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AN UPPER JURASSIC REEF COMPLEX FROM SLOVENIA, YUGOSLAVIA

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ABSTRACT

An Upper Jurassic (Oxfordian and lower Kimmeridgian) reef complex is well exposed in the area of Slovenia, northwestern Yugoslavia. This reef complex is thought to be a barrier-reef that developed along the shelf-margin of an ancient carbonate platform. From basin to lagoon the following subdivisions have been delineated: a fore-reef area characterized by carbonate breccias and blocks of reef debris; a central reef area with abundant hydrozoans and corals that can be further subdivided into actinostromariid and parastromatoporid zones; and, a back-reef area with locally developed lagoons and patch-reefs defined as the *Cladocoropsis* zone.

EXTENT OF REEF COMFLEX

In the province of Slovenia, coral-hydrozoan reefs of Middle Devonian, Upper Carboniferous, Upper Triassic, Upper Jurassic, Lower and Upper Cretaceous, and Oligocene ages are well exposed. Of these, the Upper Jurassic barrier-reef complex has the largest geographical extent. This barrier-reef complex can be traced, in a more or less continuous series of outcrops, from the Soča Valley across the central portion of Slovenia to Metlika into neighboring Croatia, and then along the entire Yugoslav Dinaric region into Albania. The reef complex also extends westward from the Seča Valley into Italy. In Slovenia, the reef complex extends for approximately 140 kilometers in length, is about 20 kilometers in width, and ranges in thickness from 200 to 600 meters (Fig. 1). Postulated restored length of the reef trend possibly amounted to at least several hundred kilometers, a distance comparable to that of the present Australian Barrier Reef.

STRATIGRAPHIC SETTING

It is thought that at the beginning of Upper Jurassic time the environment of this region changed considerably due to a pronounced warming trend. In Slovenia, the marginal portion of the Dinaric carbonate shelf passed laterally to the north and northeast into deeper water environments. Along the shelf-edge margin, between the carbonate platform and the deeper water areas to the north and northeast, a large barrier-reef complex was initiated. In places, reefal formations overlie lower Oxfordian platy, cherty limestones (Dogger micrite) with oolitic and crinoidal limestones. Occasionally, reefal limestones may lie unconformably on Liassic limestones. The basal portion of the reef complex consists of light-colored Oxfordian limestones composed of crinoids and echinoid spines. The limestones range up to 10 meters in thickness. These pass upward into massive, non-bedded reef units composed chiefly of corals and hydrozoans, which can attain a thickness of up to 600 meters. Faunal comparison of this reef interval with similar intervals in Europe and Asia indicates that these sediments range in age from Oxfordian to lower Kimmeridgian time. The reef interval is conformably overlain by limestones containing the alga *Clypeina jurassica* Favre, a form whose known stratigraphic range is from upper Kimmeridgian to Portlandian time (Buser, 1965 and 1978). It should be noted however, that some Croatian workers consider the algal interval as a reef equivalent, and regard it Tithonian in age (Nikler, 1978).

SUBDIVISIONS OF REEF COMPLEX

The reef complex is situated on the transitional portion of an ancient carbonate platform that faced towards the deeper open ocean of Upper Jurassic time. In cross-section (Fig. 2) lithological and faunal zonation can be followed from the deeper water basinal sediments of the north and northeast to lagoonal settings of the south and southeast. In the reef itself, a distinctive fore-reef zone can be distinguished, followed by a central reef area subdivided into two hydrozoan zones, this in turn giving way to a wide back-reef area with local patch-reefs.

Fore-Reef Area

This area consists of a reef-slope on which fore-reef sediments were deposited and which grades into basinal sediments. Fore-reef sediments are represented by calcareous breccias consisting of allochthonous blocks and fragments of reef lime-

