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A new exceptionally preserved biota from the Lower Silurian of Wisconsin, U.S.A.

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[Plates 1 and 2]

A new biota including lightly sclerotized and soft-bodied organisms occurs in finely laminated argillaceous dolomites of late Llandoverian age in Waukesha County, Wisconsin. This discovery fills a gap between well known Cambrian and Devonian Konservat Lagerstätten. The biota is dominated by arthropods. A dalmanitid is the most numerous of 13 genera of trilobites; the crustaceans include phyllocarids and ostracods; the chelicerates are represented by the earliest well preserved xiphosure and the fauna includes a possible marine uniramian. The earliest representative of the enigmatic class Thylacocephala, and at least three arthropods of uncertain affinity are also present. There are at least four worm taxa including a possible leech and a papillate annelid. The locality has also yielded a conodont animal, *Panderodus*. Graptolites and conulariids are common, but echinoderms, brachiopods, bryozoans, corals and molluscs are extremely rare or absent. The unusual composition and exceptional preservation of this assemblage indicates that the biota lived and died in environments rarely represented in the Silurian fossil record.

Non-mineralized skeletons and soft tissues are rarely preserved in the fossil record. No soft-bodied biotas approaching the diversity of the Middle Cambrian Burgess Shale or Upper Carboniferous Mazon Creek biotas are yet known from Silurian rocks. An exceptionally preserved biota recently reported by us (Mikulic *et al.* 1985) from the Llandoverian of Waukesha County, Wisconsin, however, adds significantly to the record of Silurian soft-bodied organisms. Here we extend that first report, but our investigation is still at a preliminary stage. Initial excavation and study of material from the only locality known has revealed a number of arthropods, annelids, and other organisms previously unrecorded from Silurian rocks. Although its diversity is limited compared with some well known Konservat Lagerstätten from other time periods, the Waukesha biota provides important information on the biology, evolution, and ecology of several taxa. More extensive collecting and research on this biota is underway that will increase our knowledge of the true diversity of Silurian biotas and the factors that control such exceptional preservation.

The biota occurs in Llandoverian Brandon Bridge strata, which compose a prominent Silurian unit in the Milwaukee–Chicago area. (The Silurian stratigraphy of southeastern Wisconsin is being revised and the names used in this paper are therefore informal.) Throughout most of its extent, the Brandon Bridge unconformably overlies Kankakee Dolomite and grades upward into Waukesha Dolomite (figure 1). The Brandon Bridge is predominantly

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a thin-bedded, light green to pinkish gray argillaceous dolomite but locally the lower half is a conspicuous dark reddish-brown colour (Mikulic 1977).

Characteristics of the unit differ markedly at the Waukesha locality. Here a 100 m north–south transect shows the Brandon Bridge thinning northward from 8 to 0 m as it wedges out against an 8 m high scarp of unnamed cherty dolomite (figure 1). The Brandon Bridge was not deposited north of Waukesha, where the equivalent thickness is occupied by the cherty dolomite (Mikulic 1977). At Waukesha the Brandon Bridge is a thin-bedded grey argillaceous dolomite which becomes finely laminated and more argillaceous in the vicinity of the scarp.

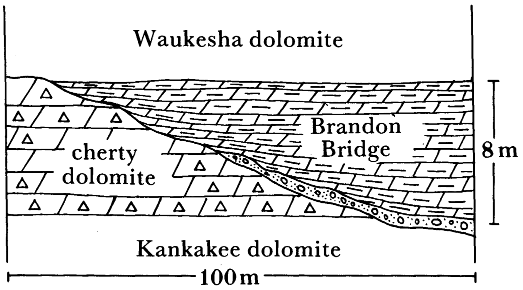


FIGURE 1. Diagram showing the relation between the lower Silurian Brandon Bridge and adjacent strata at the cherty dolomite scarp exposed at Waukesha, Wisconsin, U.S.A.

A thin conglomerate of irregular thickness unconformably overlies the lower part of the cherty dolomite scarp and part of the Kankakee Dolomite (figure 1). The conglomerate is composed of chert fragments and rare silicified fossils in a light green glauconitic clay matrix. No calcareous material is present, suggesting that the lithology may have been derived from solution of the cherty dolomite. This indicates a hiatus during which the cherty dolomite was eroded and the scarp formed. Conclusive evidence favouring either subaerial or submarine processes is lacking. The surface of the conglomerate appears to be a hardground. Regionally the erosional upper surface of the Kankakee Dolomite is marked by vertical ?borings, but has relief of less than 1 m. The Brandon Bridge was deposited over the surface of the cherty dolomite scarp formed by the erosion. Basal strata fill irregularities on the surface of both the scarp and the conglomerate. The lower strata of the Brandon Bridge appear to wedge out against the scarp; however, they were probably deposited in a downslope direction, conforming to the shape of the scarp for a short distance before thickening and levelling out distally (figure 1). Generally the lowest 2 m of Brandon Bridge consists of alternating thin layers of fissile mudstone and thicker beds of laminated argillaceous dolomite. Just above a mudstone at the base, however, is a non-laminated dolomite containing rip-up clasts of laminated dolomite. Small *in situ* cryptalgal mounds are scattered through the lower Brandon Bridge near the foot of the scarp, indicating that the environment was within the photic zone.

The biota occurs in a 12 cm thick layer of very finely laminated mudstone and dolomite (figure 5, plate 1) overlying the lowest 2 m adjacent to the scarp. Some laminae show normal grading; all are flat-lying and laterally persistent at the base of the 12 cm layer. Bioturbation is absent in these laminae, but it increases significantly in the overlying more crystalline strata. Fossils are generally uncommon and scattered through most of this 12 cm layer. Certain bedding surfaces, however, contain common to abundant dalmanitid trilobites, ostracods, papillate annelids, dendroid graptolites (figure 4) or conulariids (figure 7). Brachiopods, corals, sponges, ?algae, ?hydroids and nautiloids are rare. The unique stratigraphic and sedimentary setting of the Waukesha locality presumably controlled the preservation and possibly the distribution of the biota, and therefore further occurrences are unlikely to be found at other exposures in the area, which do not expose the scarp. The presence of rip-up clasts in the basal beds of the Brandon Bridge suggests a relatively high energy environment. The laminated strata that dominate the Brandon Bridge, however, indicate deposition under much lower energy conditions. Fine laminae, and the absence of bioturbation and limited degree of decay suggest rapid deposition perhaps under anoxic bottom conditions; the rhythmic nature of bedding indicates cyclicity, possibly in a tidal setting. The sedimentology of the Brandon Bridge both at this locality and regionally requires further study to determine fully depositional environments.

The strata containing the soft-bodied biota have been dated as latest Llandoverian on the basis of the graptolite *Monograptus spiralis* (W. B. N. Berry, personal communication, 1977). Conodonts near the top of the Brandon Bridge at Waukesha indicate a late Llandoverian–early Wenlockian age (J. Barrick, personal communication, 1977). Presence of the trilobite *Stenopareia* indicates that this unit is early Wenlockian or older.

Quality of preservation varies widely among specimens even within the same taxon. All fossils are flattened. Conulariids show the most pronounced effects; the majority are laterally compacted but a few are oriented dorsoventrally. Trilobites and other shelly taxa are decalcified to varying degrees, and poorly preserved. Some specimens of soft-bodied or lightly sclerotized organisms are preserved only as thin films, others are infilled by diagenetic fluorapatite which may preserve delicate features, such as the lenses of compound eyes.

The overall composition of the Waukesha biota contrasts sharply with assemblages typical of the Silurian of this area, which are dominated by brachiopods, molluscs, rugosan and tabulate corals, bryozoans, and echinoderms. Away from the vicinity of the scarp, the Brandon Bridge is less argillaceous and poorly fossiliferous, containing scattered trilobites (mainly *Stenopareia imperator*), orthocones, brachiopods, and echinoderm debris. Arenaceous foraminiferans and conodonts are locally common and diverse. Argillaceous strata contain common trace fossils.

Trilobites, represented by 13 genera, dominate the biota in both diversity and abundance. Unfortunately decalcification reduces the quality of preservation, making specific and, in some cases, generic identification difficult. An undescribed dalmanitid (figure 6) is the most abundant trilobite; *Stenopareia*, *Meroperix*, *Leonaspis*, and *Scotoharpes* are characteristic but uncommon. Other trilobites (*Arctinurus*, calymenids, phacopids, otarionids, cheirurids, encrinurines, proetids) are rare. Trilobites are scattered throughout the 12 cm productive layer, but both articulated and disarticulated dalmanitids locally cover bedding surfaces. Nearly all the articulated specimens are outstretched and dorsal side uppermost. However, only the ventral surfaces of most specimens is exposed when the rock is split.

Trilobite hypostomes are rare; none has been observed *in situ* on any of the numerous ventrally exposed complete specimens. No trilobite appendages have been discovered, although preservation of other lightly sclerotized arthropods suggests that they may yet be found. The absence of hypostomes and appendages in the locally abundant articulated specimens suggests that the trilobites are represented by transported exuviae. Trilobites in the rest of the Brandon Bridge, both at this locality and regionally, are not decalcified and their relative abundance differs from that in the 12 cm fossil layer. Disarticulated *Stenopareia* is common in overlying more calcareous strata at Waukesha and is scattered through much of the Brandon Bridge elsewhere. Rare disarticulated cheirurids, scutelluids, and calymenids also occur.

In addition to trilobites, the three other major groups of arthropods, crustaceans, chelicerates and uniramians, are also represented in the Waukesha biota. The crustaceans are represented by at least two ostracods, one of which, a large leperditicopid (figure 10) occurs in large numbers on some bedding planes. Some specimens are preserved in the 'butterfly' position, with the two valves attached, suggesting limited transport. Two ceratiocarid phyllocarids (figure 8) are also present. Details of the carapace sculpture are beautifully preserved, and traces of poorly preserved thoracic appendages are evident on some specimens.

The earliest example of an enigmatic group of bivalved arthropods which range to the lower Jurassic is also present (figures 2 and 9). The carapace, which encloses the body and all but the distal extremities of the appendages, reaches lengths of up to 70 mm in the specimens so far discovered at Waukesha. A shallow anterodorsal concavity accommodates the eye, which projects beyond the valves. The head bears at least three massive spinose raptorial appendages. There are more than 20 trunk somites, each bearing elongate flap-like limbs. The separate status of these arthropods has been established only recently; Pinna *et al.* (1982) described new exceptionally preserved species from the Jurassic of Osteno, northern Italy (see also this symposium) and referred them to a new class of crustaceans, the Thylacocephala. Secretan (1983) described related taxa from the Jurassic of southern France and she also erected a new class, Conchyliocarida (see also Secretan & Riou 1983). Briggs & Rolfe (1983) described material lacking preserved soft parts from the Upper Devonian of Australia and referred it to a new order, Concavicarida, tentatively identified as Crustacea. The oldest previously known example is from the early Devonian of Czechoslovakia (Chlupáč 1963). The Waukesha occurrence is the first Palaeozoic example with preserved soft parts and extends the range of these extraordinary arthropods some 40 million years. The possibility of crustacean affinity remains equivocal.

The Waukesha biota includes at least one chelicerate, the earliest completely preserved xiphosure, but no eurypterids have been found. The prosoma (figure 11) is semicircular, with pronounced radiating ridges in the interophthalmic area. Six pairs of prosomal limbs are evident (figures 3 and 12), the sixth showing equivocal evidence of a chela. The trunk comprises 10 or 11 segments and is divided into a pre- and post-abdomen. The telson is short and styliform. This xiphosure shows some similarity to *Bunaia woodwardi*, a monospecific genus from the Silurian Bertie Waterlime of New York. Eldredge (1974) restudied the four known specimens of *B. woodwardi* and assigned it to the Suborder Limulina. The Waukesha chelicerate, which is better preserved, may represent a new synziphosurine. The only other Palaeozoic xiphosurid with preserved appendages is the younger *Weinbergina* from the Lower Devonian Hunsrück Slate of West Germany (Stürmer & Bergström 1981); its prosomal appendages lack chelae.

