THE MICROSPORE GENUS *SIMOZONOTRILETES*

by H. J. SULLIVAN

ABSTRACT. The microspore genus *Simozonotriletes* is reinterpreted in the light of new material obtained from three horizons in the Westphalian sequence of Great Britain. The spores are assigned to nine varieties of the type species *Simozonotriletes intortus* (Waltz). The species *S. sublobatus* (Waltz) is reduced to varietal status; *Triquitrites trivalvis* (Waltz) is transferred to *Simozonotriletes* and also recognized as an infraspecific category. The variation in the spore assemblages is described and the stratigraphical occurrences noted.

INTRODUCTION

THIS account deals with the morphological variation exhibited by a group of triangular zonate microspores which have been obtained from a cannel coal at the top of the Middle Fenton Seam and its overlying non-marine shale at the Coldbath opencast site, near Barnsley, Yorkshire (Floral Zone Upper Westphalian A). These spores formed only a small proportion of the total assemblage from any one microscope separation and, in the sense of Raistrick, would be termed 'accessory'. However, in the course of examining a large number of slides over 100 specimens have been recognized, and these have been used to illustrate the present study. Other examples from the cannel coal, Hazelwood opencast site, Coed Talon, Flintshire (Floral Zone Middle Westphalian A); and a cannel coal in the Barnsley Seam, Firbeck Colliery, near Worksop, Nottinghamshire (Floral Zone Middle Westphalian B), have been included in this paper to supplement the evidence provided by the Fenton assemblages.

The spores showed a considerable amount of variation principally in the structure of the exine external to the central area, and in the shape of the grain in proximo-distal orientation. A number of the examples could readily be referred to *Simozonotriletes* Potonié and Kremp, but in addition there were allied forms which possessed characters hitherto undescribed in this genus. Many diverse types were represented, but were all related in that the entire collection displayed continuous morphological variation along certain well-defined trends. The end members of these trends were of widely dissimilar aspect, and on the basis of the existing classifications, the differences could be interpreted as sufficient to warrant generic status. However, since there were no demonstrable discontinuities in the variational pattern all the forms are here considered as constituting one species; any subdivision should therefore be limited to the infraspecific level.

While a trinomial nomenclature may appear cumbersome to the stratigraphical palynologist, whose prime concern is the application of spores to the practical problems of zoning and correlation, it is nevertheless amply justified in that it gives a more precise expression of morphological relationship and possibly also of botanical affinity.

Due regard has been paid to the range and pattern of variation in the erection of taxonomic units. In the analysis of a small number of specimens undue emphasis may be given to individual variants because of the incomplete representation of their relationships. This applies particularly in the present instance when we are dealing with one of the rarer types of spores. If a restricted number of spores had been considered, divorced from the picture of continuous variation which emerges when the total population is

[Palaeontology, Vol. 1, Part 2, 1958, pp. 125–138, pls. 26–28.]

studied, the apparent differences they displayed would have suggested the existence of several species or even genera. The nomenclatural treatment would then have borne no relation to their natural alliance. The evidence is not conclusive to show whether or not these spores were derived from the same species of parent plant, but the close and intergrated morphological similarities they display may well suggest a common origin.

The range and pattern of variation of the spores in the shale were comparable in almost every respect to those in the underlying cannel coal, and the assemblages are treated as one in the description of the morphology. The morphological terms used in the designation of the taxonomic units are those defined by Potonié and Kremp (1955, pp. 9–15).

The spores were isolated by macerating a crushed sample of coal with Schulze solution followed by washing with 10 per cent. caustic potash and distilled water. Preliminary treatment with warm hydrofluoric acid was necessary in the case of the shale to remove the mineral matter. Permanent mounts of the microscope separations were made in glycerine jelly and all the slides are now housed in the collection of the Micropalaeontological section of the Geology Department, Sheffield University.

The author is deeply indebted to Professor L. R. Moore for his constant help and guidance throughout all stages of the work, and to Mr. P. C. Sylvester-Bradley for much useful discussion and advice. Mr. R. Neves has read the manuscript and offered a number of suggestions. Thanks are also due to Mr. G. S. Bryant for his help in the production of the plates, and to Miss P. Linnett for her assistance in drawing the text-figures.

The contents of this paper form part of an investigation into the microfloral remains of cannel coals and associated carbonaceous sediments. The work is being carried out at the Geology Department, University of Sheffield, under a tenure of a Town Trustees Fellowship and a State supplemental award.

SYSTEMATIC REVISION

The name *Simozonotriletes* was introduced by Naumova (1937, p. 355) for a 'subgroup' of microspores included in *Zonotriletes* Waltz 1935. The 'subgroup' is now considered equivalent to a taxon of generic rank. Naumova gave only a brief diagnosis and named no species. Three species of spores *Zonotriletes intortus*, *Z. sublobatus*, and *Z. auritus*, described by Waltz in Luber and Waltz (1938), were subsequently transferred to *Simozonotriletes* by Potonié and Kremp (1954, p. 159; 1956*a*, pp. 109–10). They gave a more complete account of the generic characters and selected *S. intortus* as the type species.

When the genus *Simozonotriletes*, as herein interpreted, is placed within the framework of the classification proposed by Potonié and Kremp (1954), certain inconsistencies arise. It is hoped to discuss the question of its systematic position in a later paper, but a revision of the diagnostic characters used in the definition of the suprageneric taxa of the subdivision Zonales would seem to be indicated.

Genus SIMOZONOTRILETES Potonié and Kremp, 1954

Type species *Simozonotriletes intortus* (Waltz) Potonié and Kremp 1954

Diagnosis. Trilete isospores or microspores; triangular in equatorial plane with convex to markedly concave sides and rounded apices; central area triangular, margin well defined and runs approximately parallel to the equator of the spore; exine levigate to infrapunctate or infragranulate; trilete rays exceed $\frac{2}{3}$ radius of central area; cingulum may be of uniform width and thickness but is frequently wider and thicker at the apices; it can also be differentiated into an outer dark zone and inner light zone; dark zone often expanded and thickened into smooth, pad-like valvae at the apices, and may be absent or discontinuous along the sides; in some forms thickened areas are also present in interradial regions; secondary folds absent due to good proximo-distal orientation; extrema lineamenta smooth to sinuous, sometimes incised.

Comparison and remarks. This genus resembles *Triquitrites* Wilson and Coe 1940, but may be distinguished from it by the presence of a well-defined central area. The auriculae in *Tripartites* Schemel 1950 are usually larger and show a tendency to frilling and fluting. *Anulatisporites* Potonié and Kremp 1954 has a more circular outline and the cingulum decreases in thickness towards the equator. Two species of *Simozonotriletes* are now recognized, viz. *S. intortus* and *S. auritus*. These can be differentiated on the basis of the trilete suture. The rays in *S. auritus* possess broad, prominent lips, whereas in *S. intortus* the lips are thin.