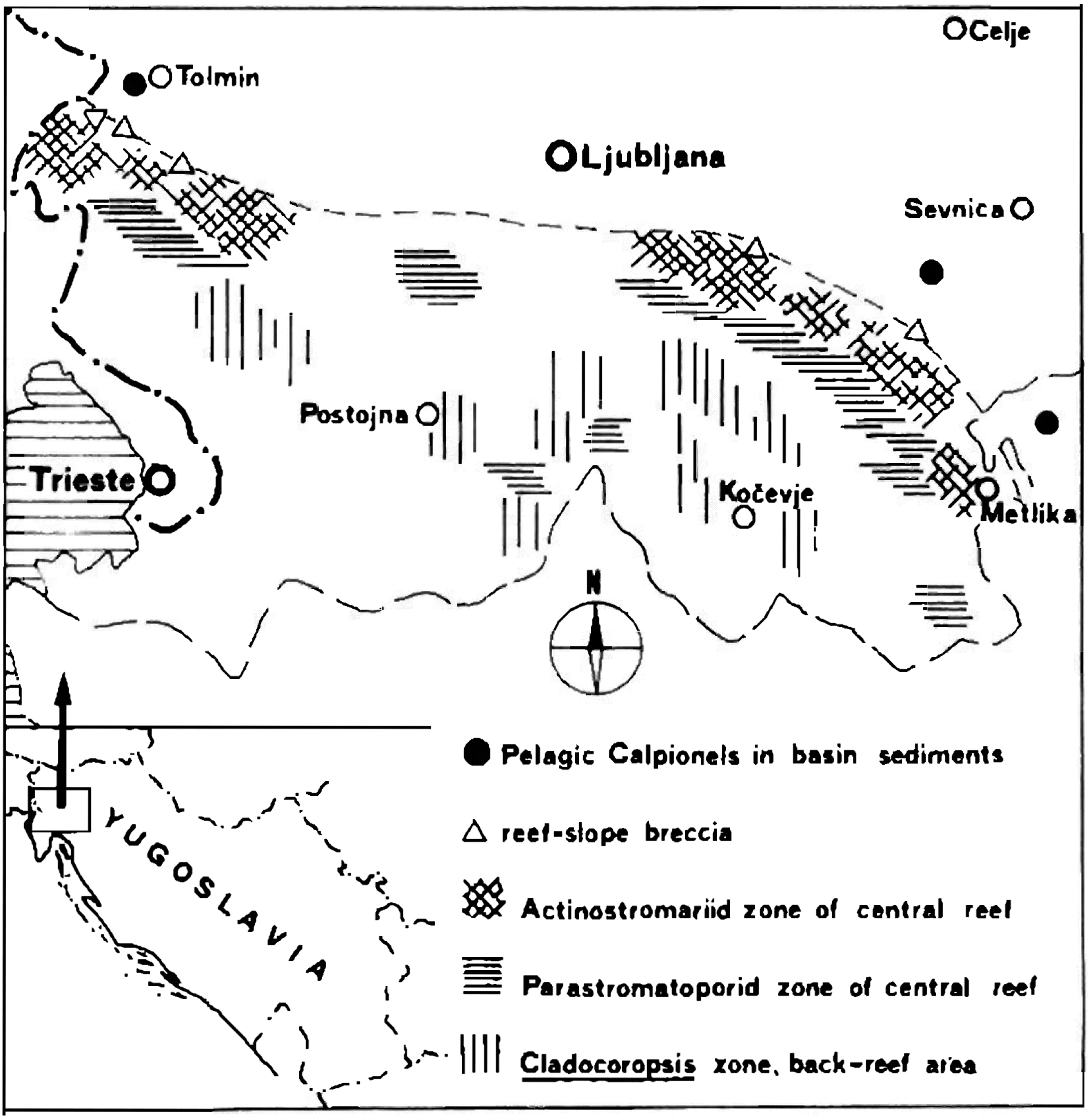

FIG. 1.—Index map showing location and extent of the Upper Jurassic barrier-reef complex exposed in Slovenia, northwestern Yugoslavia.

stone, usually cemented with reef detritus, crinoidal fragments, and echinoid spines. In some fore-slope beds graded breccias may be seen. Basinward of the breccias there is a conspicuous two mile wide belt of limestone consisting almost entirely of crinoidal fragments and echinoid spines. Some areas within this zone contain sporadic corals and hydrozoans. Deeper water basinal sediments consist mainly of marly limestones in which pelagic tintinnids and cephalopods are found.

Central Reef Area

This is a massive barrier-reef complex approximately 15 kilometers in width, which extends, with several interruptions, across the entire area of central Slovenia. The principal barrier-reef framebuilders are corals and hydrozoans. Based mainly upon hydrozoan distribution, two faunal subzones have been delineated. These are: actinostromariid zone on the platform-edge, and the parastromatoporid zone directly behind the above zone (Turnšek, 1966 and 1969).

