THE UNIVERSITY OF ALBERTA

PERMIAN SPIRIFERELLA FROM THE YUKON TERRITORY

A THESIS

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DEPARTMENT OF GEOLOGY

by

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ABSTRACT

The Permian genus Spiriferella from the Yukon Territory is analyzed by detailed study of internal and external morphology along with stratigraphic occurrence. Among characters of specific importance are the muscle platform, bundling of ribs, sinus angle, median fold and micro-ornament. Five species are recognized, Spiriferella saranae, S. rajah var A, S. rajah var B, S. keilhavii, S. ordinaria and S. editiareatus, which fall in two slightly overlapping intervals. The lowest of these, of probable Wolfcampian and Leonardian age, represented in the upper third of the Middle Recessive Unit and lower half of the Tahkandit Formation, contains Spiriferella saranae, S. rajah var A, S. ordinaria and S. editiareatus. The upper interval, of probable Upper Leonardian to Guadalupian age, is represented in the upper half of the Tahkandit Formation and contains Spiriferella rajah var B and S. keilhavii.

ACKNOWLEDGEMENTS

The writer wishes to express his heartfelt gratitude to Dr. Samuel J. Nelson who, in addition to providing the material for this study, aided with advice, guidance and penetrating insight during the course of the work. His patience and forbearance during the many readings of the manuscript are also deeply appreciated.

The writer expresses his sincere gratitude to the California Standard Company for the financial assistance rendered by the California Standard Company Graduate Fellowship in Geology and to the Robert Tegler Trust for the Robert Tegler Research Scholarship, without which the writer would have been unable to carry out the study.

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Introduction. -- Fossils of the genus Spiriferella are among the most abundant, ubiquitous and easily recognizable in the Permian System. They occur in U.S.S.R., Mongolia, India, Pakistan, Australia, the East Indies, Mexico, parts of the Western United States, western, northern and Arctic Canada, Greenland and Spitzbergen. Unfortunately the genus has appeared to embrace a group of highly variable, intergrading species. These have been described with little or no stratigraphic data and have thus been of little use in correlation. During the past few years, Dr. S. J. Nelson of the University of Alberta personally collected a large number of Spiriferella from nine sections in the Yukon Territory (see figs. 1,3), over which the broad stratigraphic relations had been established by faunal and lithological correlation. In addition, accurately dated fusulinids occur in one horizon which establishes a tie-point for broader correlation (Nelson, 1961, 1962; Cameron, 1962). The opportunity to rigorously analyze the genus was thus provided.

History of the genus. -- The name Spiriferella was first applied by Tschernyschew (1902) using de Verneuil's (1845) Spirifer saranae as the type species. Tschernyschew described three species based on over one hundred pedicle valves and ten poorly preserved brachial valves from the collections of Keyserling, Gruenewaldt, Moeller and Stuckenberg as well as his own from Timan and the Urals. His paper, however, makes no mention as to whether he actually examined de Verneuil's specimens. Because of its supposed punctate condition, Tschernyschew considered Spiriferella closely related to

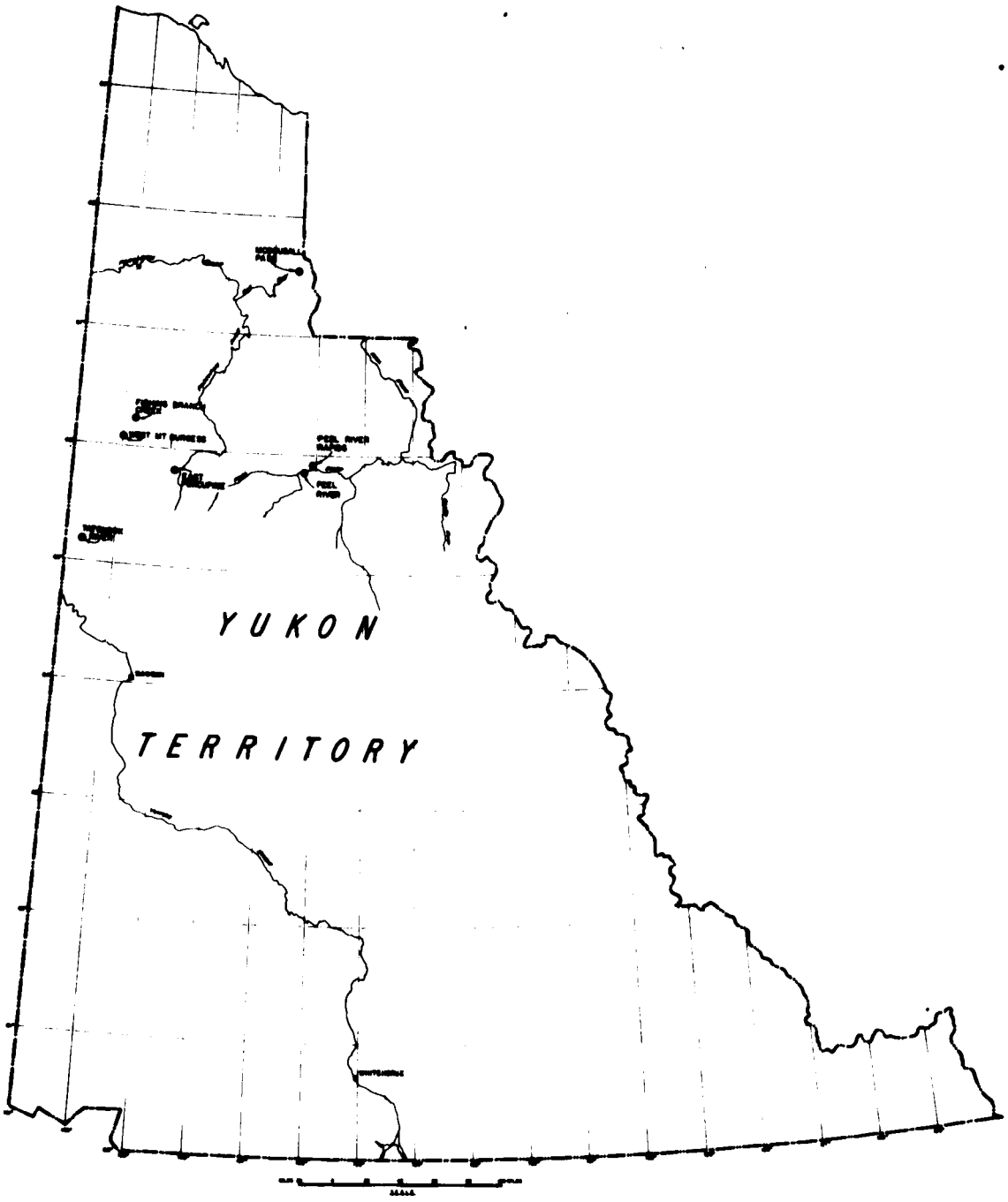


Figure 1. Locality map showing location of key sections.

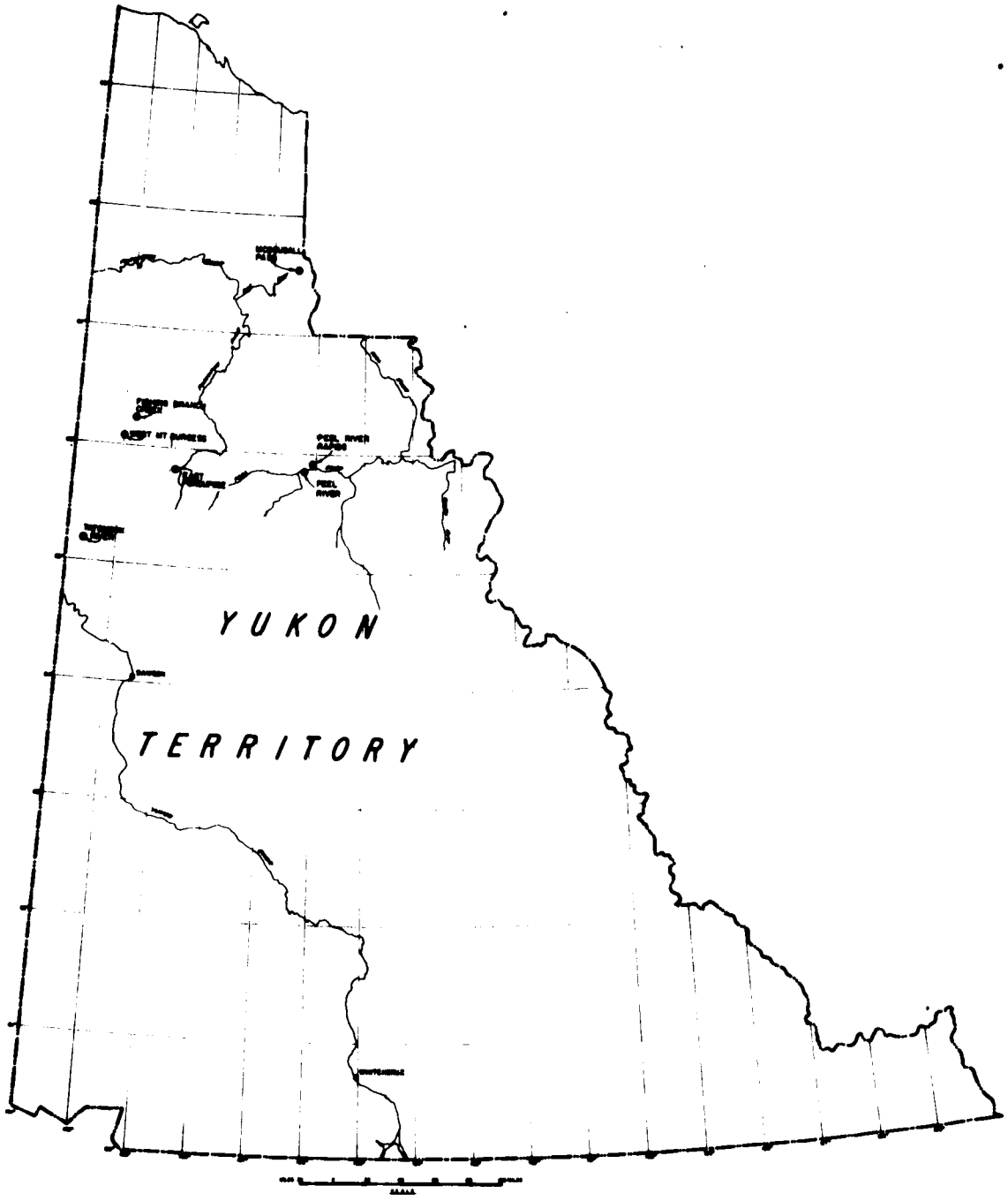


Figure 1. Locality map showing location of key sections.

the Triassic Spiriferina, although he stated that internal structure, particularly callus filling, muscle arrangement and spiralia supports indicated close affinity to Palaeozoic Spirifer's. He thus proposed the name Spiriferella saranae, "which is a subgenus of Spiriferina or Spirifer . . . though it is apparent, however, our form is distinguished from typical representatives of these genera and stands in the interval between them" (author's translation from the Russian, p. 126).

Subsequently many species of Spiriferella have been described; notable works are those of Grabau (1931), Einor (1939) and Dunbar (1955). The shell structure, which Tschernyschew regarded as punctate, has proven to be impunctate, and the median septum of the pedicle valve described by Tschernyschew (1902) has been shown not to exist (see Miloradovich, 1938; Stepanow, 1937; Einor, 1939; Dunbar, 1955). The genus is presently interpreted as a more or less longitudinally elongate, coarsely ribbed spiriferid.

Results of the study. -- Five species of Spiriferella are recognizable in the Permian of the Yukon, of which one is composed of two very similar but distinct varieties. These are Spiriferella saranae, the type species; and S. rajah var A, S. rajah var B, S. keilhavii, S. ordinaria and S. editiareatus. All are described and figured in the systematic descriptions.

Stratigraphic occurrence. -- The Permian succession of the Yukon, shown in fig. 2, has been described by Nelson (1961) as, in ascending order, the Middle Recessive Unit, 500 to 1000 feet of shaly

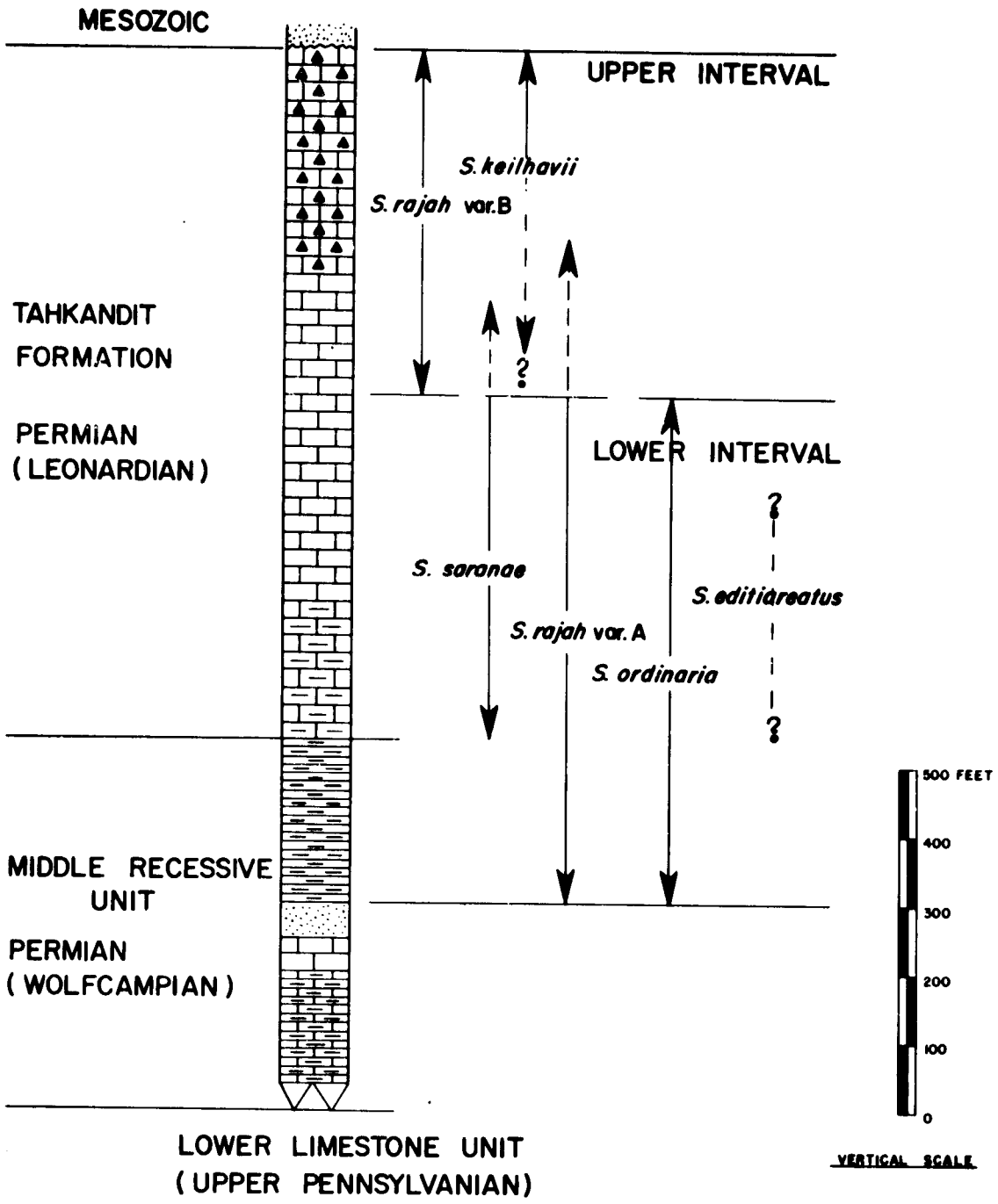
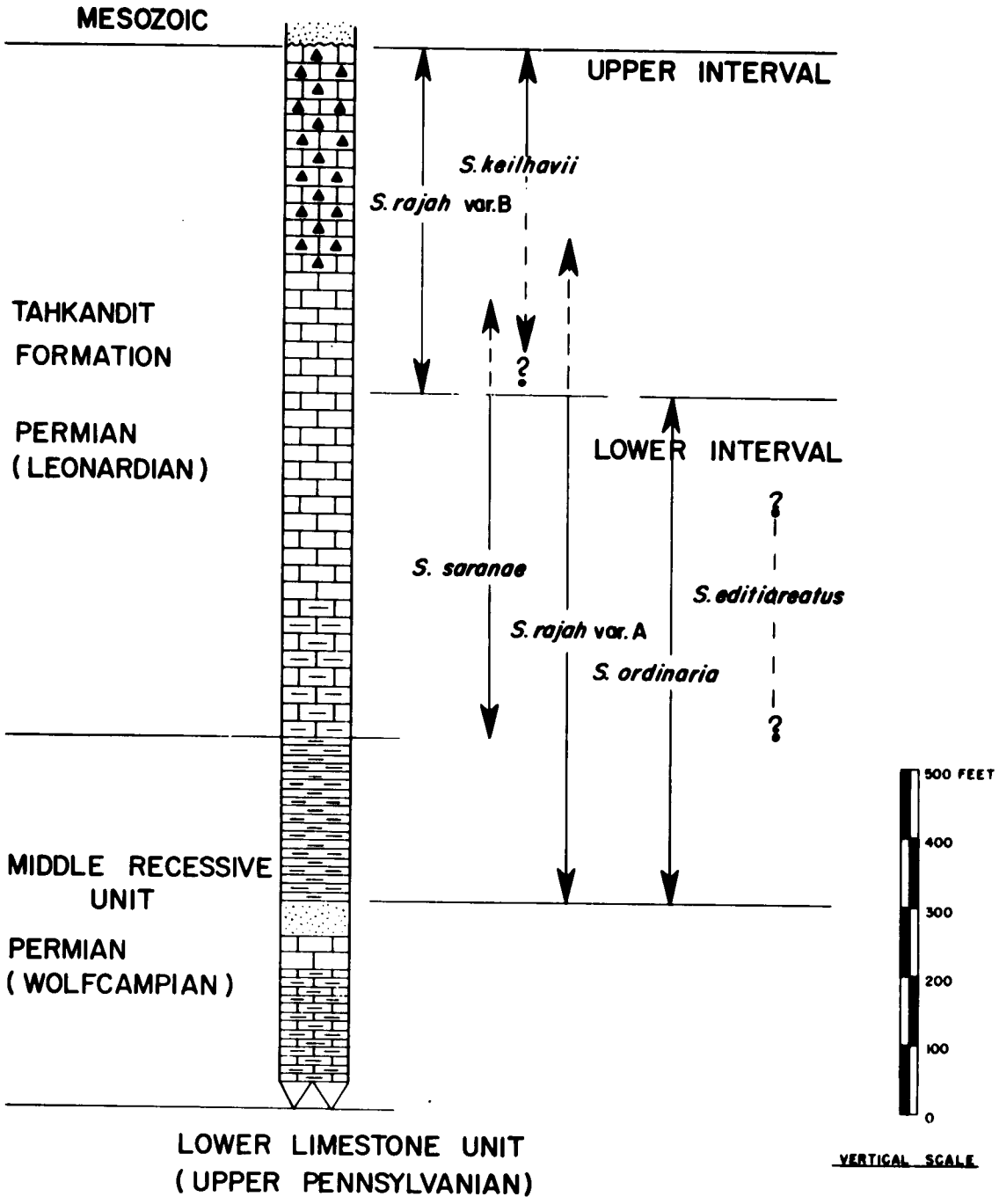


Figure 2. Generalized stratigraphic section showing the range of species of Spiriferella in the Permian of the Yukon. Stratigraphy after Nelson (1961).



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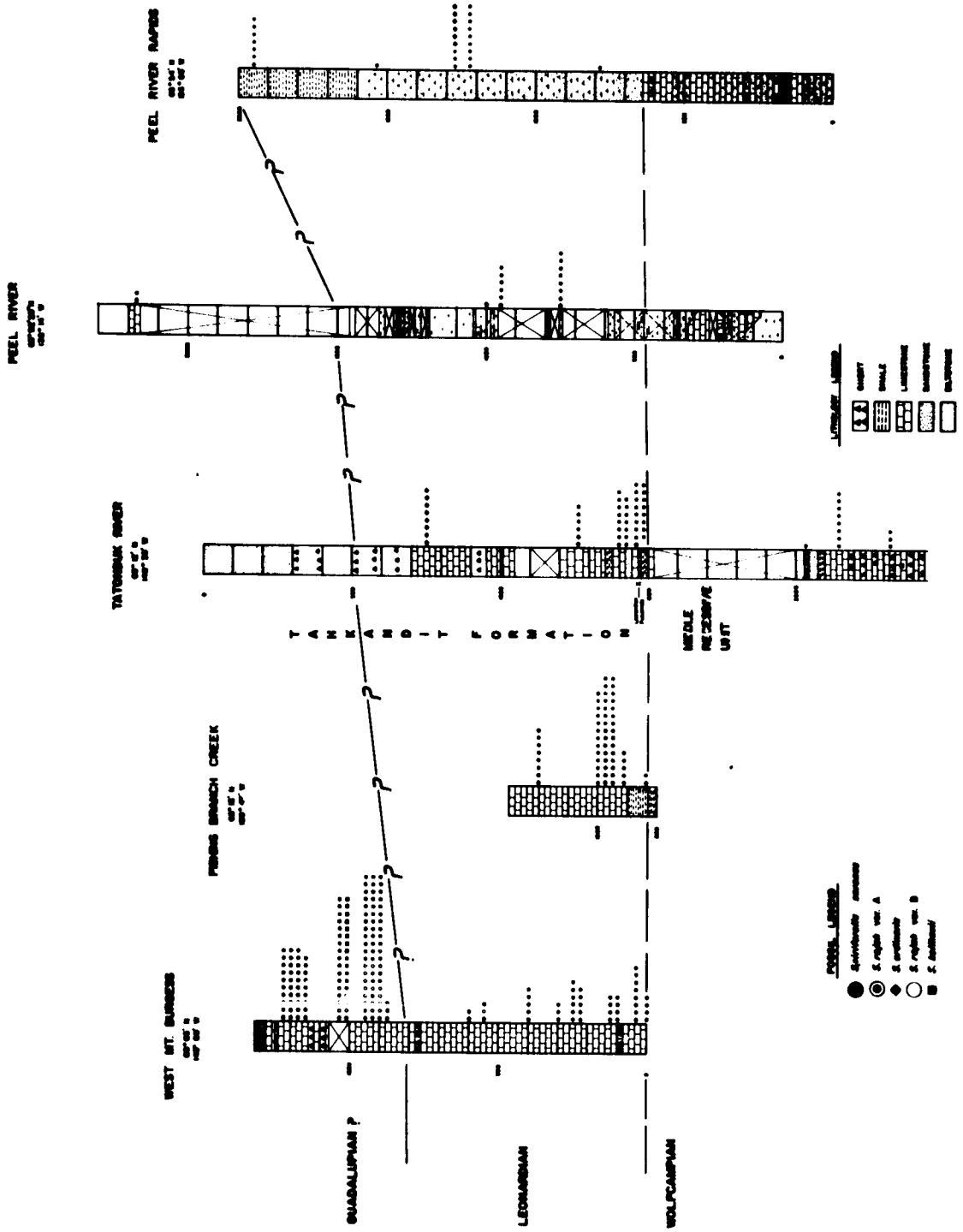

Figure 3. Occurrence of Spiriferella in key stratigraphic sections of the Permian of the Yukon.

