fig.	Diameter of proloculus (microns)	Half length (millimeters) V_1	V_2	V_3	V_4	V_5	V_6	Radius vector (millimeters) V_1	V_2	V_3	V_4	V_5	V_6	Form ratio V_1	V_2	V_3	V_4	V_5	V_6
1	6	1	56	0.088	0.125	0.206	0.275	0.431	0.563	0.063	0.088	0.131	0.175	0.250	0.340	1.4	1.4	1.6	1.6	1.7	1.7
2	6	3		.063	.125	.188	.313	.438	.594	.063	.113	.163	.225	.300	.413	1.0	1.1	1.2	1.4	1.5	1.4
3	6	6	35	.069	.144	.225	.338	.463	.601	.075	.119	.175	.244	.338	.431	.9	1.2	1.3	1.4	1.4	1.4
4	6	7		.050	.125	.200	.326	.444	.594	.069	.144	.219	.288	.388	.525	.7	.9	.9	1.1	1.1	1.1
5			63	.081	.144	.231	.345	.470		.075	.113	.169	.244	.326		1.1	1.3	1.4	1.4	1.4	
6	6	2								.081	.138	.200	.282	.381							
7	6	11								.081	.144	.219	.288	.375	.500						
8										.081	.150	.231	.319	.419	.532						
9	6	13	75							.077	.119	.194	.282	.375	.482						
Mean			57	.070	.133	.210	.319	.449	.588	.074	.125	.189	.261	.350	.460	1.0	1.2	1.3	1.4	1.4	1.4
Standard deviation			13	.015	.010	.018	.028	.017	.017	.007	.020	.032	.043	.052	.070	.3	.2	.3	.2	.2	.2

Specimen	Shown on— Pl.	Shown on— Fig.	Thickness of spirotheca (microns)						Height of volution (microns)						Septa per volution					
1	6	1	8	5	5	6	13	25	44	25	50	38	80	88						
2	6	3	7	9	10	13	18	19	38	56	53	63	85	113						
3	6	6	5	7	8	8	13	11	32	44	50	72	91	100						
4	6	7		13			22	25	44		63	81	103	131						
5			10	7	9	9	32		44	32	56	75	88							
6	6	2	4	10	7	13	14		32	56	63	81	106		6	10	13	15	14	
7	6	11	4	5	6	6	5		44	53	69	69	100	119	8	10	13	14	14	14
8			8	10		7	6	9	44	63	75	81	106	106	5	8	10	15	18	18
9	6	13		8	9	9	10	10	38	44	70	78	106	106		11	12	13	14	15
Mean			7	9	8	9	15	17	40	47	61	71	96	109	6	10	12	14	15	16
Standard deviation			3	2	2	3	8	8	5	13	9	14	10	14	2	1	1	1	2	

M. minor (Deprat) of Fujimoto, 1936
M. ibukiensis Kobayashi, 1957
M. ibukiensis Kobayashi of Morikawa and Isomi, 1961
M. iisikai (Toriyama) of Suyari, 1962
M. cf. *termieri* (Deprat) of Suyari, 1962
M. aliciae (Deprat) of Ishizaki, 1963
M. subelliptica (Deprat) of Ishizaki, 1963
M. aff. *ibukiensis* Kobayashi of Ishizaki, 1963
M. cylindrica Ishizaki, 1963

All the above are small thin-walled forms of the genus and occur in the early part of the age range. They have been distinguished from each other by differences in shape, rate of expansion of the shell, and development of parachomata. The samples from California contain a variety of shapes, rates of expansion, and shapes of parachomata; yet they are all so closely similar, I believe that they represent a single population. The specimens described by Suyari (listed above) are both from the same sample, and although they are identified with named species, Suyari points out that the identification of *M. iisaki* is tentative and that the identification of *M.* cf. *termieri* is based on a single equatorial section and is also tentative. He points out that *M. termieri* and *M. subelliptica* cannot be distinguished.

Ishizaki (1963, p. 55–62) studied a single sample containing *Misellina* and noted many similarities between the specimens, but he assigned them to three previously described and one new species. It is a little difficult to compare the specimens, as the sections are not cut in the standard orientations. His counts on number of parachomata are about double the number illustrated in any one volution.

The specimens from California could be assigned to several of the named forms in this group, and perhaps they should all, then, be assigned to *M. aliciae* (Deprat) which has priority. The nature of the wall, however, has led me to recognize these as a new species. None of the early forms described show the thickening of the wall toward and along the septa as in *M. californica*. Deprat's illustration (Deprat, 1912, p. 42, fig. 25, 1b) is diagrammatic, but shows no thickening at the septa. The photographs of specimens in this group show that there is some thickening at the septa, but it is more restricted. The thickening in the California forms tends to be more like that in *Misellina claudiae* (Deprat) which occurs in younger beds in Japan (pl. 6, figs. 17–20).