The actinostromariid zone is 6 to 10 kilometers in width and is principally organogenic, consisting primarily of corals and hydrozoans. Typical forms of actinostromariids and sphaeractinids are shown on Figure 3. Identified genera include: *Astrostylopsis*, *Actinostromina*, *Coenostella*, *Sporadoporidium*, *Tubuliella*, *Sphaeractinella*, *Ellipsactinia*, and *Cylicopsis*. Of the above hydrozoan genera 26 species have been determined, all characterized by the orthogonal microstructure of the skeletal elements (Turnšek, 1966). Among the corals, representatives of all groups can be found with a total of 27 genera representing 38 species. Typical coral forms from the actinostromariid zone are illustrated on Figure 4. Most frequently occurring corals are species of the genera: *Pseudocoenia*, *Heliocoenia*, *Stylosmilia*, *Complexastraea*, *Clausastraea*, *Amphiastraea*, *Schizosmilia*, *Mitrodendron*, *Donacosmilia*, *Microsolena*, *Microphyllia*, *Dermosmilia*, *Calamophylliopsis*, and others (Turnšek, 1972). Massive and phaceloid coral colonies are dominant with solitary and ramose corals and chaetetids less abundant. Total hydrozoan biomass is much greater than total coral biomass, even though more coral species are represented. Other organisms occur only rarely within the reef limestones, among these are: nonskeletal algae, foraminifers, bryozoans, crinoid debris, and echinoid spines. Occasionally, brachiopods (*Terebratula formosa* Suess) can also be found. In the highest part of the reef interval numerous pelecypods (*Diceras*) and gastropods (*Nerinea*) occur associated with such problematical forms as *Tubiphytes morronensis* Crescenti, *Marierella dacica* Dragastan, and *Baccanella* cf. *B. parvissima* (Dragastan), according to Buser, 1978.

Lithological composition of the limestones in the actinostromariid zone is variable. Large fossil organisms are dominant, while the interstices contain debris of breccia and calcarenite. Rock cement is mainly sparite suggesting a high to very high water energy index. Well-washed sediments occur in the main reef areas marginal to the slope into the basin. Locally, areas of low energy may also occur; these are characterized by intervals of pelmicrite and biomicrite.

The parastromatoporid zone occurs in an approximately 5 kilometer wide belt directly behind the actinostromariid zone (Fig. 2). This zone differs from the actinostromariid zone primarily in the occurrence of different hydrozoans, and to some extent, differences in the coral assemblages. The limestones of this zone are composed of hydrozoans, corals, and chaetetids. Among the hydrozoans, parastromatoporid types are dominant. Some typical forms are illustrated on Figure 5. The following genera, represented by 9 species, are most common: *Parastromatopora*, *Dehornella*, *Hudsonella*, *Reticulina*, and *Shuqraia*. These hydrozoan forms are also characterized by orthogonal microstructure of the skeletal elements. Numerous chaetetids are also present, represented by species of the genera: *Bauneia* (Fig. 5F), *Chaetetopsis* (Fig. 5G), and *Ptychochaetetes* (Turnšek, 1966). Within this zone coral biomass is dominant, as well as numbers of species. In all,