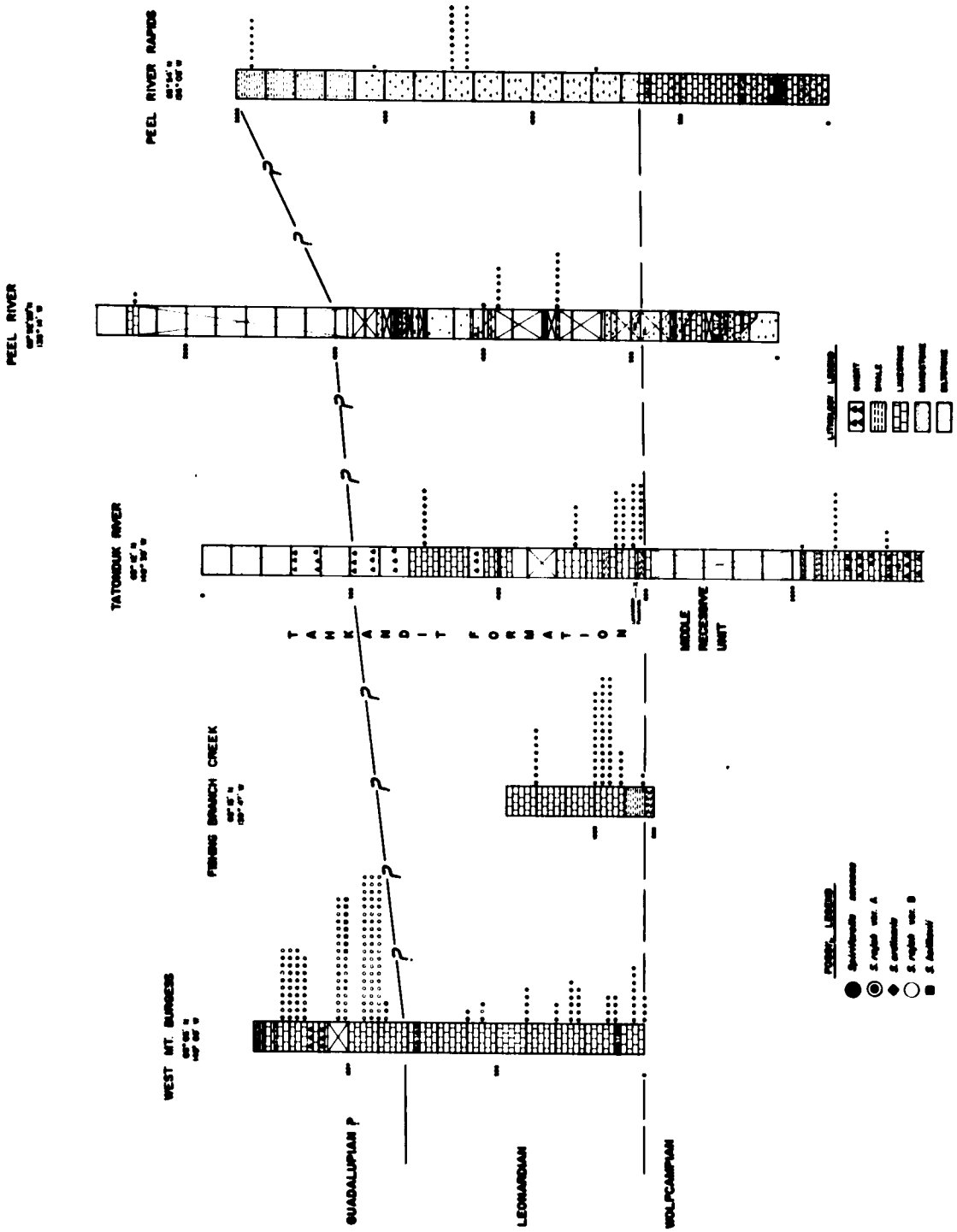

Figure 3. Occurrence of Spiriferella in key stratigraphic sections of the Permian of the Yukon.

limestone and calcareous shale often with sandstone and conglomerate interbeds, of probable Wolfcampian age, and the Tahkandit Formation, a light coloured siliceous limestone unit between 500 to 1000 feet thick, of Leonardian age. This analysis of the Yukon Spiriferella suggests that it occurs in two broad partly overlapping vertical intervals. The lower interval, which extends from the base of the Tahkandit Formation equivalents some 400 feet upward, is characterized by abundant S. rajah var A, fairly abundant S. saranae and rare S. ordinaria, though S. rajah var A ranges down into the Middle Recessive Unit. Overlying and overlapping the upper portion of this interval and extending through the upper Tahkandit formation is another containing S. rajah var B in abundance, and less abundantly, S. keilhavii. A few S. saranae and ordinaria may range into this interval but near the top only S. rajah var B is abundant and may be the only Spiriferella present. This stratigraphic occurrence is summed up in fig. 2.

Figure 4 is a compilation of the stratigraphic occurrence of Spiriferella as gleaned from the literature and grouped in the species as here interpreted. Grabau's (1931) specimens appear to fall into the lower interval as mentioned above. Spiriferella keilhavii, which occupies a fairly high stratigraphic position in our sections, appears to occur in a similar position in other areas.

A particularly significant association is that of S. saranae and Schwagerina hyperborea in the Belcher Channel Formation noted by Harker & Thorsteinsson (1962, G.S.C. locality 26407). Specimens of

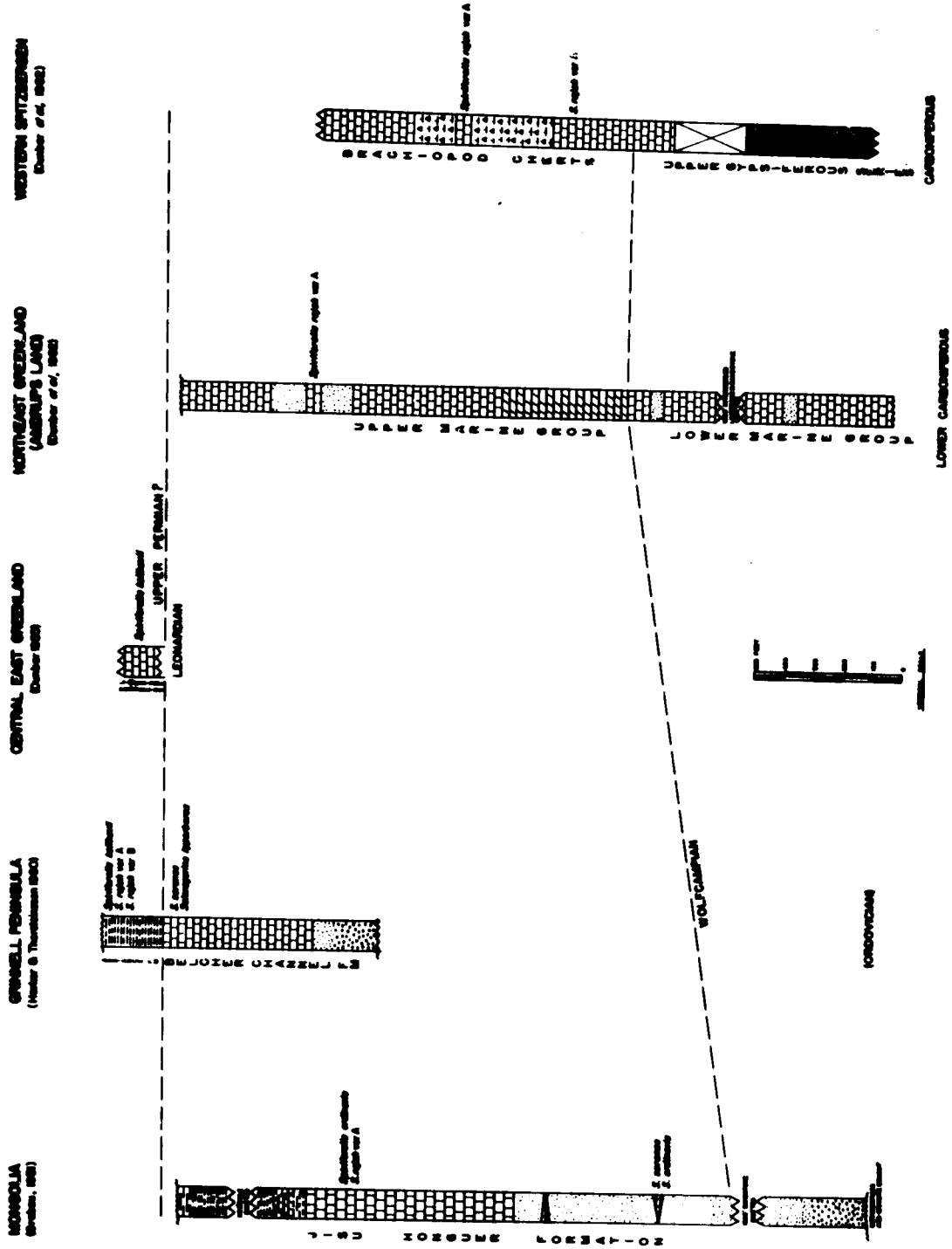

Figure 4. Generalized columnar sections from the literature indicating positions of some species of Spiriferella.

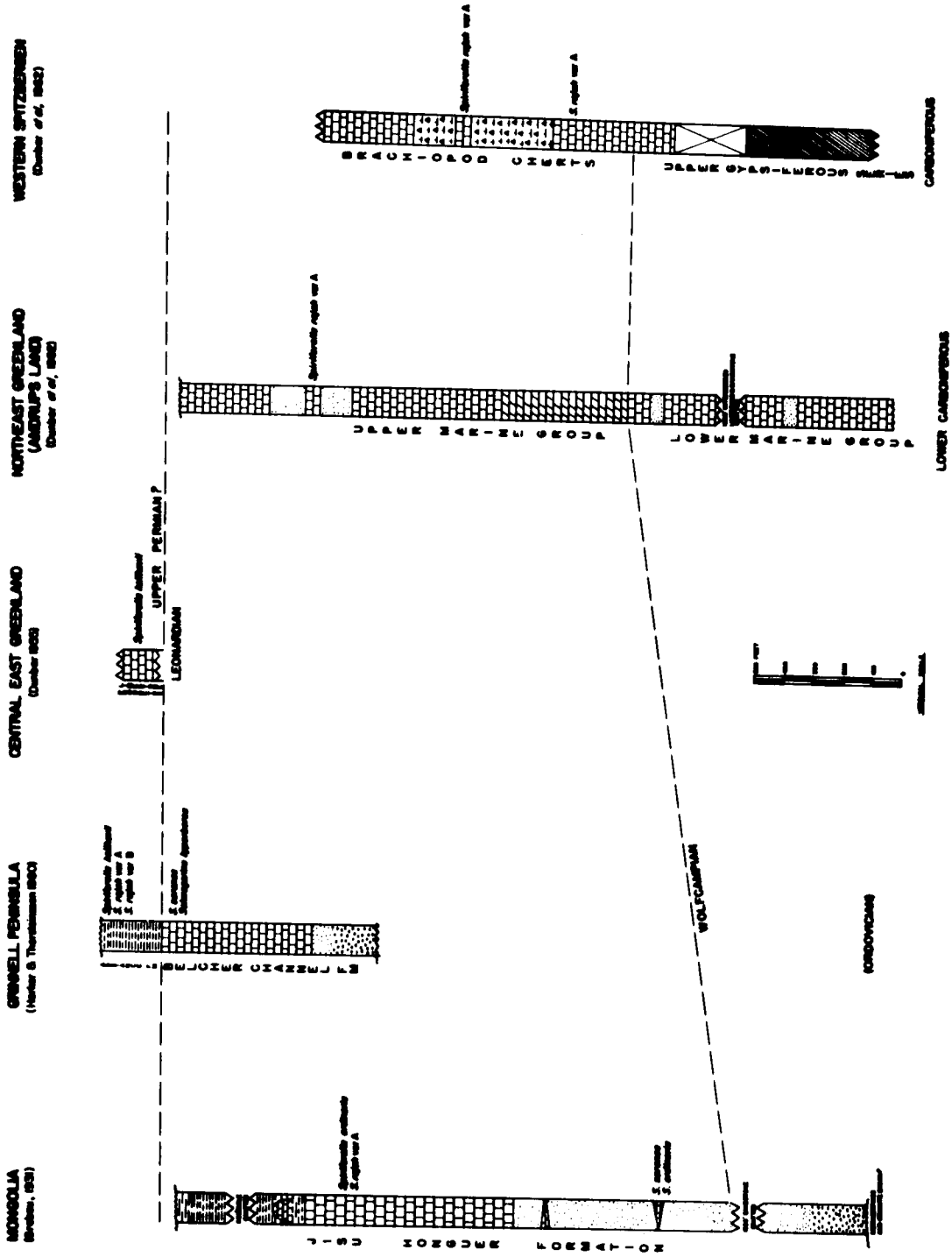

Figure 4. Generalized columnar sections from the literature indicating positions of some species of Spiriferella.

S. saranae (U.A.C. no.'s F 1110, 1133) were identified from the same position and locality as the Schwagerina hyperborea identified by Cameron (1962), who considers that this fusulinid is suggestive of an Upper Leonardian age. A further association of S. saranae with fusulinids occurs in our Fishing Branch section, but at present these have not been identified.

SYSTEMATIC DESCRIPTIONS

Phylum	BRACHIOPODA
Class	ARTICULATA
Superfamily	SPIRIFERACEA Waagen 1883
Family	SPIRIFERIDAE King 1846
Genus	SPIRIFERELLA Tschernyschew 1902

Description of genus. -- Coarsely costate spiriferids, with simple or bundled costae and plicae which decrease in size and complexity away from the sinus. The pedicle valve is strongly convex with sharply incurved beak and pronounced sinus. The cardinal area is typically large and high; the triangular delthyrium closed by a convex deltidium. The maximum width is slightly anterior or coincident with the hinge. Internally the palintrope folds back into the delthyrium ventrally and is joined near the beak by two strong dental plates which reach the floor of the valve. The apical region is filled with callus, which eventually submerged the dental plates and

was deposited laterally at a fairly high angle from them, toward both the centre and the lateral margin of the shell. In adult specimens it usually extends slightly forward between the divided diductors, terminating against the adductor and imparts a characteristic heart-shaped outline to the muscle platform. Laterally from the platform, the callus forms concave walls, minutely pitted, presumably from the papillae of the mantle. The muscle platform is always elevated in some degree, and striated longitudinally. Well defined chevron-shaped growth lines nearly parallel to the lateral margin of the platform indicate its shape was maintained during growth. The adductor attachment scar is variable. It may be a median ridge, a flat area or even a shallow groove.

The brachial is less convex than the pedicle valve. In juvenile stages it has a segment-shaped outline, the arc of which increases in curvature as growth proceeds, typically becoming transversely subrectangular in the mature stages. The fold is variable; it may be low and indistinct or high with a sharp crest or a flat keel. The cardinal area is very low.

The brachial valve internally is not well known; in some of the serial sections, crural plates which converge and rest upon a notothyrial platform may be seen (see pls. 13, 15).

Discussion. -- One striking feature of Spiriferella is wide intraspecific and interspecific variation, demonstrated by the many varieties and species that have been described. For example, Grabau (1931) described four varieties of Spiriferella rajah from the Permian

of Mongolia. Einor (1939) with a large collection and access to the original material of Spiriferella recognized five varieties of Spiriferella saranae, and four of S. keilhavii. Dunbar (1955, p. 142) with a large collection of S. keilhavii from Central-East Greenland summed up individual variation when he stated: "We are unable, . . . to find any satisfactory or useful basis for taxonomic subdivision of what appears to be a completely intergrading series in which no two shells are exactly alike". More recently the problem was reviewed by Harker and Thorsteinsson (1960, p. 71-72) who followed Einor in assigning their specimens to three broadly interpretable species, Spiriferella saranae s. l., S. keilhavii s. l. and S. rajah s. l.

In the present study, much attention was directed to the internals of the animal, particularly the muscle platform. This, by its nature in intimate contact with the muscles, should reflect any changes in position or form of the muscles occasioned by evolutionary trends of other soft parts. The platform has a surface coating of dark translucent calcite which in transverse section has a distinct crossbow-like outline (see serial sections) and which is the preserved trace of the cementing medium between muscle and shell material. This cross-sectional outline, traceable throughout the length of the muscle platform to near the tip of the beak, reveals the cross-profile of the platform throughout growth; its upswept ends mark the position of the base of the dental plates in the callus, although a fine separating line between callus and plates may sometimes be observed.

The macro-ornament, depending on the size of the specimen,

consists of either radial plicae or costae. Toward the lateral margins of most specimens the valves are plicate, i.e. the ribs involve the whole thickness of the shell, but in the median areas, where the valve is generally quite thick, the ornament is costate, i.e. the ribs do not involve the whole thickness of the shell.

In all, forty nine specimens were serially sectioned using a Croft Parallel Grinder (Croft, 1951). In addition, twenty-four pedicle valves were freed from the matrix, and sixteen more specimens were cut in three or more sections transversely and eighteen others cut along the sagittal plane.

The morphology was studied with the following features in mind:

1. The general appearance of the specimen, including
   a) convexity of valves
   b) curvature of beak
   c) type and arrangement of ornament.
2. Relative dimensions, comprising
   a) ratio of one proportion to another of both valves during growth and adult stages
   b) cardinal area of pedicle valve
   c) ratio of sinus width to width of pedicle valve
   d) degree of elevation of muscle platform
   e) in longitudinal section, dimensions of the callus during growth.
3. Measurable angles
   a) apical angle of the delthyrium

b) anterior apical angle of the muscle platform

c) the angle formed by the sinus slopes in transverse profile.

None of these morphological features alone yield significant results, but by combining them all a fairly reliable species definition is possible.

A point borne constantly in mind during this study is the problem of what actually constitutes a species. Many excellent modern discussions appear in the literature and there are thus many definitions of the concept which usually vary only on the wideness of interpretation of species. A few points are carefully noted. A species is not an individual; it is a population. This population shares a genetic pool which provides a range of variability within the species and which isolates it reproductively from other populations. A point stressed in zoological definitions is the variability between the individuals of a species, a result of being able to secure an adequate sampling of the population. A point almost always stressed in palaeontological discussions of the term is that the population is morphologically distinct, a consequence of dealing with extinct material whose chromosomes cannot be examined experimentally. Another point stressed is the limited sampling possible with fossils. This has led to the "type specimen" concept (in palaeontology), and the erecting of many similar species which, if an adequate sampling of the live population could be made, might prove to be a single species. This point has been effectively treated by Weller (1955, 1961).

Spiriferella has probably been the victim of some species profusion. However, as collections enlarged through time, adequate samples of the populations were available to some authors. Einor (1939) had access to all of the earlier Russian collections including that of Tschernyschew. Grabau (1931) cited at least sixty specimen numbers and Dunbar (1955) was in possession of more than 150 specimens.

The definition of species followed here is from Beerbower (1955, p. 52):

> "Species are groups of morphologically distinct populations within which variation is of the magnitude expected in interbreeding populations, and between which the differences are of the kind and degree expected to result from reproductive isolation of natural populations."

Our population sample amounted to more than 400 specimens of Spiriferella, which were grouped into five species.

SPIRIFERELLA SARANAE Tschernyschew

Pl. 1, figs. 1-2, pl. 3, figs. 1-2, 6-7, pl. 5, figs. 2-3, 9, pl. 6 A-C

Spirifer saranae de VERNEUIL, 1845, p. 169, pl. 6, fig. 15a-b.

Spiriferina (Spiriferella) saranae TSCHERNYSCHEW, 1902, (partim), p. 121, pl. 12, fig. 4a-d, text-figs. 41, 44a-b, 45a-b(?); TSCHERNYSCHEW and STEPANOW, 1902, p. 49, fig. 1, pl. 11, fig. 1a-c.

Spiriferina polaris WIMAN, 1914, (partim), p. 39, pl. 4, figs. 1-14, figs. 18-22(?), pl. 5, figs. 1-5(?).

Spiriferella saranae GRABAU, 1931, p. 155, pl. 22, fig. 4a-b, text-fig. 43; HARKER, 1960, (partim), p. 71, pl. 22, figs. 1-3.

Spiriferella polaris STEPANOW, 1937, p. 150, pl. 8, figs. 5-8.

Spirifer (Spiriferella) saranae EINOR, 1939, (partim), p. 133, pl. 22, fig. 1a-c; FREBOLD, 1950, p. 66, pl. 6, fig. 1.

? Spiriferella scobinoidea COOPER, 1953, p. 62, pl. 19c, figs. 28-35.

Diagnosis of species. -- The shell is of medium size and longer than wide. The average length is 42 mm., width 32 mm., with the maximum width at or near the hinge.

In lateral profile the pedicle valve is strongly curved from the incurved beak for four-fifths of the length, becoming relatively straight anteriorly. The cardinal area is high, and strongly concave near the apex, flattening toward the hinge. The delthyrium, closed by a thin deltidium added by stages of about 1 mm. each, from the apex, has an apical angle of thirty-five to fifty degrees. The sinus in transverse profile forms a sharp "V" opening anteriorly. The sinus slopes have two poorly defined costae which bifurcate from the bounding costae in the umbonal region. Each valve flank is ornamented by six or seven simple, rounded costae separated by deep, sharply rounded furrows. Both furrows and costae are traversed by very fine concentric lirae surmounted by minute, regularly spaced tubercles. One or two fine radial lirae may occur in the furrows.

Internally, the pedicle muscle field is very slightly elevated. The adductor ridge is simply the internal surface of the sharp sinus;

over the medial portion of the field the valve is not thickened. The apical angle of the muscle platform is poorly defined; measured angles range between twenty-eight and sixty degrees.

The brachial valve is gently and uniformly convex. The fold is only slightly elevated above the gently convex profile, and consists of two sharp costae separated by a rounded trough. One costa bifurcates from each bounding costa in the umbo and moves out onto the slope of the fold. Each valve flank is occupied by four coarse bundles of costae separated by deep troughs, a bundle consisting of two to three costae each; bifurcation begins in the umbo.