Distribution.—Specimens of this species were found at localities f9594 and f23617, where they are associated with the genera *Climacammina*, *Tetrataxis*, *Schubertella*, *Nagatoella*, and *Parafusulina*. The rock is a limestone composed of fragments of fossils and pieces of other limestones cemented in a silty microcrystalline groundmass. The rock has been microfractured after solidification, and recemented with crystalline calcite (pl. 6, fig. 16). The description is based principally on specimens from f23617 which has the best preserved material. The specimens in f9594 appear to be identical, but they have been distorted to some extent by compression.

Designation of types.—The specimen illustrated as figures 1a, b on plate 6 is designated the holotype. The other specimens studied are paratypes.

REFERENCES CITED

Clark, L. D., 1964, Stratigraphy and structure of part of the western Sierra Nevada metamorphic belt, California: U.S. Geol. Survey Prof. Paper 410, 70 p., 10 pls., 16 figs. [1965].

Coogan, A. H., 1960, Stratigraphy and paleontology of the Permian Nosoni and Dekkas formations (Bollibokka Group): California Univ. Pubs. Geol. Sci., v. 36, no. 5, p. 243–316, pls. 22–27, 23 figs.

Danner, W. R., 1965, Limestone of the western Cordilleran eugeosyncline of southwestern Oregon: Mining Metall. Inst. India, Dr. D. N. Wadia Commemorative Volume, p. 113–125. 2 figs., 8 photomicrographs.

Deprat, J., 1912, Étude des fusulinidés de Chine et d'Indochine et classification des calcaires à fusulinés: Indochina Service geol. Mém., v. 1, pt. 3, 76 p., 9 pls., 30 figs.

——— 1915, Étude des fusulinidés de Chine et l'Indochine et classification des calcaires à fusulinés (IV Mémoire). Les fusulinidés des calcaires carbonifériens et permiens du Tonkin, du Laos et du Nord-Annam: Indochina Service geol. Mém., v. 4 pt. 1, 30 p., 13 pls., 11 figs.

Dunbar, C. O., 1939, Permian fusulines from Central America: Jour. Paleontology, v. 13, no. 3, p. 344–348, pls. 35, 36.

Dunbar, C. O., and Skinner, J. W., 1931, New fusulinid genera from the Permian of West Texas: Am. Jour. Sci., v. 22, p. 253–268.

——— 1937, Permian Fusulinidae of Texas: Texas Univ. Bull. 3701, pt. 2, p. 517–825, pls. 42–81.

Ehrenberg, C. G., 1854, Mikrogeologie: Leipzig, L. Voss, 374 p., 40 pls.

Fujimoto, Haruyoshi, 1936, Stratigraphical and palaeontological studies of the Titibu System of the Kwanto Mountainland. Part 2, Palaeontology: Tokyo Bunrika Daigaku, Sci. Rept., sec. C, v. 1, no. 2, p. 29–125, pls. 1–26.

Ishizaki, Kunihiro, 1962, Stratigraphical and paleontological studies of the Onogahara and its neighboring area, Kochi and Ehime prefectures, Southwest Japan: Tohoku Univ. Sci. Repts., 2d ser., v. 34, no. 2, p. 95–185, pls. 7–12, figs. 1–20.

——— 1963, Verbeekiniae from the inferred upper Wolfcampian limestone in the west of Ryoseki, Kochi prefecture: Palaeont. Soc. Japan Trans. and Proc., new ser., no. 50, p. 51–64, pl. 9.

Kanmera, Kametoshi, 1963, Fusulines of the Middle Permian Kozaki Formation of southern Kyushu: Kyushu Univ., Fac. Sci. Mem., ser. D, v. 14, no. 2, p. 79–141, pls. 11–19, figs. 1–3.

Kobayashi, Manabu, 1957, Paleontological study of the Ibukiyama limestone. Shiga prefecture, central Japan: Tokyo Kyoiku Daigaku, Sci. Repts., ser. C, v. 5, no. 48, p. 247–311, 10 pls.

Meek, F. B., 1864, Description of the Carboniferous fossils: California Geol. Survey, Paleontology, v. 1, p. 1–16, pls. 1, 2.

Merriam, C. W., and Hall, W. E., 1957, Pennsylvanian and Permian rocks of the southern Inyo Mountains, California: U.S. Geol. Survey Bull. 1061–A, p. 1–15.

Morikawa, Rokuro, 1965, Solidographic study of fusulinid Foraminifera. (2) Subfamily Verbeekiniae in Japan: Saitama Univ. Sci. Repts., ser. B, v. 5, no. 1, p 15–27, pls 2–5, 2 figs.

Morikawa, Rokuro, and Isomi, Hiroshi, 1961, Studies of Permian fusulinids in the east of Lake Biwa, central Japan: Japan Geol. Survey Rept. 191, 29 p., 29 pls.

Nogami, Yasuo, 1961, Permische Fusuliniden aus dem Atetsu-Plateau Südwestjapans. Teil I, Fusulininae und Schwagerininae: Kyoto Univ. Coll. Sci., ser. B. Mem. 27, no. 3, p. 159–225.