The first unequivocal fossil uniramians are myriapods from the latest Silurian of the Scottish Midland Valley. The early fossil record of the myriapods has recently been reviewed by Almond (1985) who points out that it is often difficult to establish whether they occupied terrestrial or aquatic habitats. Those preserved as fossils normally occur in waterlain sediments and only respiratory organs (which are rarely preserved) provide a reliable criterion. Almond points out that there is some evidence of 'a diversity of aquatic uniramian lineages in the middle Palaeozoic' which might have given rise to the terrestrial Uniramia. The fossil record has yet, however, to reveal a marine uniramian (with the possible exception of the Middle Cambrian

Aysheaia (Whittington 1978; Robison 1985)). It is in this context that the occurrence of a myriapod-like animal in the Waukesha biota may be especially significant. In addition there are no records of Silurian or lower Devonian myriapods from North America. The head-region of the Waukesha animal (figure 13) is poorly preserved, yet distinct in outline; it bears possible eyes and at least three pairs of appendages. The trunk comprises about 11 'segments', each apparently divided into a longer and shorter section, only the former bearing limbs. These limbs are short with an expanded annulate proximal portion and a slender distal portion clearly divided into segments (figure 14). The material collected so far shows no evidence of additional branches to the limb. The trunk terminates in a telson with a posteriorly directed ventral process. This arthropod may represent the earliest known example of a marine myriapod.

There are at least three new arthropods that cannot be assigned to any of the four major groups, although further study and more material may clarify their affinities. All three lack a mineralized exoskeleton. The most common (figure 15, plate 2) is an elongate worm-like form with 30–40 trunk divisions, which reaches lengths of over 60 mm. The relatively short head is covered by a ridged dorsal shield or carapace. Projecting beyond this is a large compound eye (the lenses are preserved on UW 4001/18) and at least three pairs of long segmented limbs, the first directed anteriorly like an antenna. The trunk divisions show rounded pleural terminations, indicating that they represent tergites rather than sclerotized rings. The trunk limbs are poorly preserved, but appear to be short and lobe-like. Until more details of the appendage morphology are discovered the affinities of this arthropod are likely to remain uncertain. It shows some similarity to an extinct order of branchiopod crustaceans, the Jurassic Kazacharthra (see Tasch 1969), but the shared characters (multisegmented trunk, short head shield) are considered primitive for many arthropod groups and are, therefore, not a reliable indication of affinity.

The best preserved of the three new arthropods (figures 16 and 21) may also have crustacean affinities. It appears to lack a carapace. A pair of large compound eyes overlies a massive anteriorly projecting appendage which is not multisegmented like an antenna, but consists of about six articulating segments of variable length. The opposing members of the pair are preserved in a range of configurations, but it is clear that they could separate and meet in the mid-line with the tips in opposition. The appendage may have been raptorial; the specimens so far collected are not well enough preserved to reveal any distal specialization (for example, a chela). The length of the arthropod varies from about 10 to over 80 mm. The number of somites is usually about 11, but rare large specimens have as many as 30. The trunk appendages are best seen in specimens that have been infilled with a layer of fluorapatite. Each limb is composed of at least two branches, a slender segmented inner one, and a long leaf-like outer one which extends laterally beyond the trunk. The trunk ends in a short unit of apparently fused somites which lacks appendages apart from some terminal spines. This arthropod shows similarities to two crustacean classes, the branchiopods and to some extent the recently described remipedes (Yager 1981). Both may have large modified cephalic appendages but, as in the worm-like arthropod, the other similarities are essentially primitive and not a reliable indication of affinity. The earliest well documented branchiopod is *Lepidocaris* (Order Lipostraca) from the Lower Devonian Rhynie chert of Aberdeenshire, Scotland (Scourfield 1926). The remipedes have no fossil record, although Yager (1981) suggested the possibility of an affinity to the enigmatic arthropod *Tesnusocaris* from the Upper Carboniferous of Texas. Such a relationship, which also also been suggested by F. R. Schram (personal communication), is equivocal.

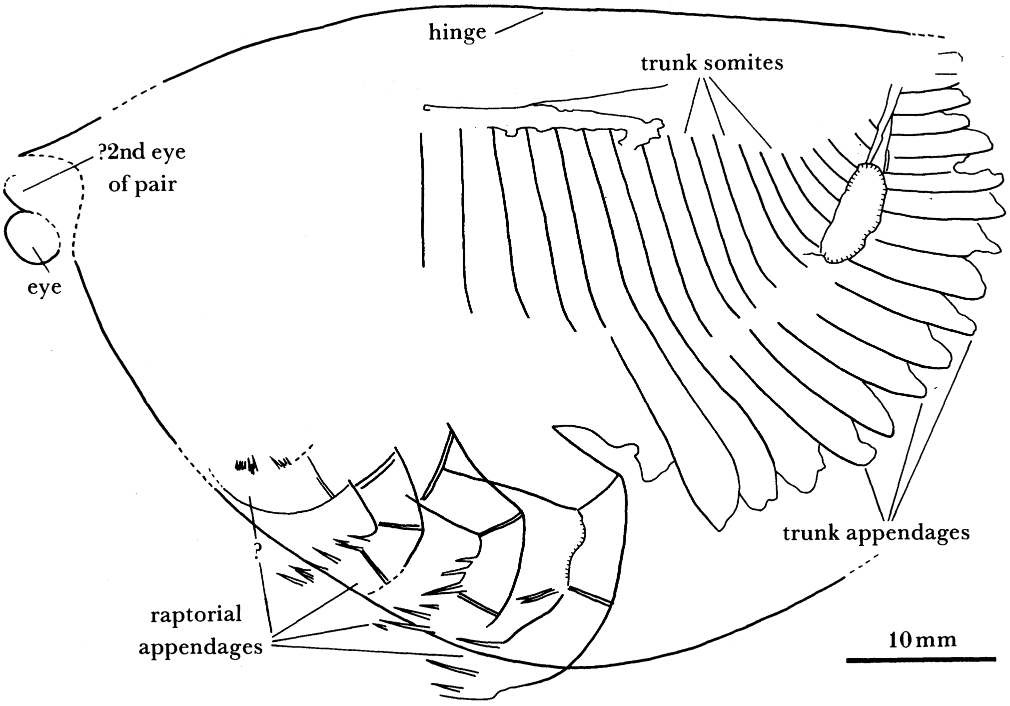


FIGURE 2. Explanatory drawing of UW 4001/8, see figure 9, plate 1.

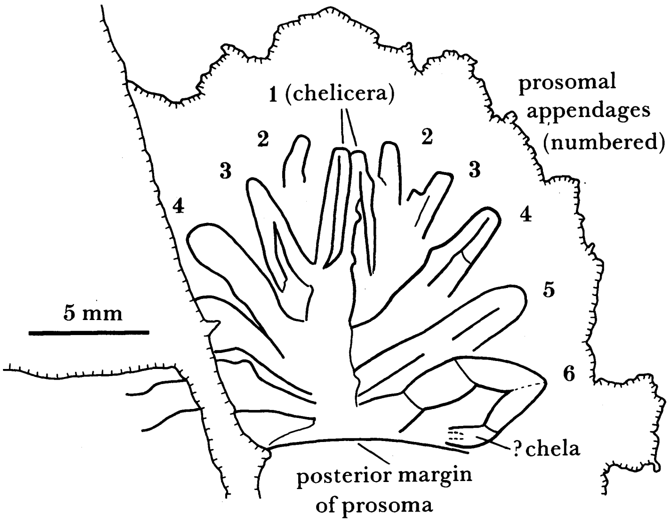


FIGURE 3. Explanatory drawing of UW 4001/9, see figure 12, plate 1.

DESCRIPTION OF PLATE 1

FIGURE 4. Dendroid graptolites, UW 4001/10. (Magn. × 2.2.)

FIGURE 5. Polished slab showing laminae in part of the 12 cm fossil-bearing horizon in the Brandon Bridge. (Magn. × 1.0.)

FIGURE 6. Undescribed dalmanitid trilobite, internal mould, UW 4001/11a. (Magn. × 1.4.)

FIGURE 7. Conulariid, UW 4001/12. (Magn. × 1.9.)

FIGURE 8. Ceratiocarid (Crustacea, Phyllocarida), UW 4001/13, right lateral view. (Magn. × 2.2.)

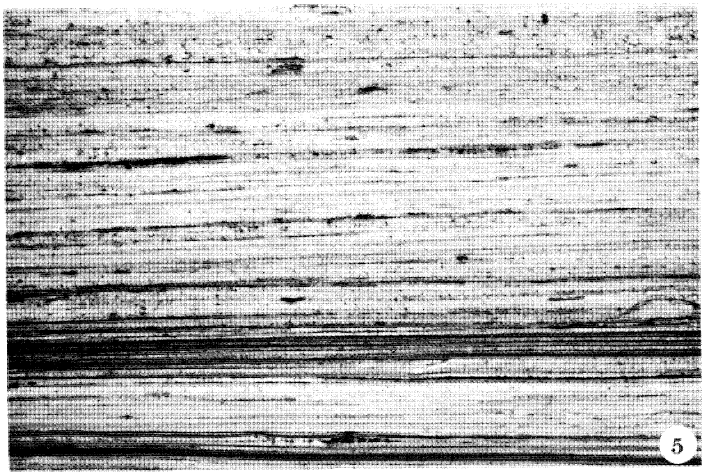
FIGURE 9. Concavicarid (?Crustacea, Thylacocephala), UW 4001/14a, left lateral view. (Magn. × 1.5.)

FIGURE 10. Leperditicopid (Crustacea, Ostracoda), UW 4001/15, right valve, internal. (Magn. × 3.0.)

FIGURES 11 AND 12. Xiphosurid (Chelicerata). FIGURE 11. UW 4001/1a, dorsal view. (Magn. × 2.) FIGURE 12. UW 4001/16a, cephalic region lacking prosomal shield and showing appendages, dorsal view. (Magn. × 2.5.)

FIGURES 13 AND 14. Myriapod-like animal (Uniramia). FIGURE 13. UW 4001/2a, left lateral view. (Magn. × 4.0.)