Remarks. -- Tschernyschew (1902) described an elevated muscle platform for this species. Some of his text-figures indeed show a strongly elevated platform (p. 123, text-fig. 42; p. 124, text-fig. 43) but in others the platform appears definitely unelevated (p. 124, text-fig. 44a-b; p. 123, text-fig. 41). His primary type material may belong to two distinct species, the former noted above to S. rajah var A and the latter to the true S. saranae. During this study it became apparent that shells of S. rajah, due to the added strength of the thick muscle platform, are far more easily removed from the matrix than the pedicle valves of S. saranae, the valve of which is quite thin in the medial part. It is the belief of this writer that the former figures mentioned above and used by Tschernyschew to illustrate the interior of S. saranae were in reality specimens of S. rajah (= S. salteri Tschernyschew) since he believed they possessed similar muscle platforms. Tschernyschew's description of the micro-

ornamentation supports this contention in that he described the spacing of the tubercles as regular, and an enlarged view (ibid., pl. 12, fig. 4c) bears this out. In our collection this distinctive micro-ornament is visible on nearly all specimens of S. saranae; the regular spacing of the tubercles gives the impression of radial lirae. Our specimens of S. rajah show a distinctly different micro-ornament in that the tubercles are irregularly spaced and do not appear as radial lirae.

Tschernyschew (ibid., p. 126) limited the species to "only those forms possessing rounded, rarely dichotomizing plications on the flanks" (present writer's translation and italics). His illustrated specimen, (1902, pl. 12, fig. 4a-c) considered the holotype, has simple ribs and shows no bundling, but elsewhere in his description he states "the ventral valve flanks carry from twelve to sixteen rounded plications separated from one another by deep but narrow furrows. These plications are usually simple . . ." (ibid., p. 122) so he allowed for some rare dichotomy. In this study it was discovered early in the serial sectioning that specimens with simple, unbundled ribs and the distinctive micro-ornamentation earlier described, that is with fine concentric lirae surmounted by regularly spaced tubercles, corresponds to a distinct cross-section of the muscle platform (c.f. pl. 6 A-C). This platform, in contrast to that possessed by specimens with bundled ribs and micro-ornament with irregularly spaced tubercles is not strongly elevated or laterally flaring. Because of these differences it is proposed that Spiriferella saranae be restricted to

specimens with typically simple, rounded costae, regularly spaced tubercles surmounting the concentric lirae and less strongly elevated muscle platform.

The brachial valve is described from only one specimen associated with, but not attached to, pedicle valves.

Spiriferella scobinoidea Cooper may be conspecific with S. saranae. The holotype was examined and compared to our specimens. Unfortunately the specimen is incomplete and silicified, so that the surface micro-ornamentation is replaced by micro-liesegang structures. On the portion of the sinus preserved, the slopes form a narrow rectangular trough at their junction. In most of our specimens the sinus slopes come to a sharp junction though in two of them the slopes do form a similar trough at the base of the "V" in transverse profile. The portion of the muscle platform of the holotype of S. scobinoidea preserved is identical to S. saranae as here interpreted.

Cooper (1953, p. 63) reports that S. scobinoidea is confined to the Anidanthus zone in the type locality of the Monos Hills, Mexico, in the Monos Formation (Word age). Specimens of S. saranae have been described from the Belcher Channel Formation on the Grinnell Peninsula by Harker and Thorsteinsson (1960). Two specimens in our collection were taken from the same Yukon Tatonduk River locality as the fusulinid Schwagerina hyperborea (Salter) described by Cameron (1962) and tentatively dated as Upper Leonardian. It should be noted that the specimens of S. saranae from the Belcher Channel Formation of the Grinnell Peninsula were also associated with Schwagerina hyperborea.

Material and horizon. -- Twenty nearly complete and numerous fragments of pedicle valves, ranging from excellent to poor states of preservation. Even in a poor state of preservation, however, the species is easily identified by serial transverse sectioning from the anterior margin (pl. 6 B.).

The species is characteristic of the lower half of the Tahkandit Formation in the Yukon. Figured specimens U.A.C. numbers F 1004, F 1018, F 1123, F 1124, F 1024, F 1043, and F 1070 were collected from the lower 400 feet of the West Mt. Burgess Section.

SPIRIFERELLA RAJAH (Salter) var A.

Pl. 1, figs. 3-5, pl. 3, figs. 3-5, 8-10, pl. 5, fig. 7, pls. 7, 8, 9, 10.

Spirifera rajah SALTER, 1865, p. 59, p. 111; DIENER, 1908, (partim) p. 38, pl. 4, figs. 1, 2, 4, 6.

Spirifer draschei FRECH, 1901, p. 498, p. 499, (text-figs.)

Spiriferella salteri TSCHERNYSCHEW, 1902 (partim), p. 128, pl. 12, figs. 5-6, pl. 6, fig. 5; GRABAU, 1931, p. 131, 133, 136, 138, pl. 19, figs. 1, 2, 3, 5, pl. 20, figs. 1-8, pl. 22, figs. 3, 5-10; CROCKFORD and WARREN, 1935, p. 149.

Spirifer lyra TSCHERNYSCHEW, 1902, (partim), p. 150, pl. 7, fig. 7, (non pl. 6, fig. 7, pl. 8, figs. 4-5).

Spirifer tibetanus TSCHERNYSCHEW, 1902, p. 151, pl. 7, figs. 2-6; DIENER, 1908, p. 45, pl. 6(?).

Spiriferina draschei WIMAN, 1914, (partim), p. 38, pl. 3, figs. 3-8, 19.

Spiriferella parryana TSCHERNYSCHEW and STEPANOW, 1916, p. 49, pl. 11, fig. 4, pl. 12, figs. 1-3; FREBOLD, 1931, p. 18, pl. 5, figs. 5-6; MILORADOVICH, 1936, p. 53, pl. 1, figs. 1-3, pl. 2, figs. 1-2, pl. 4, figs. 1-9; FREBOLD, 1937, p. 45, pl. 11, fig. 6; FREBOLD, 1938, p. 23, pl. 1, figs. 10-11.

Spiriferella rajah GRABAU, 1931, p. 148, pl. 22, figs. 1-2.

Spiriferella saranae FREBOLD, 1937, p. 45, pl. 11, figs. 7(?), 8(?), EINOR, 1939, (partim), p. 134, p. 136, p. 138, pl. 22, figs. 2, 6, 7, pl. 23, fig. 1; HARKER, 1960, (partim), p. 71, pl. 22, figs. 4-8, pl. 23, figs. 3, 4; NELSON, 1961, p. 5, pl. 4, fig. 1.

Spiriferella polaris FREBOLD, 1937, p. 47, pl. 11, fig. 1(?).

Spirifer (Spiriferella) saranae EINOR, 1939, (partim), p. 134, p. 136, p. 138, pl. 22, figs. 2, 6, 7, pl. 23, fig. 1.

Spirifer (Spiriferella) rajah EINOR, 1939, p. 147, pl. 25, figs. 1-5.

Spiriferella draschei COOPER, 1957, p. 56, pl. 11c, figs. 7-20; STEPANOW, 1937, (partim), p. 149, pl. 8, fig. 9.

Spiriferella parva COOPER, 1957, p. 57, pl. 11A, figs. 1-5.

Diagnosis of species. -- The pedicle valve has a sub-ovate outline and is longer than wide from early growth stages. The average length, width and thickness are 38 mm., 32 mm. and 23 mm., respectively. The maximum width is just anterior to mid-length. The cardinal area is high and concave near the beak, flat towards the hinge. The delthyrium, with an apical angle averaging forty degrees, is nearly closed by a

deltidium added in stages from the apex. The sinus has flat slopes which form an open "V" in transverse profile and becomes very deep anteriorly where it occupies more than one half of the width. The bottom of the sinus has one fine median costa rarely divided by a fine groove; each slope anteriorly has as many as ten fine costae, which have been added by bifurcation of the bounding costae at irregular intervals beginning near the beak. The bounding costae, forming the top of the sinus slopes, mark a definite break in transverse profile between the flat sinus slopes and the uniformly curving lateral flanks. Each flank is occupied by four or five typically tricostate bundles which develop in the umbo. Within a bundle the medial costa is always widest and most strongly expressed, followed by the adsinal costa which is stronger and earlier discrete than the absinal one. This latter is often indistinct until quite near the anterior margin. Concentric lirae surmounted by irregularly spaced tubercles traverse the entire surface while radial lirae occur in the grooves between bundles.

The pedicle valve interior is dominated by a strongly elevated muscle platform with a gently concave surface and heart-shaped outline. The margins often flare laterally so that the surface is as wide or wider than the base. The adductor attachment is typically flat or a low ridge with a fine median rib. Nearly parallel to the lateral margins are growth lines which meet anteriorly, chevron fashion, and posteriorly disappear under the callus. These are crossed by longitudinal striations. The anterior apical angle of the muscle platform

is between forty and fifty degrees, grouping around forty-five degrees.

The brachial valve is sub-rectangular in outline and typically broader than long or equidimensional, but on some large extremely elongated adult specimens the length does exceed the width. The fold, surmounted the full length by two bounding costae separated by a distinct groove, rises from the beak and is very high at the anterior margin. Its slopes are flat and ornamented by six or more costae which have bifurcated from the bounding costae in the umbo. Each valve flank is usually occupied by three tricostate bundles. On large specimens, four bundles, rarely five, may be present, and the bundle nearest the fold may achieve four minor costae near the anterior margin.

Remarks. -- Characteristic features of S. rajah var A are its small size, the longitudinally sub-ovate outline, the usually tricostate bundled ribs, and the pedicle valve muscle platform, which is elevated and typically laterally flaring. Another feature is the sharpness of the sinus and fold in transverse profile, emphasized by their flat slopes. These features it shares with S. rajah var B from which it is distinguished by its smaller size, the median groove on the crest of the fold, and the median adductor ridge which is often present the full length of the muscle platform.

The manner of bifurcation of the minor costae in the bundled ribs of this species is variable and was used by Grabau (1931) to distinguish mutations within his Mongolian specimens. His specimens, however, were usually exfoliated so that he found difficulty in distinguishing where bifurcation began. In our collection of more than

one hundred pedicle valves and twenty brachial valves of this variety, no uniformity in costae splitting exists. The flanking costae in a bundle may not appear at the same point on any two specimens or at the same point on opposite flanks of a single valve. Also they may appear on one flank of a specimen but not the other. Dunbar (1955, p. 141) has commented on a similar lack of uniformity in costae arrangement among individuals of S. keilhavii (Buch).

Though the average length of the variety is 38 mm., the largest individual (figured specimen, U.A.C. no. F 1067) measures 49 mm. and a young adult (figured specimen, U.A.C. no. F 1109) only 27 mm. In contrast, the smallest complete adult of S. rajah var B (figured specimen, U.A.C. no. F 1079) is 59 mm. in length.

No difficulty is encountered in distinguishing reasonably complete specimens of S. rajah var A from S. keilhavii (Buch), since adult specimens of that species are much larger and clearly reveal their more transverse outlines; adult specimens of S. rajah var A, equal in size to juvenile S. keilhavii are longitudinally extended, not sub-triangular in outline.

Material and horizon. -- Twelve complete or nearly complete specimens and one hundred and eighty-eight pedicle valves, almost all are well preserved. The completeness of the pedicle valves is largely the result of the strengthening muscle platform. No separate brachial valves occur in the collection, probably due to their extreme fragility.

Spiriferella rajah var "A", a long ranging variety, is found

in abundance through the upper two thirds of the Middle Recessive Unit and in the Lower Tahkandit Formation of Leonardian age.

SPIRIFERELLA RAJAH (Salter) var B.

Pl. 1, figs. 6-8, pl. 4, figs. 1-4, pl. 5, figs. 4, 11, pl. 11 B.

Spirifera rajah SALTER, (partim), 1865, p. 59, p. 111; DIENER, 1908, (partim), p. 38, pl.4, figs. 5a-b, 3(?), pl. 5, fig. 1(?).

Spiriferella saranae TSCHERNYSCHEW, 1902, (partim), text-figs. 42-43; EINOR, 1939, (partim), p. 131, pl. 22, fig. 1, pl. 23, fig. 1.

Spiriferina draschei WIMAN, 1914, (partim), p. 38, pl. 3, figs. 9-18, 20-26.

Spiriferella draschei TSCHERNYSCHEW and STEPANOW, 1916, p. 54, pl. 9, fig. 2; STEPANOW, 1937, (partim), p. 149, pl. 8, fig. 10.

Spirifer (Spiriferella) rajah EINOR, 1939, p. 147, pl. 25, figs. 1, 2, 4.

Spiriferella keilhavii HARKER, 1960, (partim), p. 72, pl. 23, figs. 1, 2.

Description. -- Externally S. rajah var B is similar to S. rajah var A. It differs only in that it is larger, and in that the fold is generally topped by a flat, ungrooved keel. The average length and width is 72 mm. and 58 mm., with an extraordinarily large specimen attaining a length of 84 mm. and 72 mm. in width; a small adult (pl. 4, fig. 4, U.A.C. no.F 1079) is 59 mm. and 50 mm. respectively.

Internally, the pedicle valve adductor attachment is usually not a ridge; when a ridge is present it is limited to the anterior

portion of the muscle platform, dying out before it reaches one half the distance posteriorly. More often the adductor attachment is flat, often even a wide shallow groove. Otherwise the platform is similar in cross-section to that of S. rajah Salter var A.

The brachial valve is closely similar to that of S. rajah Salter var A, differing in that the fold is more often surmounted by a flat keel. Rarely the keel is divided by a shallow indistinct groove, which never, however, reaches the umbo region. The valve is wider than long; no specimens are in hand which are equidimensional.

Remarks. -- Spiriferella rajah var B has the same irregular arrangement of costae as S. rajah Salter var A. Some difficulty might be encountered in distinguishing large pedicle specimens of S. rajah Salter var A from young adult specimens of S. rajah Salter var B if preservation is poor and growth lines are not visible. When preservation is good, the relative growth stages, though identical in the two varieties, are more widely spaced in S. rajah Salter var B. When the brachial valve is present the divided crest of the fold of var A, as opposed to the flat keel of var B serves to distinguish them.

Spiriferella rajah var B differs from S. keilhavii in having a deeper, wider sinus, a smaller sinus angle, a more elevated fold, a generally smaller apical angle and a different micro-ornament in addition to a less transversely extended outline. The two may be easily confused if preservation is poor and the specimens fragmentary. The following features will generally serve to distinguish them. In S. rajah (both var A and var B) the sinus angle (the angle formed by

the junction of the sinus slopes in transverse profile) typically measures about 135 degrees just anterior to midlength; the range is from 120 to 150 degrees. Spiriferella keilhavii has a corresponding sinus angle of 150 degrees, with a range from 145 to 165 degrees. The sinus of S. rajah is deeper and occupies more of the total width of the pedicle valve than that of S. keilhavii. An average ratio of width of sinus to width of valve for S. rajah is 0.6:1 with a range between 0.53:1 and 0.73:1. The corresponding values for S. keilhavii are 0.43:1, 0.36:1 and 0.48:1 respectively. The apical angle of the delthyrium of S. rajah is generally about five degrees lower than that of S. keilhavii. The fine concentric lirae of the micro-ornamentation on S. rajah is surmounted by irregularly spaced tubercles, the spacing of these tubercles on S. keilhavii is regular (c.f. pl. 5, fig. 10, fig. 11). The cardinal area of S. rajah is typically higher and narrower than that of S. keilhavii. By the inference of its usual absence, the anterior margin of the pedicle valve of the latter species is thinner than that of S. rajah, which more often retains its anterior margin.

Material and horizon. -- More than 130 well preserved specimens were studied. Of these, one is complete, and thirty are brachial valves in various degrees of completeness, the remainder are pedicle valves.

The variety appears to be confined to and is abundant in the upper Tahkandit formation of probable upper Leonardian age, in the upper portion of which it is associated with a few Spiriferella keilhavii.

SPIRIFERELLA KEILHAVII (Buch)

Pl. 2, figs. 7-9, pl. 4, figs. 5-6, pl. 5, figs. 6, 10, pls. 11 A, 12.

Spirifer keilhavii BUCH, 1846, p. 74, fig. 2.

Spiriferina (Spiriferella) keilhavii TSCHERNYSCHEW, 1902, (partim), p. 126, pl. 50, figs. 3-4(?).

Spirifer rajah DIENER, 1908, (partim), pt. 2, p. 38, pl. 4, fig. 7(?); DIENER, 1908, pt. 5, p. 105, pl. 4, figs. 3-5.

Spiriferina keilhavii WIMAN, 1914, p. 36, pl. 2, figs. 25-30, pl. 3, fig. 1.

Spiriferina draschei WIMAN, 1914 (partim), p. 38, pl. 3, fig. 2.

Spiriferella keilhavii TSCHERNYSCHEW and STEPANOW, 1916, p. 79, pl. 11, figs. 2a-c, 3a-c; FREBOLD, 1931, p. 28, pl. 5, figs. 7-9; FREBOLD, 1937, p. 46, pl. 11, fig. 9; DUNBAR, 1955, p. 139, pl. 25, figs. 1-9, pl. 26, figs. 1-11, pl. 27, figs. 1-14; HARKER, 1960, (partim), p. 72, pl. 22, figs. 9-11.

Spirifer rectangulus FREBOLD, 1931, p. 27, pl. 5, figs. 2-10.

Spirifer (Spiriferella) saranae EINOR, 1939, (partim), p. 131, pl. 23, figs. 2, 3a-c(?), 5(?).

Spirifer (Spiriferella) keilhaviiformis, EINOR, 1939, pl. 25, fig. 5.

Description of species. -- The pedicle valve is large; and wider than long in both juvenile and adult stages. The cardinal area is relatively low and broad; the apical angle of the delthyrium varies between forty-five and sixty degrees. The sinus begins as a narrow

groove but anteriorly is usually a wide, flat sloped, "V" shaped shallow trough with a sinus angle of 145 to 160 degrees. The anterior sinus width is almost half that of the shell. Six costae may occur on each anterior sinus slope; these develop by bifurcation from the bounding costae at irregular intervals starting in the umbo. Laterally from the bounding costa each valve flank usually contains five costae bundles; the outermost ones are often indistinct and sometimes simple. The bundles are separated by flat-bottomed grooves and may contain three to five costae, depending on the growth stage of the specimen. On large specimens a fourth costa and even a fifth minor costa may occur in the first bundle near the anterior margin. The medial costa in the bundle is strongest, followed in turn by the adsinal and absinal ones. Fine concentric lirae, surmounted by regularly spaced tubercles traverse the shell surface, the spacing of the tubercles providing radial lirae, as in S. saranae.

Internally the muscle attachment area is an elevated, laterally flaring platform as in S. rajah, often differing in a slightly more elevated anterior apex. The apical angle of the platform varies between forty and fifty degrees.

The brachial valve appears to be gently convex with the fold only slightly elevated.

Remarks. -- Spiriferella keilhavii is externally similar to S. ordinaria though generally larger. Internally it bears a much more elevated muscle platform (cf. pls. 11 A, 12, 13) with a smaller apical angle.

The similarity between S. keilhavii and S. rajah var B has already been discussed (p. 24). The sinus slopes of S. keilhavii, though typically flat, are sometimes slightly arched in transverse profile. This makes a measurement of the sinus angle unreliable.

The micro-ornament of this species is very similar to S. saranae, but other characters, particularly the bundled condition of the costae, the elevated muscle platform and the transversely elongate outline readily distinguish them.

Material and horizon. -- Three incomplete pedicle valves were collected from the Permian of the Yukon. In addition, twelve others in excellent condition and one poorly preserved fragment of a brachial valve, from the Tahkandit Formation in Alaska and the hypotypes of Harker & Thorsteinsson (1962) were also studied.

This species was collected from the uppermost Tahkandit Formation of Upper Leonardian or Lower Guadalupian ages where it occurs sparingly with S. rajah var B.

SPIRIFERELLA ORDINARIA (Einor)

Pl. 2, figs. 4-6, pl. 3, figs. 13-14, pl. 5, fig. 8, pl. 13.

Spirifer keilhavii BUCH, 1846, p. 74, fig. 2; FRECH, 1901, p. 499, pl. 57c, fig. 1a-c.

Spiriferina (Spiriferella) keilhavii TSCHERNYSCHEW, 1902, (partim), p. 126, pl. 50, figs. 1a-c(?), 2(?).

Spirifer interplicatus TSCHERNYSCHEW, 1902, p. 152, pl. 6, figs. 1-4.

Spirifer (Spiriferella) keilhavi var ordinaria et var altisinuata, EINOR, 1939, p. 140, p. 142, pl. 23, figs. 5, 6, pl. 24, figs. 1-3.
Spiriferella keilhaviiformis GRABAU, 1931, p. 160, pl. 21, figs. 6-7.
Spiriferella keilhavii GRABAU, 1931, p. 164, pl. 20, fig. 9, pl. 21, figs. 1-5; STEPANOW, 1937, p. 148, pl. 7, figs. 10-11; CAMERON, 1962, p. 74, pl. 6, figs. 1-4.

Diagnosis of species. -- The shell is of medium size, wider than long, with maximum width just anterior to the hingeline. The average length, width and thickness is 35 mm., 38 mm. and 23 mm., respectively. The pedicle beak is narrow. The sinus gradually deepens and widens to the anterior margin, where it is rounded or flat-bottomed. One or two fine median costae begin at the beak and extend the length of the sinus; they may remain simple or bifurcate anteriorly. The sinus slopes are occupied by one or two fine costae which bifurcate from the bounding costa, at about one third the length. Each valve flank is occupied by five or six plicae which split into bundles containing two or three minor costae. Concentric lirae surmounted by irregularly spaced tubercles traverse the shell; no radial lirae are visible. The cardinal area is wide and relatively low; the apical angle of the delthyrium ranges between fifty and sixty degrees. Internally the muscle platform is only slightly elevated and has an apical angle between 60 and 70 degrees. The adductor attachment is a low but distinct ridge, surmounted by two fine ribs.

The brachial valve is thin and slightly convex. The fold is

low and begins at the beak as two bounding costae separated by a trough which broadens anteriorly. One or two fine costae which have bifurcated from the bounding costae slightly posterior to mid-length may occur in the trough and sometimes one or more on the narrow slopes of the fold. Each valve flank has four or five plicae, simple at first and bundling anteriorly. The bundles next to the fold often contain three minor costae near the anterior margin, while the others commonly have only two. The anterior commissure is sulcate with the sinus trace well rounded or almost sharp.

Description of figured specimens. -- U.A.C. no. F 1055 is slightly larger than average, with four costae in the sinus. The sinus is a well rounded trough. Five bundled costae occur on each valve flank; the bundle next to the bounding costae is indistinctly divided into three near the anterior. The fold is low with a shallow trough 7 mm. wide near the anterior margin, with two indistinct costae within the trough. The brachial valve contains distinct concentric lirae surmounted by tubercles. The beak and umbo region of the pedicle valve was broken away (prior to which a plaster cast was made) to expose the muscle platform. The apical angle of the platform is 70 degrees.