Ozawa, Yoshiaki, 1925, Paleontological and stratigraphical studies on the Permo-Carboniferous limestone of Nagato. Part 2, Paleontology: Tokyo Imp. Univ., Coll. Sci. Jour., v. 45, art. 6, p. 1–90, pls. 1–14.

——— 1927, Stratigraphical studies of the Fusulina Limestone of Akasaka, Province of Mino: Tokyo Imp. Univ., Fac. Sci. Jour., sec. 2, v. 2, pt. 3, p. 121–164, pls. 34–46.

Ross, C. A., 1960, Fusulinids from the Hess member of the Leonard formation, Leonard series (Permian), Glass Mountains, Texas: Cushman Found. Foram. Research Contr., v. 11, pt. 4, p. 117–133, pls. 17–21, 2 figs.

Ross, C. A., and Sabins, F. F., Jr., 1966, Permian fusulinids from El Paso Mountains, California: Jour. Paleontology, v. 40, no. 1, p. 155–161, pls. 19–20, 1 fig.

Schenck, H. G., and Thompson, M. L., 1940, *Misellina* and *Brevaxina*, new Permian fusulinid Foraminifera: Jour. Paleontology, v. 14, no. 6, p. 584–589.

Skinner, J. W., and Wilde, G. L., 1965, Permian biostratigraphy and fusulinid faunas of the Shasta Lake area, northern California: Kansas Univ. Paleont. Contr. [39], Protozoa, art. 6, 98 p., 65 pls., 3 figs.

——— 1966, Permian fusulinids from Black Mountain area, northwestern Washington, *in* Skinner, J. W., and Wilde, G. L., Permian fusulinids from Pacific northwest and Alaska: Kansas Univ. Paleont. Contr., Paper 4, pt. 6, p. 41–44, pls. 34–36.

Staff, Hans von, 1912, Monographie der Fusulinen. Teil III, Die Fusulinen (Schellwienen) Nordamerikas: Palaeontographica, v. 59, p. 157–191, pls. 15–20, figs. 1–17.

Staff, Hans von, and Wedekind, Rudolf, 1910, Der Oberkarbone Foraminiferensapropelit Spitzbergens: Geol. Inst. Upsala Bull., v. 10, p. 81–123, pls. 2–4.

Suyari, Kazumi, 1962, Geological and paleontological studies in central and eastern Shikoku, Japan. Part 2, Paleontology: Gakugei Tokushima Univ. Nat. Sci. Jour., v. 12, p. 1–64, pl. 1–12.

Thompson, M. L., 1936, *Nagatoella*, a new genus of Permian fusulinids: Geol. Soc. Japan Jour., v. 43, no. 510, p. 195–202, pl. 12.

Thompson, M. L., and Hazzard, J. C., 1946, Permian fusulinids of southern California, *in* Thompson, M. L., Wheeler, H. E., and Hazzard, J. C., Permian fusulinids of California: Geol. Soc. America Mem. 17, p. 37–53, pls. 10–18.

Thompson, M. L., and Wheeler, H. E., 1946, Permian fusulinids of northern California, *in* Thompson, M. L., Wheeler, H. E., and Hazzard, J. C., Permian fusulinids of California: Geol. Soc. America Mem. 17, p. 21–36, pls. 1–9.

Toriyama, Ryuzo, 1958, Geology of Akiyoshi: part III, Fusulinids of Akiyoshi: Kyushu Univ., Fac. Sci. Mem., ser. D, v. 7, 264 p., 48 pls.

Turner, H. W., 1894, Description of the Jackson quadrangle [California]: U.S. Geol. Survey Geol. Atlas, Folio 11, 6 p.

PLATES 1–6

PLATE 1

FIGURES 1–6. *Schubertella giraudi* (Deprat) (p. A4) from loc. f23617 in the Calaveras Formation of Amador County, Calif.

1a. Fractured axial section showing juvenarium coiled at a high angle to the outer volutions, USNM 643466, × 20.

1b. Part of same specimen enlarged to show juvenarium and wall structure, × 150.

2a. Equatorial section, USNM 643467, × 20.

2b. Part of same specimen enlarged to show wall structure, × 150.

3. Incomplete axial section showing juvenarium coiled at a less than 90° angle, USNM 643468, × 20.

4. Near equatorial section, USNM 643469, × 20).

5. Tangential section showing chomata and straight septa, USNM 643470, × 20.

6. Equatorial section of a specimen with uniform coiling, USNM 643471, × 20.

7–9. *Tetrataxis* sp. (p. A4) from the same locality.

7, 8. Axial sections, × 20.