Simozonotriletes intortus (Waltz) Potonié and Kremp 1954

Diagnosis. Size 35–110 μ, trilete rays extend almost to the margin of the central area, lips thin, intratectum narrow; remainder as for genus.

Simozonotriletes intortus var. *intortus* (Waltz)

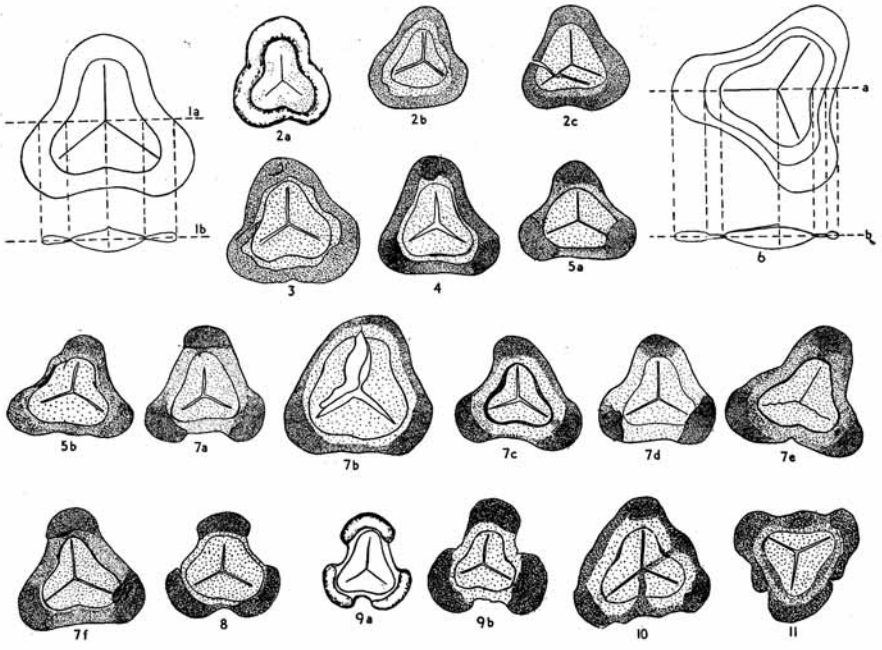
Plate 26, figs. 1–4; text-figs. 1, 2*a–c*

Zonotriletes intortus Waltz *in* Luber and Waltz 1938, pl. 2, fig. 24.
Simozonotriletes intortus (Waltz), Potonié and Kremp 1954, p. 189.
Simozonotriletes intortus (Waltz), Horst 1955, p. 183, pl. 22, figs. 52–54.

Holotype. Plate 2, fig. 24 of Luber and Waltz (1938), Moscow Brown Coal (reproduced as text-fig. 2*a*). *Figured material.* Slides M2C1d (152831), M2E7a (168719), M2C1c (295786), Middle Fenton coal and shale, near Barnsley, Yorkshire. Slide M9A3 (355654), Barnsley Seam, near Worksop, Nottinghamshire. Slide 17A1f (182710), Flint Cannel Coal, near Wrexham, Flintshire. All slides are in the collection of the Geology Department, University of Sheffield.

Diagnosis. Size 35–110 μ, holotype (measured from figure) approximately 60 μ; cingulum homogeneous or may show a division into dark and light zones; dark zone, if present, maintains a uniform width and thickness around the equator; cingulum not expanded and thickened at the apices.

Description. Colour yellow to brown. Triangular in equatorial outline with slightly concave or convex sides and rounded apices. The exine of the central area is levigate to infragranulate and often shows evidence of corrosion and decay. Trilete rays long and straight, extend almost to margin of central area. Some of the forms (e.g. text-fig. 2*a*; Pl. 26, fig. 1) possess an undifferentiated cingulum which is rounded at the equator (text-fig. 1), but in others (Pl. 26, fig. 4; text-fig. 2*b*) dark and light zones are present. In the spore figured on Pl. 26, fig. 3 the cingulum tends to be wider in the interradial regions where it overlaps on to the central area.



TEXT-FIGS. 1–11. *Simozonotriletes intortus* (Waltz).

Figs. 1, 2, var. *intortus* (Waltz). 1*a*, *b*, diagrammatic representation of polar view and hypothetical meridianal section, with undifferentiated cingulum. 2*a*, holotype redrawn from Luber and Waltz (1938), ×275. 2*b*, slide M2E7a ref. 168719 (see Pl. 26, fig. 2), Fenton shale, ×250. 2*c*, slide M17A1f ref. 182710, Flint Cannel Coal, ×250.

Fig. 3, var. *fentonensis* nov., holotype, ×250.

Fig. 4, var. *lineatus* nov., holotype, ×250.

Fig. 5, var. *sublobatus* (Waltz), ×250. 5*a*, slide M1B5 ref. 358698 (see Pl. 26, fig. 11), Fenton Cannel Coal. 5*b*, slide M2E4 ref. 169767, Fenton shale.

Figs. 6, 7, var. *polymorphosus* nov. 6*a*, *b*, diagrammatic representation of polar and hypothetical meridianal section. 7*a*, holotype. 7*b*, slide M2C1e ref. 208695. 7*c*, slide M2E7 ref. 101845. 7*d*, slide M2E7a ref. 237769. 7*e*, slide M1B5 ref. 338647. 7*f*, slide M1B4 ref. 210763 (see Pl. 27, fig. 11). 7*a*, *c*, *d* from Fenton shale, ×250; 7*b*, *e*, *f* from Fenton Cannel Coal, ×250.

Fig. 8, var. *concavus* nov., holotype, ×250.

Fig. 9, var. *trivalvis* (Waltz), ×250. 9*a*, holotype, redrawn from Luber and Waltz 1938. 9*b*, slide M2E7b ref. 460653 (see Pl. 28, fig. 3), Fenton shale.

Fig. 10, var. *reinschi* nov., holotype, ×250.

Fig. 11, var. *mediolobatus* nov., holotype, ×250.

Remarks. The spores which have previously been described as *S. intortus* are all included in this variety. The size limits of our examples, based on the measurement of twenty-three specimens, were 66–110 μ; the mean was 79·5 μ, and the standard deviation 14·0 μ. Reinsch (1884) figured many spores which are comparable to *S. intortus* var. *intortus*. These were included in the subdivisions VIII and XIV of subfamily 1 (nucleus triangularis) and are listed here: pl. 4, figs. 45, 47, 48, 51, 51A, 54; pl. 5, fig. 58; pl. 6, figs. 77 (right-hand figure), 80, 84, 86; pl. 15, figs. 48A, 51B (given as 51A in explanation of plates), 59A; pl. 18, fig. 106A; pl. 19, fig. 45B; pl. 49B, figs. 1, 6–8. Their dimensions ranged from 35–105 μ. Many of the above forms were assigned by Horst (1955, p. 184) to *S. intortus*. In the description of subdivision XIV Reinsch states 'exosporium bi-tri-lamelosum' which in some cases probably indicates a differentiated cingulum.