Figured specimen (U.A.C. no. F 1101) is similar to F 1055 above but was serially sectioned (see pl. 13). The fold slope contains two ribs near the anterior margin, which bifurcate from a simple one itself bifurcated from the bounding costa of the fold in the umbo.

Figured specimens (U.A.C. numbers) F 1103, F 1106 and F 1061 are similar but have a less elevated more angular fold and a more

angular sinus.

Remarks. -- The muscle platform of this species closely resembles that of S. editiareatus Einor, but has a larger apical angle. The muscle platform of S. ordinaria also shows close relationship to that of Spirifer, being only more elevated and broader.

The species appears to have a thinner shell than others of Spiriferella. The specimens have all been partially silicified, possibly in consequence of this.

Material and horizon. -- Six complete specimens, four more nearly complete, and numerous more or less complete pedicle valves occur in the collection.

Spiriferella ordinaria, never abundant, is limited, in our sections, to the lower portion of the Tahkandit Formation of Leonardian age. Other specimens have been recorded by Cameron (1962) from a Lower Tahkandit equivalent in a section at Tika Creek, Yukon.

SPIRIFERELLA EDITIAREATUS Einor

Pl. 2, figs. 1-3, pl. 3, figs. 11-12, pl. 5, figs. 1, 5, pls.14-15.

Spirifer (Spiriferella) editiareatus, EINOR, 1939, p. 152, pl. 26, figs. 1-4.

Spirifer (Spiriferella) editiareatus var shevtchenki EINOR, 1939, p. 152, pl. 25, figs. 7-9, pl. 26, fig. 5.

Diagnosis of species. -- The shell is of medium size, much

longer than wide and has its maximum width about mid-length. The average length, width and thickness are 47 mm., 30 mm. and 26 mm., respectively. All costae, both on the brachial and pedicle valve, are very fine for the genus.

The pedicle valve is elliptical in outline. The sinus begins as a shallow furrow and becomes a broad, very shallow trough near the anterior margin. The valve flanks are ornamented by bundles of three fine costae each, the bundling disappearing laterally. The cardinal area is very high and narrow. The apical angle of the delthyrium is between forty and fifty degrees.

Internally the muscle platform is slightly elevated and has an apical angle which varies between forty-five and sixty degrees. The posterior margin usually lacks the callus projection between diductors so that the outline is more like that of a top than a heart. The adductor attachment is a broad ridge with a fine median rib (see pls. 14, 15).

The brachial valve is strongly convex in transverse profile. The fold begins near the beak as a single costa, becoming a high, sharp-crested wedge anteriorly. The fold, separated from the valve flanks by a distinct furrow, has slopes which are flat and contain three or four costae each in an indistinct bundle. The first flank bundle may contain as many as five costae, with four in the second, thereafter laterally the bundling is indistinct.

Internally, the spiralia contain at least nine complete loops each (see pls. 14, 15).

Remarks. -- The holotype (Einor, pl. 26, fig. 3a-c), stored in Leningrad, U.S.S.R., was not available, but the original description and illustrations are clear, so that the identification of our specimens is certain. The concentric striae or tubercles, present on the primary type, are not preserved on our specimens (see Material and horizon).

This species is very easily recognizable by its longitudinally extended form and the sharp-crested, elevated fold in contrast to its shallow sinus. It is closest to S. rajah var A in size and outline, but has no dividing groove on the fold, much finer costae, a much more shallow sinus and a more elongate outline.

Unfortunately, weathering has caused a loss of surface sculpture. Most specimens however, retain portions well enough preserved to allow description.

Material and horizon. -- Eleven specimens, one of which is complete, most of the others lack some portion of the beak, but almost all retain the brachial valve. All specimens were collected from 235 feet above the base of a probable lower Tahkandit equivalent in the East Porcupine section of Leonardian age.

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EXPLANATION OF PLATE 1

Author's concept of species of Spiriferella. Most drawings based upon several specimens. All figures natural size.

Figures 1-2. Spiriferella saranae. Pedicle and lateral views of pedicle valve.

Figures 3-5. Spiriferella rajah var A. Brachial, pedicle and lateral views of complete specimen.

Figures 6-8. Spiriferella rajah var B. Lateral, pedicle and brachial views of complete specimen.

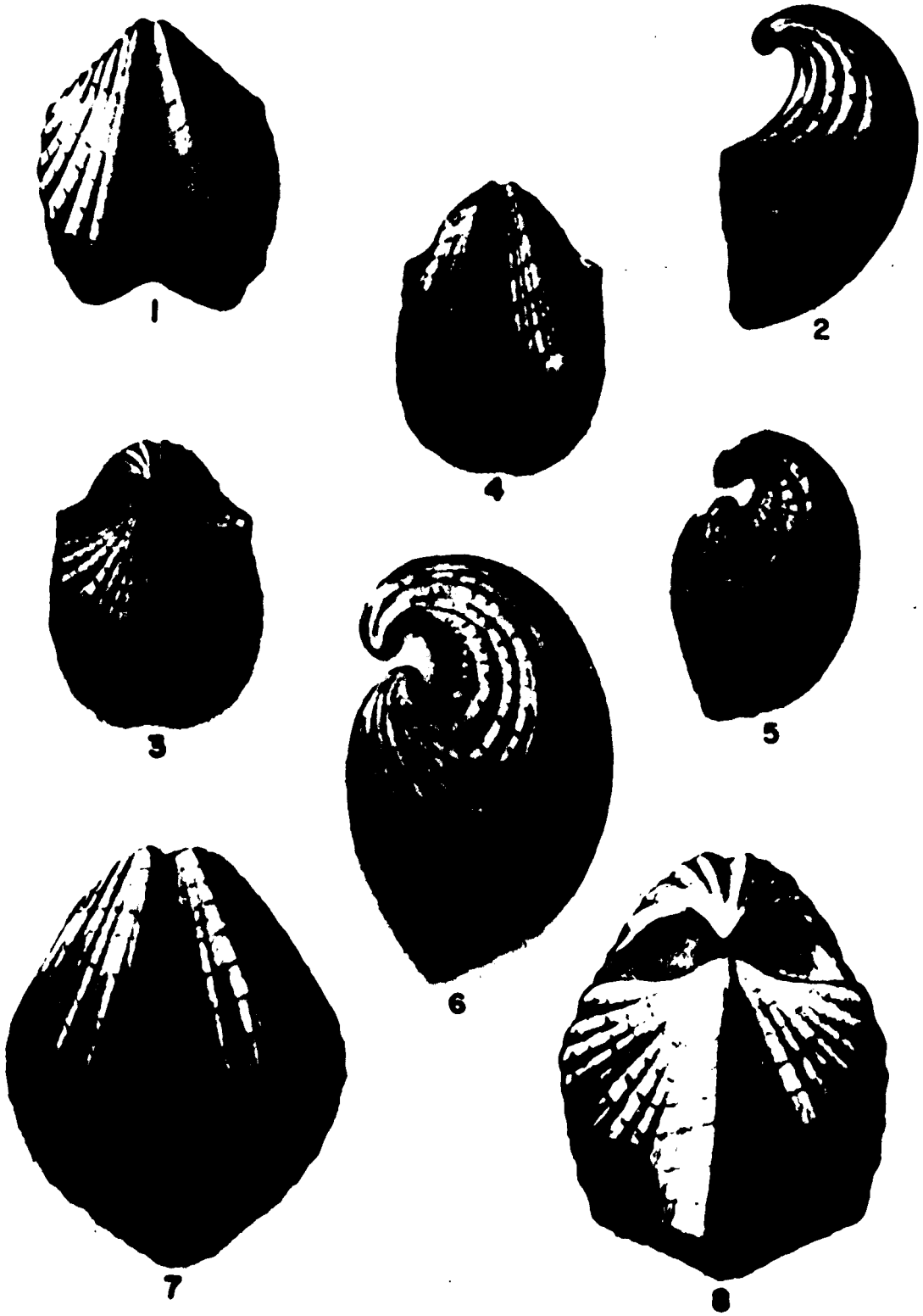

PLATE 1.

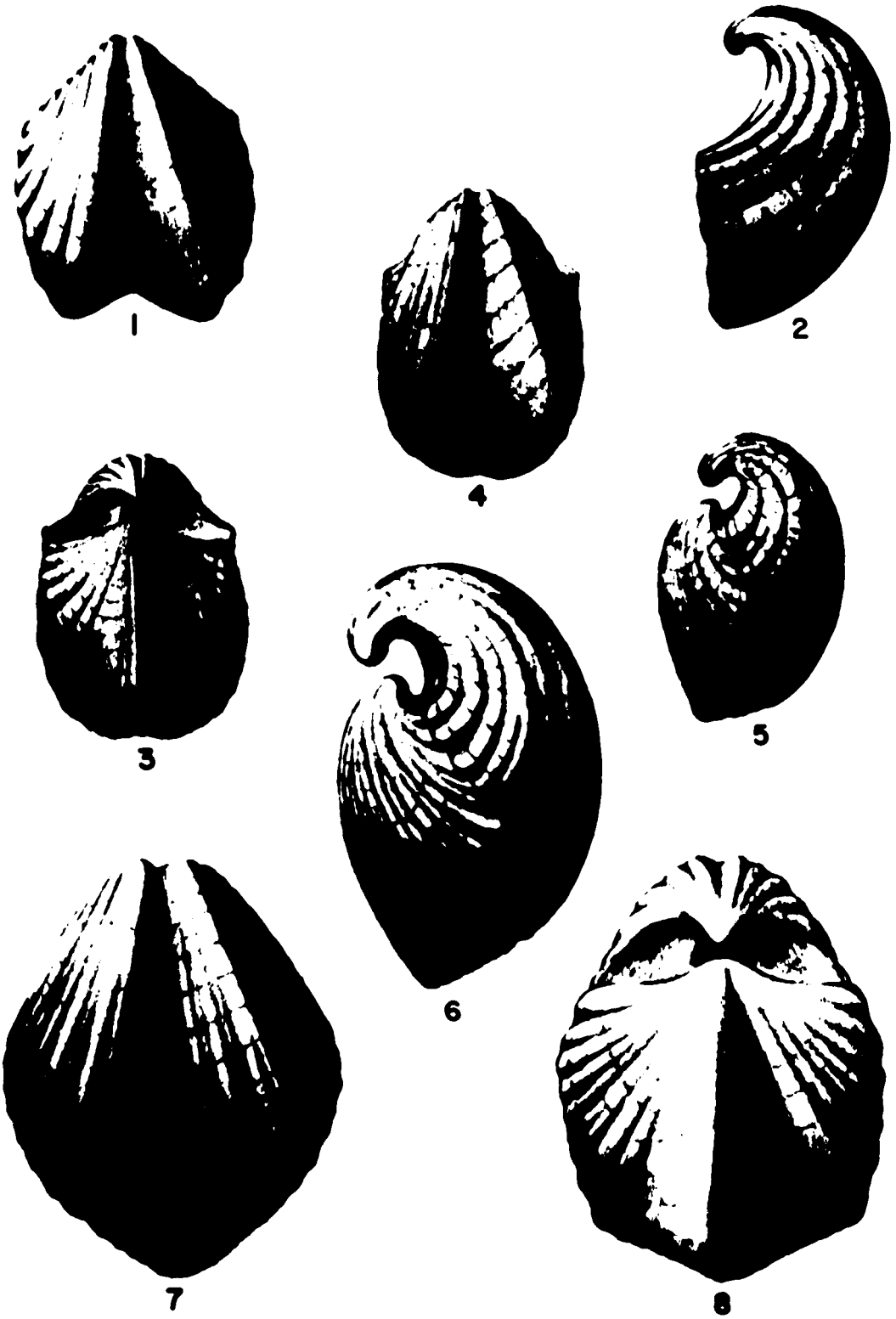

PLATE 1.

EXPLANATION OF PLATE 2

Author's concept of species of Spiriferella. Most drawings based on several specimens. All natural size.

Figures 1-3. Spiriferella editiareatus. Pedicle, lateral and brachial views of complete specimen.

Figures 4-6. Spiriferella ordinaria. Pedicle, lateral and brachial views of complete specimen.

Figures 7-9. Spiriferella keilhavii. Pedicle, lateral and brachial valves of complete specimen.

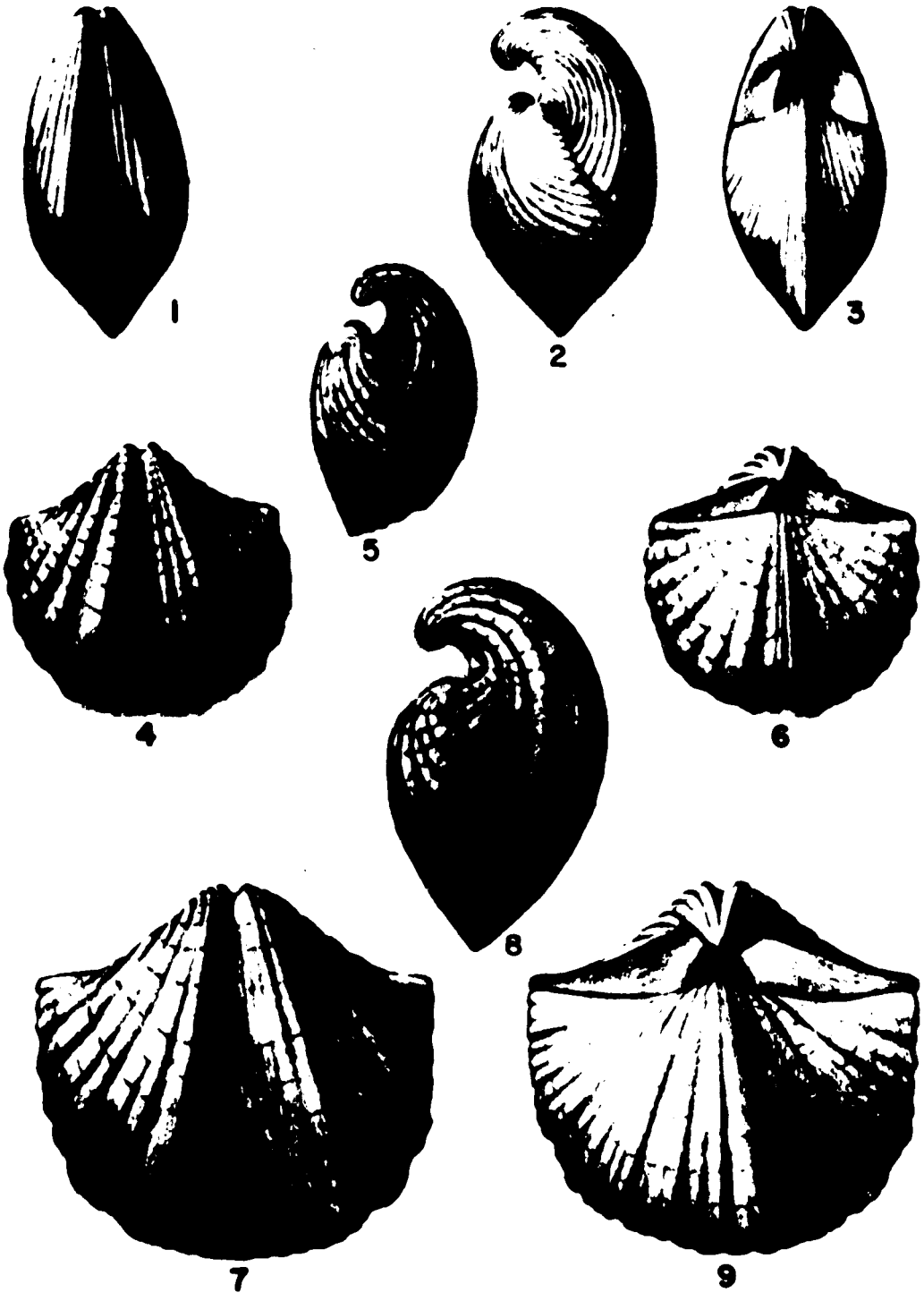

PLATE 2.

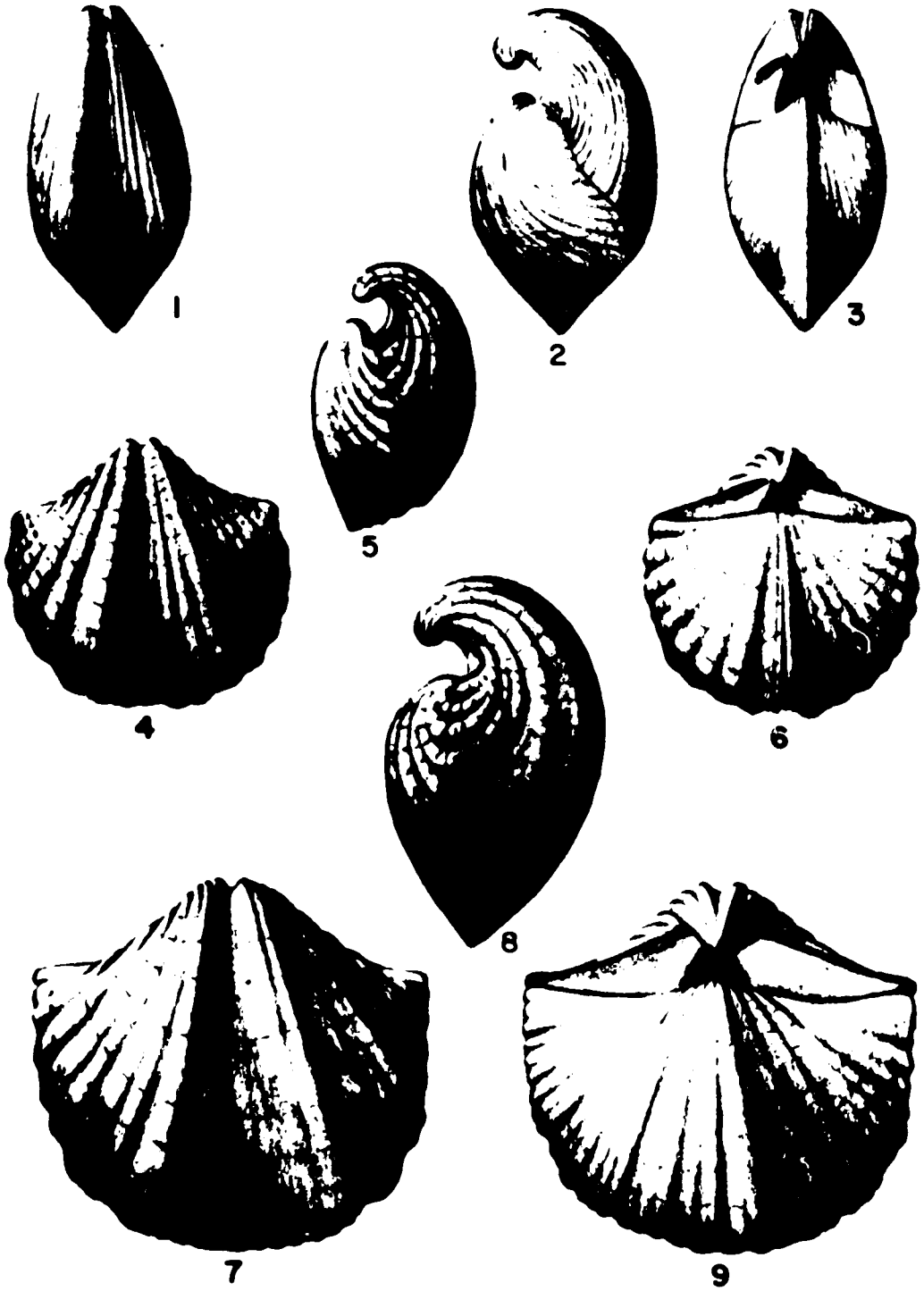

PLATE 2.

EXPLANATION OF PLATE 3

All figures natural size.

Figures 1-2. Spiriferella saranae. Pedicle and lateral views of typical adult valve. Figured specimen U.A.C. no. F 1004 collected from 138' to 140' above the base of the Tahkandit Formation, West Mount Burgess Section, Yukon. Same locality as F 1018.

Figures 3-5. Spiriferella raiah var A. Pedicle, brachial and lateral views of complete, juvenile specimen. Figured specimen U.A.C. no F 1065 collected from 2340' below the top of the Tahkandit Formation, Tatonduk River Section, Yukon Territory.

Figures 6-7. Spiriferella saranae. Pedicle and lateral views of incomplete adult valve. Figured specimen U.A.C. no F 1018 collected from 229' above the base of the Tahkandit Formation, West Mount Burgess section, Yukon Territory.

Figures 8-10. Spiriferella raiah var A. Figure 8. Pedicle view of adult valve with rather shallow sinus. Figured specimen U.A.C. no F 1137 collected from 1470' below the top of the Tahkandit Formation, Tatonduk River section, Yukon Territory. Figures 9-10. Pedicle and lateral views of typical adult. Figured specimen U.A.C. no F 1134 collected from 150' above the base of the Tahkandit Formation, Fishing Branch section, Yukon Territory.

Figures 11-12. Spiriferella editiareatus. Brachial and lateral views of complete, but weathered specimen. Figured specimen U.A.C. no F 1115 collected from 235' above the base of a section measured in the Tahkandit Formation, East Porcupine section, Yukon Territory.

Figures 13-14. Spiriferella ordinaria. Pedicle and lateral views of two average specimens. Figure 13. Figured specimen U.A.C. no F 1055 collected from 670' above the base of the Tahkandit Formation, Peel River Rapids section Yukon Territory. Figure 14. Figured specimen U.A.C. no F 1106 collected from the lower Tahkandit Formation, Peel River section, Yukon Territory.