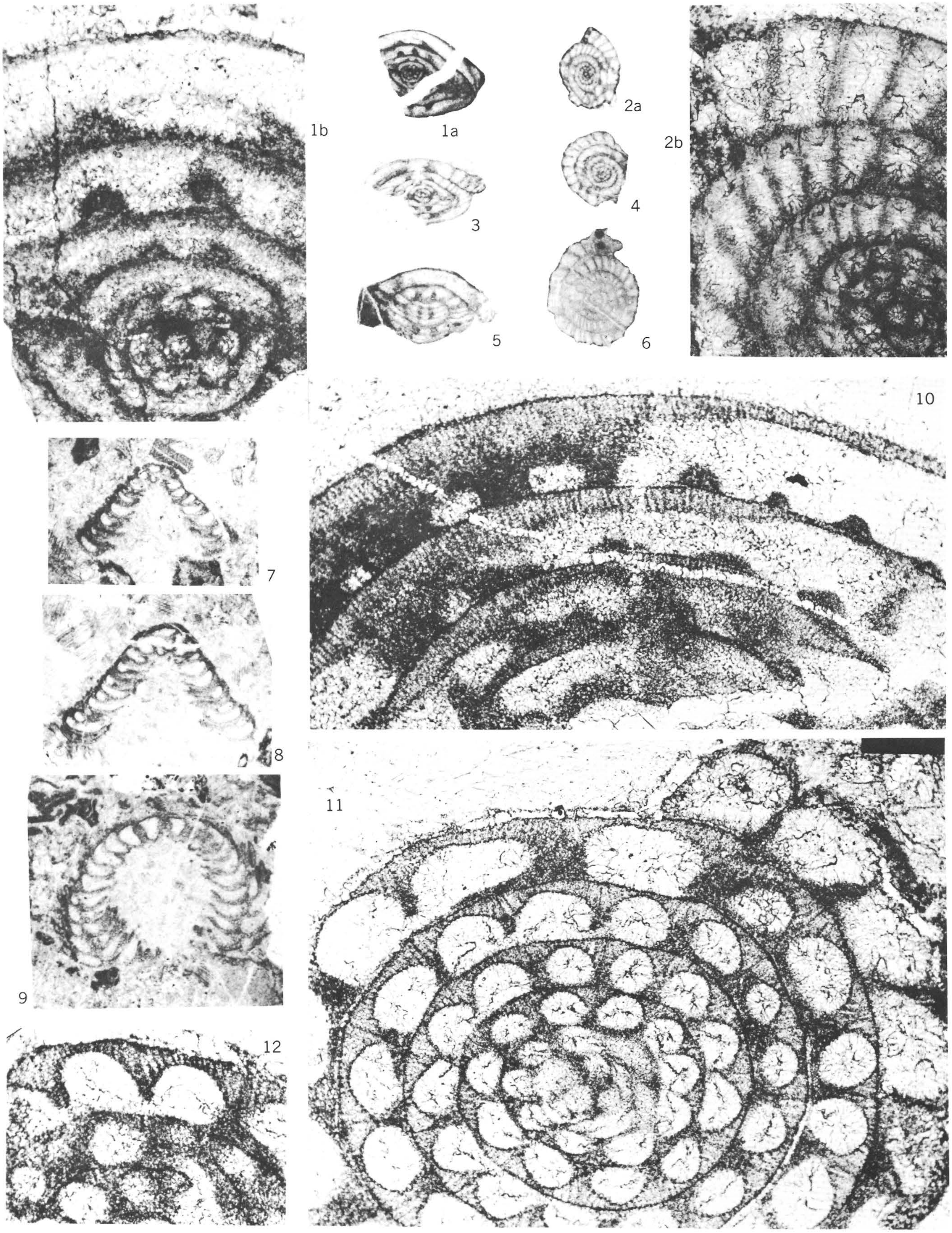
9. Near basal section, × 20.

10–12. *Misellina californica* Douglass, n. sp. (p. A8) from the same locality.

10. Same specimen as fig. 9 on pl. 6, enlarged to show wall structure and the spreading of secondary deposits along the base of the keriotheca leaving low openings between the parachomata, × 150.

11. Same specimen as fig. 2 on pl. 6 enlarged to show keriotheca, × 150.

12. Part of same specimen as fig. 14 on pl. 6 enlarged to show coarse keriotheca on the septa, × 150.



TETRATAXIS, *SCHUBERTELLA*, AND *MISELLINA* FROM CALIFORNIA

PLATE 2

FIGURES 1–5. *Nagatoella orientis* (Ozawa), 1925 (p. A4) from loc. f23617 in the Calaveras Formation, Amador County, Calif.

1a. Part of an axial section, USNM 643472, × 10.

1b. Same specimen, × 20.

2a. Eroded equatorial section, USNM 643473, × 10.

2b. Same specimen enlarged to show wall structure, × 20.

