DISCOVERY OF THE GENUS *Aulina* SMITH IN THE CARBONIFEROUS OF JAPAN

by

M. MINATO and C. L. ROWETT*

(with 1 Text-figure and 2 plates)

(Contribution from the Department of Geology and Mineralogy, Faculty of Science, Hokkaido University, No. 1056)

A massive compound corallum referrable to the genus *Aulina* recently was collected from a locality in Honshu, Japan, by M. NAKAZIMA, a student in this department. Limestones at this locality may be correlatives of the Viséan Onimaru Series, which is widely distributed throughout the southern Kitakami Mountains. Although the microstructure is poorly preserved, this specimen can be identified as an example of the type species of *Aulina*, *A. rotiformis* SMITH. This is the first recorded occurrence of the genus *Aulina* in Japan.

Genus ***AULINA*** SMITH, 1916

Type species: Aulina rotiformis SMITH, 1916, p. 2; 1917, p. 290, pl. 22, figs. 6–11, text-figs. 3, 4.

The taxonomic history of the genus *Aulina* consists of a series of revisions of the generic diagnosis which, the present authors believe, ultimately has resulted in the referral of a polyphyletic group of species to this genus. Inasmuch as it is our intent here to propose the restriction of *Aulina* (*sensu stricto*) to corals exhibiting a common origin with respect to their growth form, a short summary of this history is necessary.

The original generic diagnosis, based on the type species, was given by SMITH (1917, p. 290), and is as follows:

> The corallum is massive, and the corallites are united by their extrathecal tissue. All the septa dilate at the theca, and those of the major cycle again dilate at their axial edges, in such a manner as to fuse together

* Visting Professor of the Department of Geology and Mineralogy, Hokkaido University, University of Alaska, College, Alaska.

and so to form a cylindrical wall or tube within the theca.

The presence of a " tube " or tubular wall in the axial area that divides the inner and outer tabularium thus was regarded by Smith to be of prime importance in distinguishing this genus from such similar genera as *Phillipsastrea* d'ORBIGNY (1849) and *Orionastraea* SMITH (1916). It is also pertinent to note that the massive growth form forms a part of the original diagnosis.

On the occassion of describing additional specimens of the type species and a similar, but fasciculate, form, the generic diagnosis was emended by SMITH (1925, p. 486) as follows:

> Compound Rugose coral. The corallum may be fasciculate or massive and the corallites free, cylindrical and invested by epitheca, or continuous and united by confluent septa and dissepimental tissue. The major septa extend well into the intrathecal region and there form by union of their deflected axial edges a perfect tube; the minor septa terminate near the theca. All the septa are dilated at the theca. The tabulae lie both inside and outside the tube, but whereas those within are fairly regular and horizontal, those without are less regular, are inclined towards the periphery, and are slightly more numerous.

The fasciculate coral thus was included in *Aulina* and described by Smith as *A. furcata* (ibid., 1925, p. 490).

In 1943 additional species of *Aulina* were described by SMITH and YÜ; the generic diagnosis was again revised to " possibly " include solitary forms as the result of HILL's (1934) description of a simple coral as *Aulina simplex*. This revision (SMITH and YÜ, 1943, p. 43) is quoted below:

> Compound, and possibly also simple, rugose corals typically plocoid, derived from *Lithostrotion* but homeomorphic with *Eridophyllum* in their general internal structures and differing only in details. Typically, the septa are more dilated, the tabulae closer together, the periaxial tabulae more steeply inclined, the dissepiments smaller and the carinae less strongly developed and of more common ' alternating ' kind.

However, SMITH and YÜ expressed doubt at that time whether solitary corals such as those described by HILL could be considered to be congeneric with *Aulina* and were " inclined to view . . . their structural resemblance to the aulate lithostrotionids [as] due to homeomorphy."

Following this final revision and enlargement of the generic concept of *Aulina* a considerably large number of species from the Carboniferous of many parts of the world have been referred to this genus, including the following:

§§ SOLITARY FORMS TENTATIVELY ASSIGNED TO *AULINA*

Aulina simplex HILL (Upper Viséan, Australia)

1934 *Aulina simplex* HILL, p. 93, pl. 5, figs. 12–29, text-fig. 4

1943 *Aulina simplex* HILL, SMITH and YÜ, p. 52, pl. 9, figs. 11–15.

§§ FASCICULATE FORMS ASSIGNED TO *AULINA*

Aulina? yohi (YÜ) (Upper Viséan, China, Viet Nam)

1933 *Crepidophyllum? yohi* YÜ, p. 88, pl. 19, figs. 1a-c.
1940 *Aulina yohi* (YÜ), HILL, 1940, p. 193.
1943 *Crepidophyllum? yohi* YÜ, SMITH and YÜ, p. 54.
1961 "*Aulina*" cf. *yohi* (YÜ), FONTAINE, p. 122, pl. 20, figs. 11–12.