PLATE 3

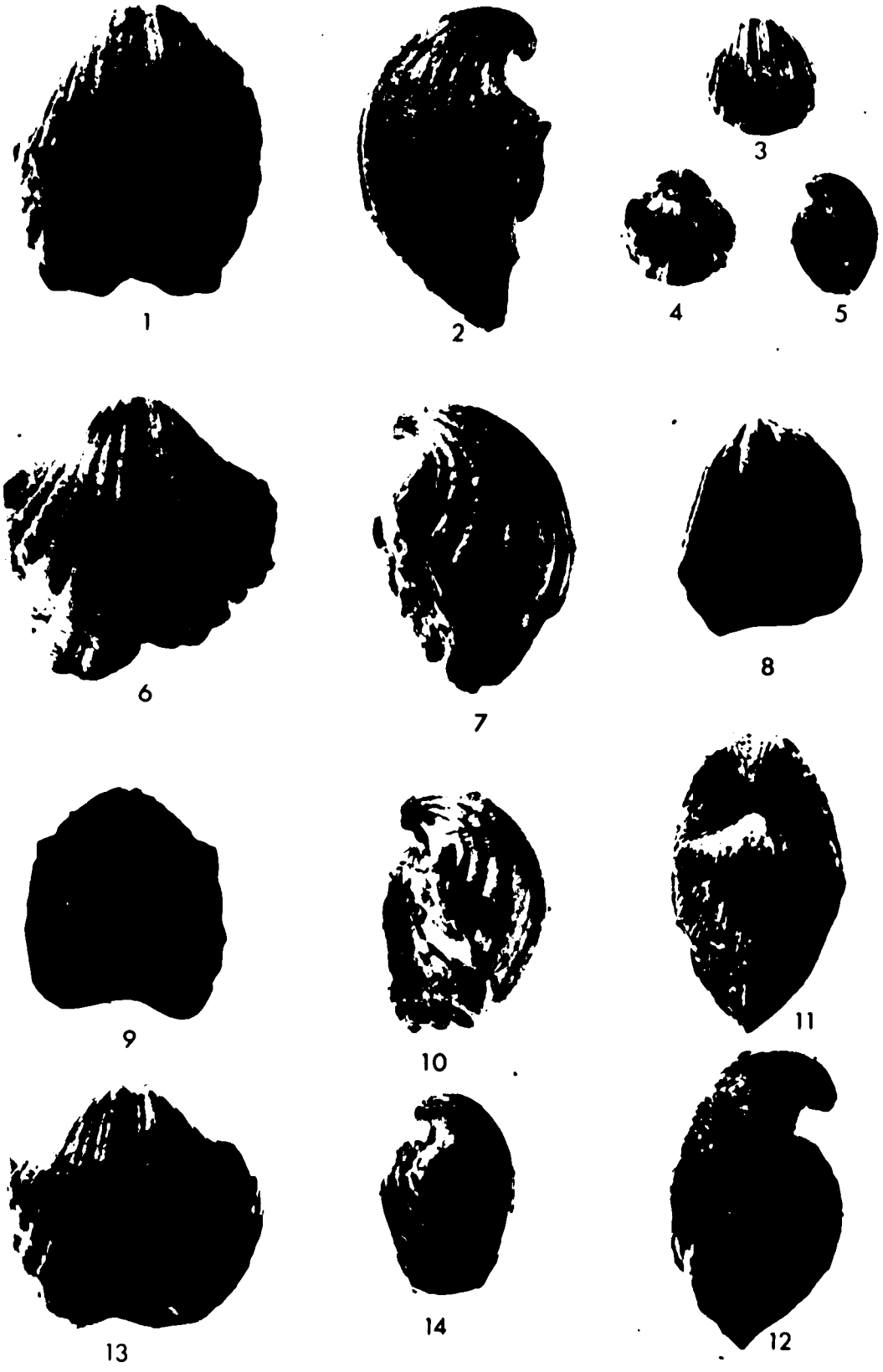

PLATE 3

EXPLANATION OF PLATE 4

All figures natural size.

Figures 1-4. Spiriferella raiah var B. Figures 1-2. Pedicle and lateral views of large adult valve. Figured specimen U.A.C. no F 1136, collected from 1030' above the base of the Tahkandit Formation, West Mount Burgess section, Yukon Territory. Figure 3. Brachial valve of adult specimen. Figured specimen U.A.C. no F 1120 collected from 1030' above the base of the Tahkandit Formation, West Mount Burgess section, Yukon Territory. Figure 4. Lateral view of complete specimen. Figured specimen U.A.C. no F 1079 collected from 950' above the base of the Tahkandit Formation, Yukon Territory.

Figures 5-6. Spiriferella keilhavii. Pedicle and lateral views of an adult valve. Figured specimen U.A.C. no F 1121 from the Tahkandit Formation, Alaska.

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PLATE 4

EXPLANATION OF PLATE 5

All figures natural size except 7, 9, 10 and 11.

Figure 1. Spiriferella editiareatus. Brachial view of incomplete specimen. Serial sections of this specimen shown in Plate 14. Figured specimen U.A.C. no F 1112 collected from 235' above the base of a section measured in the Tahkandit Formation, East Porcupine section, Yukon Territory.

Figures 2-3. Spiriferella saranae. Photographs of rubber molds of muscle platforms. Figure 2. Figured specimen U.A.C. no F 1123 collected from 229' above the base of the Tahkandit Formation, West Mount Burgess section, Yukon Territory. Figure 3. Figured specimen U.A.C. no F 1124 collected from the same locality.

Figure 4. Spiriferella rajah var B. Photograph of rubber mold of muscle platform. Figured specimen U.A.C. no F 1066 collected from 950' above the base of the Tahkandit Formation, West Mount Burgess section, Yukon Territory.

Figure 5. Spiriferella editiareatus. Photograph of rubber mold of muscle platform. Figured specimen U.A.C. no F1113 collected from 235' above the base of the East Porcupine section measured in the Tahkandit Formation, Yukon Territory.

Figure 6. Spiriferella keilhavii. Photograph of rubber mold of muscle platform. Figured specimen U.A.C. no F 1062 collected from the Tahkandit Formation, Alaska.

Figure 7. Spiriferella rajah var A. Photograph of micro-ornament. X5. Figured specimen U.A.C. no F 1109 collected from 2260' above the base of the Tahkandit Formation, Peel River Rapids section, Yukon Territory.

Figure 8. Spiriferella ordinaria. Photograph of rubber mold of muscle platform. From figured specimen U.A.C. no F 1055 pl. 3, fig. 13.

Figure 9. Spiriferella saranae. Photograph of micro-ornament. X5. From figured specimen U.A.C. no F 1004, pl. 1, figs. 1-2.

Figure 10. Spiriferella keilhavii. Photograph of micro-ornament. X5. From figured specimen U.A.C. no 1121, pl. 4, figs. 5-6.

Figure 11. Spiriferella raish var B. Photograph of micro-ornament. X5. From figured specimen U.A.C. no F 1136, pl. 4, figs. 1-2.

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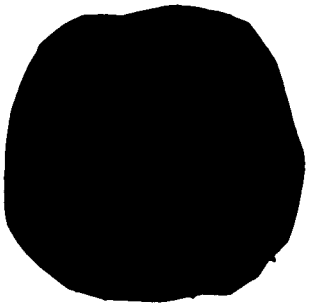

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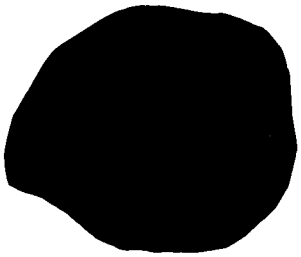

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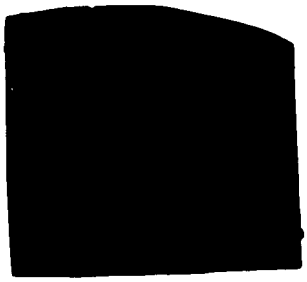

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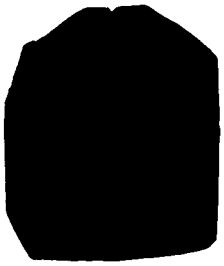

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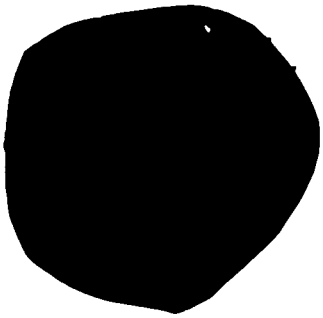

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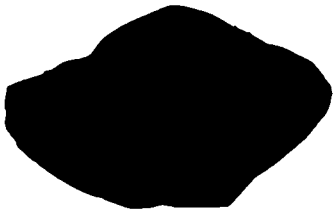

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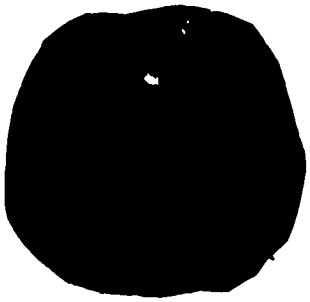
PLATE 5

1



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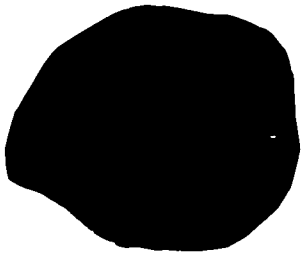

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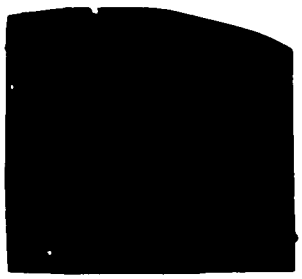

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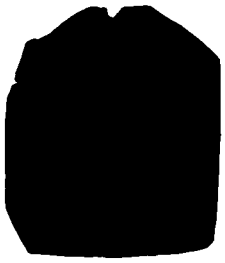

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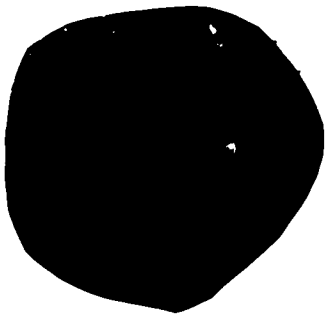

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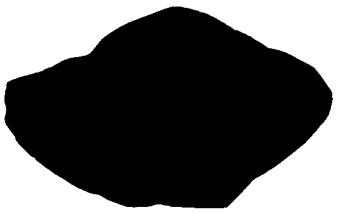

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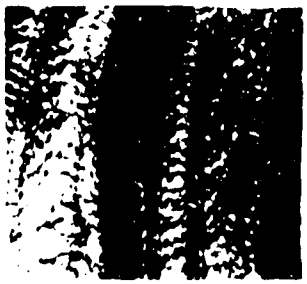

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PLATE 5

EXPLANATION OF SERIAL SECTION PLATES

The sections are transverse serial sections beginning from the anterior margin. Due to the curved nature of the pedicle valve it was found necessary to slightly rotate the valve from time to time about an axis normal to the sagittal plane. This was done to keep the grinding plane as perpendicular as possible to the growth axis, in which position maximum relief in the valve section could be seen. Thus though the sections are serial they are not always parallel. An R adjacent to a section indicates that the valve was rotated and ground a distance in mm. indicated by the small numeral placed next to it from the preceding section. For instance, R 2 indicates the valve was rotated and ground 2 mm. Where a small numeral occurs alone the section is parallel to the preceding section and a distance in mm. from it indicated by the numeral. The large numerals correspond to the lines of section indicated on the outline drawings.

All sections are natural size.

EXPLANATION OF PLATE 6

A. Spiriferella saranae. Transverse serial sections of typical adult pedicle valve illustrating the less elevated nature of the muscle platform. Figured specimen U.A.C. no F 1024 collected from 150' above the base of the Tahkandit Formation, West Mount Burgess section, Yukon Territory.

B. S. saranae. Transverse serial sections of small youthful pedicle valve, with external surface partly broken away. Figured specimen U.A.C. no F 1043 collected from the base of the Tahkandit Formation, West Mount Burgess section, Yukon Territory.

C. S. saranae. Transverse serial sections of smaller than average adult pedicle valve. Note the appearance of the callosity in the fifteenth and sixteenth sections which may be mistaken for a median septum. This is due to callosity filling in between the divided diductors as far as the adductor. Figured specimen U.A.C. no F 1070 collected from 250' above the base of the Tahkandit Formation, West Mount Burgess section, Yukon Territory.

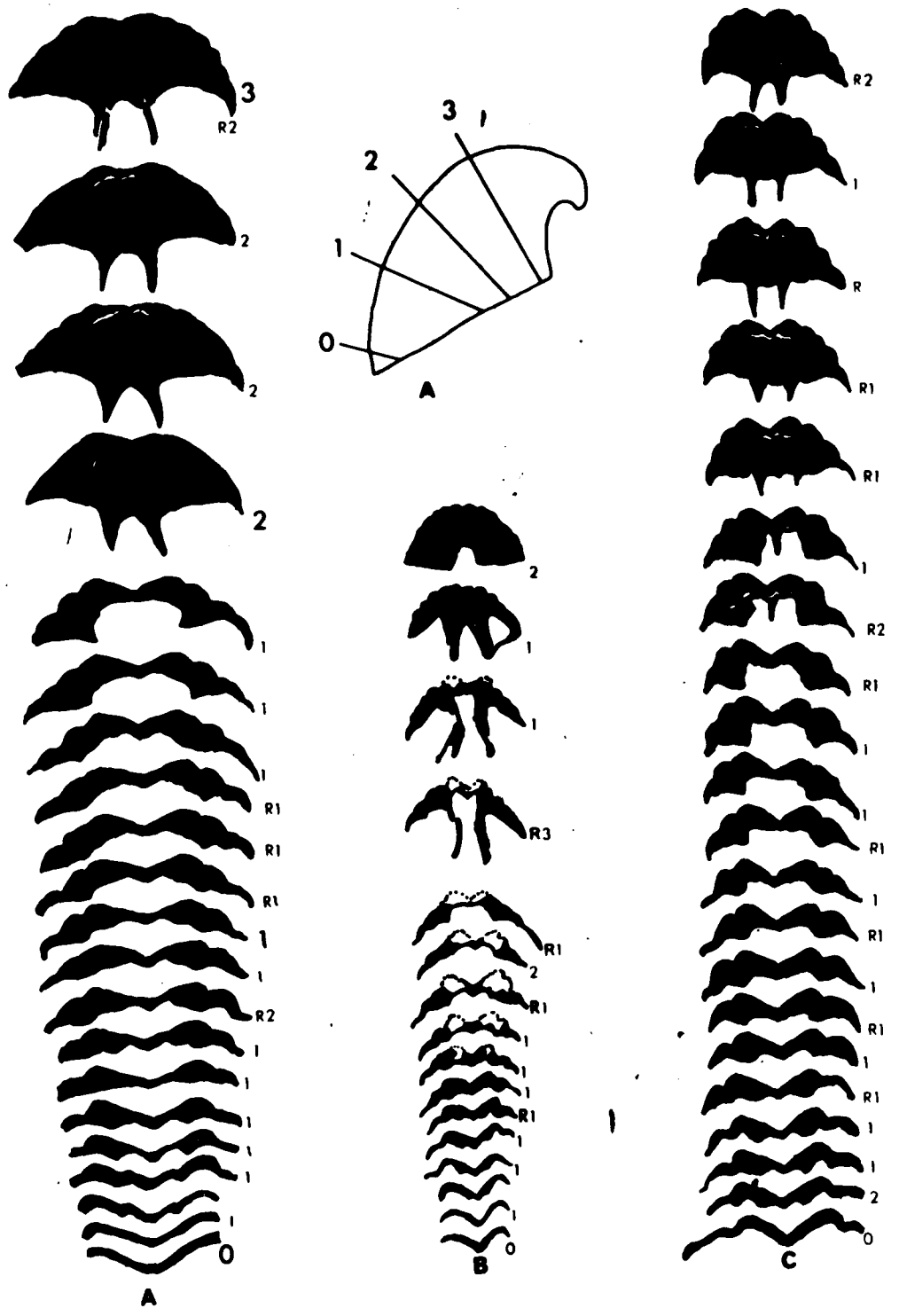
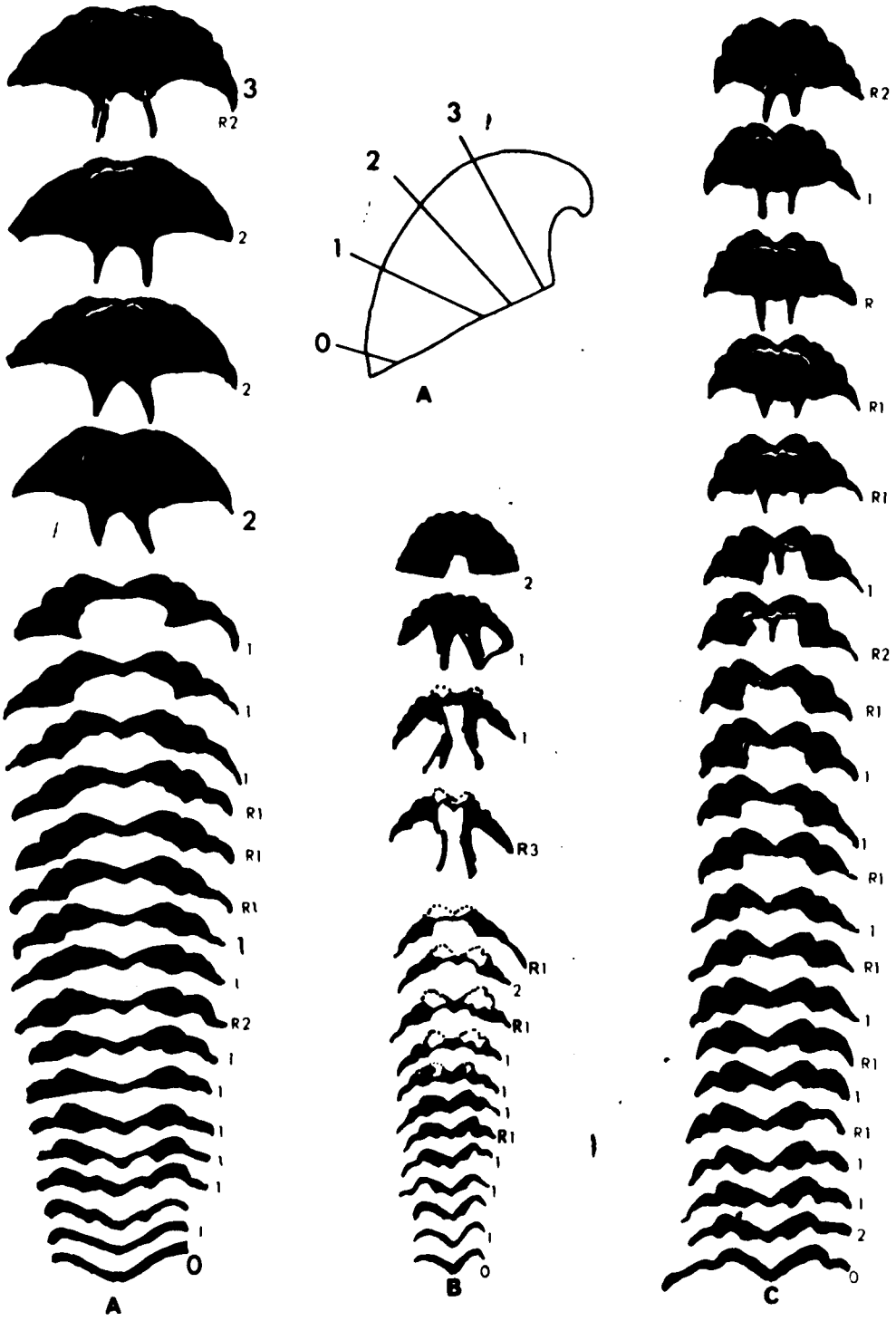

3
R2
2
2
2
1
1
1
R1
R1
R1
1
1
R2
1
1
1
1
1
0
A
3
2
1
0
A
2
1
1
R3
R1
2
R1
1
1
1
R1
1
1
1
0
B
R2
1
R
R1
R1
1
R2
R1
1
1
R1
1
R1
1
R1
1
1
2
0
C

PLATE 6


3
R2
2
2
2
1
1
1
R1
R1
R1
1
1
R2
1
1
1
1
1
0
A
3
2
1
0
A
2
1
1
R3
R1
2
R1
1
1
1
R1
1
1
0
B
R2
1
R
R1
R1
1
R2
R1
1
1
R1
1
R1
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R1
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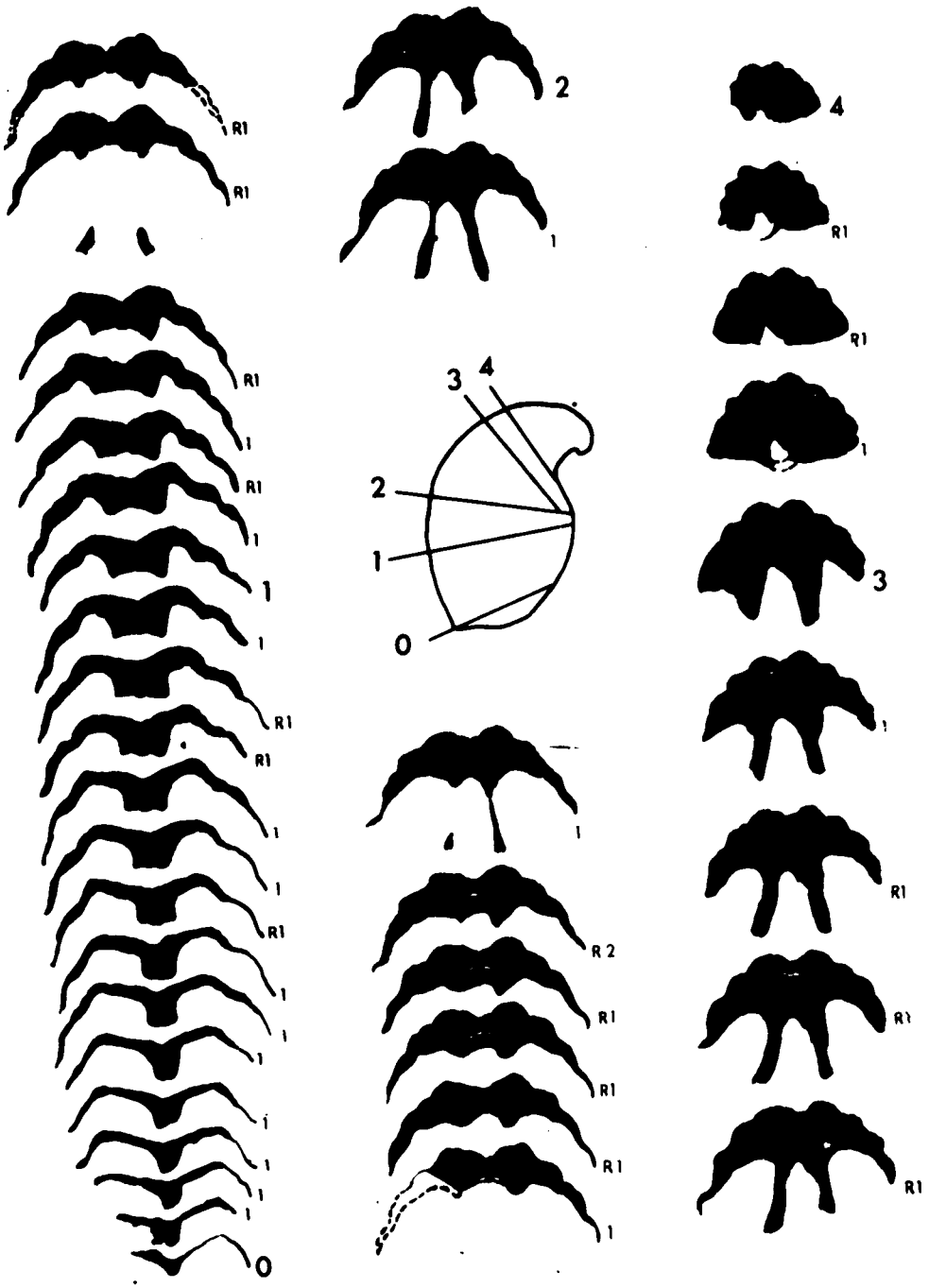
1
2
0
C