FIGURE 14. UW 4001/2b, counterpart, right lateral view, showing jointed appendages. (Magn. × 10.0.)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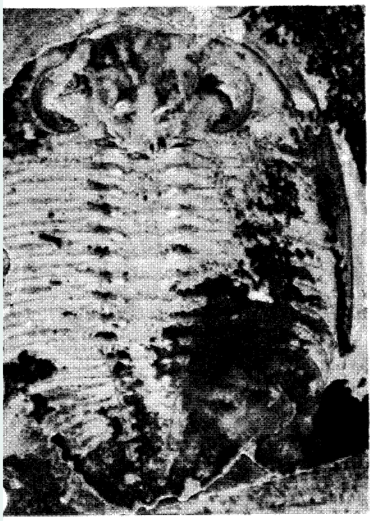

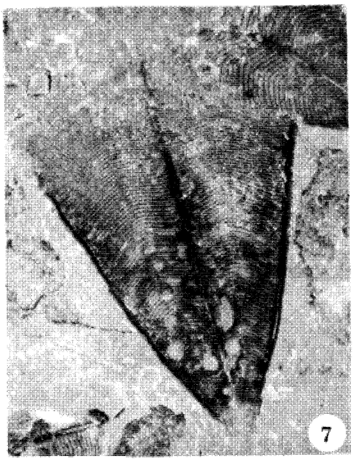
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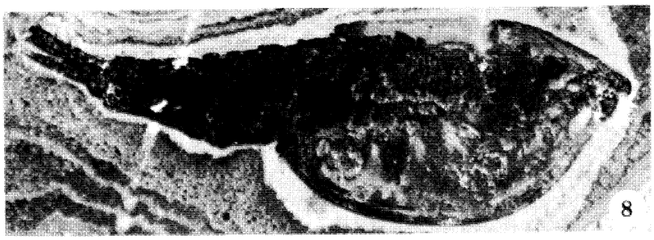
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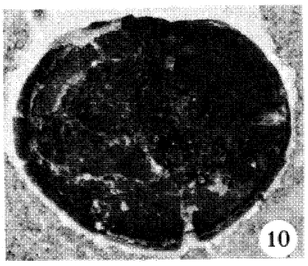
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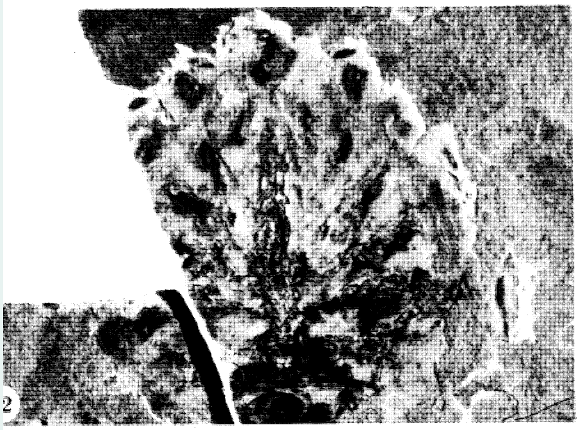
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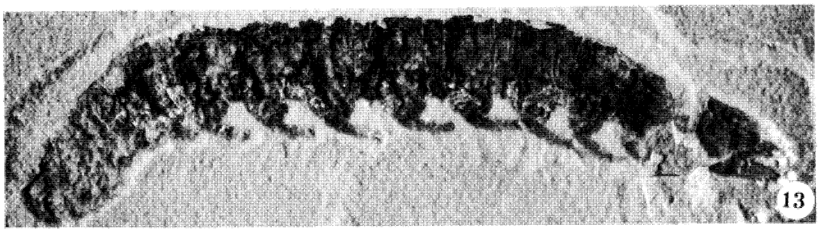
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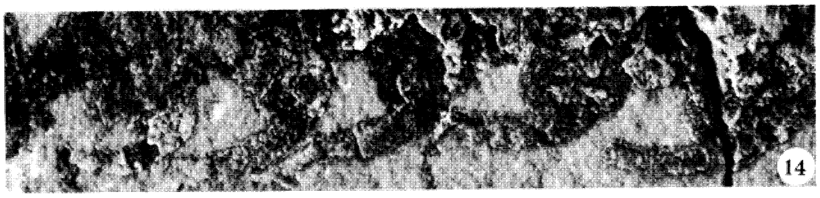
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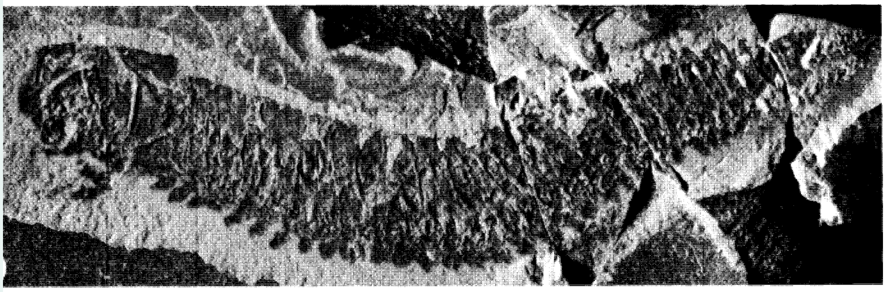
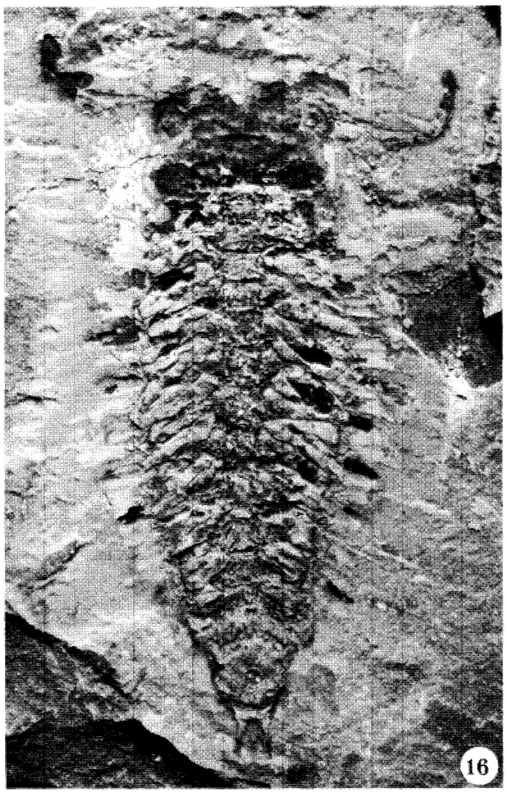
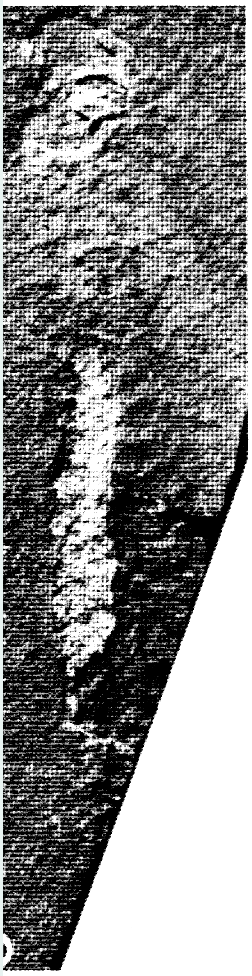
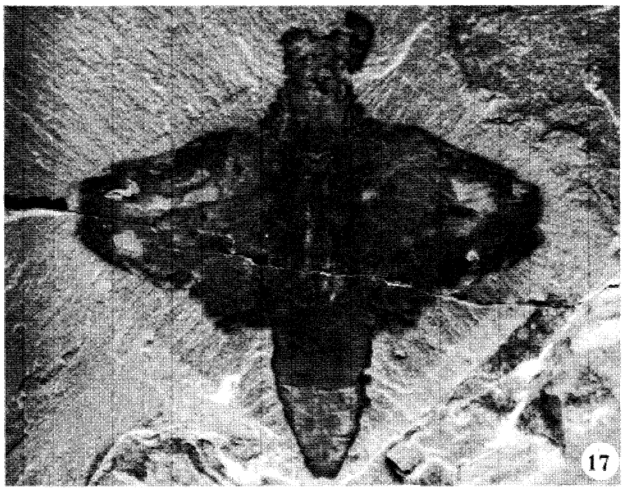
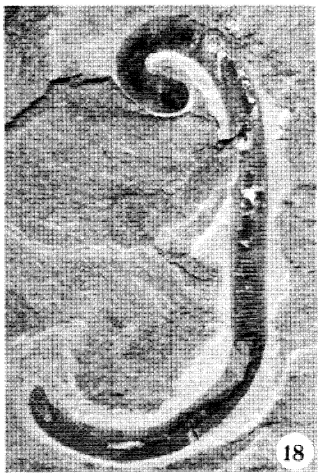
FIGURES 4–14. For description see opposite.











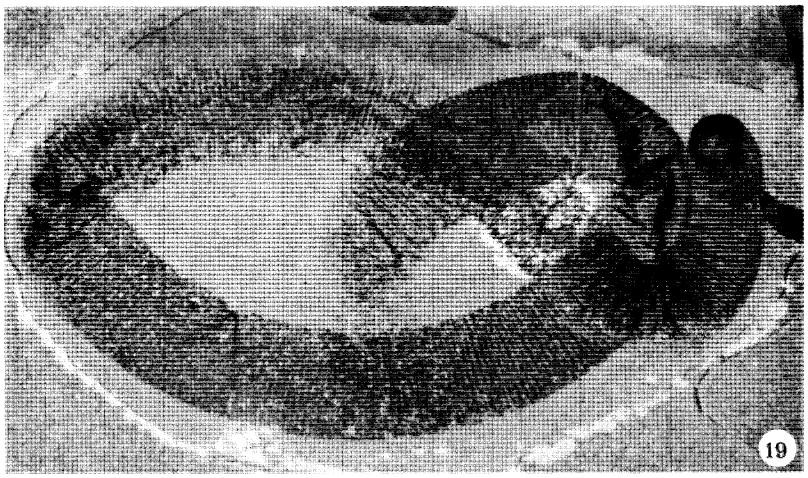


Figure 15. Worm-like arthropod, UW 4001/3, left lateral view. (Magn. × 2.0.)

Figure 16. Arthropod showing some similarity to both branchiopod and remipede Crustacea, UW 4001/4, ventral view showing appendages and axial segmentation. The fluorapatite infill is missing from the cephalic region. (Magn. × 4.0.)

Figure 17. Bizarre arthropod with possible bivalved carapace, UW 4001/5, dorsal view. (Magn. × 2.5.)

Figure 18. Papillate worm, UW 4001/17. (Magn. × 2.0.)

Figure 19. ?Leech, UW 4001/6. (Magn. × 1.8.)

Figure 20. *Panderodus* conodont animal, UW 4001/7a, dorsal view, conodont apparatus preserved anteriorly, traces of transverse segmentation evident along the trunk, part of which is preserved as fluorapatite. (Magn. × 8.0.)

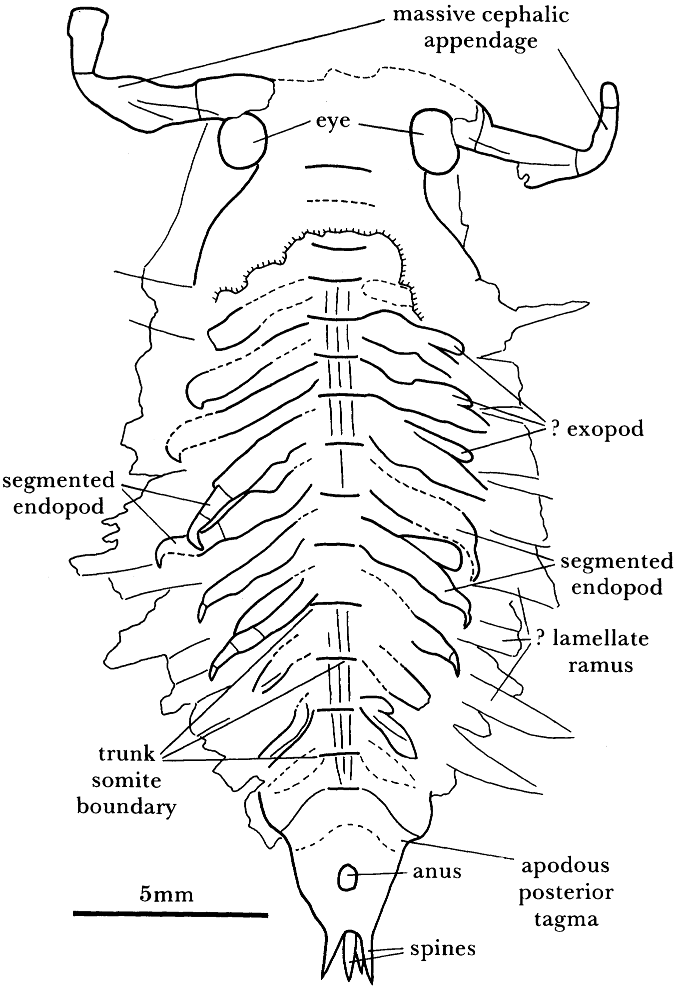


FIGURE 21. Explanatory drawing, UW 4001/4, see figure 16, plate 2.