The type 4K of Knox (1942, fig. 4, p. 6; 1947, fig. 45) from the Limestone Coal Group of Northumberland and Fife, and the Middle Coal Measures of Cumberland resembles *S. intortus* var. *intortus*.

Occurrence. Karaganda Basin, Russia (after Luber and Waltz 1938), Tournaisian–Viséan. Central Russia (after Reinsch 1884), Carboniferous. Western Upper Silesia (after Horst 1955), Westphalian A. Moravska Ostrava (after Horst 1955), Namurian B. Fife and Northumberland (after Knox 1942, 1947), Lower Carboniferous. Cumberland (after Knox 1942), Westphalian. Yorkshire, Middle Fenton Cannel Coal and shale, Upper Westphalian A; Barnsley Seam, Middle Westphalian B. Flintshire, Cannel Coal, Middle Westphalian A.

Simozonotriletes intortus var. *fentonensis* nov.

Plate 26, figs. 5–6; text-fig. 3

Holotype. Slide M1B4 ref. 250847 in the collection of the Geology Department, Sheffield University, from Middle Fenton Cannel Coal, Coldbath opencast site, near Barnsley, Yorkshire. Upper Westphalian A.

Diagnosis. Size 85–95 μ, holotype 88 μ; triangular in equatorial outline with convex or concave sides and rounded apices; dark zone of cingulum is of constant thickness, but tends to be wider at the apices.

Description. Colour yellow, dark zone brown. Equatorial outline is triangular with convex or concave sides and rounded apices. Central area often corroded, exine finely infrapunctate to infragranulate. Trilete rays about $\frac{3}{4}$ radius of central area. Cingulum is differentiated into dark and light zones. Inner margin of dark zone is irregular in outline, but tends to be wider at the apices where it may overlap on to the central area. Apices not thickened.

Comparison and remarks. In *S. intortus* var. *intortus* the dark zone maintains a uniform width and thickness around the equator. A total of nine specimens were assigned to *S. intortus* var. *fentonensis*; the mean was 92 μ, and the standard deviation 5 μ. The name *fentonensis* is used to denote the horizon of the type material.

Occurrence. Middle Fenton Cannel Coal and shale, Upper Westphalian A.

Simozonotriletes intortus var. *lineatus* nov.

Plate 26, figs. 7–9; text-fig. 4

Holotype. Slide M2E4 ref. 258748 in the collection of the Geology Department, University of Sheffield, from shale above the Middle Fenton Seam, Coldbath opencast site, near Barnsley, Yorkshire. Upper Westphalian A.

Diagnosis. Size 75–90 μ, holotype 85 μ, triangular in equatorial outline with straight sides; dark zone continuous along the interradial margins, apices variously thickened; width of dark zone to radius of central area is about 1:1 to 1:2.

Description. Colour yellow, dark zone brown. Equatorial outline triangular with almost straight sides. Trilete rays extend to margin of central area, exine infrapunctate. Cingulum differentiated into dark and light zones, dark zone thickened and sometimes expanded at the apices. Thickening not uniform and may be more pronounced in one of the valvae.

Comparison and remarks. In *S. intortus* var. *polymorphosus* the sides are usually more concave, the dark zone less well defined in interradial regions, and the valvae tend to be larger. The dark zone is not thickened at the apices in *S. intortus* var. *fentonensis*. The size limits of this variety are erected on the measurement of seven specimens. The calculated mean and standard deviation were 82 μ and 4 μ respectively. The name *lineatus* is used to indicate the straight sides which are characteristic of this variety.

Occurrence. Middle Fenton Cannel Coal and shale, Upper Westphalian A.

Simozonotriletes intortus var. *sublobatus* (Waltz)

Plate 26, figs. 10–12; text-figs. 5*a*, *b*

Zonotriletes sublobatus Waltz *in* Luber and Waltz 1938, p. 17, pl. 2, fig. 22.
Simozonotriletes sublobatus (Waltz), Potonié and Kremp 1956*a*, p. 110.

Holotype. Plate 2, fig. 22 of Luber and Waltz (1938). *Figured material*. Slides M1B4 (144639), M1B5 (358698), M1B1 (258791), M2E4 (169767) in the collection of the Geology Department, University of Sheffield, from the Middle Fenton Cannel Coal and shale, Coldbath opencast site, near Barnsley, Yorkshire. Upper Westphalian A.

Diagnosis. Size 35–80 μ, holotype (measured from figure) approximately 60 μ; cingulum displays no clear differentiation into dark and light zones, and is wider and thicker at the apices.

Description. Colour yellow to brown. Triangular in equatorial outline with straight to concave sides and rounded apices. Central area outline may be indistinct, exine levigate to infrapunctate. Trilete rays exceed $\frac{3}{4}$ radius of central area, suture usually closed. The cingulum shows no clear differentiation into dark and light zones in the interradial region, and is expanded and thickened at the apices. Thickening is irregular and may be more marked at one apex. Inner margin of the valvae sometimes overlap on to the central area.

Comparison and remarks. The differential thickening of the cingulum is not as marked as in *S. intortus* var. *polymorphosus*. The dimensions of the forms found by Waltz, and described under *Zonotriletes sublobatus*, ranged from 37·5 to 60 μ. He noted that the cingulum was smooth, and thickened and expanded at the apices. To conform with the original diagnosis *S. intortus* var. *sublobatus* is now restricted to forms in which the undifferentiated cingulum is wider and thicker at the apices. The maximum diameter of fourteen specimens obtained from the Fenton horizon varied between 66·5 and 80 μ. They possessed a mean diameter of 73 μ, and had a standard deviation of 5 μ. The figure of Reinsch (1884, pl. 6, fig. 77) was referred by Waltz to his species *Zonotriletes sublobatus*. The spore figured in Reinsch (1884, pl. 3, fig. 34) is included here.

Occurrence. Karaganda Basin, Russia (after Luber and Waltz 1938), Tournaisian–Viséan. Pruckscha, central Russia (after Reinsch 1884), Carboniferous. Middle Fenton Cannel Coal and shale, Upper Westphalian A.

Simozonotriletes intortus var. *polymorphosus* nov.

Plate 27, figs. 1–12; text-figs. 7*a–f*

Holotype. Slide M2E7a ref. 196712 in the collection of the Geology Department, University of Sheffield, from the shale above the Middle Fenton Seam, Coldbath opencast site, near Barnsley, Yorkshire. Upper Westphalian A.