Aulina furcata Smith (Upper Viséan, England, Germany?, Viet Nam)

1925 *Aulina furcata* SMITH, p. 490, pl. 24, figs. 3–7.
1938 *Aulina furcata* SMITH, HILL, p. 13, 24, 29.
1940 *Aulina furcata* SMITH, HILL, p. 192, pl. 11, fig. 8.
1943 *Aulina furcata* SMITH, SMITH and YÜ, p. 48, pl. 10, figs. 1, 2.
1961 *Aulina furcata* SMITH, FONTAINE, p. 120, pl. 10, fig. 10; pl. 14, fig. 2; pl. 18, fig. 1; pl. 19, fig. 6.

Aulina vesiculata DOBROLYUBOVA (Lower Carboniferous, Kutnetzc basin, Russia)

1966 *Aulina vesiculata* DOBROLYUBOVA, p. 163, pl. 33, fig. 1.

Aulina carinata (Carruthers) (Upper Viséan, Novaya Semilya, China, Viet Nam)

1909 *Campophyllum carinatum* CARRUTHERS, p. 150, pl. 1, figs. 3–6.
1943 *Campophyllum carinatum* CARRUTHERS, SMITH and YÜ, p. 52.
1960 *Aulina carinata* (CARRUTHERS), VASSILJUK, p. 100, pl. 24, figs. 1–1c.
1961 *Aulina carinata* (CARRUTHERS), FONTAINE, p. 121, pl. 20, figs. 5, 6.

Aulina horsfieldi SMITH and YÜ (Upper Tournaisian to upper Viséan, England, France)

1943 *Aulina horsfieldi* SMITH and YÜ p. 49, pl. 10, figs. 3–6.

§§ MASSIVE FORMS OF *AULINA* WITH ASTRAEOID TREND

Aulina rotiformis Smith (Upper Viséan or Namurian, England, Scotland; Upper Viséan of China, Namurian and Upper Viséan, Russia)

1916 *Aulina rotiformis* SMITH, p. 2.
1917 *Aulina rotiformis* SMITH, p. 290, pl. 22, figs. 6–11, text-figs. 3, 4.
1933 *Aulina rotiformis* SMITH, YÜ, p. 80, pl. 13, figs. 1a-d.
1943 *Aulina rotiformis* SMITH, SMITH and YÜ, p. 43, pl. 8, figs. 9–11; pl. 9, figs. 1–4.
1958 *Aulina rotiformis* SMITH, DOBROLYUBOVA, p. 208, pl. 34, figs. 3a-b.
1960 *Aulina rotiformis* SMITH, VASSILJUK, p. 98, pl. 23, figs. 1–1c.
1962 *Aulina rotiformis* SMITH, LO and ZHAO, p. 177, pl. 24.
1962 *Aulina rotiformis* SMITH, YÜ, LIN and FAN, p. 19, pl. 4, figs. 2a-b. figs. 5a–b; pl. 25, figs. 2a–b.
1964 (?) *Aulina rotiformis* SMITH, VASSILJUK, p. 92, pl. 7, fig. 8.

Aulina carinata YÜ non FONTAINE, 1961 (Upper Viséan, China, ?Russia)

1933 *Aulina carinata* YÜ, p. 81, pl. 14, figs. 4a–c.
1964 ?*Aulina carinata* YÜ, VASSILJUK, p. 92, pl. 7, fig. 9.

Aulina carinata var. *chui* YÜ (Upper Viséan, China)

1933 *Aulina carinata* SMITH var. *chui*, YÜ, p. 82, pl. 13, figs. 2a–b.

Aulina carcer SMITH and YÜ (Upper Viséan, China)

1943 *Aulina carcer* SMITH and YÜ, p. 46, pl. 8, figs. 4–6.

Aulina puerilis SMITH and YÜ (Upper Viséan, China)

1943 *Aulina puerilis* SMITH and YÜ, p. 47, pl. 8, figs. 7–8.

Aulina rotiformis SMITH var. *irregularis* LO (Upper Viséan, China)

1962 *Aulina rotiformis* SMITH var. *irregularis*, LO, p. 178, pl. 24, figs. 4a–b.

Aulina semimuralis SANDO (Upper Mississippian Meramec or Chester, North America)

1963 *Aulina semimuralis* SANDO, p. 1077, pl. 146, figs. 1–5.

§§ MASSIVE FORMS OF *AULINA* WITH APHROID TREND

Aulina senex HILL (Upper Viséan—Namurian of England and Scotland, Viséan of China)

1937 *Aulina* sp. YÜ, p. 54 listed only.

1940 *Aulina senex* HILL, p. 193, pl. 11, figs. 9, 10.

1943 *Aulina senex* HILL, SMITH and YÜ, p. 47, pl. 9, figs. 6–10.

1964 *Aulina senex* HILL, WU, p. 32, pl. 3, figs. 1, 2.

Aulina manchuriensis YABE and MINATO (Upper Viséan, China)

1944 *Aulina manchuriensis* YABE and MINATO, p. 148, pl. 14, figs. 1–5; pl. 15, figs. 1–3; text-figs. 1–10.

Aulina cystoides LO (Upper Viséan, China)

1962 *Aulina cystoides* LO, p. 178, pl. 25, figs. 3a–b, 4.