The most problematic member of the biota (figure 17) also appears to be an arthropod. All the smaller specimens (10–20 mm long) show a pair of large convex structures which cover most of the anterior part of the body and extend laterally beyond it. These structures are symmetrical about the axis and vary in outline from subtriangular to semicircular. They may represent some sort of bivalved carapace. The 'valves' are traversed by striations in a criss-cross pattern which may be emphasized by diagenetic fluorapatite. Specimens are commonly poorly preserved, particularly at the periphery, but structures preserved in some, extending anteriorly beyond the 'carapace', may represent eyes or cephalic appendages. Posteriorly a short segmented trunk of seven or eight divisions extends beyond the 'carapace' but no indication of appendages is preserved. Future discoveries of more completely preserved material may be necessary to determine the affinities of this animal. The bivalved 'carapace' and segmented 'trunk' are reminiscent of the phyllocarid crustaceans, but the similarity may be superficial. A smaller number of very large specimens have been found which are similar in outline to the 'carapace' (although their 'valves' are relatively wider) but lack the trunk or cephalic area. These reach total widths (measured normal to the axis) of up to 20 cm. These specimens may represent the remains of exuviae of large individuals, the 'carapace' being slightly more heavily sclerotized than the rest of the exoskeleton. No specimens which could represent the exuviae of the smaller individuals have so far been discovered, however, and more complete material will be necessary to confirm the hypothesis.

The fauna includes at least four worm taxa, including polychaetes which are represented only by scolecodonts. The most common worm is an annulate form (figure 18) the well preserved cuticle showing two rows of papillae per annulation. The papillae may have borne setae but none is preserved. This worm belongs to a group of papillate forms referred to species of *Protoscolex* and *Palaeoscolex*. They range from Lower Cambrian to Upper Silurian and may represent a separate class of annelids (Conway Morris 1977; Conway Morris *et al.* 1982). The longest complete individual from Waukesha is 70 mm and 2 mm wide, but an incomplete example 4.5 mm wide (UW 4001/19) is in the upper part of the size range for the group (Conway Morris 1977, table 4). The worm is uniform along its length, tapering rapidly at both ends to a conical termination. No unequivocal evidence of jaws has been observed, but this may be preservational. The gut is usually evident in relief, possibly sediment-filled, and the worm may have been an infaunal deposit feeder. A range of well preserved specimens from Waukesha appears to show a transition between the configuration of papillae characteristic of *Protoscolex* and *Palaeoscolex*.

The best preserved specimen of a larger, very rare annulate worm (figure 19) is over 160 mm long and tapers from a maximum width of about 8 mm to less than half that where it ends in a clearly defined circular structure. The other end is not preserved. No cuticle is preserved and there is no evidence of papillae, setae or other lateral projections. The circle is reminiscent of the sucker of a leech, but the paucity both of other diagnostic characters, and of specimens, prevents a confident assignment to the Class Hirudinea. The only known fossil leeches are two species from the Upper Jurassic lithographic limestones of Bavaria, West Germany (Kozur 1970). If the Waukesha worm is a leech it probably preyed on small invertebrates as do living non-parasitic forms.

A single specimen (UW 4001/20) of a large worm with irregular annulations and short curved ?spines or setae is too poorly preserved to be interpreted. Tiny thread-like features evident on some surfaces may represent a further worm taxon.

The Waukesha locality has so far yielded a single specimen of a conodont animal (Mikulic *et al.* 1985), a bedding plane assemblage of coniform euconodont elements referable to *Panderodus*, with associated soft parts (figure 20). The soft parts are poorly preserved; a layer of fluorapatite partly obscured by sediment reveals little except an elongate outline and traces of transverse divisions which may represent segmentation. The discovery is important, however, as Waukesha is only the second locality to yield a conodont animal. The first is in lower Carboniferous rocks near Edinburgh, Scotland (Briggs *et al.* 1983), and the animals that occur there bear much more complex multielement apparatuses, including ramiform and pectiniform, but no coniform elements. Briggs *et al.* (1983, p. 12) elected to follow Clark (1981) in assigning the conodonts to a separate phylum Conodonta 'until more specimens with preserved soft-parts are discovered'. In doing so they compared the conodonts with both chordates and chaetognaths and pointed out that the 'segmentation' evident in the posterior part of the trunk of the Edinburgh animal was similar to the myotomes of amphioxus and fish. Segmentation also appears to be present in the Waukesha animal. There is no comparable structure in the chaetognaths. Bengtson (1983, p. 15) suggested that the traces of segmentation in the

Edinburgh animal 'could possibly be cuticular bandings or gonad structures, but both of these interpretations offer problems'. We hope that further collecting at Waukesha will reveal more conodont animals. More detailed information on the soft parts of *Panderodus* (and those of the Carboniferous animal) would help to clarify the affinities and mode of life of conodonts.

Our investigation of both the biotic composition and sedimentary history of the Waukesha biota is at a preliminary stage. Arthropods dominate in both abundance and diversity, and most are likely to have been vagile benthos. The worm taxa may have been infaunal. The sessile benthos is dominated by dendroid graptolites and conulariids; brachiopods, corals, sponges, and ?hydroids are very rare. The intact preservation of trilobite dorsal exoskeletons and ostracod carapaces, for example, suggests that transport was minimal, although some is required to explain the concentrations of trilobites that lack hypostomes and are therefore presumably exuviae. The preservation of soft and lightly sclerotized tissues, and the lack of bioturbation in the productive layers, indicates that decay was inhibited, probably by anoxic conditions. The thickness of the laminae, which presumably represent single influxes of sediment, or cyclic increments, does not suggest that the introduction of sediment was an important factor in 'trapping' the biota and excluding oxygen.

The Waukesha biota represents an association of Silurian organisms that is unusual apart from the exceptional preservation of soft-bodied taxa. Most notable is the low diversity of the fauna and absence or rarity of many shelly taxa which are characteristic of the Silurian carbonates of the mid-western United States: brachiopods, molluscs, rugosan and tabulate corals, bryozoans, and echinoderms. The Waukesha fauna is clearly not representative of that kind of assemblage, but may be no less important as an example of an environment only rarely preserved in the fossil record. A number of grossly comparable faunas have been described from the mid-western United States in which the sessile benthos is dominated by dendroid graptolites rather than corals. None, however, preserves the same proportion of soft-bodied and lightly sclerotized taxa, but they will none the less provide a basis for detailed comparison at a later date. Erdtmann & Prezbindowski (1974), for example, described a late Silurian fauna from Indiana containing dendroid graptolites, sponges, brachiopods, algae, scolecodonts, *Protoscolex*, nautiloids and trilobites, but also gastropods, pelecypods and crinoids. This biota is preserved in very fine grained carbonate–clastic muds in interreef basins. The *Lecthaylus* fauna (Weller 1925; Roy & Croneis 1931) from the late Silurian of northern Illinois occurs in a similar geological context and is made up of the enigmatic worm *Lecthaylus gregarius*, dendroid and monograptid graptolites, inarticulate brachiopods, phyllocarids and poorly preserved worms, including *?Protoscolex* (Roy & Croneis 1931). The late Silurian faunas of the Bertie Waterlime of New York State (Ruedemann 1925; Monahan 1931) contain some of the elements of the Waukesha biota, but also include diverse eurypterids which are totally unrepresented at Waukesha. The Konservat Lagerstätten of the Lower to Middle Silurian of the Midland Valley of Scotland (Rolfe 1973) which have yielded the problematic soft-bodied organism *Ainiktozoon* (Scourfield 1937) are also characterized by eurypterids. These eurypterid faunas may indicate different environmental conditions to those that prevailed at Waukesha. Our future work will focus on the sedimentology and taphonomy of the Waukesha occurrence, as well as describing the constituent taxa, to interpret the ecology, preservation and evolutionary significance of the biota.