Diagnosis. Size 60–100 μ, holotype 81·5 μ; apices thickened, cingulum in interradial regions may be homogeneous or differentiated into dark and light zones; dark zones, if present, are usually absent from one or more of the sides.

Description. Colour yellow, valvae brown. Equatorial outline triangular with straight to concave sides and rounded apices. Central area outline distinct, exine levigate to infrapunctate. The trilete rays exceed $\frac{3}{4}$ of the radius of the central area. Apical regions of the cingulum are thickened, the form of the valvae being dependent on the configuration of the apices. The inner boundary of the valvae may overlap on to the central area (e.g. Pl. 27, fig. 12).

Comparison and remarks. In *S. intortus* var. *concavus* the sides are more concave, the apices more rounded, and the cingulum tends to be narrower along the margins. In *S. intortus* var. *lineatus* there is a well-defined dark zone between the valvae. *S. intortus* var. *polymorphosus* was the dominant variety present in the Fenton assemblages. A total of thirty specimens were recognized, having a mean and standard deviation of 83 μ and 7·5 μ. The spore on pl. 6, fig. 79 of Reinsch (1884) resembles *S. intortus* var. *polymorphosus*. The name *polymorphosus* is used to indicate the wide variation displayed by forms assigned to this variety.

Occurrence. Zwickau, Saxony; and Towarkowa, central Russia (both after Reinsch 1884), Carboniferous. Middle Fenton Cannel Coal and shale, Upper Westphalian A.

Simozonotriletes intortus var. *concavus* nov.

Plate 28, figs. 1–2; text-fig. 8

Holotype. Slide M1B2 ref. 342845 in the collection of the Geology Department, University of Sheffield, from the Middle Fenton Cannel Coal, Coldbath opencast site, near Barnsley, Yorkshire. Upper Westphalian A.

Diagnosis. Size 60–90 μ, holotype 80 μ; sides concave, apices broad and rounded, cingulum in interradial regions is narrow (up to about 8 μ), and expanded and thickened into valvae at the apices; inner lines of valvae may overlap on to the central area.

Description. Colour yellow, apices brown. Triangular in equatorial outline with concave sides and broad rounded apices. Exine of central area is infrapunctate to infragranulate, rays frequently open and are about ⅔ radius of central area. Valvae are present at the apices which may be joined by a narrow, ill-defined dark zone along one or more of the interradial regions.

Comparison and remarks. In *S. intortus* var. *trivalvis* the valvae are more prominent and there is no dark zone along the margins. The mean and standard deviation of the five specimens included in this variety were 73·5 μ and 8·5 μ respectively. The figure of Reinsch (1884, pl. 6, fig. 78) is probably *S. intortus* var. *concavus*. The varietal name denotes the concave sides characteristic of the forms included here.

Occurrence. Malowka, central Russia (after Reinsch 1884), Carboniferous. Middle Fenton Cannel Coal and shale, Upper Westphalian A. Barnsley Coal, Middle Westphalian B.

Simozonotriletes intortus var. *trivalvis* (Waltz)

Plate 28, fig. 3; text-figs. 9*a*, *b*

Zonotriletes trivalvis Waltz *in* Luber and Waltz 1938, p. 18, pl. 4, fig. 41.
Triquitites trivalvis (Waltz), Potonié and Kremp 1956*a*, p. 88.

Holotype. Plate 4, fig. 41 of Luber and Waltz (1938), reproduced here as text-fig. 9*a*.
Figured material. Slide M2E7b ref. 460653 in the collection of the Geology Department of the University of Sheffield, from the Middle Fenton shale, Coldbath opencast site, near Barnsley, Yorkshire. Upper Westphalian A.

Diagnosis. Size 45–80 μ, holotype (measured from figure) approximately 65 μ; equatorial outline trefoil in shape with markedly concave sides and prominent apices; three equatorial auriculae lie opposite the angles of the central area; the remainder of the equatorial region unthickened.

Description. Colour yellow, auriculae brown. Triangular in transverse plane, sides concave, apices broad and well rounded. Margin of central area less concave, exine levigate to finely infrapunctate. The trilete rays are distinct and exceed ⅔ radius of central area. The auriculae are smooth, pad-like thickenings of the exine. The structureless, unthickened equatorial region is narrow along the interradial margins and may be absent at the apices.

EXPLANATION OF PLATE 26

All figures × 500

Figs. 1–4. *Simozonotriletes intortus* var. *intortus* (Waltz). 1, Fenton cannel coal, slide M2C1d ref. 152831—66·5 μ. 2, Barnsley coal, slide M9A3 ref. 355654—107 μ. 3, Fenton cannel coal, slide M2C1c ref. 295786—71 μ. 4, Fenton shale, slide M2E7a ref. 168719—66·5 μ.
Figs. 5–6. *Simozonotriletes intortus* var. *fentonensis* nov. 5, Holotype, Fenton cannel coal, Slide M1B4 ref. 250847—88 μ. 6, Fenton cannel coal, slide M2C1f ref. 261796—93 μ.
Figs. 7–9. *Simozonotriletes intortus* var. *lineatus* nov. 7, Holotype, Fenton shale, slide M2E4 ref. 258748—85 μ. 8, Fenton shale, slide M2E2 ref. 221812—83 μ. 9, Fenton shale, slide M2E7a ref. 158817—84 μ.
Figs. 10–12. *Simozonotriletes intortus* var. *sublobatus* (Waltz). 10, Fenton cannel coal, slide M1B4 ref. 144639—83 μ. 11, Fenton cannel coal, slide M1B5 ref. 358698—75 μ. 12, Fenton cannel coal, slide M1B1 ref. 258791—76 μ.

Comparison and remarks. *S. intortus* var. *trivalvis* resembles *S. intortus* var. *concavus*, but the auriculae are larger and more prominent. Although represented by only two specimens in the Fenton assemblages, their distinctive nature warranted varietal discrimination. The morphological characters they displayed were in complete harmony with the original diagnosis of *Z. trivalvis* Waltz. The maximum diameters of the two spores were 76 μ and 80 μ.

Potonié and Kremp (1956*a*, p. 88) placed this form in *Triquitites* Wilson and Coe. The auriculae are similar in construction to those of *Triquitites*, but the presence of a well-defined central area obviates its inclusion in that genus. The specimen figured by Reinsch (1884, pl. 24, fig. 79D) was referred by Waltz to his species *Z. trivalvis*.

Occurrence. Karaganda Basin, Russia (after Luber and Waltz 1938), Tournaisian–Viséan. Central Russia (after Reinsch 1884), Carboniferous. Middle Fenton shale, Upper Westphalian A.

Simozonotriletes intortus var. *reinschi* nov.