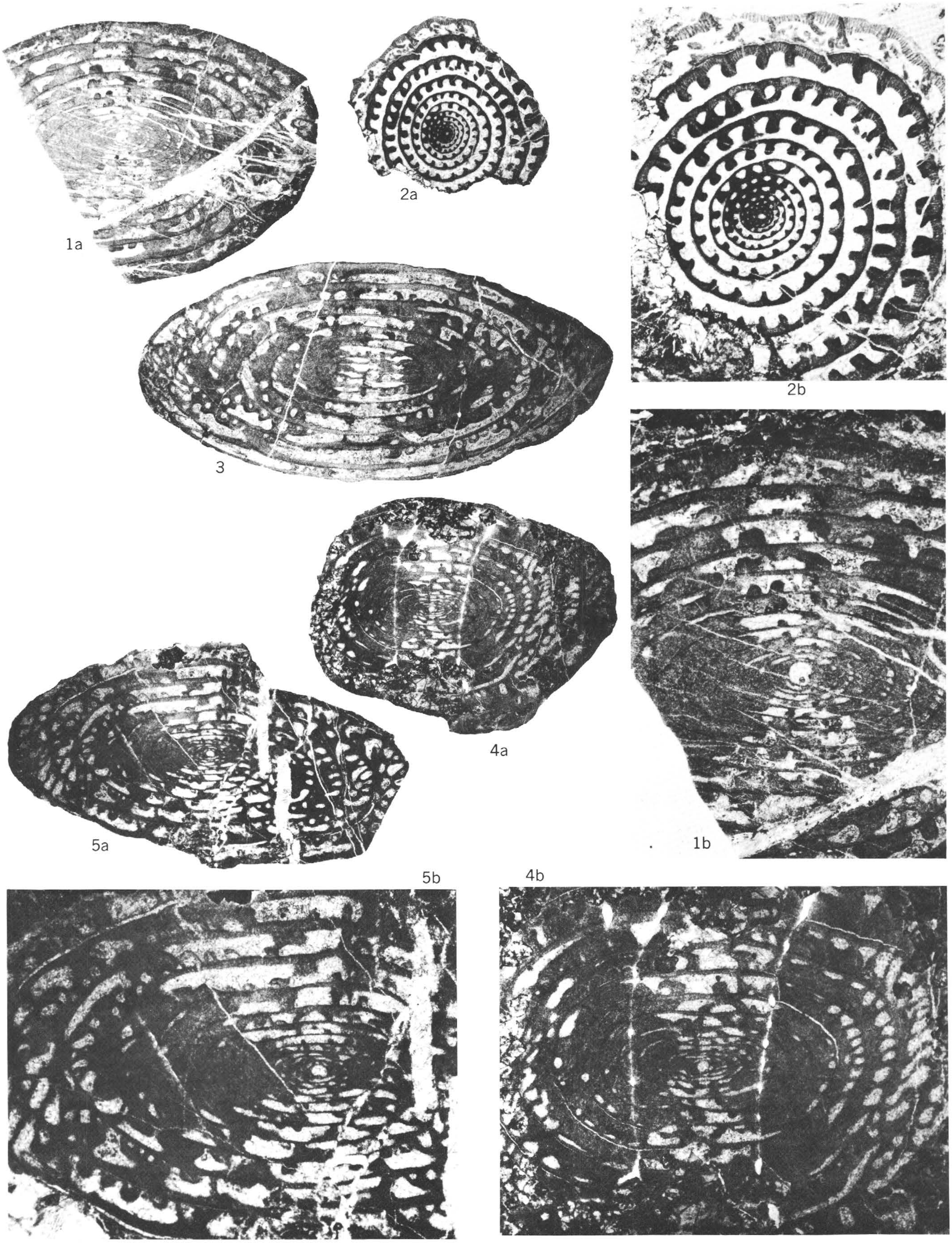
3. Deep tangential section, USNM 643474, × 10.

4a. Slightly oblique axial section, USNM 643475, × 10.

4b. Same specimen enlarged to show changes in shape through the early ontogeny and the distribution of axial filling, × 20. Compare with pl. 3, fig. 9b.

5a. Fractured axial section, USNM 643476, × 10.

5b. Same specimen enlarged to show distribution of axial filling as it appears in the axial plane, × 20.



NAGATOELLA ORIENTIS (OZAWA) FROM CALIFORNIA

PLATE 3

FIGURES 1–10. *Nagatoella orientis* (Ozawa), 1925 (p. A4) from the type locality at Kaerimizu doline on the Akiyoshi Plateau, Japan.