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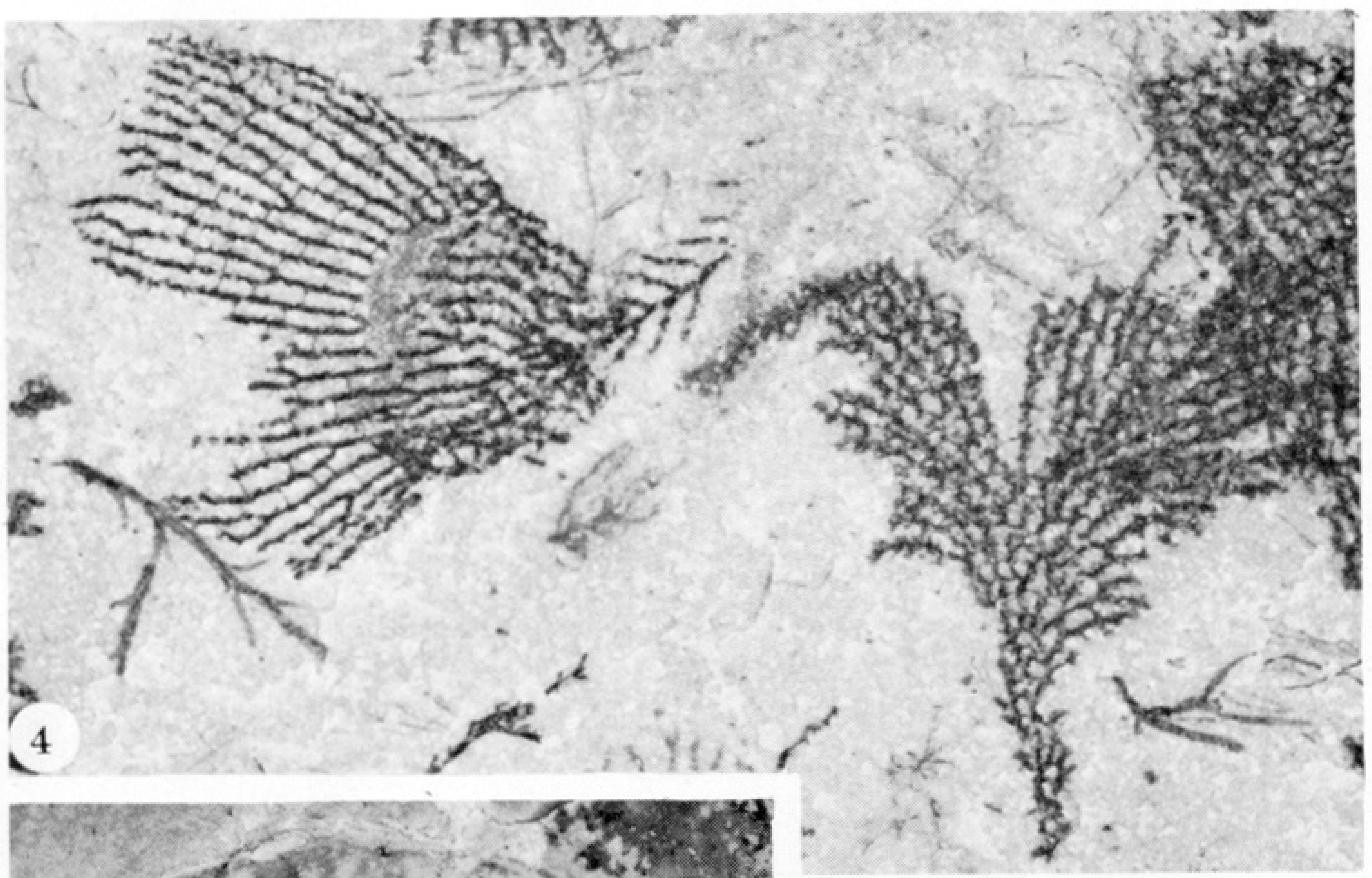
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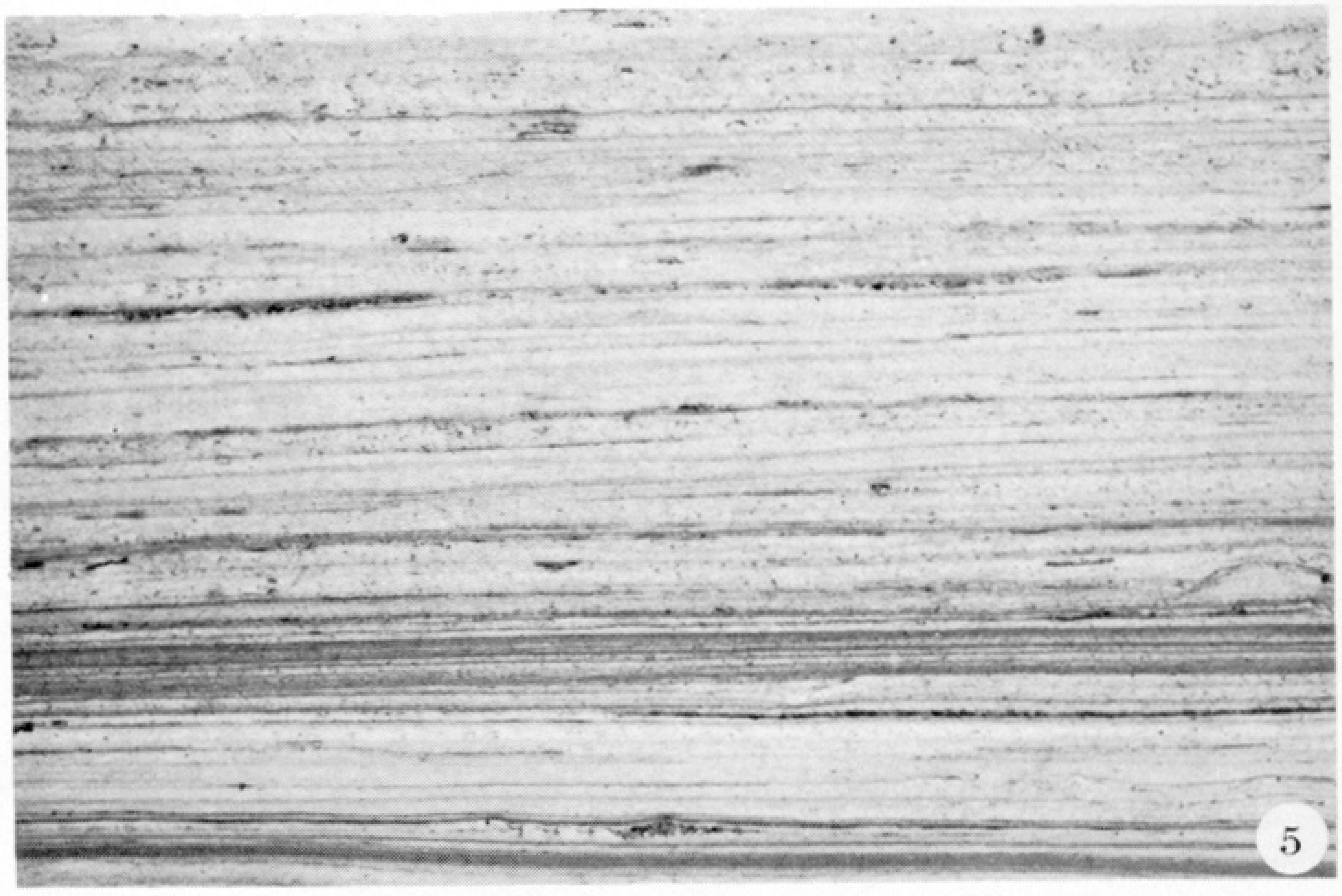
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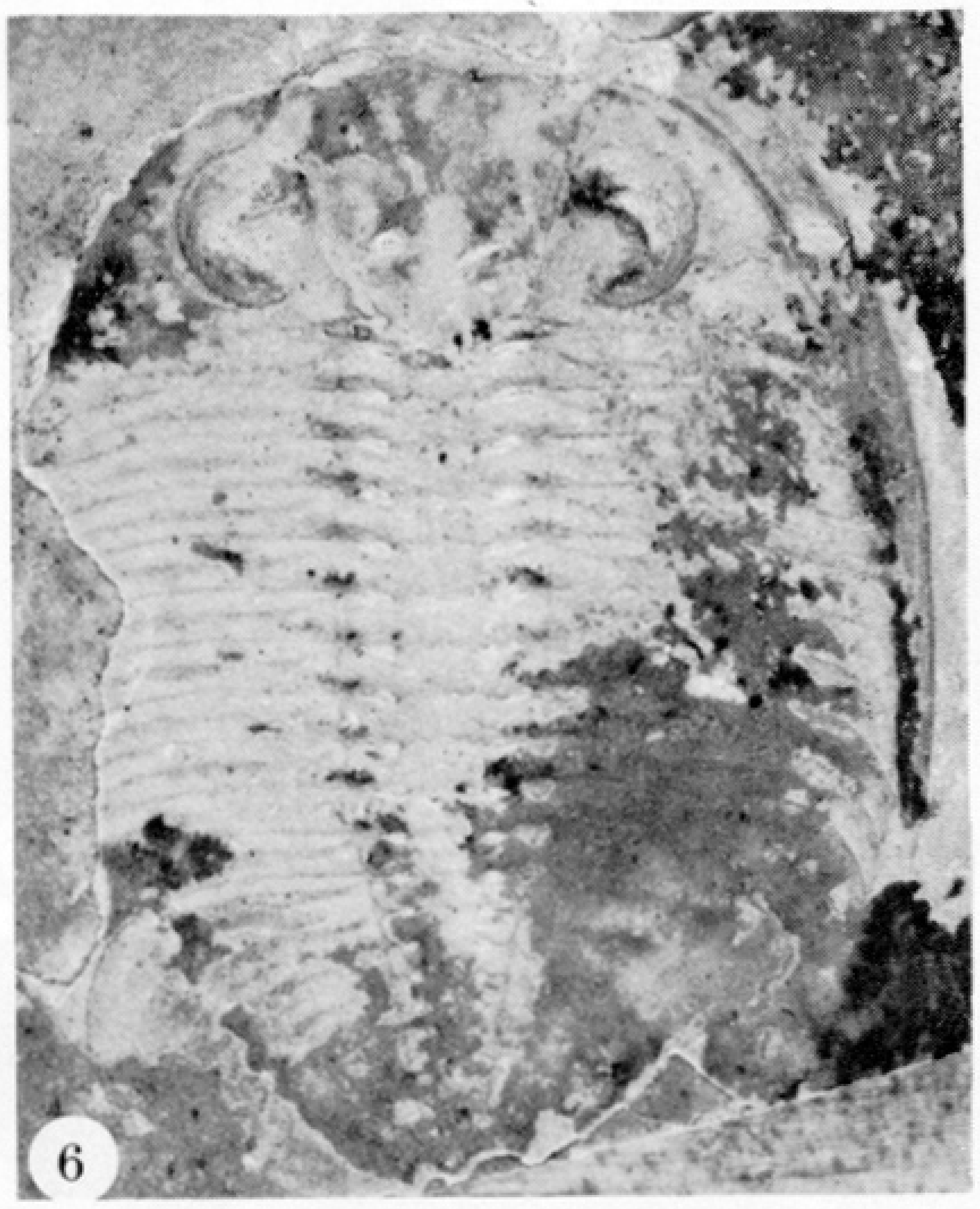
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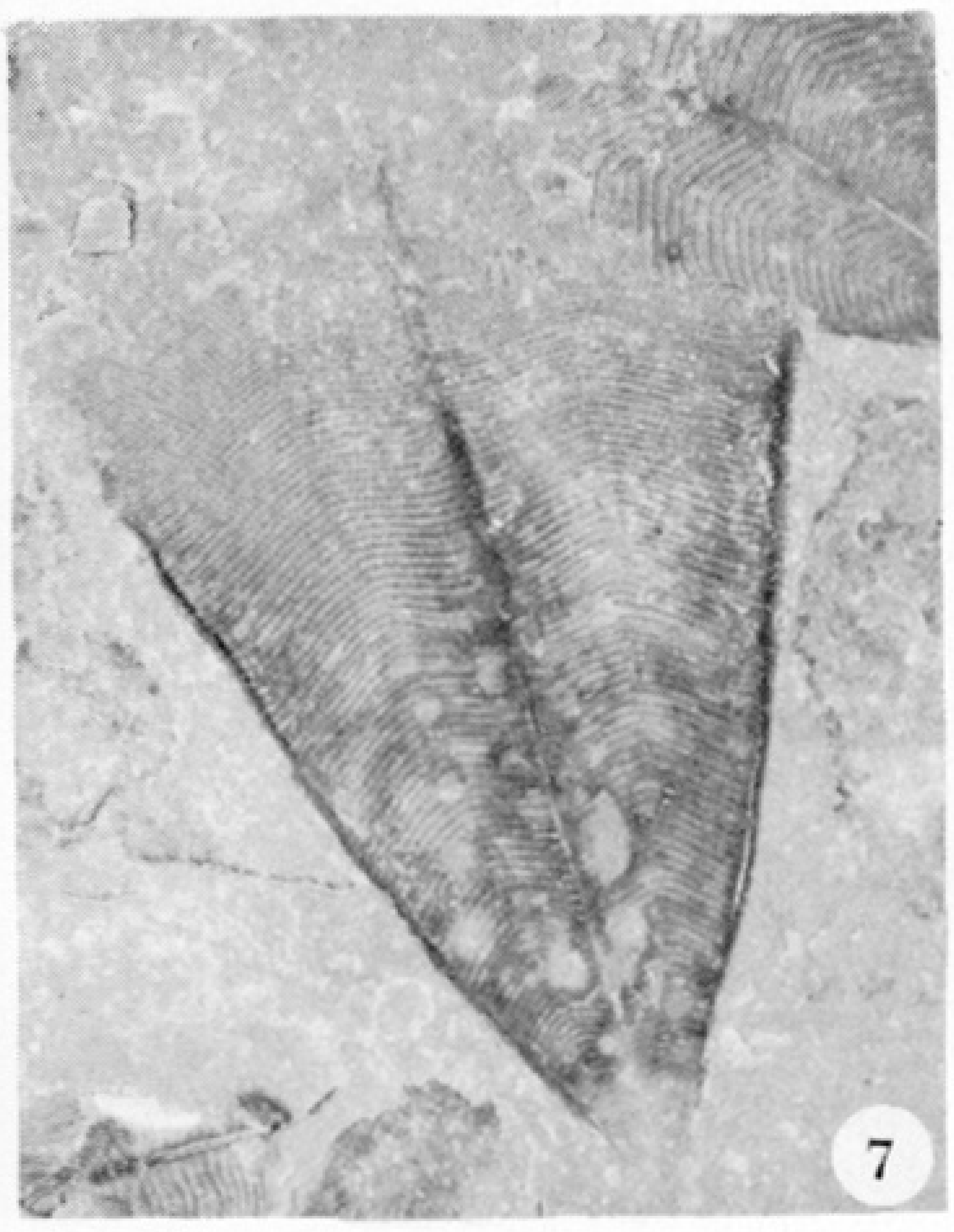