Aulina cystoides var. *a* LO (Upper Viséan, China)

1962 *Aulina cystoides* var. *a* LO, p. 179, pl. 26, figs. 1a–b.

Aulina occidentalis SANDO (Upper Mississippian Meramec or Chester, SW North America)

1963 *Aulina occidentalis* SANDO, p. 1078, pl. 146, figs. 6–10.

Aulina parasenex VASSILJUK (Viséan, Donetz basin, Russia)

1960 *Aulina parasenex* VASSILJUK, p. 99, pl. 24, fig. 2, 2a.

The genus *Aulina* thus has been considered to embrace at least the 19 species and varieties listed above, on the basis of the original and subsequently revised and enlarged interpretations of the genus. This has resulted in a large and heterogeneous group of species which the present authors, in agreement with SMITH and YÜ (1943, p. 38 and elsewhere), believe to be polyphyletic in origin. Aside from having a tube-like structure (aulos) in the axial area, the list above embraces both simple and compound forms; within the latter group, both fasciculate and massive species are present; moreover, species possessing massive coralla are divisible into those which are decidedly astraeoid and those which exhibit a partial or complete aphroid trend.

Recent studies by the senior author and M. KATO (1965a, 1965b) have suggested that insufficient importance has been accorded differences in growth habit in rugose corals, especially from the standpoint of classification designed to show phylogenetic relationships as well as morphological distinctions. To this end, also, homeomorphy, when it can be recognized, must be rejected as the basis of taxonomic

assignments. Commonly, of course, homeomorphic forms can not be recognized as such, but that this phenonemon occurs with regularity in lithostrotionid and related corals is now well known. With respect to the development of an aulos in particular, tubular axial structures appear to have evolved independently in diverse groups of rugose corals throughout the Paleozoic: typical Siluro-Devonian genera in which an aulos is present include *Eridophyllum* MILNE-EDWARDS & HAIME (1850), *Syringaxon* LINDSTRÖM (1882), *Barrandophyllum* POCTA (1902) and *Acervularia* SCHWEIGGER (1819); Carboniferous aulate genera include, in addition to *Aulina* SMITH (1916), some species of *Lithostrotion* (such as *L. tubifera* HAYASAKA, 1936), *Diphyphyllum* LONSDALE (1845) and *Trochophyllum* MILNE-EDWARDS & HAIME (1850; =*Permia* STUCKENBERG, 1895); in rocks of Permian age, *Amplexocarinia* SOSHKINA (1928) is an example of an aulate rugose coral. It nevertheless has been possible, as the result of careful studies of other characters of these corals, including growth form, to separate them into taxa which have some phylogenetic significance as well as morphological distinctiveness . . . the genera mentioned above consequently are now classified (e.g., HILL, 1956) in at least four separate families: Laccophyllidae, Craspedophyllidae, Acervulariidae and Lithostrotionidae.

On the basis of its growth form and other characters, for example, *Aulina simplex* HILL might well be regarded as an early example of the genus *Amplexocarinia* SOSHKINA. This reassignment would require careful prior study of the type materials, which prevents us from making such a proposal at this time. This species is, however, clearly inadmissable to the genus *Aulina* in our view. Similarly, as already suggested by SANDO (1963, p. 1076), fasciculate forms of *Aulina* might well be referred to *Diphyphyllum* LONSDALE or recognized as a new genus. These species include *Aulina carinata* (Carruthers) non YÜ, 1933, *A. horsfieldi* SMITH and YÜ, *A. furcata* Smith, *A. vesiculata* DOBROLYUBOVA and probably *A. yohi* (YÜ). While the final disposition of these species, in particular *A. vesiculata*, will also require a separate study, we are inclined to agree to the extent that they are not congeneric with *Aulina*, sense strict, we therefore here restrict this genus to species exhibiting a massive " plocoidal " growth habit.

A further problem remains, however: within the species embraced by *Aulina* (*sensu stricto*) two main types are clearly present—the first of these includes forms that are astraeoid, in which corallite walls are generally absent and major septa are fully developed and commonly alternate with those of neighboring corallites. The second type includes aphroid coralla in which corallites are united with adjacent corallites by lonsdaleoid dissepiments and are further characterized by partial reduction of septa. Although a completely aphroid condition is not invariably present, these two basic types can invariably be distinguished inasmuch as lonsdaleoid dissepiments never occur among those forms with an astraeoid septal arrangement. On the basis of the forgoing, it appears desirable to refer species belonging to the first (astraeoid) group to a new subgenus, *Aulina* (*Aulina*) *nom.*

nov., erected here to include the type species, *A. rotiformia* Smith and the following basically astraeoid forms: *A. rotiformis* var. *irregularis* LO; *A. carcer* SMITH and YÜ; *A. carinata* YÜ; *A. carinata* var. *chui* YÜ; *A. puerilis* SMITH and YÜ; and *A. semimuralis* SANDO. Coralla exhibiting an aphroid trend are here referred to *Aulina* (*Pseudoaulina*) *nom. nov.*, with *A. senex* HILL as the type species. Other aphroid forms include *A. manchuriensis* YABE and MINATO; *A. cystoides* LO; *A. cystoides* var. *a* LO; *A. parasenex* VASSILJUK and *A. occidentalis* SANDO. Our diagnosis of this genus and the newly proposed subgenera is as follows:

Genus *Aulina* (sensu stricto); emend. MINATO and ROWETT.-Massive rugose corals in which individual corallites contain an aulos formed by the deflection of the axial ends of major septa; minor septa present but short; tabulae regularly disposed, typically complete and subhorizontal within aulos but irregularly disposed and commonly incomplete and inclined in outer tabularium; zigzag carinae variously developed or absent; a weak discontinuous axial structure is produced in some species by penetration of the axial ends of major septa into the aulos.