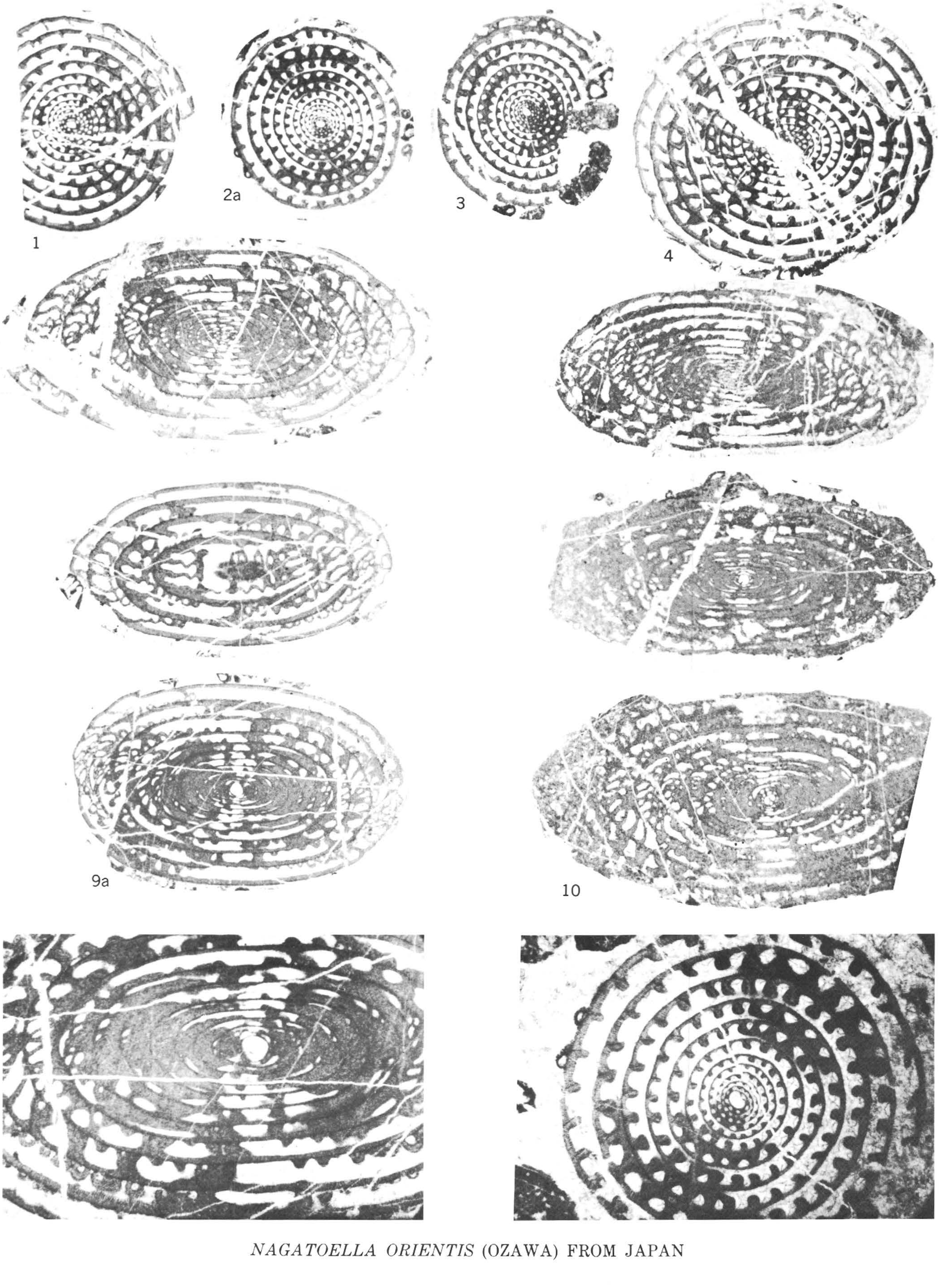
1–4. Equatorial sections showing variation in septa shape and tightness of coiling, USNM 643497–643500, × 10.

2b. Same specimen as 2a enlarged to show some wall structure and the spreading of the secondary deposits onto the septa, × 20.

5, 6, 8, 10. Axial sections 5, 6, USNM 643501; 8, USNM 643503; 10, USNM 643505, × 10.

7. Tangential section, USNM 643502, × 10.

9a, b. Oblique axial section showing very rounded appearance of poles, USNM 643504, × 10 and × 20.



NAGATOELLA ORIENTIS (OZAWA) FROM JAPAN

PLATE 4

[All figures × 150]

FIGURES 1–3. *Nagatoella orientis* (Ozawa) (p. A4) from loc. f23617 in the Calaveras Formation, Amador County, Calif.

1. Outer volutions of the specimen illustrated on pl. 2, as fig. 2a, b, showing coarse keriothecal structure continuing down the inner face of the septa.
2. Inner volutions of the same specimen showing the thin wall and subtriangular septa.
3. Middle volutions of the same specimen showing heavy secondary coating on the septa in the vicinity of the chomata.
4. *Parafusulina impensa* n. sp. (p. A8) from the same locality showing the coarse keriothecal structure in the outer volutions, and phrenothecae USNM 643477.

NAGATOELLA ORIENTIS (OZAWA) *AND PARAFUSULINA IMPENSA* N. SP. FROM CALIFORNIA

PLATE 5

[All figures × 10]

FIGURES 1–10. *Parafusulina impensa* Douglass, n. sp. (p. A8) from loc. f23617 in the Calaveras Formation of Amador County, Calif.

1, 2. Equatorial sections, USNM 643468 and 643478.

