



Title	A New Species of Yuanophyllum Yü from the Kitakami Mountains, Japan
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Citation	Journal of the Faculty of Science, Hokkaido University. Series 4, Geology and mineralogy, 13(4), 333-342
Issue Date	1967-04
Doc URL	http://hdl.handle.net/2115/35967
Type	bulletin (article)
File Information	13(4)_333-342.pdf



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A NEW SPECIES OF *Yuanophyllum* Yü FROM THE KITAKAMI MOUNTAINS, JAPAN

by

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(with 1 Text-figure and 1 plate)

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Among corals recently collected by the senior author from the Viséan Onimaru Series in the Kitakami Mountains of NE Honshu, Japan, a solitary coral of comparatively large size is of particular interest. It is herein referred to the genus *Yuanophyllum*, established by Yü in 1931, with *Y. kansuense* as the type species.

As is well known, the validity of this genus has been disputed owing to its similarity in several respects to the genus *Arachnolasma* GRABAU (1922). Even after a thoroughgoing review of *Yuanophyllum* and allied genera it must be admitted that some ambiguity remains as to its relationship to *Archnolasma*. However, we nevertheless are inclined to regard *Yuanophyllum* as a valid genus for reasons that are discussed in detail below.

Although *Yuanophyllum* has been described from many widely scattered localities in China, Iran and the Soviet Union (Donez and Kazak basins, for example), it seems to be restricted stratigraphically to rocks of upper Viséan age. The presence of this genus in Japan, although represented here by a new species, is thus of interest inasmuch as it occurs in strata (Onimaru limestones) that are stratigraphic equivalents of those formations in Europe and Asia from which *Yuanophyllum* previously has been reported.

The authors wish to thank Mr. S. KUMANO of this department for his assistance in preparing photographs for the accompanying plates.

Genus *Yuanophyllum* Yü, 1931

HILL (1956, p. 288) placed *Yuanophyllum* Yü in synonymy with the genus

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Arachnolasma GRABAU (1922) and regarded the latter as a member of the Family Aulophyllidae DYBOWSKI (1873). In contrast, the recent Soviet treatise on invertebrates (1962, p. 331) lists both *Arachnolasma* and *Yuanophyllum* as valid genera and, moreover, regards both as representatives of the Family Lophophyllidae GRABAU (1928).

No firm answer can be provided as yet as to the phylogenetic relations of these two genera. However, there is some evidence that suggests a lophophyllid ancestor for both *Arachnolasma* and *Yuanophyllum*; this is discussed below. A more immediate problem is that of the validity, or lack thereof, of *Yuanophyllum* as well as its relationship to several allied genera. In an effort to arrive at a taxonomically and stratigraphically satisfactory decision, the present authors studied the morphology of the type species of both genera. Although the type materials were not available, the original illustrations fortunately are of unusually good quality.

Yuanophyllum was proposed by YÜ (1931) with *Y. kansuense* as the type species (by monotypy; *ibid.*, 1931, p. 27, figs. 4a, b). The holotype was reillustrated and redescribed by YÜ (1933, p. 46, pl. III, fig. 4) as well as several topotypes (*ibid.*, 1933, pl. III, figs. 1, 5) and three varieties (*ibid.*, 1933, p. 47–48, pl. III, fig. 7, pl. IV, figs. 1–3). YÜ's original (1931) inked figures of the holotype are, however, superior to the subsequent illustrations with respect to illustration of the essential characters of this species.

The genus *Arachnolasma* was proposed by GRABAU (1922, p. 59), with *A. sinense* (YABE and HAYASAKA) as the type species. This species was originally illustrated as "*Lophophyllum*" *sinense* by YABE and HAYASAKA (1920, pl. VI, figs. 2a-g) but apparently was not described by those authors. One of their figures of the holotype (*ibid.*, 1920, pl. VI, fig. 2b) was reproduced as an inked drawing by GRABAU (1922, fig. 66, p. 60).

In comparing *Yuanophyllum* with similar genera YÜ (1931, 1933) mentioned its similarity to *Heterocaninia* YABE and HAYASAKA (1920), which has as its type species *H. tholusitabulata* (*ibid.*, 1920, pl. XI, figs. 2a-d). *Yuanophylloides*, with *Y. gorskyi* FOMICHEV, 1953, as its type species is a related form that also bears comparison. The latter species was originally illustrated by V. D. FOMICHEV (1953, pl. 16, figs. 12–14) and later reproduced in the Soviet treatise (1962, p. 331, pl. XVI, figs. 2a, b).