Plate 28, figs. 4–9; text-fig. 10

Holotype. Slide M2E7b ref. 465792 in the collection of the Geology Department, University of Sheffield, from the shales above the Middle Fenton Seam, Coldbath opencast site, near Barnsley, Yorkshire. Upper Westphalian A.

Diagnosis. Size 75–90 μ, holotype 91 μ; thickened areas present along the interradial margins which may extend as narrow bands over the proximal and distal surfaces of the central area; width of cingulum is $\frac{1}{2}$–$\frac{2}{3}$ radius of the central area; extrema lineamenta sinuous.

Description. Equatorial outline triangular with slightly concave or convex sides and rounded apices. Cingulum differentiated into an outer dark zone and inner light zone. Dark zone often expanded and thickened at the apices. The presence of thickened areas in the interradial regions of the spore is diagnostic of this variety. The thickening may originate in the dark zone (e.g. Pl. 28, figs. 4, 6; text-fig. 10), or at the junction of the cingulum and central area (Pl. 28, fig. 7). In some forms the thickening continues on to the proximal and distal surfaces of the central area; in the holotype (Pl. 28, fig. 4; text-fig. 10) the thickened bands extend to points above and below the intersection of the trilete rays.

Remarks. The mean diameter of the six specimens referred to this variety was 84·5 μ and the standard deviation 3·5 μ. Reinsch, to whom this variety is dedicated, figured (1884, pl. 17, fig. 79C) a specimen from the 'Blatterkohle', Malowka, central Russia, which shows thickened areas in the dark zone of the cingulum.

Occurrence. Malowka, central Russia (after Reinsch), Carboniferous. Middle Fenton Cannel Coal and shale, Upper Westphalian A.

Simozonotriletes intortus var. *mediolobatus* nov.

Plate 28, figs. 10–12; text-fig. 11

Holotype. Slide M2E7b ref. 248685 in the collection of the Geology Department, University of Sheffield, from the shale above the Middle Fenton Seam, Coldbath opencast site, near Barnsley, Yorkshire. Upper Westphalian A.

Diagnosis. Size 60–90 μ, holotype 81·5 μ; cingulum in interradial regions is inciso-lobate; width of cingulum to radius of central area is in the ratio 1:3 to 2:5.

Description. Equatorial outline triangular with almost straight sides. Apices are rounded and sometimes thickened. The cingulum is differentiated into an inner light zone and outer dark zone. The equatorial margin is broken up into a number of lobate structures.

Comparison and remarks. S. intortus var. *mediolobatus* and var. *reinschi* are both characterized by complications of the cingulum along the interradial margins. The size limits of this variety were erected on the measurement of five specimens. The mean diameter was 74·5 μ and the standard deviation 10·5 μ. The name refers to the lobate nature of the margin.

Occurrence. Middle Fenton Cannel Coal and shale, Upper Westphalian A.

GENERAL DESCRIPTION OF THE VARIATION

The study of the variation has been concerned with the structure of the equatorial region, the shape of the spore in proximo-distal orientation, and the nature of the central area. The general triangular shape and the presence of a well-defined, sculptureless central area with long simple trilete rays are features shared by all the spores, and can be taken as indicative of their specific indentity. The modifications of the cingulum, although producing a wide variety of structures, do nevertheless take place along certain well-defined trends. The assemblages represent a continuously intergrading sequence of forms and it is solely for ease of reference and communication that the infraspecific categories are erected. The overall result of this gradation is to give rise to spores which display considerable differences in external form at the ends of several transitional series. Within the limits of the extreme examples any differentiation of the intermediate types is often a matter of conjecture and mainly dependent on the choice of a single variable character as the basis for subdivision. Such a character of prime importance in this particular group of spores is the cingulum, but the shape of the spore has been accorded a secondary role in the definition of the nomenclatural units.

The cingulum in its simplest case is a homogeneous equatorial border which is rounded at the equator and decreases in thickness towards the junction with the central area. A possible reconstruction is given in text-fig. 1. Spores which possess such a cingulum (Pl. 26, fig. 1; text-fig. 2*a*) are referred to *S. intortus* var. *intortus*; likewise the examples in which the dark and light zone of the cingulum maintain a constant width and thick-

---

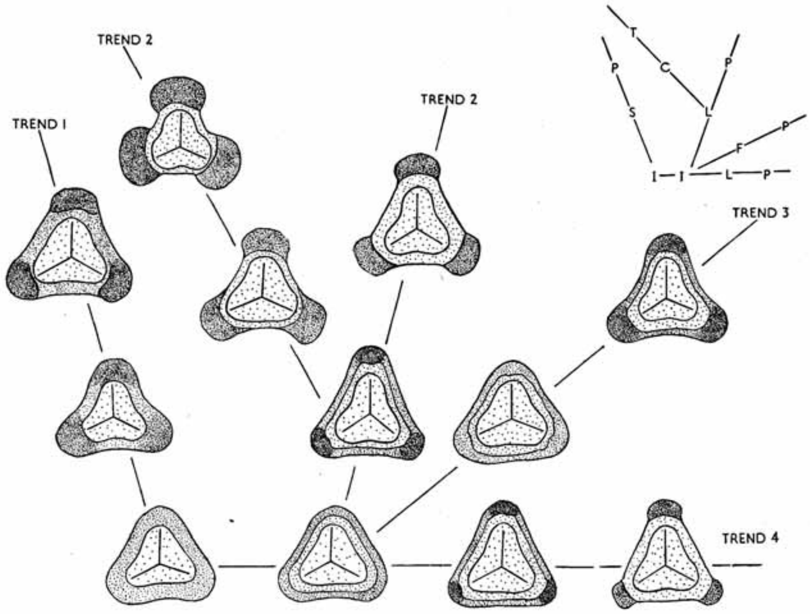
EXPLANATION OF PLATE 27

All figures ×500 unless otherwise stated

Figs. 1–12. *Simozonotriletes intortus* var. *polymorphosus* nov. 1, Fenton shale, slide M2E4 ref. 207665—92·5 μ. 2, Fenton shale, slide M2E7a ref. 445680—87 μ. 3, Fenton shale, slide M2E7a ref. 234730—86·5 μ. 4, Fenton shale, slide M2E6 ref. 325770—71·5 μ. 5, Fenton shale, slide M2E4 ref. 337726—87·5 μ. 6, Fenton shale, slide M2E6 ref. 238772—80 μ. 7, Fenton shale, slide M2E4 ref. 339778—73·5 μ. Note regular arrangement of hyphae-like structures on the central area. 8, Fenton shale, slide M2E4 ref. 273711—74 μ. 9, Fenton cannel coal, slide M1B3 ref. 311809—77 μ. 10, Holotype, Fenton shale, slide M2E7a ref. 196712—81·5 μ. 11, Fenton cannel coal, slide BM14 ref. 210763—76 μ. 12, Fenton shale, slide M2E6 ref. 238740—91 μ (×675).

ness around the equator (Pl. 26, fig. 2; text-fig. 2*b*), and those forms intermediate between the two (text-fig. 2*c*).