3. Axial section of one of the most elongate specimens, USNM 643479.

4. Immature specimen with relatively small proloculus, showing axial filling developed in early stages, USNM 643480.

5. Part of a tangential section showing tightly fluted septa, USNM 643481.

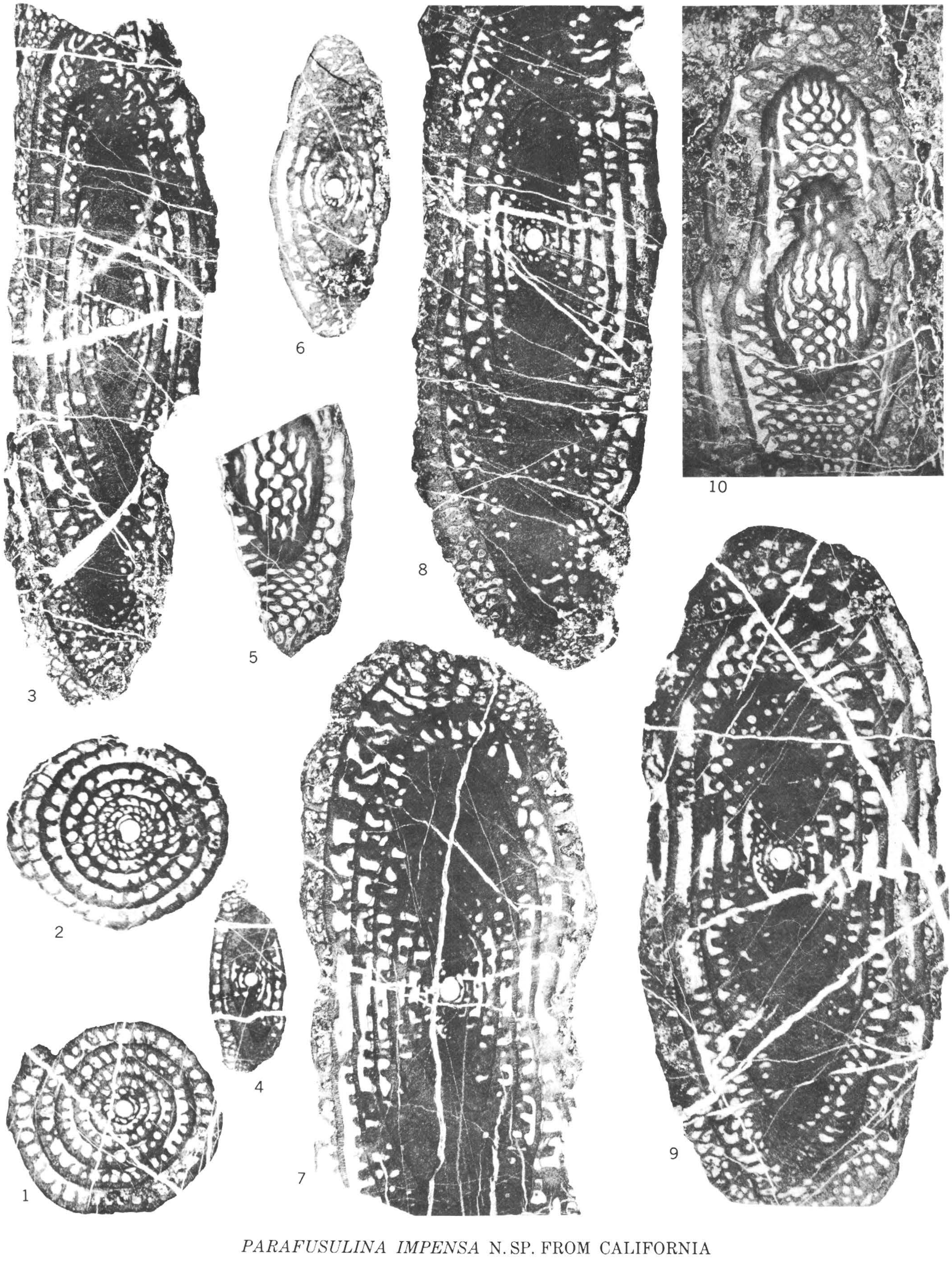
6. Immature specimen showing only partial deposition of filling along the axis, USNM 643482.

7. Axial section showing phrenothecae developed in several outer volutions, USNM 643483.

8. Axial section of the holotype, USNM 643484.

9. Oblique axial section of a specimen with rapidly expanding shell, USNM 643485.

10. Tangential section showing cuniculi and phrenothecae, USNM 643486.



PARAFUSULINA IMPENSA N. SP. FROM CALIFORNIA

PLATE 6

FIGURES 1–15. *Misellina californica* Douglass, n. sp. (p. A8) from loc. f23617 in the Calaveras Formation, Amador County, Calif.

1a. Axial section of holotype, USNM 643487, × 20.

1b. Same specimen, × 50. Note low passages through the septa in upper left and lower right.

2a. Near equatorial section of a paratype, USNM 643488, × 20.

2b. Same specimen, × 50. Note thickening of the keriotheca at the septa. (See also pl. 1, fig. 11.)

3–8. Axial and near axial sections showing variation in shape and irregularities in coiling, USNM 643489, –490, –467, –491, –467, and –492, × 20.