In general, *Yuanophyllum* and *Arachnolasma* have a number of morphological characters in common and are comparable with respect to the fundamental nature of the axial structure. *Heterocaninia*, although possessing several characters in common with both *Yuanophyllum* and *Arachnolasma*, seems not to be closely related to either genus. The internal structure of *Yuanophylloides* is comparatively much more simple than any of the above-named genera but it seems to be rather clearly more closely related to *Yuanophyllum* or *Arachnolasma* and may be ancestral to the latter.

More specifically, *Yuanophyllum* resembles *Arachnolasa* with respect to overall size, number of septa, and in possessing a pseudocolumella (restricted to the early growth stages in the latter). Although the axial end of the counter septum extends into the axial area as a pseudocolumella throughout the ephelic stages in the type species of *Yuanophyllum*, the axial structure is isolated from the counter septum in the middle and late ephelic stages of the type species of *Arachnolasma*. However, in one of YABE and HAYASAKA's illustrations of the holotype (1920, pl. VI, fig. 2f), the thickened median plate of the axial structure is continuous with the counter septum; this figure represents an early ephelic stage, and it thus seems likely that a pseudocolumella may have been present in the neanic stages in *A. sinense*.

This observation, also pointed out by GRABAU (1922, p. 60), may have been the basis for HILL's (1956) conclusion that *Yuanophyllum* and *Arachnolasma* are synonymous. There are, however, numerous differences between these two forms which are as follows:

- (1) minor septa are absent or extremely rudimentary in the type species of *Yuanophyllum*, even in the latest growth stages; this is in contrast to *Arachnolasma*, in which minor septa appear in the early ephelic stages and are well developed in later stages of growth.
- (2) major septa are strongly dilated in the cardinal quadrants in the type species of *Yuanophyllum*, while septal dilation is slight and uniform in all quadrants in *Arachnolasma*.
- (3) a pronounced cardinal fossula, occupied by a short cardinal septum, is present in *Yuanophyllum*; conversely, the fossula is weak in *Arachnolasma* and the cardinal septum is comparatively long throughout the ephelic stages.
- (4) concentric dissepiments dominate the dissepimental zone of *Arachnolasma*, while dissepiments are almost invariably of the herringbone type in *Yuanophyllum*.
- (5) as noted above, the axial structure of *Yuanophyllum* is comparatively simple throughout all growth stages and a pseudocolumella is present in the ephelic stages; *Arachnolasma* lacks a pseudocolumella in the ephelic stages and is characterized by a well developed arachnoid column in the mature stages.

The forgoing analysis of *Yuanophyllum* is based upon the characters exhibited by the holotype specimen, described by Yü in 1931. However, it must be added that in describing several new "varieties" of *Yuanophyllum* in 1933, Yü greatly broadened his original interpretation of this genus. If *Yuanophyllum* is to be considered *sensu lato*, it will be seen that each of these varieties is similar to *Arachnolasma* in one or more respects. For example, in *Yuanophyllum kansuense* var. γ , minor septa are fairly long (Yü, 1933, pl. IV, fig. 3a); in *Y. kansuense* var.

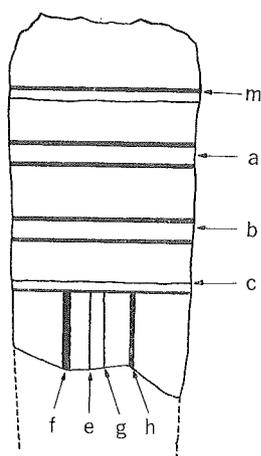
**Fig. 1**

Diagram of the holotype specimen (UHR. no. 18639) of *Yuanophyllum kitakamiense*, new species, showing the position and orientation of transverse and longitudinal sections and replicas, $\times \frac{1}{2}$

β septal dilation is not prominent and the cardinal fossula, although clearly visible, is not pronounced (pl. IV, fig. 1a, 2a); in *Y. kansuense* var. γ the fossula also is not marked; and in all three varieties, especially in α and γ , numerous concentric dissepiments are present in the inner portion of the dissepimentarium.