Subgenus *Aulina* (*Aulina*), *nom. nov.*-As in the genus but with a well developed astraeoid trend, partial or complete reduction of corallite walls and normal interseptal dissepiments.

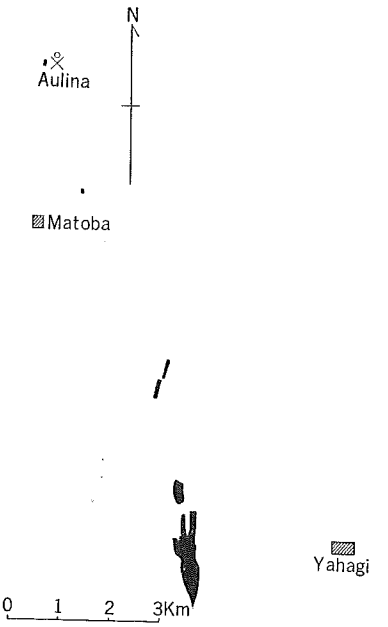


Fig. 1
Locality at which the rugose coral *Aulina* was found. Shaded areas indicate outcrops believed to be of Namurian or Upper Viséan in age.

Subgenus *Aulina* (*Pseudoaulina*), *nom. nov.*-As in the genus but with aphroid trend in which septa are reduced and adjacent corallites are united by lonsdaleoid dissepiments.

Aulina (*Aulina*) *rotiformis* SMITH

Pl. 47, figs. 1–9; pl. 48, figs. 1–2

Material.: One limestone fragment on which the weathered surface of a massive plocoidal corallum is visible, including corallites with faintly preserved radially disposed septa and shallow calicular hollows (UH Reg. no. 18850). Prior to coming to our attention a number of randomly oriented thin sections were made by Mr. M. NAKAZIMA, here numbered 18820–18827.
Subsequently three transverse and two longitudinal sections were prepared by the senior author (UH Reg. nos. 18832–18836).
Locality: Upper course of Togeno-sawa, Matoba, village of Yahagi, Kesen district, Iwate Prefecture (Kitakami Mountains): about 39°06′,3 N and 141°30′,6 E (See text-fig. 1)
Coll: Mr. M. NAKAZIMA
Description.: The corallum is embedded in matrix and slightly deformed; it appears to have undergone slight erosion prior to fossilization, as the boundary between the corallum and surrounding matrix is irregular in thin sections. The preserved portion suggests that the original form of the corallum was tabular and at least 10 cm in diameter.
Transverse sections.: The corallum is massive, plocoidal and astraeoid; corallites are united by their septa with complete loss of intervening corallite walls. Individual corallites are separated by distances ranging from 2.5 to 5.0 mm, with an average separation of between 3.0 to 3.5 mm. Corallites vary in overall size; the diameter of the tabularium ranges from 1.5 to 2.1 mm in well oriented transverse sections while the diameter of the central aulos equals one-third to one-fourth the width of the tabularium. This tube is sub-circular or polygonal (commonly tetragonal) in outline but may be elliptical or irregularly polygonal in deformed or poorly oriented corallites.

The thickness of the aulos wall is approximately the same as that of the axial portions of major septa, from which it is constructed. Septa are of two orders, major and minor; major septa regularly alternate with the minor septa and number 11 or 12 in mature corallites. Major septa invariably reach the aulos, while minor septa extend only a short distance into the tabularium. Major septa are dilated adjacent to the boundary between the dissepimental zone and the tabularium and

become thiner both axially and peripherally; the same tendency is present in the minor septa, although as noted, they do not extend to the aulos. Septal microsstructure has been destroyed by recrystallization, but septal carinae apparently are present and are manifested as a slightly zig-zag pattern in the major septa. All septa are slightly undulatory and curved into the peripheral region of neighboring corallites. Septa are nowhere interrupted by lonsdaleoid dissepiments; the dissepiments that are present are comparatively few in number and rather widely spaced; at the boundary of the dissepimentarium and tabularium they are somewhat thickened and form a poorly defined inner wall.

Longitudinal sections.: The separation of the tabularium into an inner and outer zone is seen in longitudinal sections; the central part (aulos) is occupied by tabulae that with rare exceptions are complete, sub-horizontal or only slightly sagging and regularly spaced at about 10 through a vertical distance of 2.5 mm. In the outer area, (*viz.*, outer tabularium), tabulae are inclined upward axially and incomplete. The dissepimental zone is occupied by numerous rows of nearly horizontally disposed dissepiments that are slightly convex upward or almost flat.