PLATE 6

EXPLANATION OF PLATE 7

Spiriferella raigh var *A*. Transverse serial sections of adult pedicle valve. Figured specimen U.A.C. no F 1132 collected from 1470' below the top of the Tahkandit Formation, Tatonduk River section, Yukon Territory.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R1
R1
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R1
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R1
R1
1
1
R1
1
1
1
1
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2
1
3
4
2
1
0
1
R2
R1
R1
R1
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4
R1
R1
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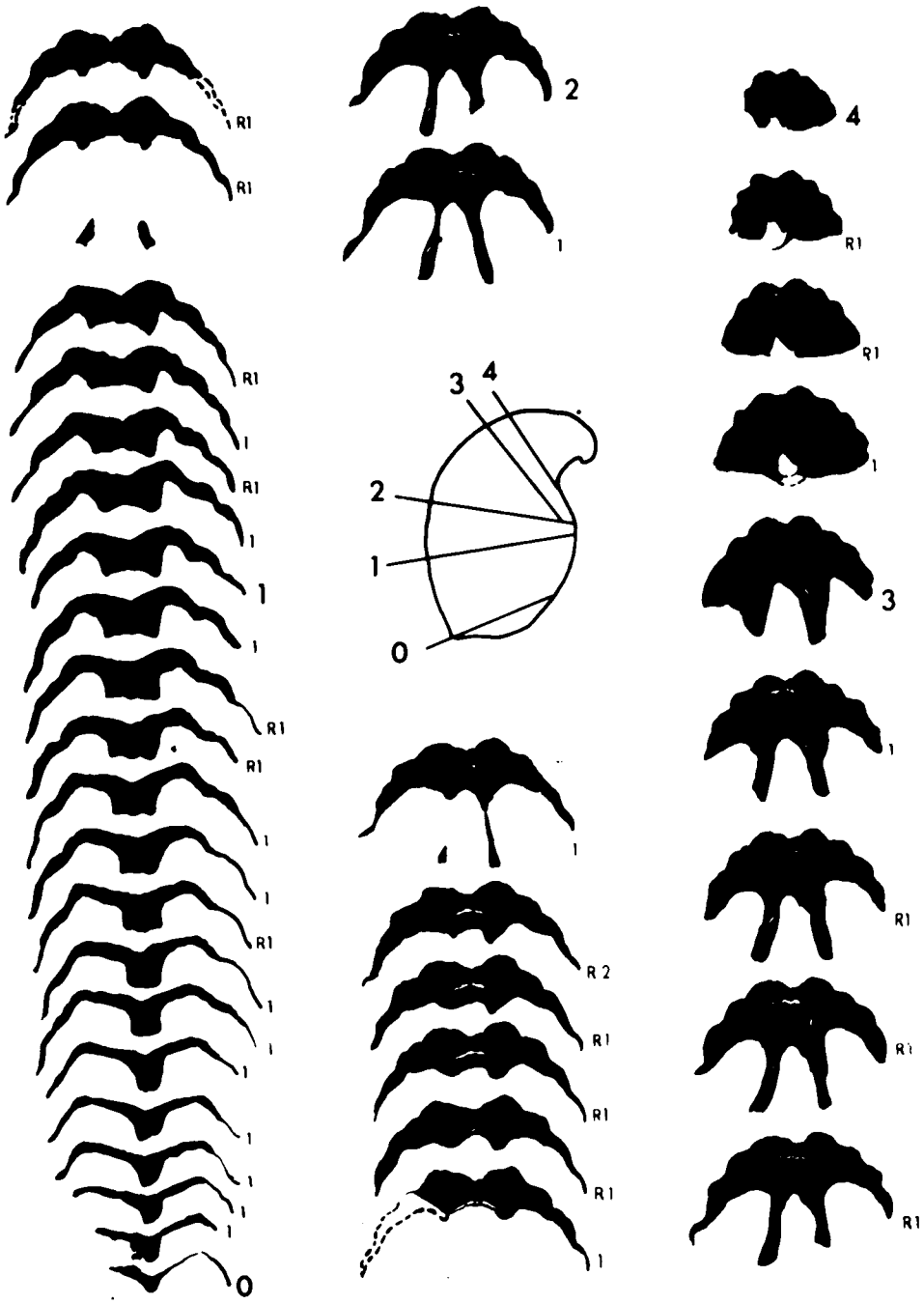
3
1
R1
R1
R1

PLATE 7


R1
R1
R1
R1
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R1
R1
1
1
R1
1
1
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1
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1
3
4
2
1
0
1
R2
R1
R1
R1
1
4
R1
R1
1
3
1
R1
R1
R1

PLATE 7

EXPLANATION OF PLATE 8

A. Spiriferella raiah var A. Transverse serial sections of average adult pedicle valve. Figured specimen U.A.C. no F 1139 collected from 1470' below the top of the Tahkandit Formation Tatonduk River section, Yukon Territory.

B. S. raiah var A. Transverse serial sections of average adult pedicle valve. Figured specimen U.A.C. no F 1140 collected from 2330' below the top of the Tahkandit Formation, Tatonduk River section, Yukon Territory.

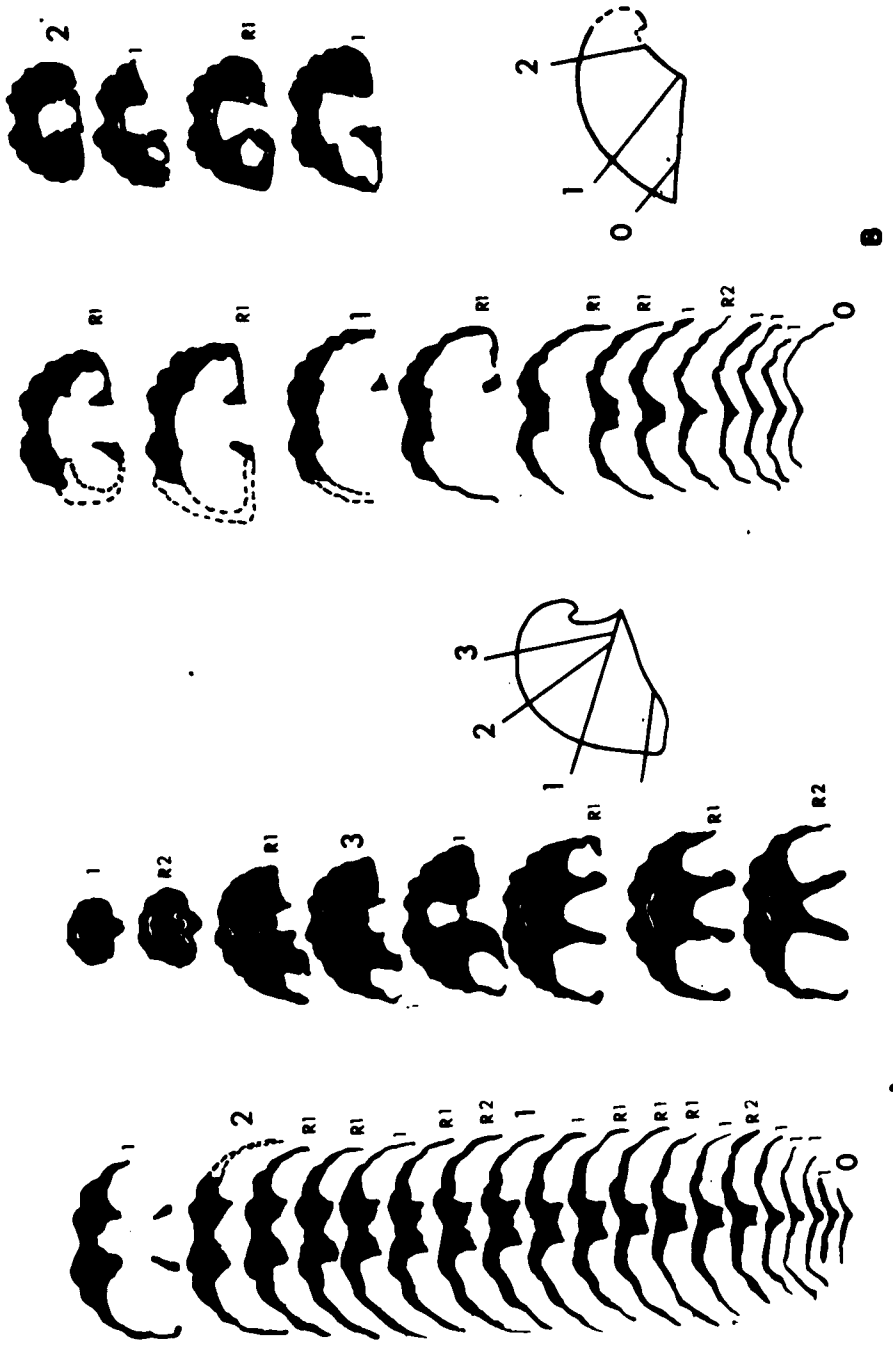


PLATE 8

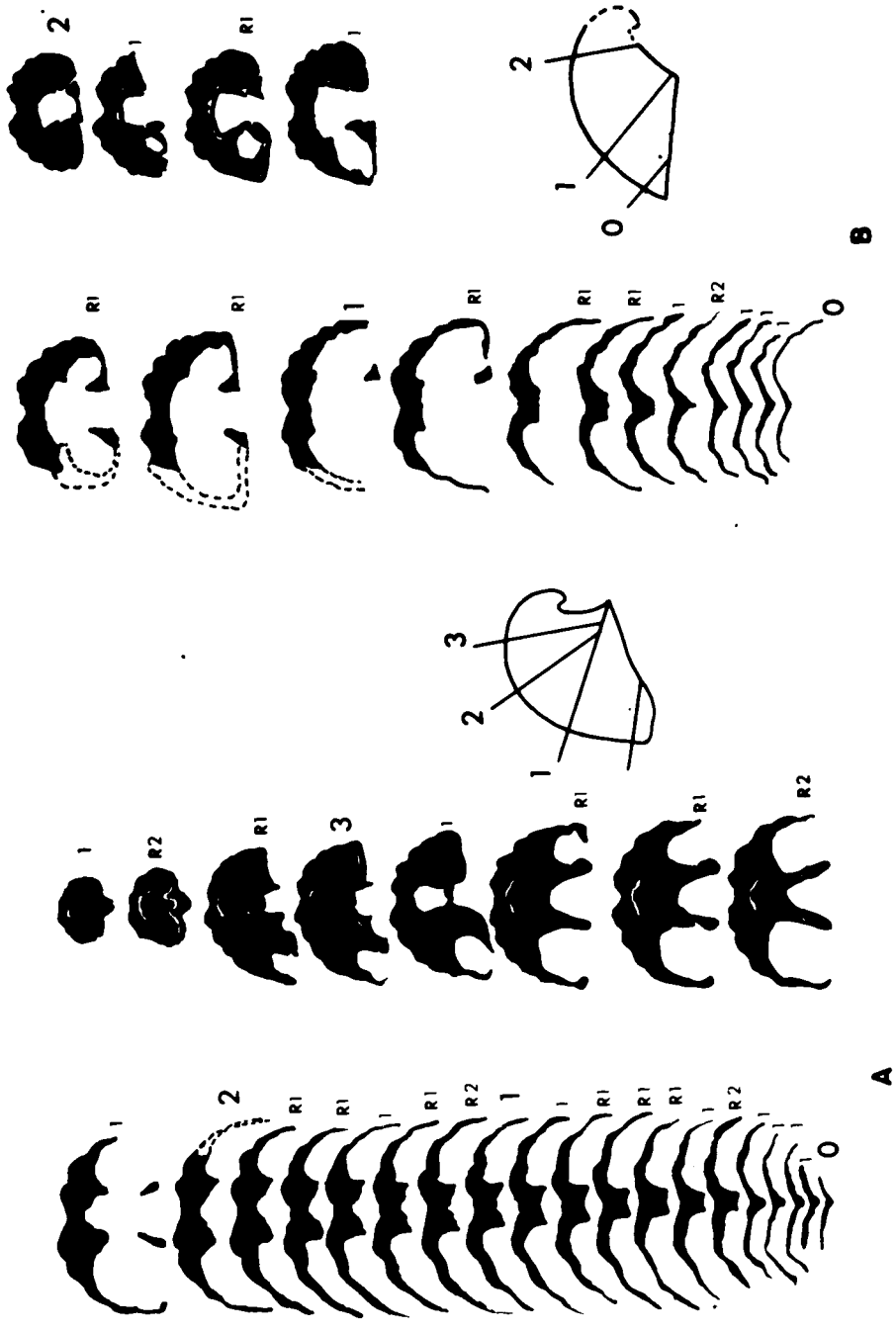
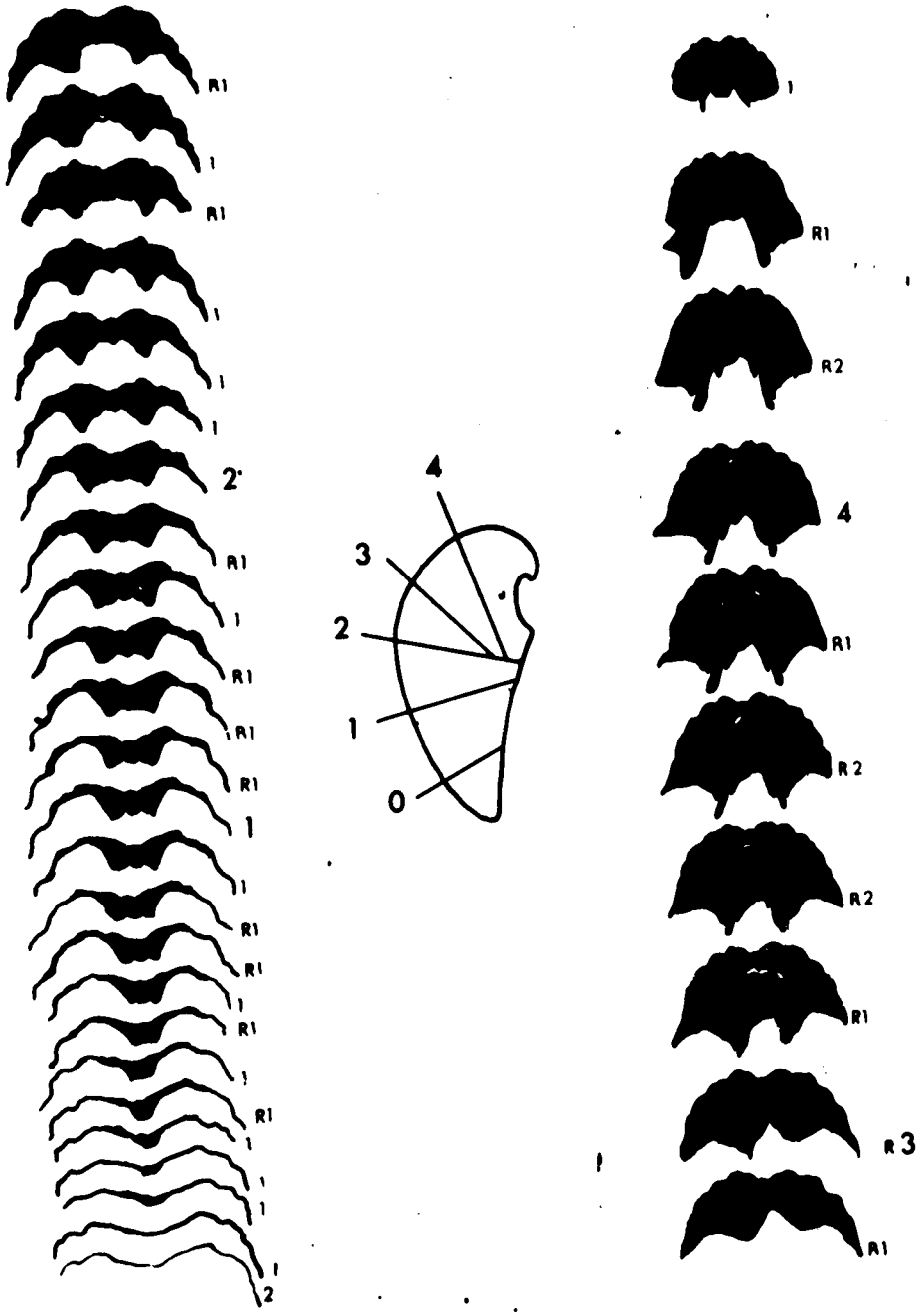


PLATE 8

EXPLANATION OF PLATE 9

Spiriferella raiah var *A*. Transverse serial sections of adult pedicle valve. Figured specimen U.A.C. no F 1071 collected from 1220' above the base of the Peel River Rapids section, Yukon Territory.


R1
1
R1
1
1
1
2
R1
1
R1
R1
R1
1
1
R1
R1
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1
R1
1
1
1
2
4
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R2
4
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R2
R2
R1
R3
R1

PLATE 9

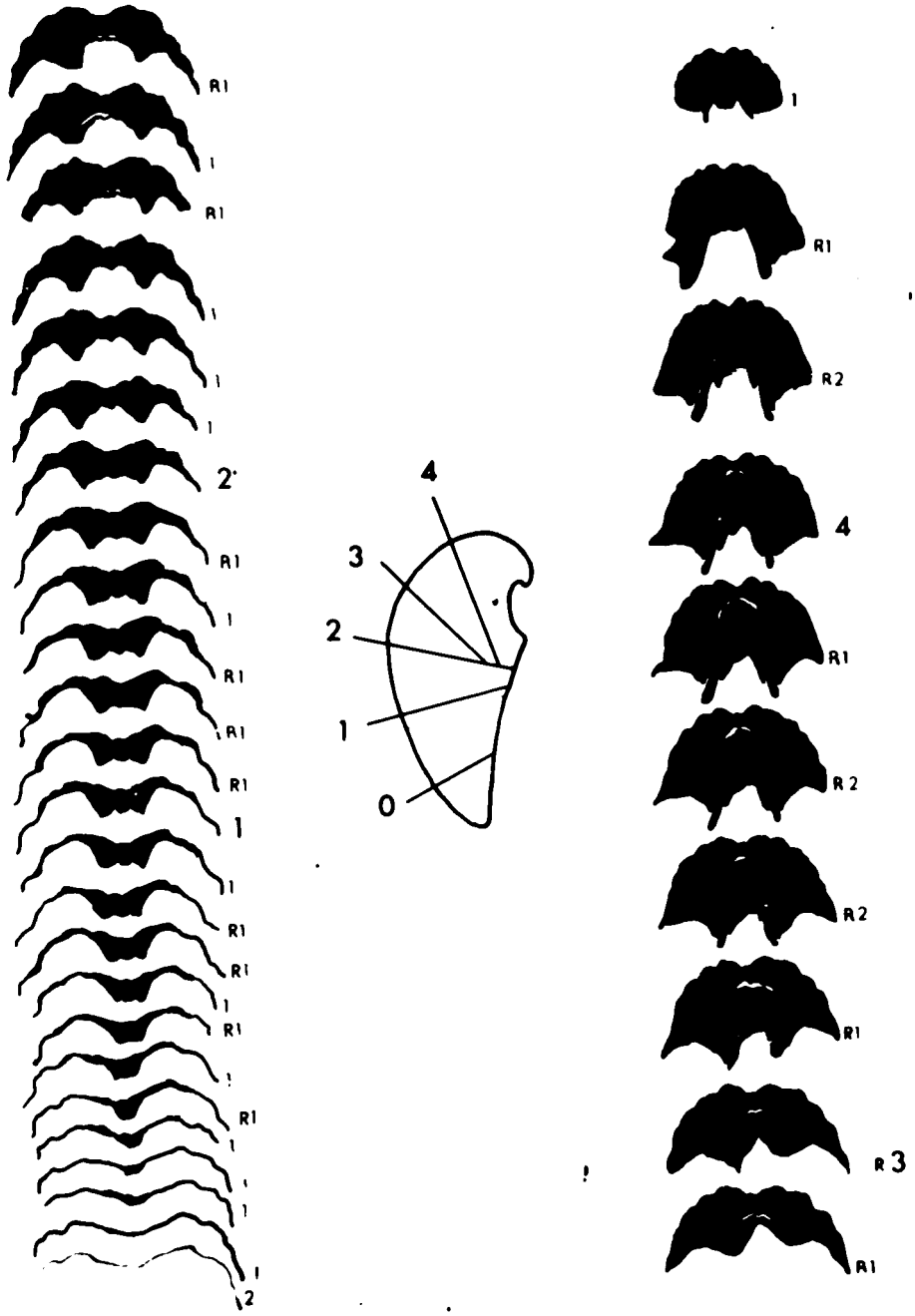
R1
1
R1
1
1
1
2
R1
1
R1
R1
R1
1
1
R1
R1
1
R1
1
R1
1
1
2
4
3
2
1
0
1
R1
R2
4
R1
R2
R2
R1
R3
R1

PLATE 9

EXPLANATION OF PLATE 10

A. Spiriferella raiah var A. Transverse serial sections of youthful pedicle valve illustrating extreme elevation of the muscle platform. Figured specimen U.A.C. no F 1041 collected from 2100' below the top of the Tahkandit Formation, Tatonduk River section, Yukon Territory.

B. S. raiah var A. Transverse serial sections of small adult pedicle valve illustrating muscle platform which does not have the typical laterally flared margins. A and B illustrate the range of variation in outline which the muscle platform of this variety can achieve. Figured specimen U.A.C. no F 1142 collected from the same locality as A.