Considerable variability is evident in the degree of septal dilation and prominence of the fossula in the several varieties of the type species of *Yuanophyllum*. However, caution must be exercised in evaluating the significance of this character. For example, the several transverse sections of our specimen from Japan illustrated in pl. 42 show that septal dilation in the cardinal quadrants, and consequently the degree of prominence of the fossula, is quite variable throughout a few centimeters within the ephebic stages of this single corallite. It thus seems probable that, although Yü's varieties of *Y. kansuense* all differ from the holotype with respect to the spacing and attitude of tabellae, the variability observable in septal dilation and in the cardinal fossula may be in large part due to simple ontogenetic variability.

In several important respects, however, the essential characters of the original holotype (*sensu stricto*) are incorporated by these "varieties"; a pseudocolumella invariably is present throughout the ephebic stages, and in no instance is an arachnoid axial structure developed. Moreover, although concentric dissepiments are present in several of Yü's varieties, herringbone dissepiments predominate in all cases. Thus although Yü did not indicate an intent to emend his original diagnosis of *Yuanophyllum kansuense* (*sensu stricto*) in 1933, the described varieties are never-

theless distinguishable from *Arachnolasma*. The genus thus is distinct, even broadly interpreted.

Certain tentative conclusions pertaining to the phylogenetic relationship of *Yuanophyllum* and *Arachnolasma* are also significant. Although some aspects of the Carboniferous stratigraphy of China are still disputed, it can be shown that the range of *Arachnolasma* extends upward into younger strata than that of *Yuanophyllum*. Morphologically, the more complex axial structure and presence of minor septa seem to support the view that *Arachnolasma* is somewhat more advanced in these respects. However, as regards the strong dilation of septa in the counter quadrants and pronounced cardinal fossula, *Yuanophyllum* would seem to be the more advanced form. Thus the hypothesis that either form arose from the other appears to be untenable; it is more likely that *Arachnolasma* and *Yuanophyllum* arose from a common ancestor and developed along independent, albeit in part parallel, lines. The presence of a pseudocolumella in the early ontogenetic stages of the genus *Arachnolasma* can be cited as arguing for this common ancestry.

Turning now to the genus *Heterocaninia*, it has been observed that this form has several characters in common with both *Arachnolasma* and *Yuanophyllum*. The type species, *H. tholusitabulata*, resembles *Yuanophyllum kansuense* with respect to its strongly dilated septa in the cardinal quadrants, pronounced fossula, short cardinal septum and rudimentary or absent minor septa. Similarly, this species resembles *Arachnolasma sinense* with respect to its dominantly concentric dissepimental pattern. However, the herringbone dissepiments and pseudocolumella of *Yuanophyllum* are in marked contrast to *Heterocaninia*, just as the presence of minor septa, uniform and slight septal dilation, weak fossula and arachnoid column of *Arachnolasma* find no parallel structures in *Heterocaninia*. Moreover, the numerous major septa of *Heterocaninia* (100 or more in mature stages), pronounced pinnate septal arrangement in the cardinal quadrants and weakly aulophylloid axial structure of that genus are completely unlike either *Arachnolasma* or *Yuanophyllum*.

Yuanophylloides FOMICHEV (1953) does not compare closely to *Heterocaninia* in any respect. However, like *Yuanophyllum* and, in the early stages, *Arachnolasma* it possesses a pseudocolumella. However, FOMICHEV's genus is a comparatively small ceratoid form and has a narrow dissepimentarium, relatively few and thin major septa, moderate development of minor septa and lacks a cardinal fossula. Collectively, these structures are much simpler than the morphology of either *Arachnolasma* or *Yuanophyllum* but suggest a closer relationship to the former.

To summarize, the significance of the purely morphological differences between *Yuanophyllum* and *Arachnolasma* might be considered to justify a distinction only at the sub-generic level. However, taking into account the phylogenetic considerations discussed above, it is our view that *Yuanophyllum* should be treated as a separate genus; it therefore is so regarded here. A common lophophyllid an-

cestor seems probable for both *Yuanophyllum* and *Arachnolasma*, but there appears to be little doubt that *Heterocaninia* is an aulophylloid coral as it is regarded by HILL (1956). *Yuanophylloides* may be ancestral to *Arachnolasma*, but speculation as to the actual phylogenetic relations of this coral must await more precise stratigraphic information from the type area in the Donetz Basin.