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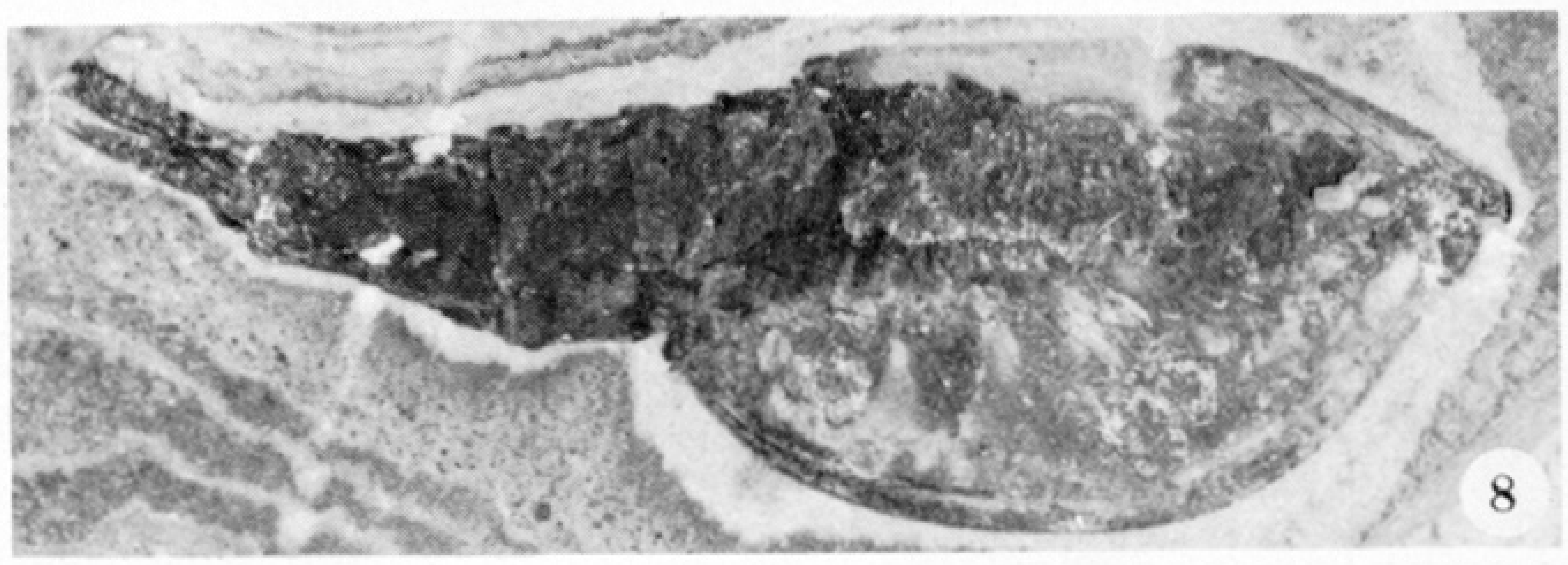
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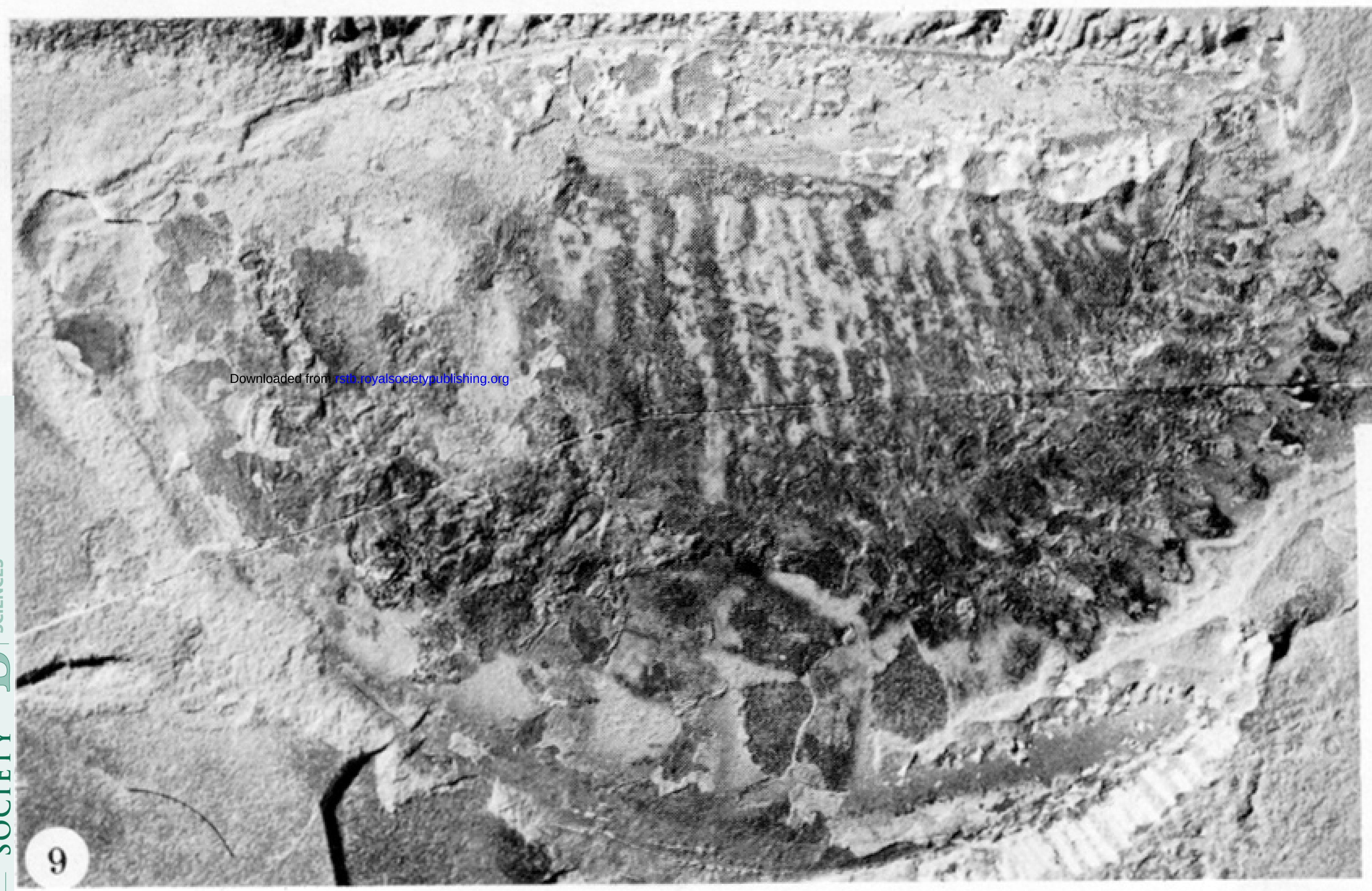
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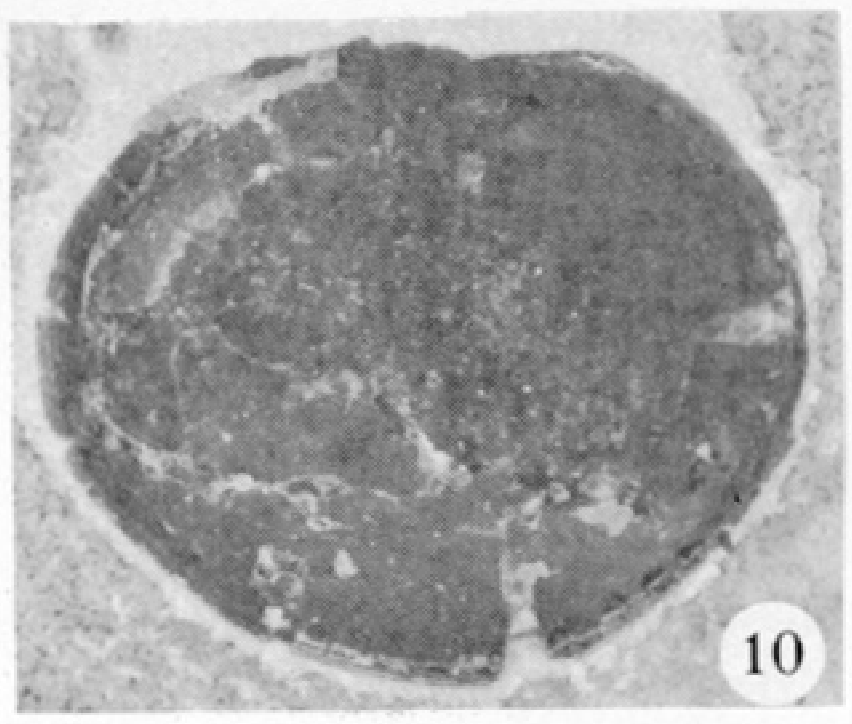
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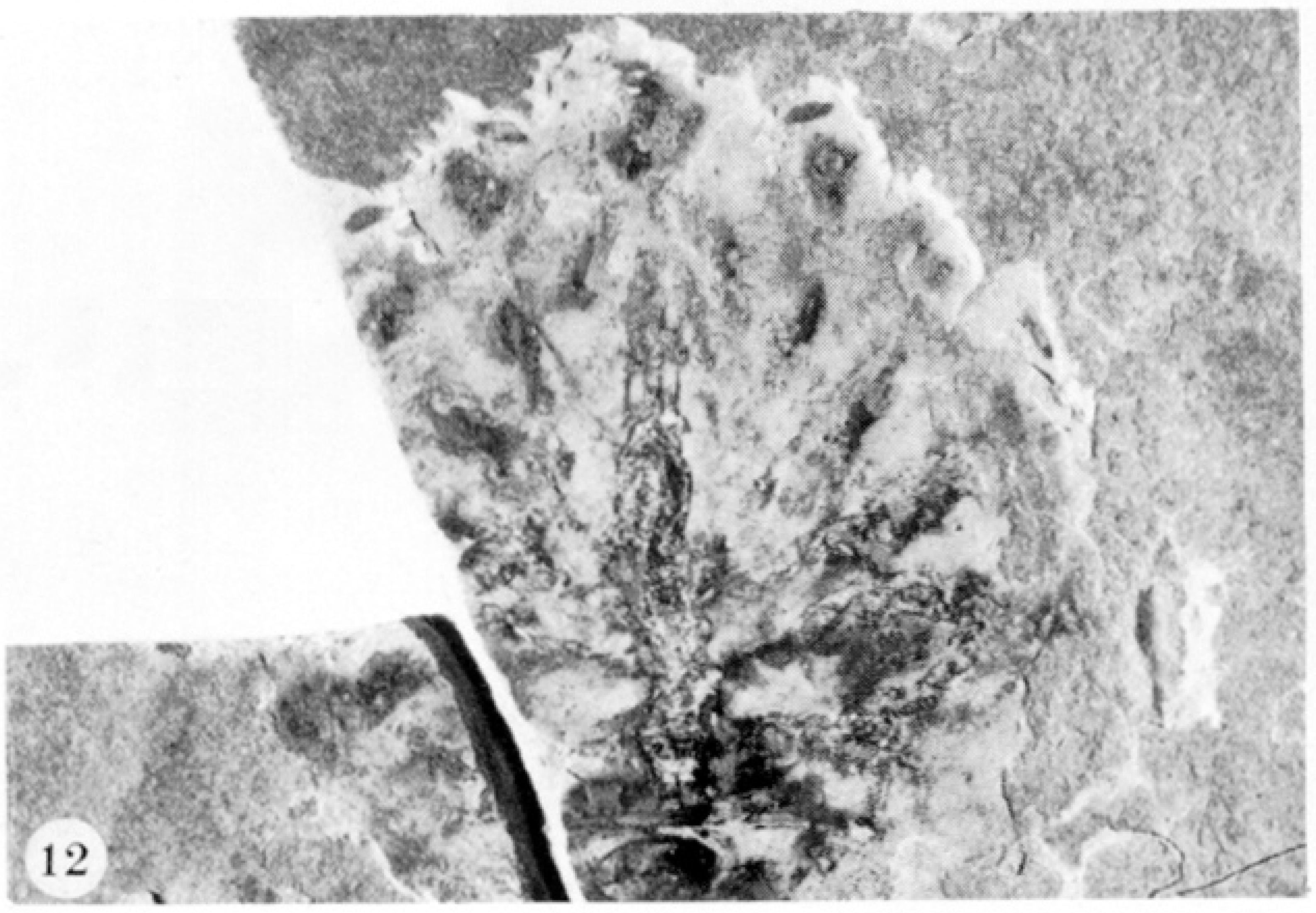
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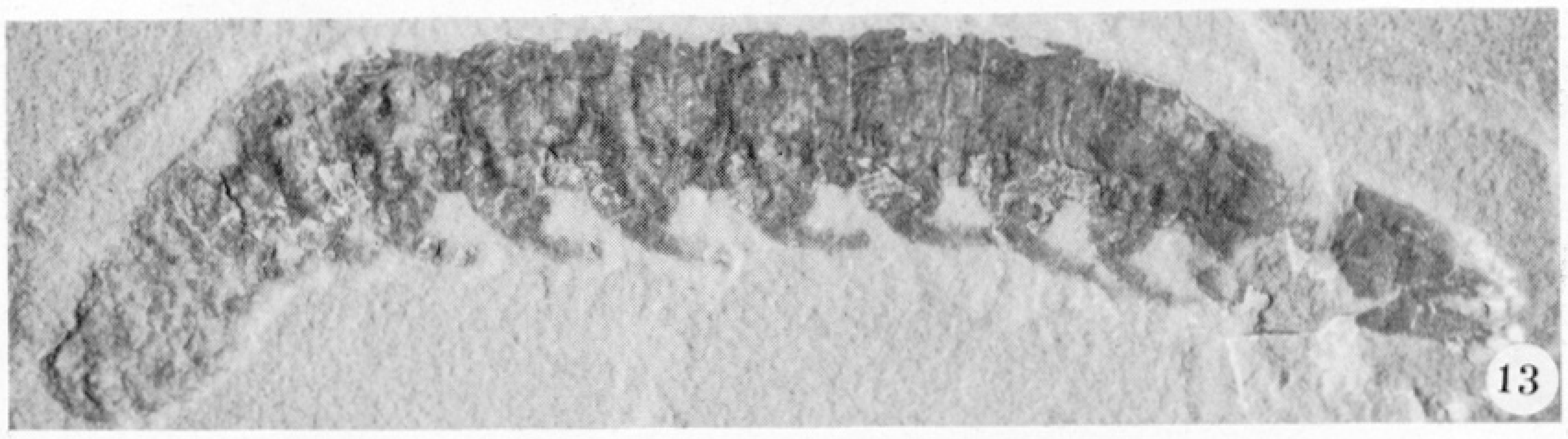