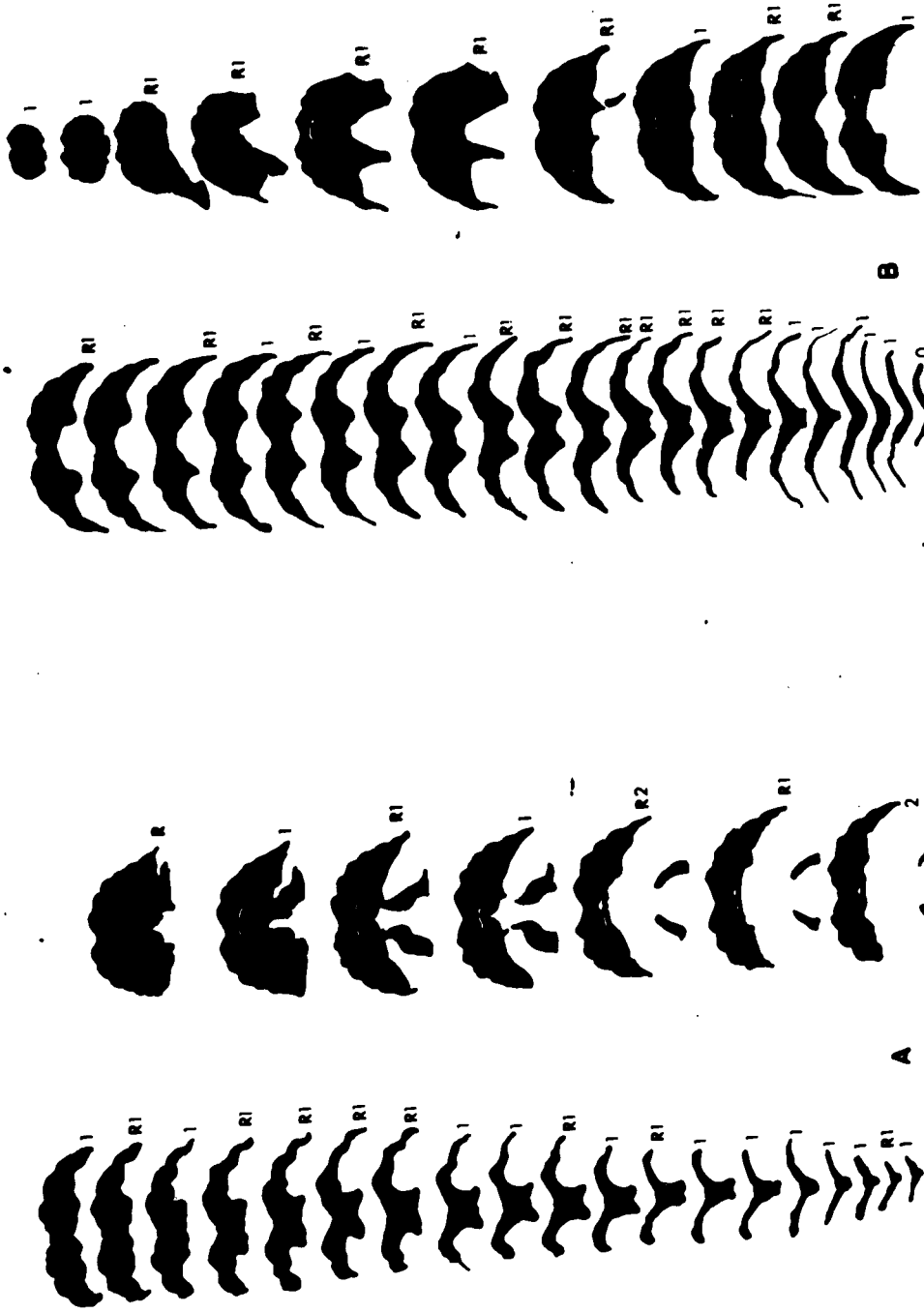

PLATE 10

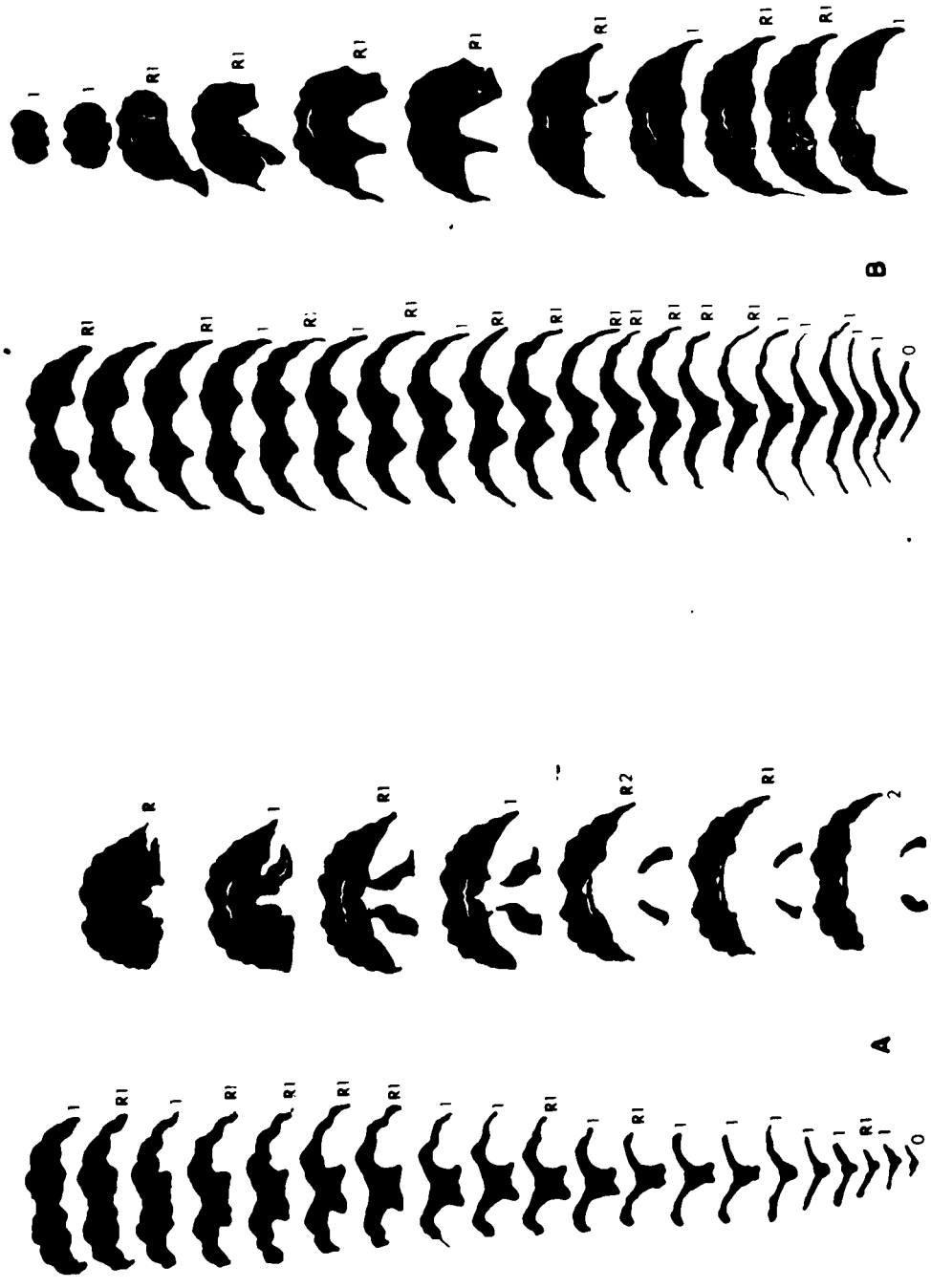

PLATE 10

EXPLANATION OF PLATE 11

A. Spiriferella keilhavii. Transverse serial sections of pedicle valve; medium sized adult. Figured specimen U.A.C. no F 1040 from the Tahkandit Formation, Alaska.

B. S. rajah var B. Transverse serial sections of rather small adult pedicle valve. Figured specimen U.A.C. no F 1022, collected from 950' above the base of the Tahkandit Formation, West Mount Burgess section, Yukon Territory.

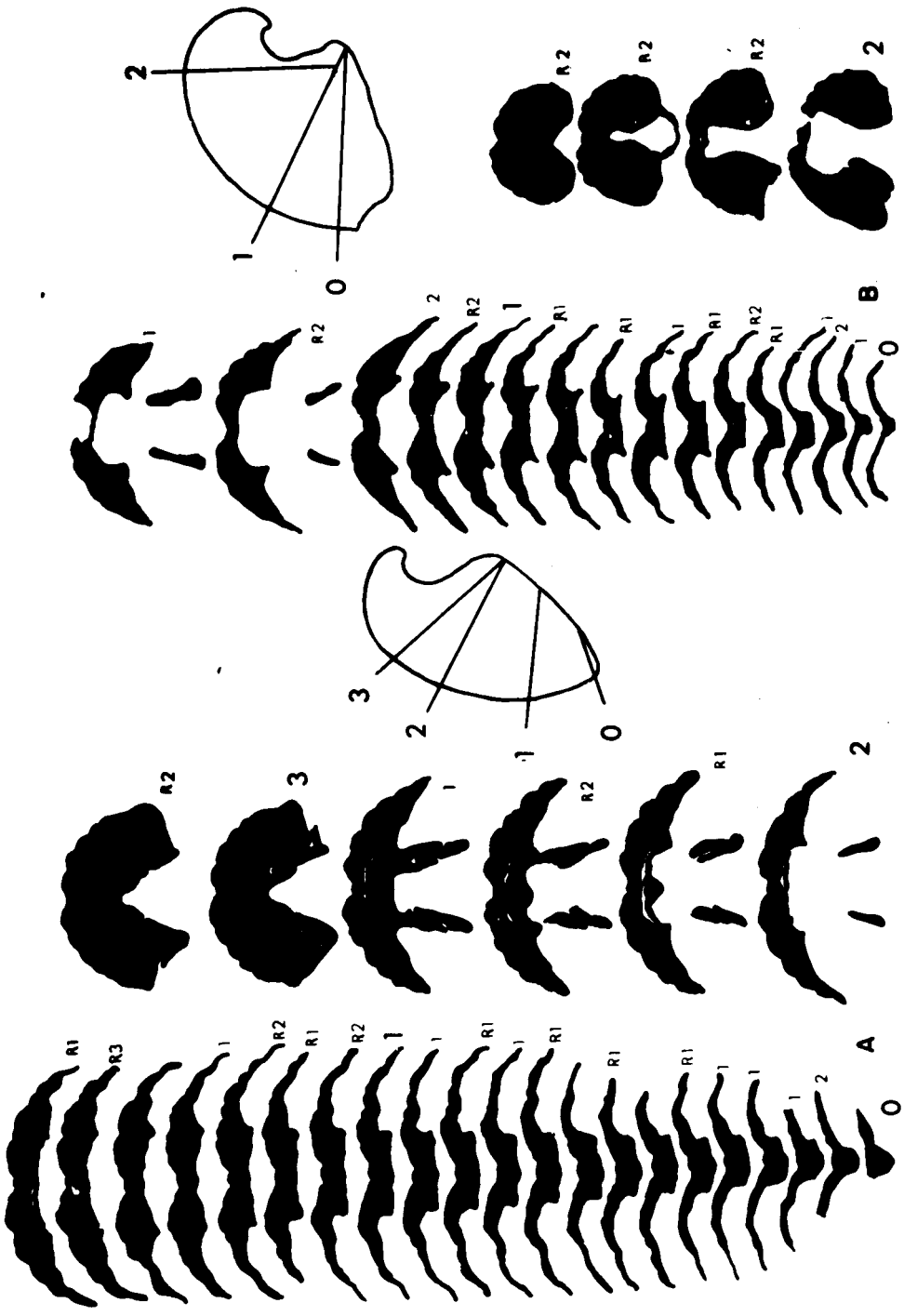

PLATE 11

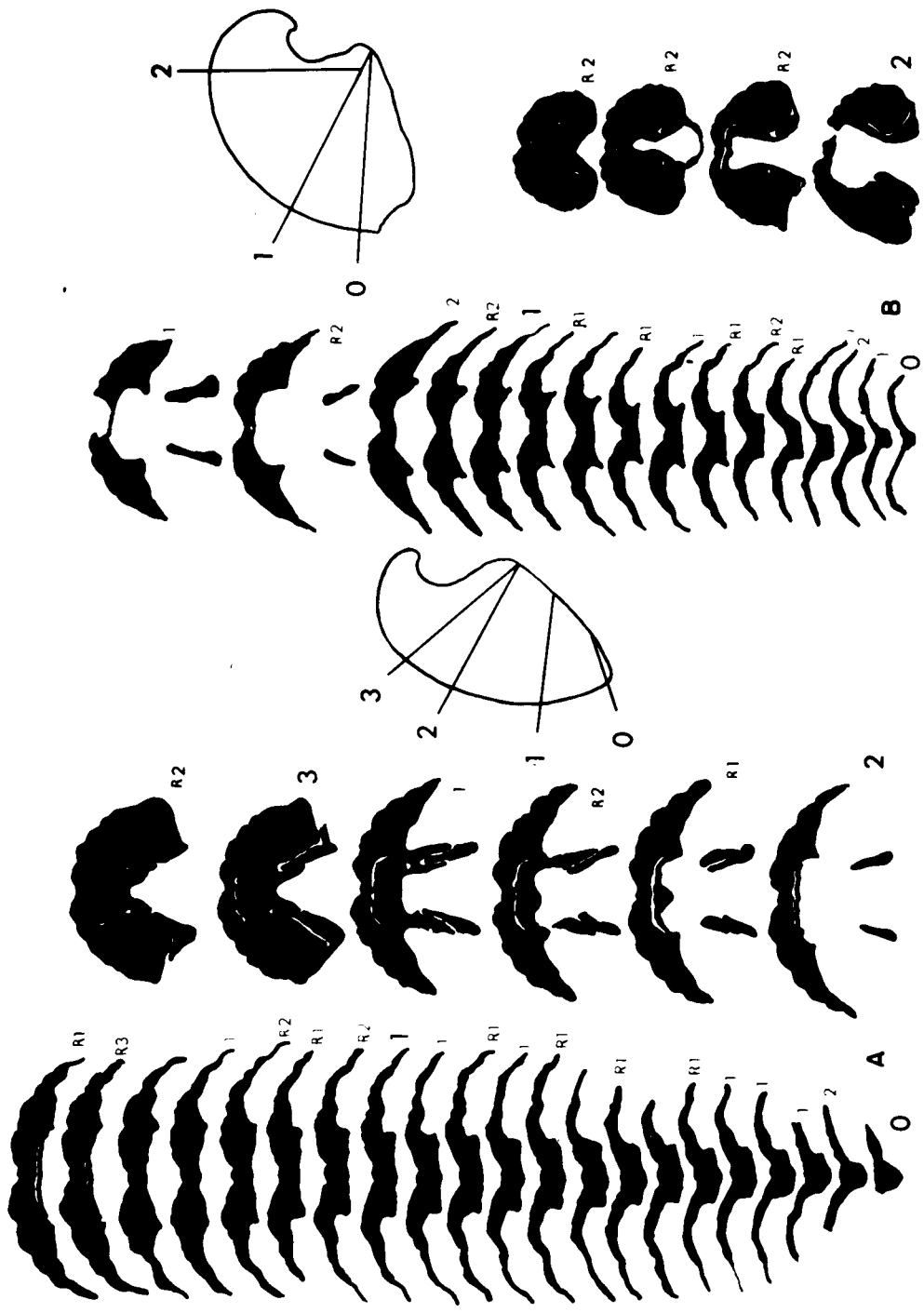

PLATE 11

EXPLANATION OF PLATE 12

Spiriferella keilhavii. Transverse serial sections of typical adult pedicle valve. Figured specimen U.A.C. no F 1025 collected from 1030' above the base of the Tahkandit Formation, West Mount Burgess section, Yukon Territory.

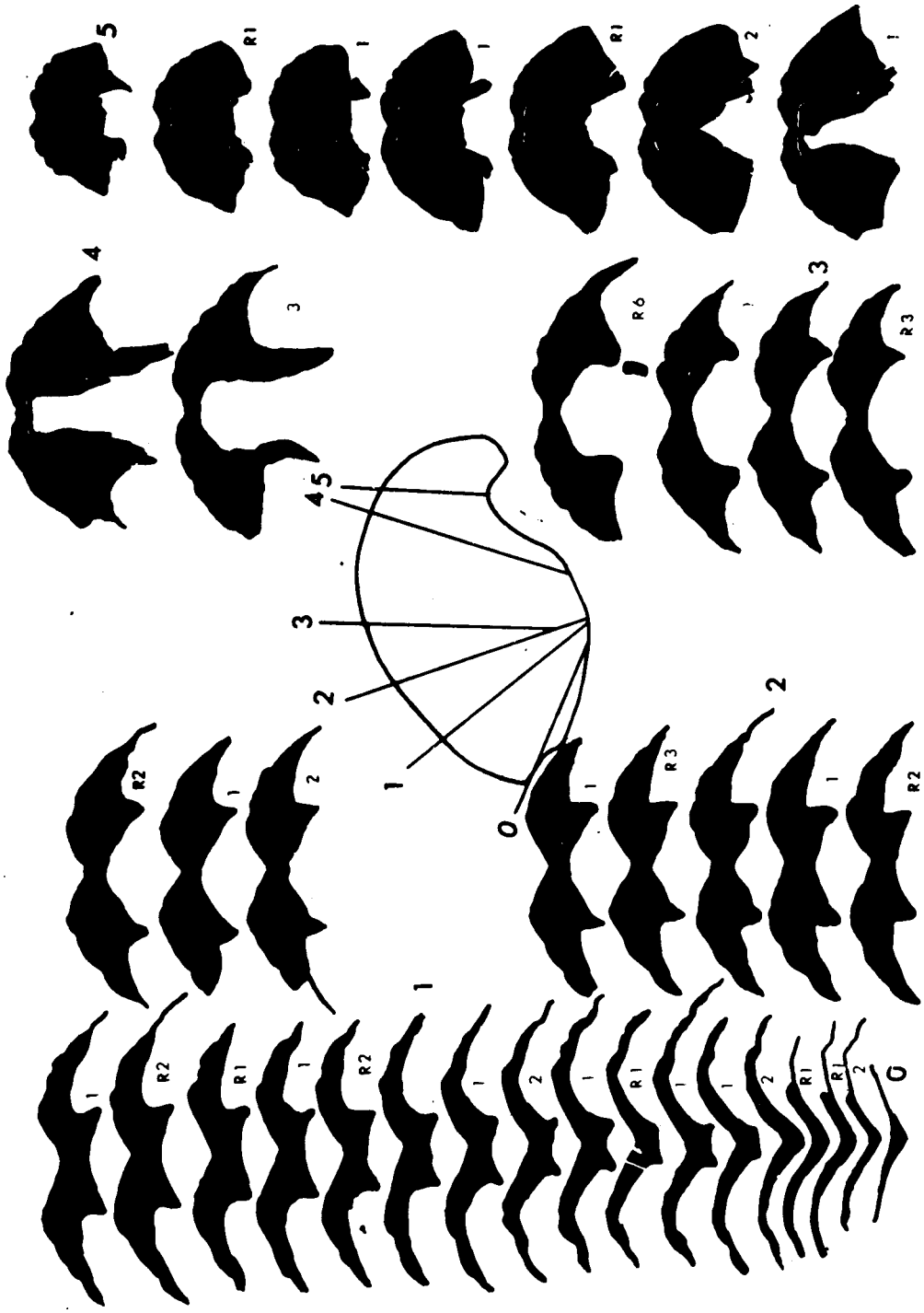

PLATE 12

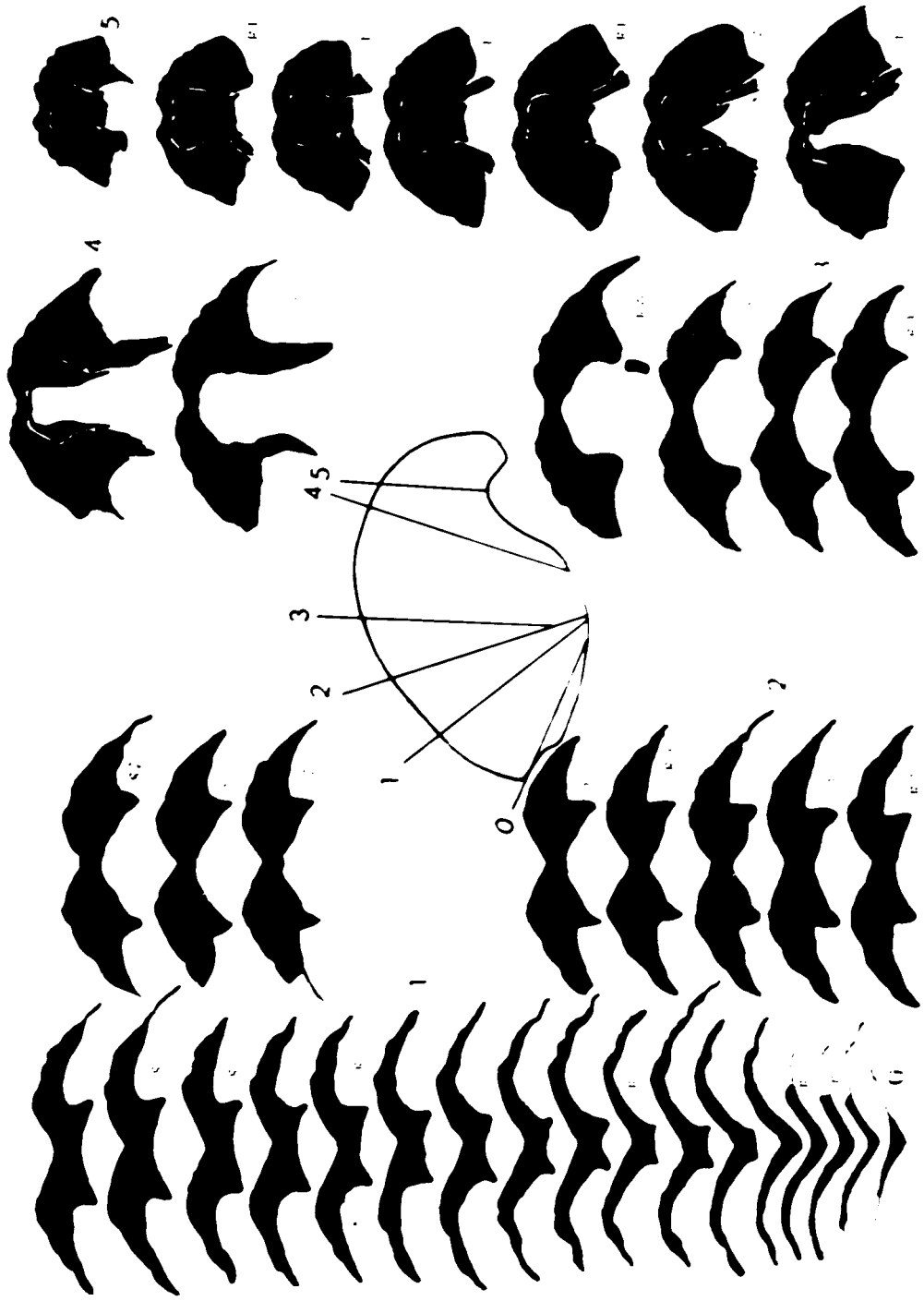

PLATE 22

EXPLANATION OF PLATE 13.

Spiriferella ordinaria. Transverse, serial and parallel sections of complete typical adult. The shell was only partly preserved. The section at 15 mm was from an enlarged thin section and shows the cross-section of spiralia most accuratly. Figured specimen U.A.C. no F 1101 collected from 650' above the base of the Tahkandit Formation, Peel River Rapids section, Yukon Territory.