The overall pattern of variation displayed by the assemblages involved differential thickening of the cingulum. The principal trends were those leading to apical thickening,



TEXT-FIG. 12. Pictogram to illustrate the relationships of the varieties of *S. intortus* (Waltz) in four trends leading to apical thickening. The enumerated trends are described in the text. Key to insert diagram: I—*S. intortus* var. *intortus*; F—*S. intortus* var. *fentonensis*; L—*S. intortus* var. *lineatus*; S—*S. intortus* var. *sublobatus*; P—*S. intortus* var. *polymorphosus*; C—*S. intortus* var. *concavus*; T—*S. intortus var. trivalvis.*

and are diagrammatically represented in text-fig. 12. From the evidence furnished by our examples this can arise in four possible ways:

(*a*) By localization of thickening at the expanded apices of an originally undifferentiated cingulum; trend 1 in text-fig. 12. The valvae of the specimens (Pl. 27, figs. 10, 11; text-figs. 7*a*, *f*) were probably derived from an undifferentiated cingulum.

(*b*) By an expansion and thickening of the dark zone at the apices, concomitant with a reduction in width and thickness along the margins; trend 2 in text-fig. 12.

(*c*) By expansion of the dark zone at the apices and reduction in interradial regions; trend 3 in text-fig. 12.

(*d*) By withdrawal of the dark zone between the apices; the amplitude of the valvae will then correspond to the original width of the dark zone, e.g. top apex of the spore in Pl. 27, fig. 9. Trend 4 in text-fig. 12.

The culmination of these trends is expressed by forms (Pl. 27, figs. 9, 12; text-fig. 7*a*) with three prominent valvae at the angles of an otherwise unthickened equatorial border. The variability of the shape of the valvae in a particular spore (e.g. Pl. 26, fig. 8; Pl. 27, fig. 3) is an indication that more than one of the four processes were operative during its development.

The progressive reduction in width and thickness of the dark zone along the margins is well illustrated in a series of forms assigned to *S. intortus* var. *polymorphosus*. The dark zone is continuous between the valvae in the specimens (Pl. 27, figs. 1, 4, 6; text-figs. 7*b*, *c*), but is absent from the lower border in the spore (Pl. 26, fig. 2), while in the example (Pl. 27, fig. 3) it is visible only as a narrow discontinuous band along the right-hand margin of the cingulum.

The rate of withdrawal of the dark zone is not necessarily uniform, and it may tend to persist along one or two of the sides (e.g. Pl. 27, figs. 7, 8). In a number of forms there would appear to be some relationship between the degree of development of the dark zone and the concavity of the sides (e.g. Pl. 27, fig. 8; text-fig. 7*c*).

The members of the *S. intortus* var. *concavus*–*S. intortus* var. *trivalvis* lineage are characterized by concave sides and broad, well-rounded apices. Forms referred to *S. intortus* var. *trivalvis* (Pl. 28, fig. 3; text-figs. 9*a*, *b*) represent the extreme expression of localized thickening at the apices.

Thickened areas are also present in the interradial regions, and this character becomes co-ordinated into the structures of the cingulum already described. In *S. intortus* var. *reinschi* (Pl. 28, figs. 4–9; text-fig. 10) the thickening usually originates in the dark zone of the cingulum, but in the spore (Pl. 28, fig. 7) a dark, semicircular area is situated at the junction of the cingulum and the central area. The specimen (Pl. 28, fig. 9) shows an early stage in the development of interradial thickening. Narrow bands may extend inwards from these thickened areas over the proximal and distal surfaces of the central area. In the spores (Pl. 28, fig. 4; text-fig. 10) they continue to points above and below the intersection of the trilete rays. The acquisition of the radial sculpture is reminiscent of the ornament found in other spore genera, e.g. *Knoxisporites* Potonié and Kremp 1954.

The outer margin of the cingulum is typically smooth to sinuous, but in the spores assigned to *S. intortus* var. *mediolobatus* it is incised along the interradial margins (Pl. 28, figs. 10–12; text-fig. 11). The dark zone is irregular in width due to the presence of the lobate projections.

Many of the forms described above have their counterparts in the spores illustrated by

---

EXPLANATION OF PLATE 28

All figures ×500

Figs. 1–2. *Simozonotriletes intortus* var. *concavus* nov. 1, Holotype, Fenton cannel coal, slide M1B2 ref. 342845—80 μ. 2, Barnsley coal, slide M9A3 ref. 169735—63 μ.

Fig. 3. *Simozonotriletes intortus* var. *trivalvis* (Waltz). Fenton shale, slide M2E7b ref. 460653—80 μ.

Figs. 4–9. *Simozonotriletes intortus* var. *reinschi* nov. 4, Holotype, Fenton shale, slide M2E7b ref. 465792—91 μ. 5, Fenton shale, slide M2E7b ref. 342641—84·5 μ. 6, Fenton shale, slide M2E6 ref. 406740—83 μ. 7, Fenton cannel coal, slide M1B5 ref. 260663—87 μ. 8, Fenton shale, slide M2E4, ref. 279834—78 μ. 9, Fenton shale, slide M2E4 ref. 226762—83·5 μ.

Figs. 10–12. *Simozonotriletes intortus* var. *mediolobatus* nov. 10, Holotype, Fenton shale, slide M2E7b ref. 248685—81·5 μ. 11, Fenton cannel coal, slide M2C1a ref. 396699—86·5 μ. 12, Fenton shale, slide M2E1b 406745—60 μ.

Reinsch (1884), and this tempts an observation that the pattern of variation is simulated at other stratigraphical levels. However, the horizon of much of the material figured by Reinsch is not sufficiently well known to draw too close a comparison. Also the three species *Zonotriletes intortus*, *Z. sublobatus*, and *Z. trivalvis* described by Waltz *in* Luber and Waltz (1938) may well have represented a continuous morphological series.

SUMMARY OF STRATIGRAPHICAL DISTRIBUTION

The genus *Simozonotriletes* is known to have a widespread distribution in Europe and Asia. It has been found in Tournaisean-Viséan strata of the Karaganda Basin, Russia, by Luber and Waltz (1938); and at other localities in central Russia, mentioned by Reinsch (1884), in rocks the age of which cannot be ascertained more precisely than 'Carboniferous'.