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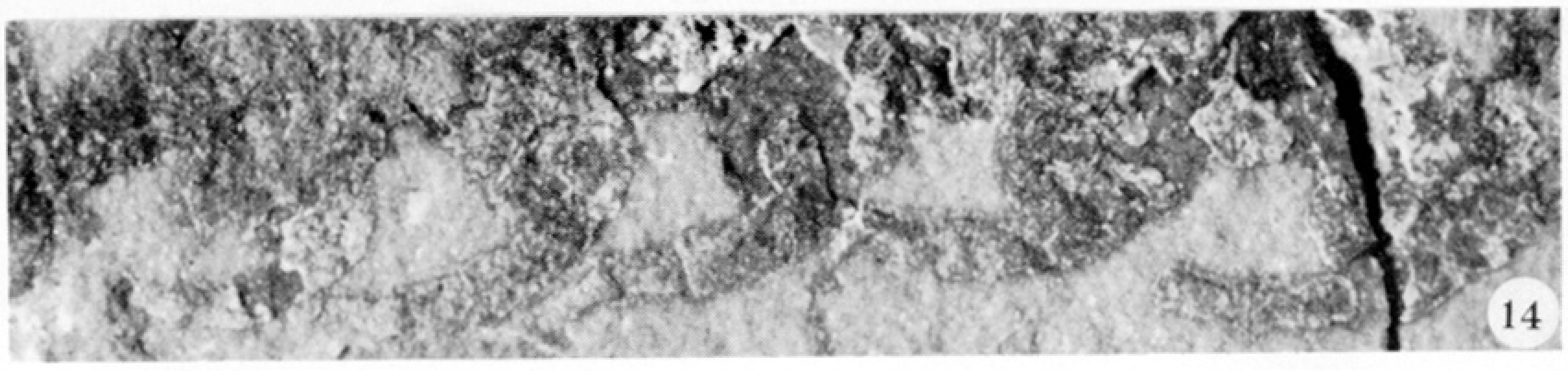
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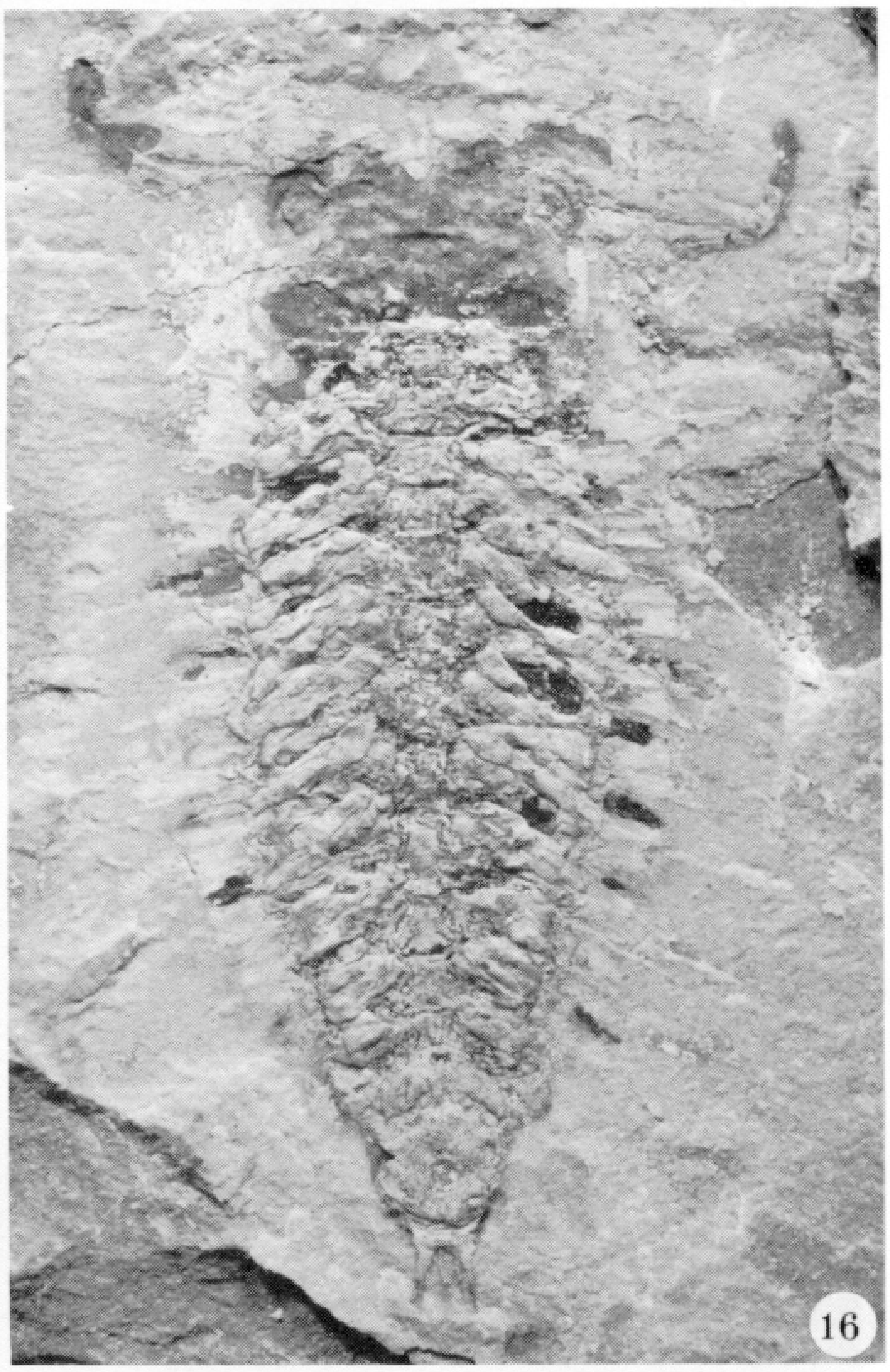
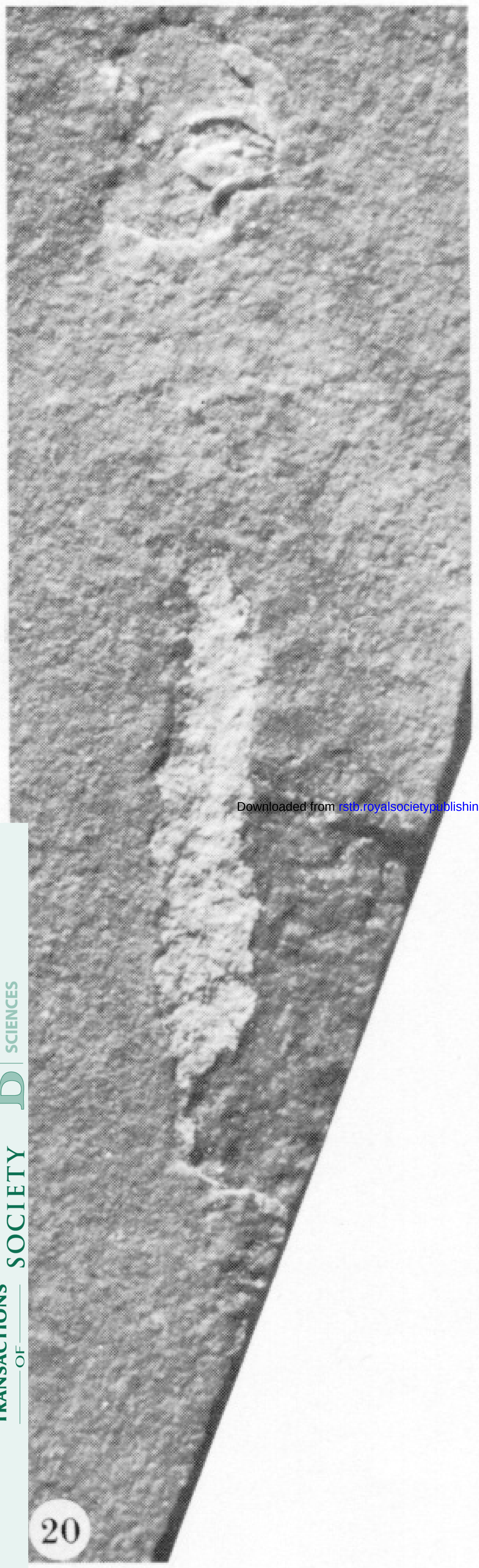
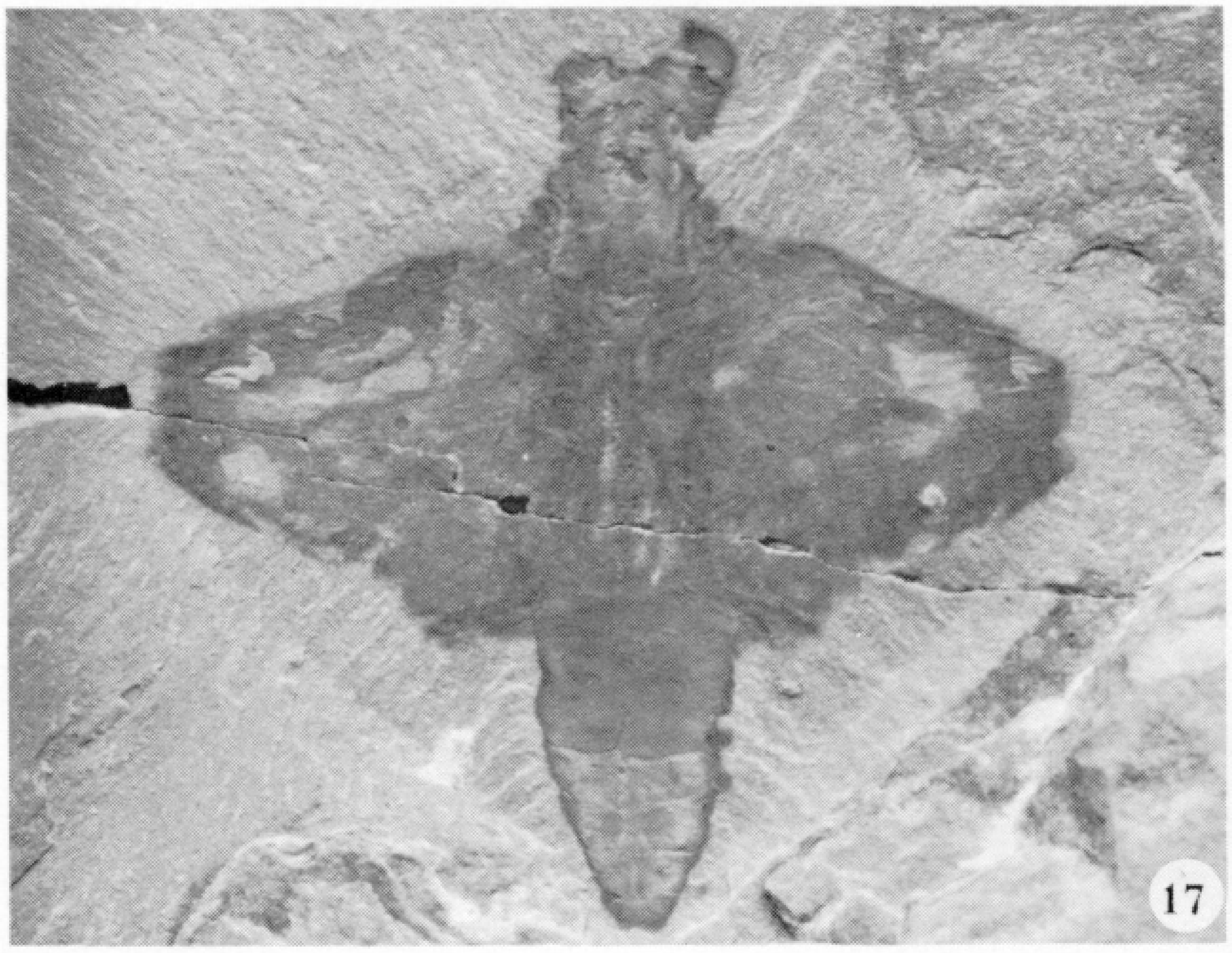
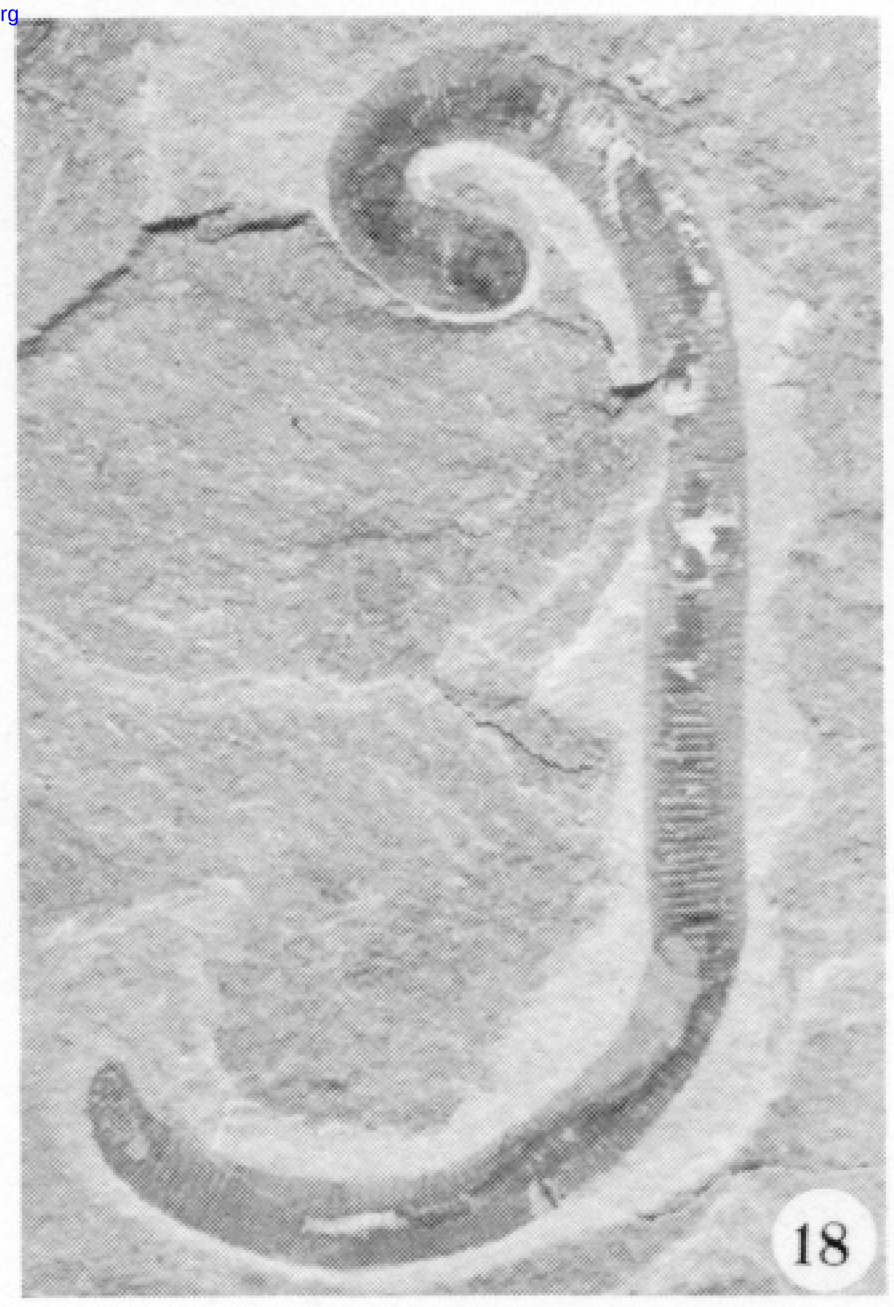
Figures 4–14. For description see opposite.