Stratigraphic distribution of Yuanophyllum.—“*Yuanophyllum*” (*Kesenella*) *yabei*, described by NAGAO and MINATO from the Viséan Onimaru Series of Japan in 1941, was restudied and described by MINATO (1955, p. 143) as “*Yuanophyllum*” *yabei* as the result of the discovery that long minor septa actually are lacking. However, in view of the comparatively large number of major septa (63) in an early ephebic stage and its rather complex axial structure, it no longer is possible to regard this specimen as representing an early ontogenetic stage of *Yuanophyllum*. Although the concentric dissepimental pattern and septal dilation in the cardinal quadrants are similar to *Heterocaninia*, its axial structure is not entirely typical of that genus. Nevertheless, the authors now believe that this species should be transferred from the genus *Yuanophyllum* into *Heterocaninia*.

In China, *Yuanophyllum kansuense* occurs widely in the Fengningian System in Kansu, Anhwei, and Kueichou provinces (Yü, 1931, 1933). More recently, this species was reported from Sinkiang province (Yü et al., 1962). *Y. kansuense* has also been described from the Kuznetzk Basin by DOBROLYUBOVA et al., (1966) and by Bikova (1966, as *Y. aff. kansuense*) from the Kazak Basin. The present new species was collected from the Onimaru Series of Japan. In all these areas, strata are Lower Carboniferous (Viséan) equivalents.

***Yuanophyllum kitakamiense* n. sp.**

pl. 42, figs. 1-5, text-fig. 1

Material.—One large, cylindrical, somewhat deformed and incomplete corallite embedded in black shaly limestone. This specimen (UHR no. 18639) was collected by the senior author from the Onimaru limestone of Viséan age in NE Honshu, Japan. The limestone outcrop from which this specimen was obtained occurs at an elevation of about 450 m, near the top of Inugashirayama (Inugashira mountain), Setamai-machi, Iwate Prefecture.

Both the calicular and proximal portions of the corallite are missing. The preserved portion, which represents the early and middle ephebic stages, is approximately 102 mm long. In cross section this fragment is slightly elliptical and is compressed in the cardinal-counter plane; it has a minimum (alar) diameter of

about 39 mm and a maximum diameter of about 50 mm.

Two transverse thin sections (18639a and 18639b) and two transverse replicas (18639c and 18639m) were prepared (text-fig. 1) as well as one orthologitudinal thin section (19639e), and three tangential replicas (18639f, g, h). The longitudinal section was made from the lower portion of the corallite and therefore shows a somewhat earlier stage of growth than the transverse replicas and sections.

Description.—The corallite is solitary, large and subcylindrical; curvature is slight, with the cardinal septum on the convex side of the corallite. There is no evidence of rejuvenescence in this specimen: in the four transverse sections available, there is no remarkable difference in either the diameter or septal number—the lowest section (replica 18639c) is only slightly smaller than the highest (replica 18639m) and has only three fewer septa than the maximum number recorded (56).

In all transverse sections minor septa, although present, are very short and seldom exceed 1 mm in length. The septal formulae* for four successive growth stages (all ephebic) are as follows, beginning with the earliest observed stage:

Replica 18639c (47+36 mm), K 13 A 12 C 11 A 13 K
 Section 18639b (50+39 mm), K 14 A 13 C 12 A 13 K
 Section 18639a (69+39 mm), K 14 A 13 C 12 A 13 K
 Replica 18639m (50+39 mm), K 14 A 13 C 12 A 13 K

In the two lower sections (18639c and 18639b) major septa are thickened in the cardinal quadrants to as much as 1 mm and are locally in lateral contact; major septa in the counter quadrants are much thinner (0.5 mm or less). In sections 18639a and 18639m, which represent somewhat later growth stages, septa in the cardinal quadrants, although thicker than those in the counter quadrants, are 0.7 mm or less in width and do not touch laterally. This suggests, as is typical of corals of this type, that septal thickening in the cardinal quadrants is more pronounced in the early ephebic than in later ephebic growth stages. All major septa are somewhat thinner in the dissepimental zone, and those of the cardinal quadrants markedly so.

The cardinal septum is easily distinguished in all transverse sections by its shorter length (14 to 15 mm in the sections studied, while adjacent metasepta in the cardinal quadrants range from about 18 to 22 mm in length). Thickening of the cardinal septum is about equal to that of the metasepta in the cardinal quadrants and is also restricted to the tabularium. The counter septum is similar in thickness to other septa in the counter quadrants but in most sections extends from 2 to 5 mm further into the axial region than adjacent major septa.