Remarks.: This coral seems clearly to be assignable to the type species of *Aulina* (sensu stricto), *A. rotiformis*, and is here referred to *Aulina* (*Aulina*) *rotiformis* SMITH because of its strongly astraeoid trend.

Aulina carinata YÜ and the variety *A. carinata chui* YÜ both differ from the type species in having well developed and pronounced carinae as well as a wider tabularium and aulos. *A. carcer* SMITH and YÜ is a somewhat unusual form in which the aulos is very narrow and major septa locally extend into the axial area to form a discontinuous columella. Both of these features are absent in the type species.

A. puerilis SMITH and YÜ is comparable to the type species with respect to the overall size of corallites but also has a very small axial tube (0.3 to 0.35 mm). *A. rotiformis* var. *irregularis* LO differs from the type species principally in having both complete and incomplete, cystose tabulae in the aulos; *A. semimuralis* SANDO is consideralby larger than the type species and locally retains corallite walls.

species	diameter of tabularium	diameter of aulos	septal number	tabulae/ 5 mm in aulos
A. (*Aulina*) *rotiformis* SMITH	1.5–2.0	0.5–0.7	11–12	20
A. (*A.*) *carinata* YÜ	2.0–2.5	1.0–1.2	13–16	13–18
A. (*A.*) *carinata* var *chui* YÜ	1.8–2.0	0.7–1.0	10–11	17–20
A. (*A.*) *carcer* SMITH and YÜ	1.8–2.0	very narrow	8–10	?
A. (*A.*) *puerilis* SMITH and YÜ	1.5–2.0	0.3–0.35	11–22	35
A. (*A.*) *rotiformis* var. *irregularis* LO	1.6–2.0	1.0	10	18–22
A. (*A.*) *semimuralis* SANDO	1.0–1.5	0.5–1.0	14–18	20–25
A. (*A.*) *rotiformis* SMITH*	1.5–2.1	0.5–0.7	11–12	20

* Specimen from the Kitakami Mountains of Japan

These species of *Aulina* share an astraeoid trend and are here referred to the subgenus *Aulina* (*Aulina*); all other described species are aphroid and differ from the type species principally in this respect; they are here referred to *Aulina* (*Pseudoaulina*) spp. A comparison of the parameters of species assigned to *Aulina* (*Aulina*) is given above.

Geological distribution of Aulina.: According to SMITH and YÜ (1943, p. 45) the type species of *Aulina* occurs in both England and Scotland in horizons somehat higher than the Upper Viséan of this region. They assign the *Aulina*-bearing strata of these areas to the Namurian (*Eumorphoceras* Zone, E_2). However, the this species subsequently was described from China and the Soviet Union from formations assigned to the Upper Viséan of those regions. The corals described above as *Aulina* (*Aulina*) *rotiformis* were collected from gray to black shaly limestones that resemble the typical limestones of the Viséan Onimaru Series of the Kitakami Mountains in most respects. The Upper Viséan age of these limestones elsewhere in this area has been fimly established on the basis of a great deal of fossil evidence, including such reliable rugose coral genera as *Kuichouphyllum*, *Dibunophyllum* and *Yuanophyllum*. However, the only corals found in association with *Aulina* at the locality in question were indeterminate species of *Dibunophyllum* and *Siphonodendron*. Although both of these genera are typical elements of the Onimaru fauna, our reservation in suggesting that these strata are precise equivalents is based on several aspects of this occurrence:

(1) Conglomerates have been reported to occur in the limestones at this locality; although the senior author has carried out field studies in the Kitakami Mountains over a period of many years, conglomeratic facies in the Onimaru Series heretofor have not been observed.

(2) These exposures are geographically and structurally isolated from the principal exposures of the Onimaru Series and consequently can not be traced laterally as a basis of physical correlation. They are overlain unconformably by conglomerates and superjacent *Pseudoschwagerina*-bearing limestones of lower Permian age or are in fault contact with both older and younger rocks.

(3) The detailed physical stratigraphy of the Onimaru Series in this region has yet to be determined: there is some evidence that it may represent a deposit that is transgressive from east to west; the possibility therefor exists that isolated exposures to the west of the principal areas of exposures may be somewhat younger in age.

Thus, although the probability that these strata are essentially equivalent in age to the Upper Viséan portion of the Onimaru limestones elsewhere in the Kitakami Mountains is strong, these factors, plus fact that this species is known to range into Namurian strata in Great Britian, makes it marginally possible that they are of Namurian age. Further study of the nature and position of the conglomerates

and collection of additional fossils hopefull will resolve this problem in the near future.

References cited

CARRUTHERS, R. G. (1909): Notes on the Carboniferous Corals collected in Nowaja Semlja by Dr. W. S. BRUCE. In G. W. LEE, A Carboniferous Fauna from Nowaja Semlja collected by Dr. W. S. BRUCE. Trans. Roy. Soc. Edinburgh, xlvii (1), pp. 143–86, pls. i–ii.