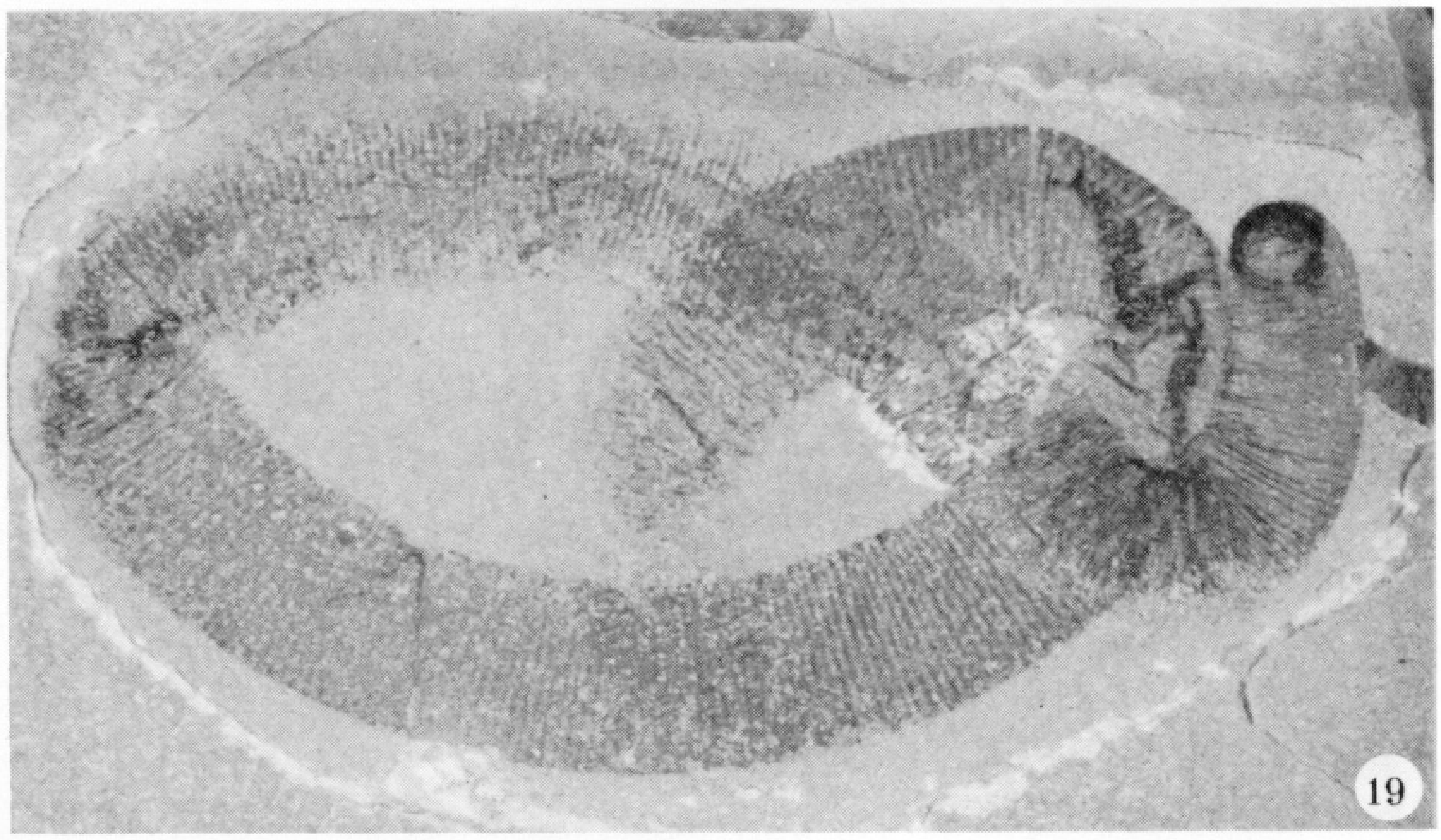


Figure 15. Worm-like arthropod, UW 4001/3, left lateral view. (Magn. ×2.0.)

Figure 16. Arthropod showing some similarity to both branchiopod and remipede Crustacea, UW 4001/4, ventral view showing appendages and axial segmentation. The fluorapatite infill is missing from the cephalic region. (Magn. ×4.0.)

Figure 17. Bizarre arthropod with possible bivalved carapace, UW 4001/5, dorsal view. (Magn. ×2.5.)

Figure 18. Papillate worm, UW 4001/17. (Magn. ×2.0.)

Figure 19. ?Leech, UW 4001/6. (Magn. ×1.8.)

Figure 20. *Panderodus* conodont animal, UW 4001/7a, dorsal view, conodont apparatus preserved anteriorly, traces of transverse segmentation evident along the trunk, part of which is preserved as fluorapatite. (Magn. ×8.0.)