In south-eastern Europe *S. intortus* has been identified by Horst (1955, p. 184) in the Prokop Coal (Namurian B), Upper Silesia; and in Seam VI Rudaer Schichten (Westphalian A) of Moravska Ostrava. The type 4K of Knox (1942, 1947), now equated with *S. intortus* var. *intortus*, appears in the Lower Carboniferous of Fife and Northumberland, and the Middle Coal Measures of Cumberland. *Simozonotriletes* has been described from Canada by Summers as *Muraspora*.

Simozonotriletes is dominantly a Lower Carboniferous and Namurian genus, and Potonié and Kremp (1954, p. 159; 1956*a*, p. 109) have gone so far as to state 'Tournai-Visé bis Namur B, vielleicht nicht höher', and have indicated no Westphalian occurrences on their distribution charts (1954, p. 184; 1956*b*, p. 89). The spores found in this investigation extend up to Middle Westphalian B, and *Simozonotriletes* is thus shown to have a greater vertical range than had previously been supposed. Its sporadic appearance in rocks of Westphalian age, coupled with a distinctive morphology, may serve to establish this spore as an important stratigraphical index.

REFERENCES

HORST, U. 1955. Die Sporae dispersae des Namurs von Westoberschlesien und Mährisch-Ostrau. *Palaeontographica*, **98**, 137–226, 9 pls.

KNOX, E. M. 1942. The microspores of some coals of the Productive Coal Measures of Fife. *Trans. Inst. Min. Eng.* **101**, pt. 4, 98–112.

—— 1947. The microspores in coals of the Limestone Coal Group in Scotland. Ibid. **107**, 155–63.

LUBER, A. A. and WALTZ, I. E. 1938. Classification and stratigraphic value of spores of some Carboniferous coal deposits in the U.S.S.R. *Central. Geol. Prosp. Inst.* **105**, 1–45, 10 pls.

NAUMOVA, S. N. 1937. Spores and pollen of the coals of the U.S.S.R. *Internat. Geol. Cong. Rept. XVII Session, U.S.S.R.* **1**, 353–564 (English translation *c.* 1947).

POTONIÉ, R. and KREMP, G. 1954. Die Gattungen der paläozischen Sporae dispersae und ihre Stratigraphie. *Geol. Jb.* **69**, 111–94, 17 pls.

—— 1955. Die Sporae dispersae des Ruhrkarbons, ihre Morphographie und Stratigraphie mit Ausblicken auf Arten anderer Gebiete und Zeitabschnitte. Teil I. *Palaeontographica*, **98**, 1–136, 16 pls.

—— 1956*a*. Teil II. Ibid. **99**, 85–191, 22 pls.

—— 1956*b*. Teil III. Ibid. **100**, 65–121.

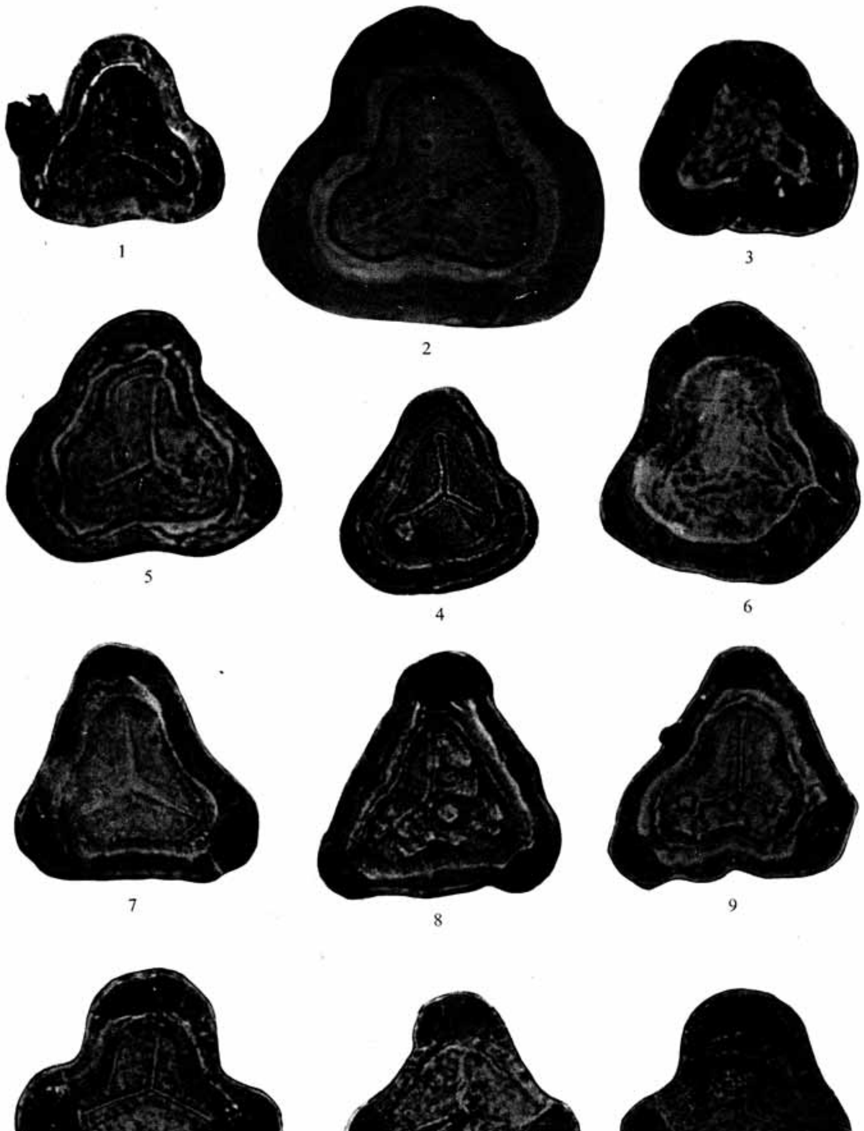
REINSCH, P. F. 1884. *Micro-Palaeophytologia Formationis Carboniferae. Vol. 1, Continens Trileteas et Stelideas.* vii+80, 66 pls. Erlangen and London.

SCHEMEL, M. P. 1950. Carboniferous plant spores from Dagget County, Utah. *J. Paleont.* **24**, 232–44, 2 pls.