DOBROLYBOVA, T. A. (1958): The Lower Carboniferous Tetracorals from Russian Platform, Acad. Sci. SSSR, Report of Palaeont. Inst. Vol. 70, pp. 1–224, pls. 1–38, (in Russian).

DOBROLYBOVA, T. A., KABAKOVITSH, N. V., & SAYUTINA, T. A. (1966): Lower Carboniferous Corals of the Kuznetzk Basin, Acad. Sci. SSSR, Contribution, Palaeont. Inst. No. III, pls. 1–45, (in Russian)

FONTAINE, H. (1961): Les madreporaires paleonzoiques du Viet-Nam, du Laos et du Cambodge, Archives geologiques du Viet-Nam, Numero 5, pp. 9–227, pls. 1–35.

HILL, D. (1934): The Lower Carboniferous Corals of Australia, Proceedings of the Royal Society of Queensland, Vol. 14, No. 12, pls. 7–11, Text-figs. pp. 62–115.

HILL, D. (1935): British Terminology for Rugose corals, Geol. Mag., vol. 72, pp. 482–519.

HILL, D. (1938, 1940): A monograph on the Carboniferous Rugose Corals of Scotland, Pt. 1 (1938), pp. 1–78, pls. 1–2; Pt. III (1940), pp. 115–204, pls. 6–11, Mon. Palaeont. Soc.

HILL, D. (1956): Rugosa, *in* R. C. Moore's Treatise on Invertebrate Palaeontology, pt. F, pp. 233–324.

LO, C. T. and ZHAO, J. M. (1962): Lower Carboniferous Tetracorals of the district Chilien-shan (Tsinghai), Geology of Chilien-shan Mountain range, Vol. 4, part 3, p. 111–199, pls. 1–30. (in Chinese)

MINATO, M. and KATO, M. (1965a): Waagenophyllidae, Jour. Faculty Sci., Hokkaido Univ., ser. 4, vol. 12, nos. 3–4, pp. 1–241, pls. 1–20.

MINATO, M. and KATO, M. (1965b): Durhaminidae, ibid, ser. 4, vol. 13, no. 1, pp. 13–86, pls. 1–5.

SANDO, J. (1963): New species of colonial rugose corals from the Mississippian of Northern Arizona, Journal of Paleontology, Vol. 37, pp. 1074–1079, pls. 145–146.

SMITH, S. (1916): *Aulina rotiformis*, gen. et sp. nov., *Phillipsastraea hennahi* (Lonsdale), and the Genus *Orionastraea*, Abstr. Proc. Geol. Soc. London, No. 995, pp. 2–5.

SMITH, S. (1917): *Aulina rotiformis*. gen. et sp. nov., *Phillipsastrea hennahi* (LONSDALE), and *Orionastraea*, gen. nov., Quart. Jour. Geol. Soc. London, vol. 72, pp. 280–306, pls. 22, 23, 24.

SMITH, S. (1925): The Genus *Aulina*, Annals and Magazine of Natural History, vol. 16, pp. 485–496, pls. 24.

SMITH, S. and YÜ, C. C. (1943): A Revision of the Coral Genus *Aulina* SMITH and Descriptions of New Species from Britain and China, Quart. Jour. Geol. Soc. Lon-

don, vol. 99, pp. 37–58, pls. 8, 9, 10.

VASSILJUK, N. P. (1960): Lower Carboniferous Corals of Donetz Basin, Acad. Sci. Ukraine, SSR., Ukrainian SSR., Inst. Geol. series on Stratigraphy and Palaeontology Bull. 13, pls. 1–42. (in Russian).

VASSILJUK, N. P. (1964): Coral Zone $C_1^v g$—$C_1^n a$ of the Donetz Basin (Matrials for the Upper Palaeozoic fauna of Donetz Basin II), Acad. Sci. Ukraine, SSR, Ukrainian SSR., series on Stratigraphy and Palaeontology, Bull. 48, pp. 60–102, pls. 1–8 (in Russian)

WU, Wang-shin. (1964): Lower Carboniferous Corals in Central Hunan, Memoirs of the Institute of Geology and Palaeontology, no. 3, pp. 1–100, pls. 1–21. (in Chinese)

YABE, H. and MINATO, M. (1944): Eine *Aulina*-Art aus der Mandschurei, Japanese Jour. Geology & Geography, vol. 19, nos. 1–4, pp. 147–150, pls. 14, 15, text-figure plate.

YÜ, C. C. (1933): Lower Carboniferous Corals of China, Paleontologia Sinica, vol. 7, pp. 1–133, pls. 1–24.

YÜ, C. C. (1937): The Fenginian corals of South China, Acad. Sinica, Mem. National Research Inst. Geology, no. 16, pp. 1–70, pl. 1–12.