9–10. Tangential sections showing nearly straight septa and the thickening of the keriotheca at the septa, USNM 643493 and –494, × 20. (See also pl. 1, fig. 10.)

11–14. Equatorial and near equatorial sections showing variability of coiling, USNM 643495, –466, –496, and –490, × 20. (See also pl. 1, fig. 12.)

15. Tangential section with unusually well developed parachomata, USNM 643467, × 20.

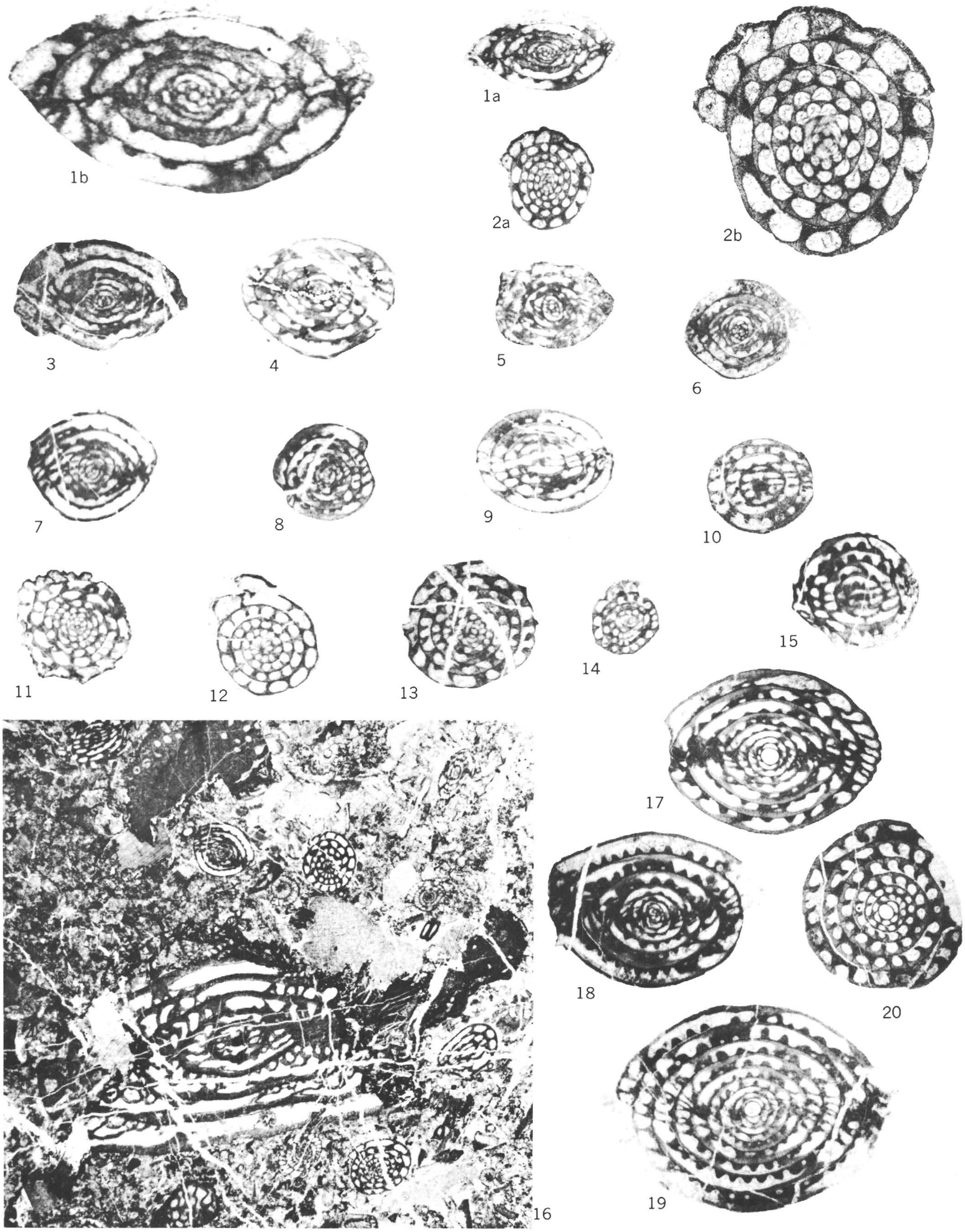
16. Rock section showing association and lithology. Note *Schubertella, Misellina,* and fragmental schwagerinids.

Note also the postlithification fracturing, × 10.

17–20. *Misellina claudiae* (Deprat) from Kaerimizu doline, Akiyoshi Plateau, Japan, USNM 643506–643509, × 20.

17–19. Axial and near axial sections showing regular and endothyroid juvenaria. Note the variation in shape of the parachomata and the thickening of the keriotheca along the septa.

20. Equatorial section showing the parachomata joining the septa.



MISELLINA FROM CALIFORNIA AND JAPAN

U. S. GOVERNMENT PRINTING OFFICE : 1967 O - 262-867