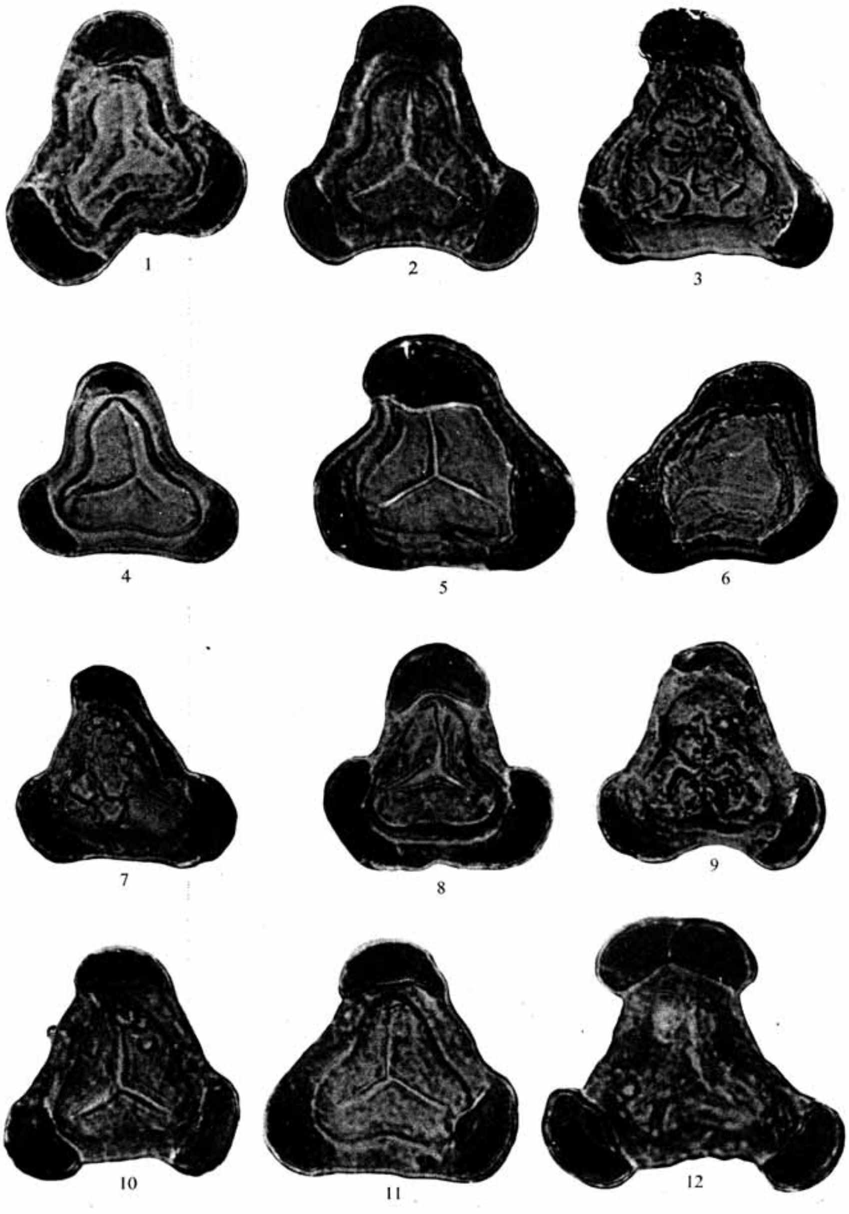
WILSON, L. R. and COE, E. A. 1940. Description of some unassigned plant microfossils from the Des Moines Series of Iowa. *Amer. Mid. Nat.* **30**, 182–6.

H. J. SULLIVAN
Department of Geology,
The University,
Sheffield

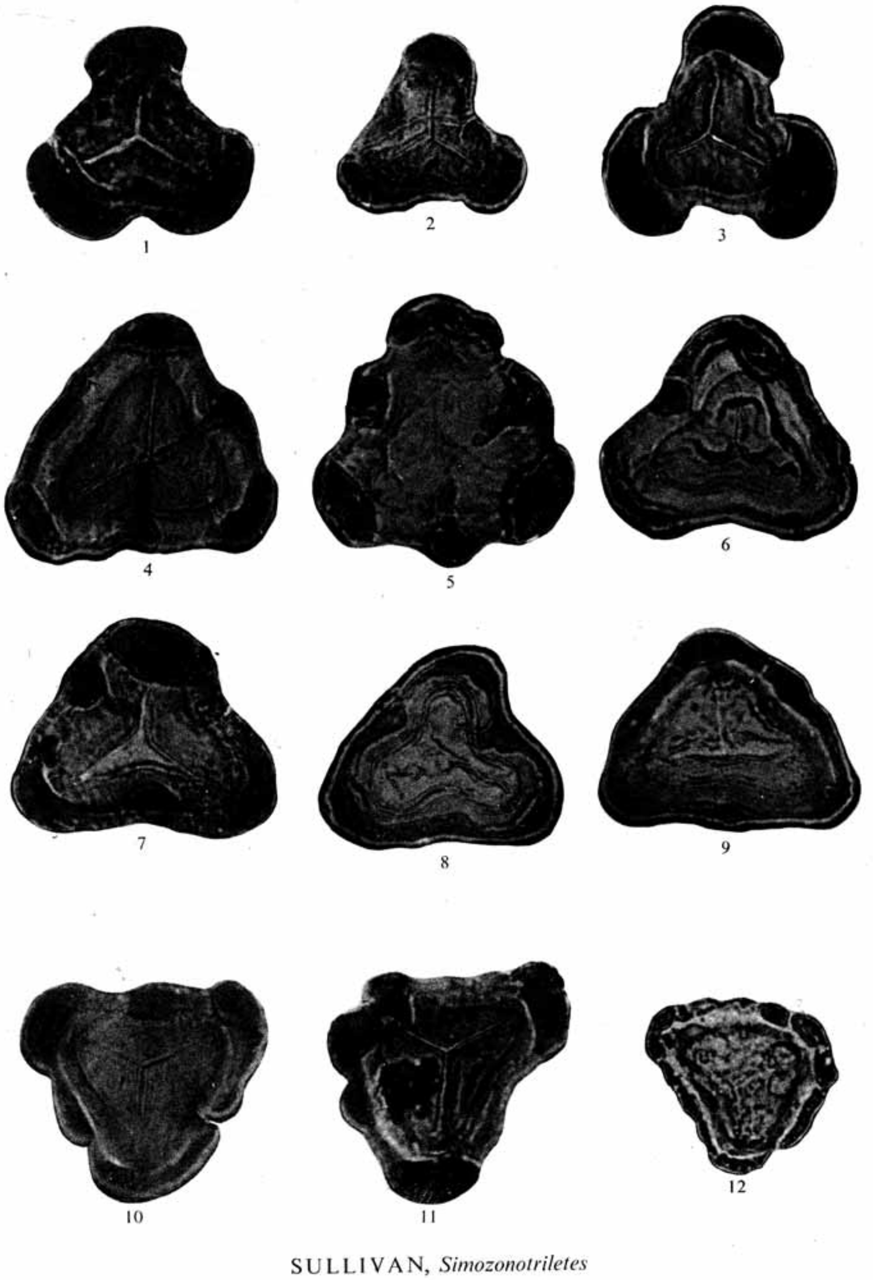
Manuscript received 20 November 1957



SULLIVAN, *Simozonotriletes*



SULLIVAN, *Simozonotriletes*



SULLIVAN, *Simozonotriletes*