Septa are highly recrystallized and septal microstructure is preserved in only

* In this notation, septal counts (of major septa) are made in a clockwise direction, beginning and ending with the counter septum (K).

a few places. Septa may be of the diffusotrabeular type, as some sort of bundling appears to be present under a phase contrast microscope. Septa have a median translucent line, commonly 0.03 mm or less in width, which locally is flanked by narrow darker zones.

Most major septa extend into the axial area, except for the short cardinal septum; the cardinal fossula consequently is well developed. Its prominence is increased by the tendency of adjacent major septa to enclose the cardinal fossula by their axial ends. There are no pseudofossulae.

The axial area is variable in width, but this is primarily due to variation in the degree of crushing of the corallite. The exact nature of the axial structure is somewhat obscure because of fragmentation and recrystallization, but in general appears to have consisted of a sporadically developed median plate, thickened axial tabellae and few radial elements. In section 18639b axial tabellae appear to dominate; in 18639c a thin (0.02 mm) and short (1.4 mm) median plate is present, aligned in the cardinal-counter plane, with a few radial elements and irregularly curved tabellae.

The dissepimentarium is wide, up to about 12 mm in section 18639a (alar diameter of this section is 39 mm), and is separated from the tabularium by a thin inner wall formed by thickening of the innermost dissepiments in the cardinal quadrants. Individual dissepiments are highly varied in type: the innermost dissepiments tend to be concentric in transverse sections (concave axially) but these are replaced by a well developed herringbone dissepiments and a few angulo-concentric dissepiments in the intermediate part of the dissepimental zone. Within one or two millimeters of the epitheca pseudoherringbone dissepiments are developed between the short minor septa and major septa.

In longitudinal section a triaxial arrangement is quite evident. The axial structure occupies the central area and although it is five millimeters or less in width it is sharply differentiated from the tabularium. The axial tabellae are largely fragmental but in general closely spaced and inclined steeply upward toward the axis of the corallite. Many tabellae are highly irregular and sinuous.

The median plate is traceable throughout most of the axial structure and is also sinuous; although locally crushed it appears to have been continuous vertically.

The tabularium is occupied by incomplete tabulae whose strongly convex upper surfaces face upward and outward. Most tabellae ascend axially at from 20 to 40 degrees, but a few are inclined at about 50 degrees.

The dissepimentarium consists of up to ten or more rows of dissepiments that are inclined downward axially at approximately 45 degrees. From 8 to 12 dissepiments occur through a vertical distance of 10 mm in the central part of the dissepimentarium. Individual dissepiments, although somewhat variable in shape, are of subequal size. The boundary between the tabularium and dissepimentarium

is well defined, inasmuch as the innermost one or two rows of dissepiments are somewhat smaller than average and are oriented with their long axes approximately parallel to the growth axis of the coral.

Remarks.—This corallite can be assigned to *Yuanophyllum kansuense* on the basis of its strongly dilated major septa in the cardinal quadrants, prominent cardinal fossula, short cardinal septum, rudimentary minor septa and herringbone dissepimental pattern.

Unfortunately, the axial end of the counter septum is not distinguishable in all transverse sections due to poor preservation. In most section, however, (cf. pl. 42, figs. 1–4) a pseudocolumella appears to have been present; this appears to be borne out by the single available longitudinal section. An arachnoid axial structure, such as that of the genus *Arachnolasma*, is definitely absent.

This specimen most nearly resembles the type species, *Y. kansuense* Yü, 1931 (*sensu stricto*), but differs from that species in having somewhat more numerous major septa, more numerous axial tabellae and tabulae that are slightly more steeply inclined. This specimen can also be distinguished from the three varieties described by Yü (1933) by its comparatively dense axial structure and fewer and more steeply inclined peripheral tabellae, as well as by its lack of concentric dissepiments. However, the morphology of this corallite falls well within the range of variability exhibited by the holotype and subsequently described “varieties”.

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(Manuscript received December 20, 1966)

PLATE 42 AND EXPLANATION

Explanation of Plate 42

(All figures enlarged $\times 1.6$)

Yuanophyllum kitakamiense MINATO and ROWETT n. sp.

Fig. 1 Replica of transverse section, UHR. no. 18639c

Fig. 2 Transverse section, UHR. no. 18639b

Fig. 3 Transverse section, UHR. no. 18639a

Fig. 4 Replica of transverse section, UHR. no. 18639m

Fig. 5 Ortholongitudinal section, UHR. no. 18639e

(See also Text-fig. 1, in which the position of sections are schematically shown)

Plate 42