YÜ, C. C., LIN, I. D. & FAN., Y. N., (1962): Permo-Carboniferous Rugosa of the Chinhai Province (Sinkiang-Tinghai), China, Scientific Articles for the Commemoration of 10th Anniversary of the Changchun Geological College, pp. 1–11. (in Chinese)

(Manuscript received January 23, 1967)

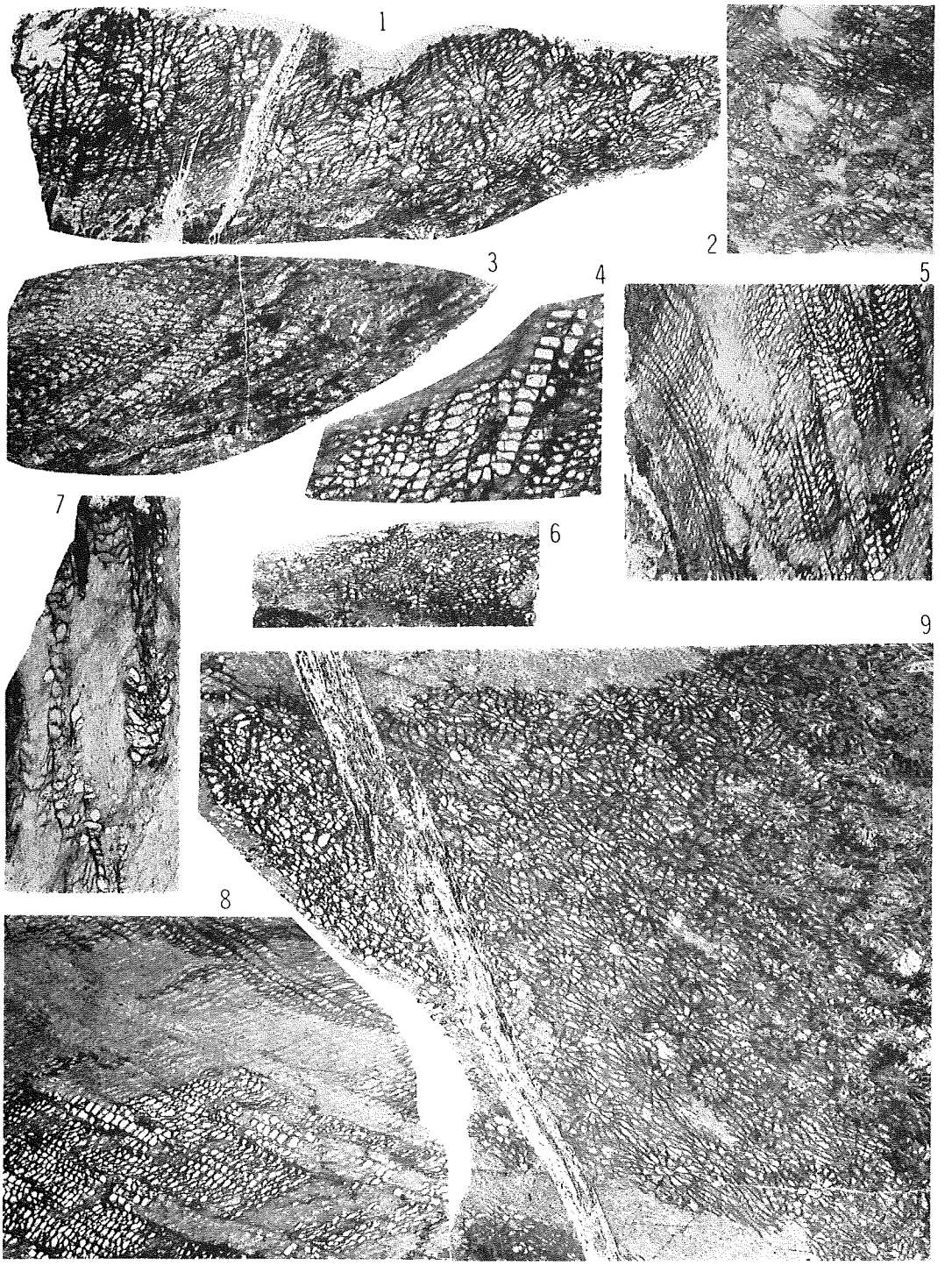
PLATE 47 AND EXPLANATION

Explanation of Plate 47

Aulina rotiformis SMITH

Fig. 1 UHR. no. 18832 × 2.5
Fig. 2 UHR. no. 18826 × 2.5
Fig. 3 UHR. no. 18834 × 2.5
Fig. 4 UHR. no. 18823 × 5.0
Fig. 5 UHR. no. 18821 × 2.5
Fig. 6 UHR. no. 18825 × 2.5
Fig. 7 UHR. no. 18836 × 2.5
Fig. 8 UHR. no. 18823 × 2.5
Fig. 9 UHR. no. 18833 × 2.5