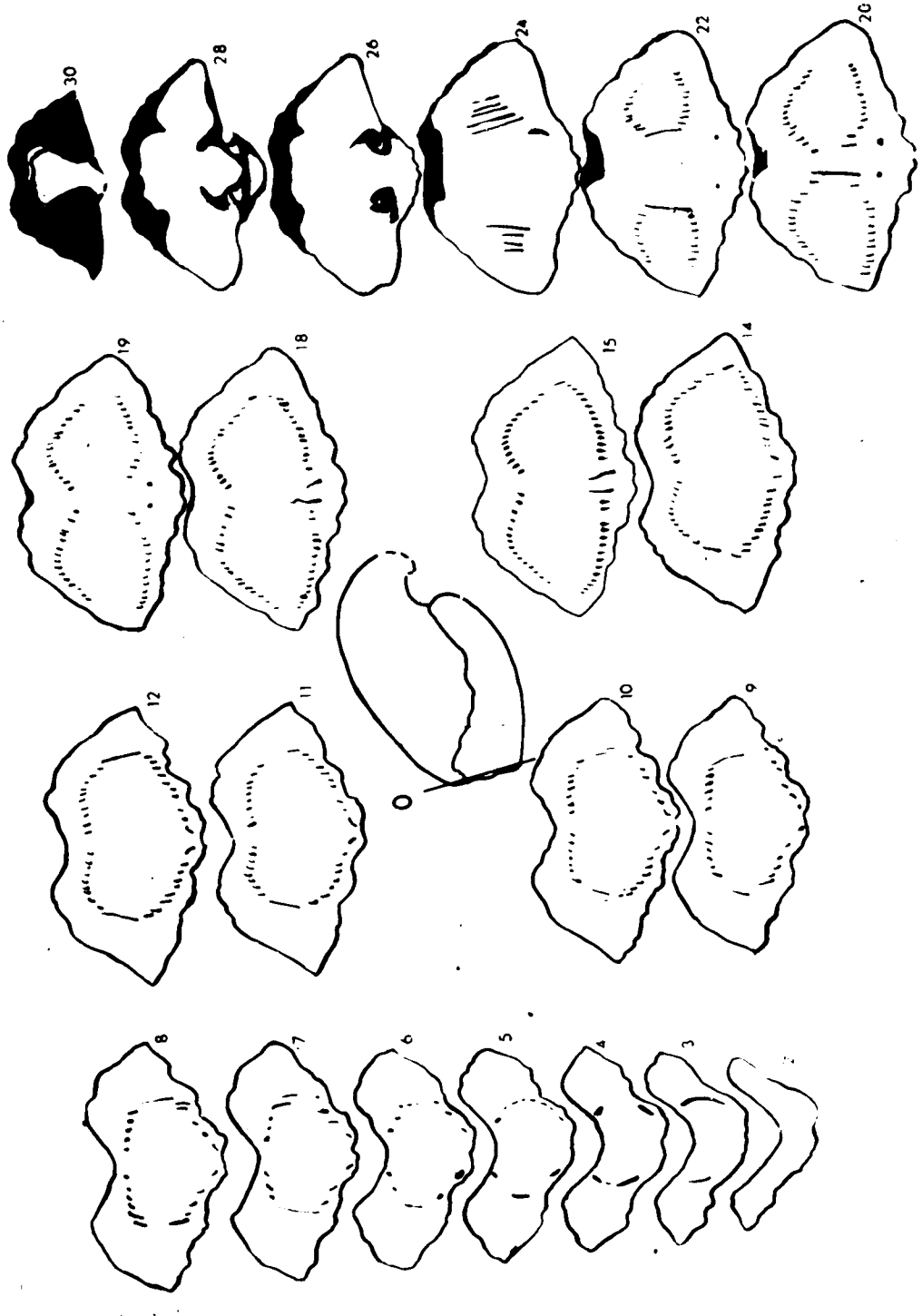

PLATE 13

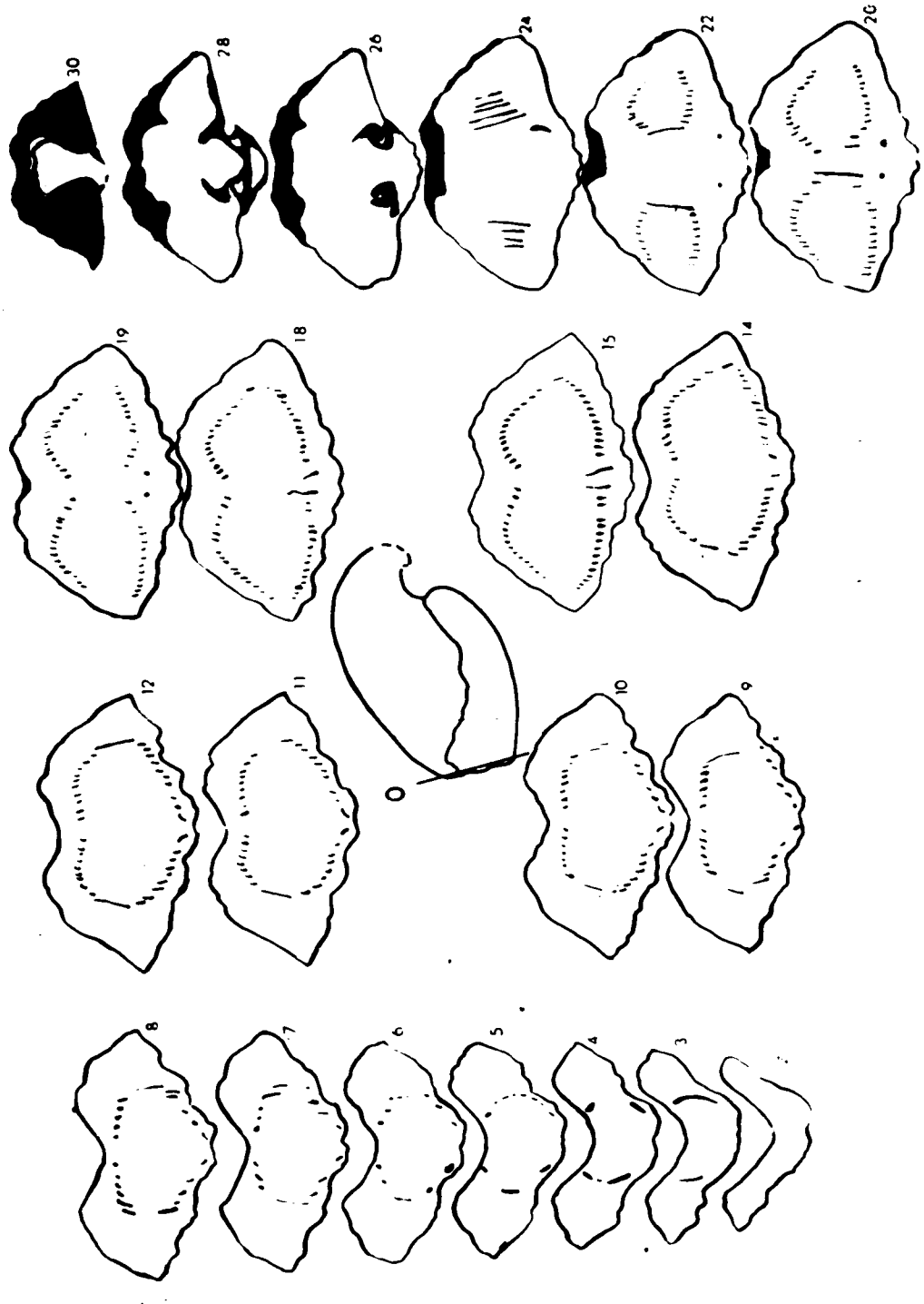

PLATE 13

EXPLANATION OF PLATE 14.

Spiriferella editiareatus. Transverse, serial and parallel sections of typical adult. Though spiralia could be seen, they were not in place. Figured specimen U.A.C. no F 1112 collected from 235 feet above the base. of the Fishing Branch section, Yukon Territory.

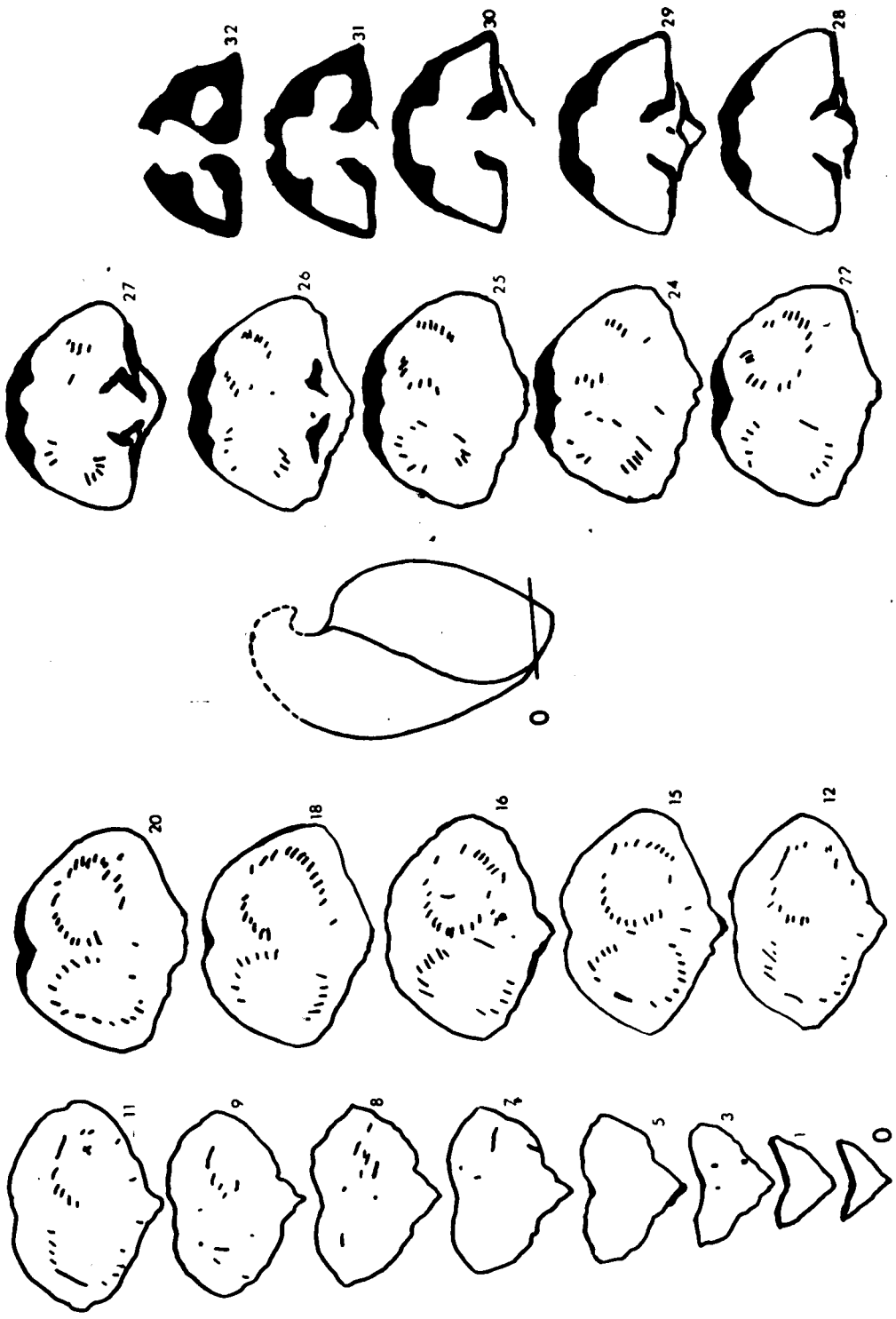

PLATE 14

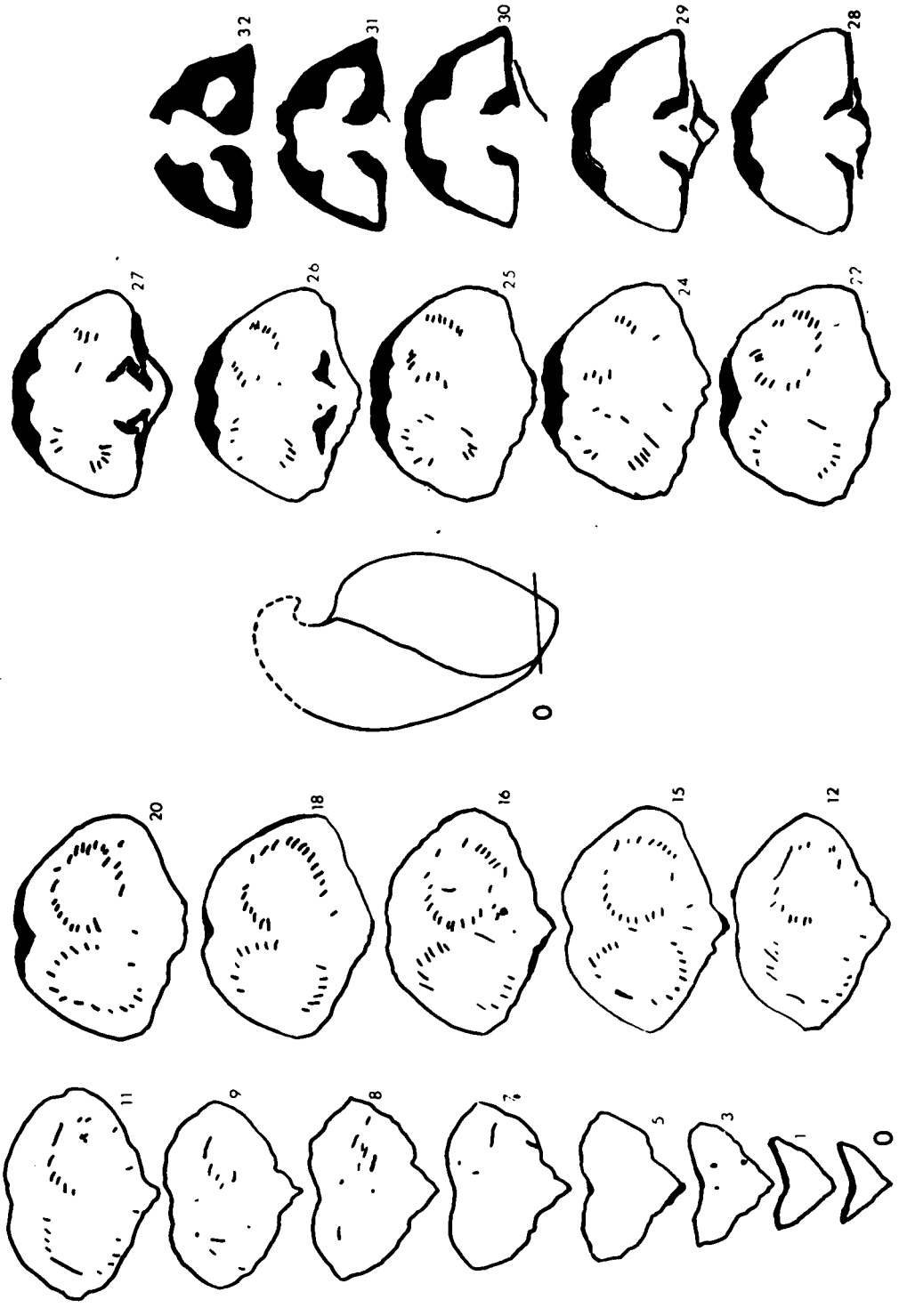

PLATE 14

EXPLANATION OF PLATE 15

Spiriferella editiareatus. Transverse serial sections of typical adult. Spiralia preserved but not in original position. Figured specimen U.A.C. no F 1069 collected from 235' above the base of a section measured in the Tahkandit Formation, East Porcupine section, Yukon Territory.

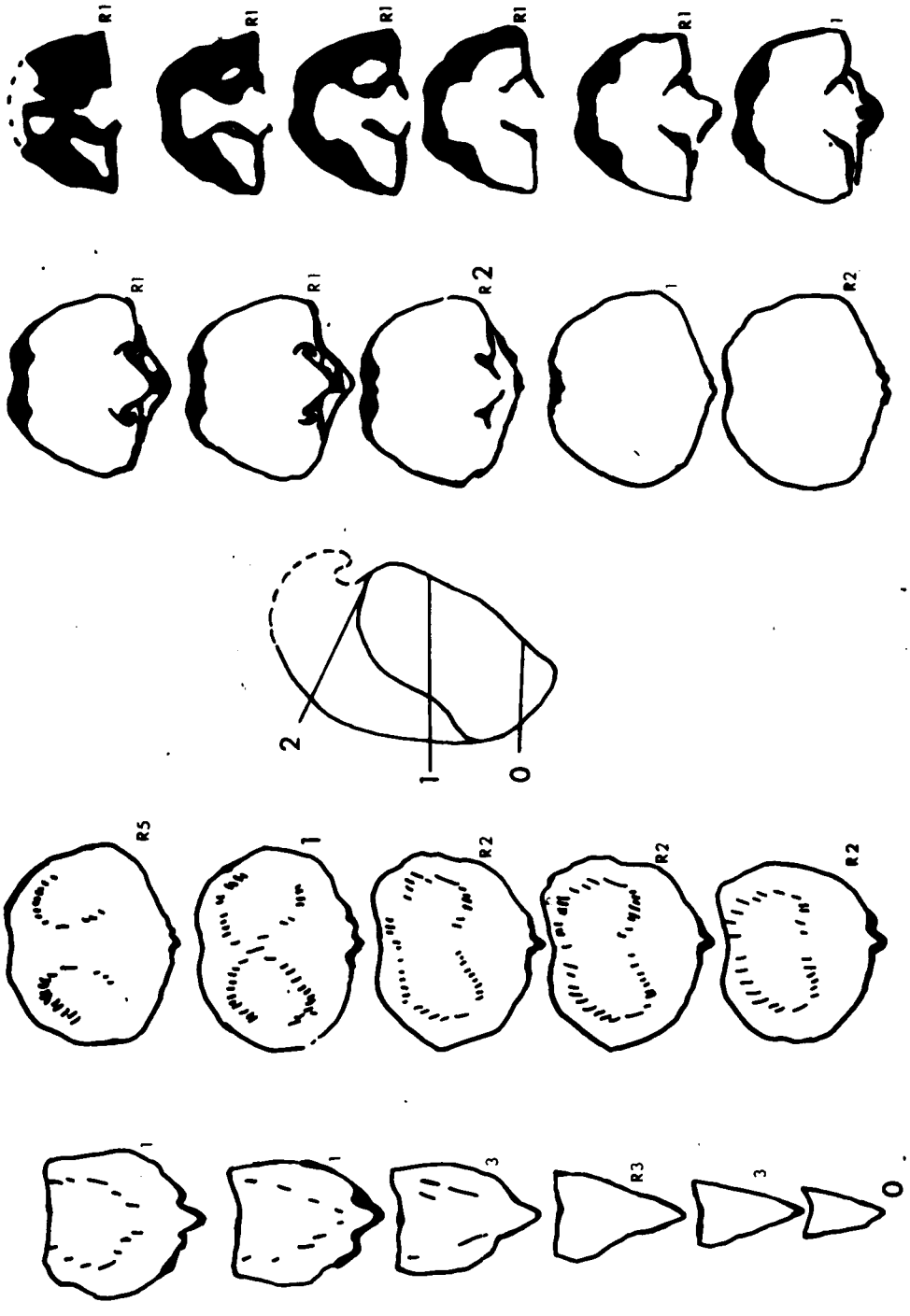

PLATE 15

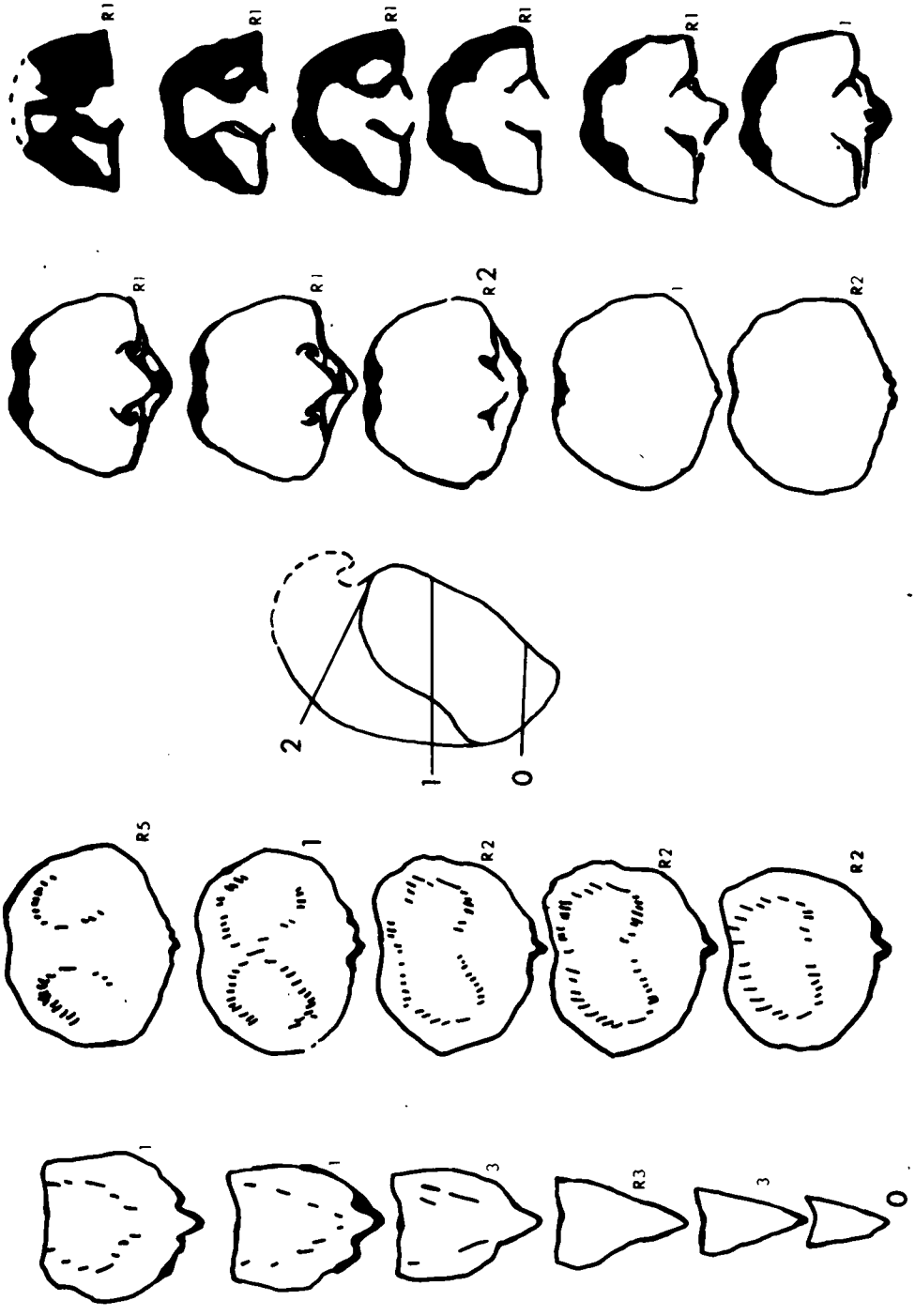

PLATE 15