Plate 47



S. KUMANO Photo

PLATE 48 AND EXPLANATION

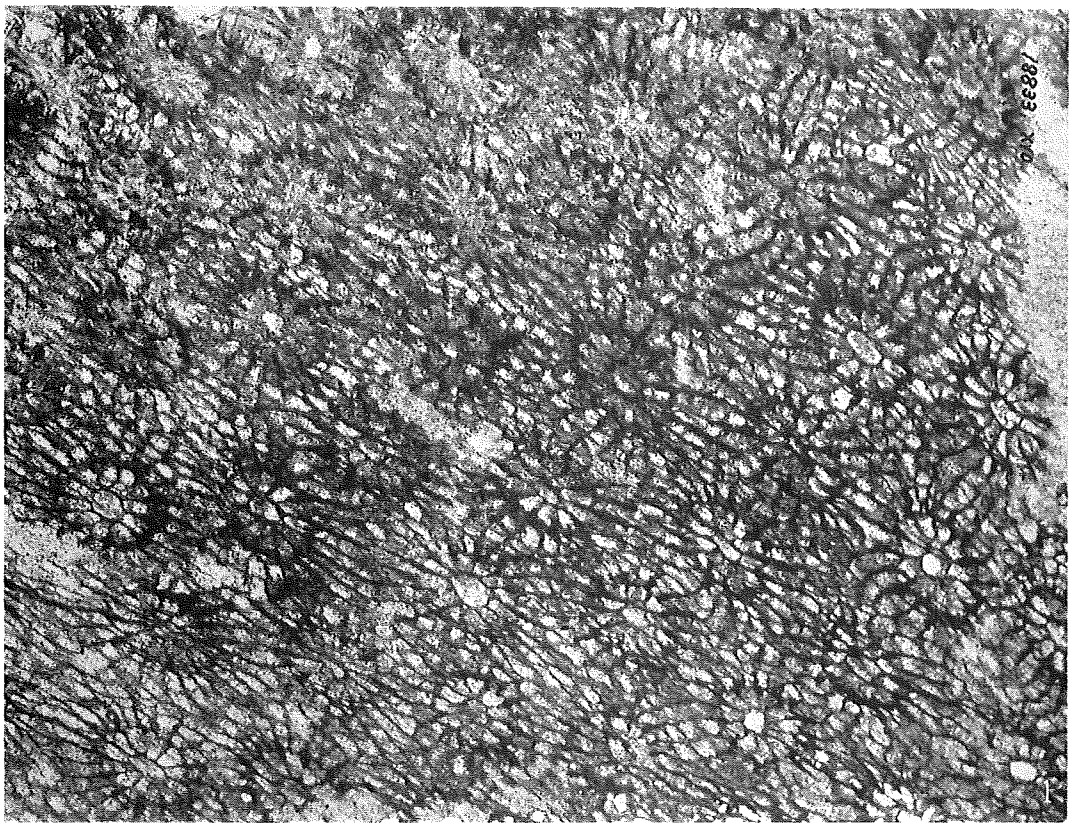
Explanation of Plate 48

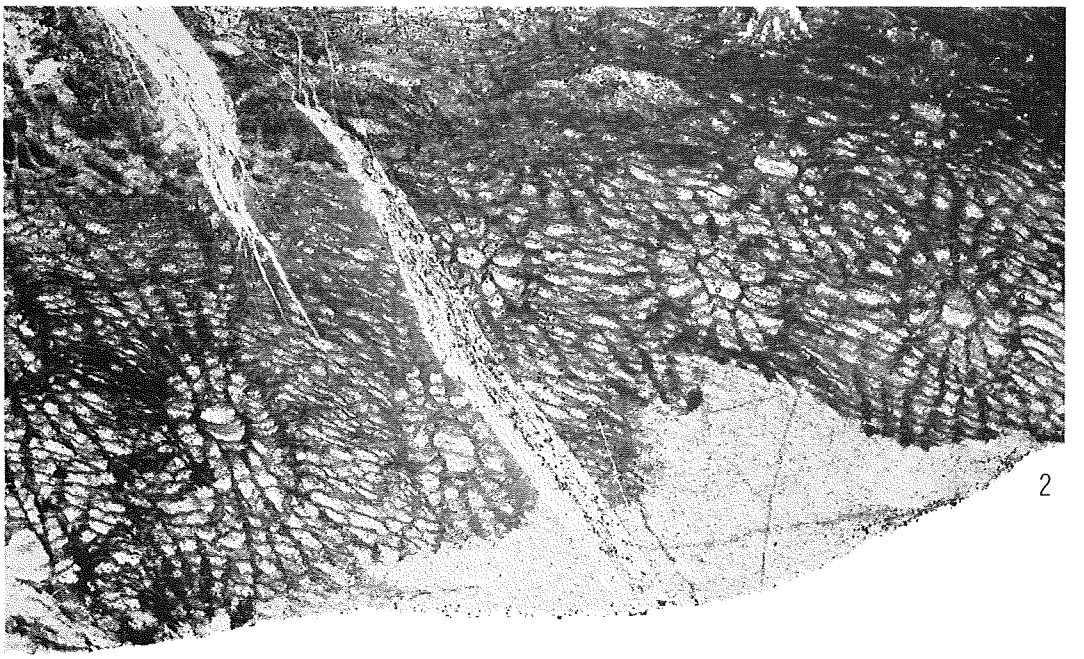
Aulina rotiformis SMITH

Fig. 1 UHR. no. 18833 × 5.0

Fig. 2 UHR. no. 18832 × 5.0
(somewhat larger than average corallites near the edge of corallum)

Plate 48





S. KUMANO Photo