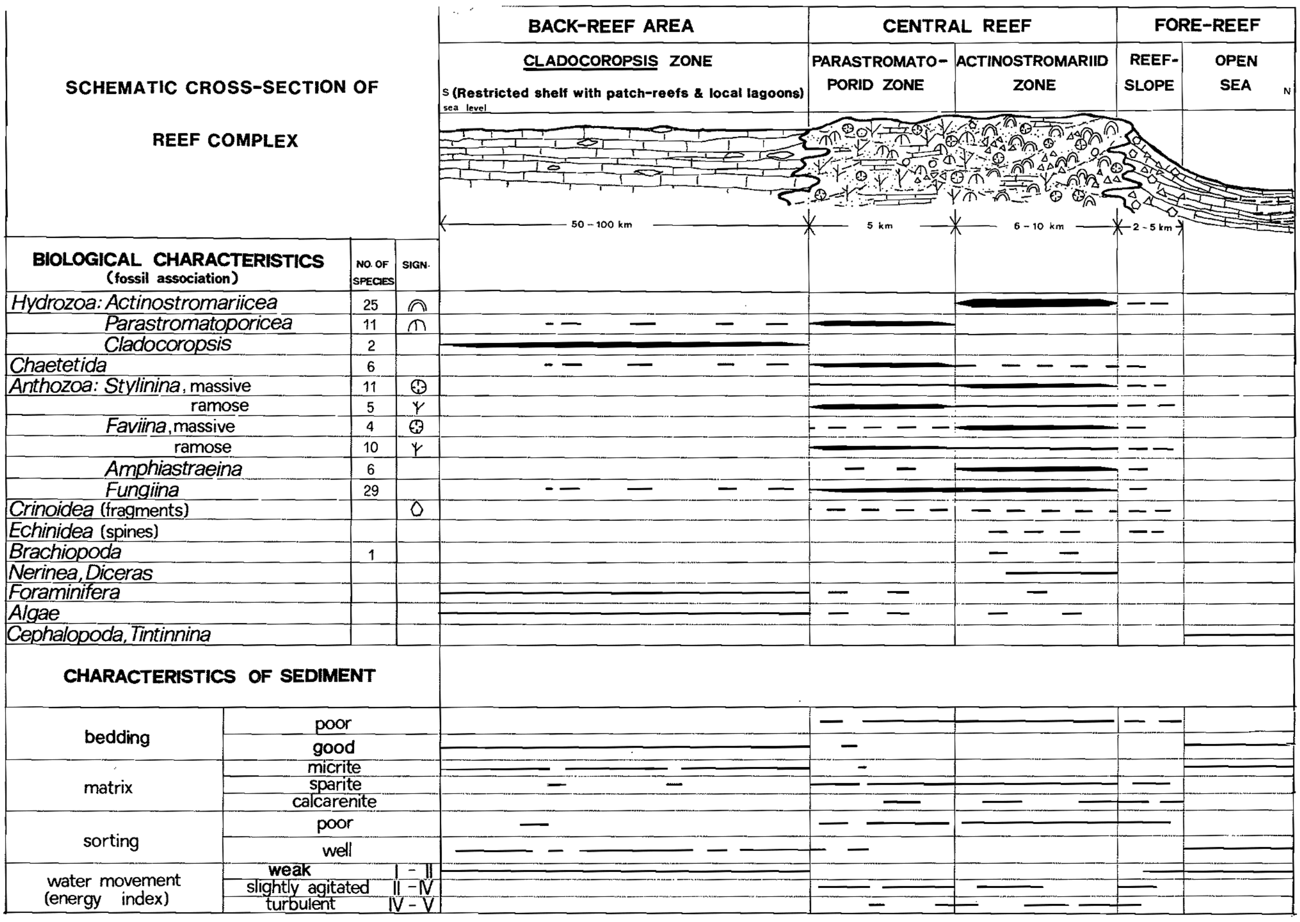

FIG. 2.—Schematic cross-section of the Upper Jurassic barrier-reef complex in Slovenia, northwestern Yugoslavia, showing its facies zonation, faunal associations, and characteristic sediments.

this zone contains 36 identified coral species, some of the more typical forms are illustrated on Figure 6. Most frequently occurring genera are: *Pseudocoenia, Stylina, Heliocoenia, Goniecora, Stylosmilia, Aplophyllia, Montlivaltia, Thecosmilia, Ceratothecia, Dermosmilia, Calamophylliopsis, Microsolena, Comoseris, Meandrophyllia, Thamnasteria, Fungiastraea*, and others (Turnšek, 1972). Compared to the corals of the actinostromariid zone, corals in this zone are dominantly ramose stilinids and faviids, and crust-like fungids. Less common are massive colonial growth forms, while amphiastraeids are very rare. Of a total of 65 coral species identified from the central reef area, only 6 coral species are common to both zones. In addition to the above organisms, only rare occurrences of red algae, foraminifers, brachiopods, gastropods, pelecypods, and echinodermal debris have been identified. These fossil remains are often coated with non-skeletal algae.

The lithological characteristics of the limestones in the parastromatoporid zone are similar to those noted in the actinostromariid zone. Here too, biolithites predominate with the skeletons of reef builders broken and deposited in place. Some calcarenitic debris, from poor- to well-sorted, is also present. The water energy index appears to have been variable reflecting varying depositional settings. For areas of moderately agitated water environment biomicrites are common. The occurrences of geopetal cements in the interstices of some biolithic material suggests that the reef complex was periodically emerged above sea level, and that cementation occurred under vadose conditions. At the Otlica locality oolites have been found; however, these are believed to have been transported from a different source area.

Faunal differentiation within the central reef area is the result of different ecological conditions. The reef grew along the shelf-edge or margin of a carbonate shelf-platform. Reef subsidence seems to have been continuous with the top of the barrier remaining within a constant depth range interval. On the ocean-facing side water movement was strongest, hence leading to an abundant supply of nutrients, accompanied by thorough water aeration. These conditions appear to have been ideally suited to the actinostromatiid hydrozoans, especially those forms with massive coenostea. Here too, massive colonial coral forms are abundant. Conversely, in areas farther back from the reef-front, as in the parastromatoporid zone, ramose and crust-like forms of reefs organisms thrived. During growth, the barrier-reef was constantly subjected to wave and current erosion and destruction, and broken reef blocks and fragments were redeposited and incorporated with skeletal debris forming calcarenites. It is to be noted that the present writers, on the basis of this study, regard hydrozoans as more environmentally sensitive organisms than corals, and thus more meaningful indicators of paleoecological environments.

Back-Reef Area (Cladocoropsis Zone)

The parastromatoporid zone of the central reef passes landward into the lagoonal shelf-area (Fig.

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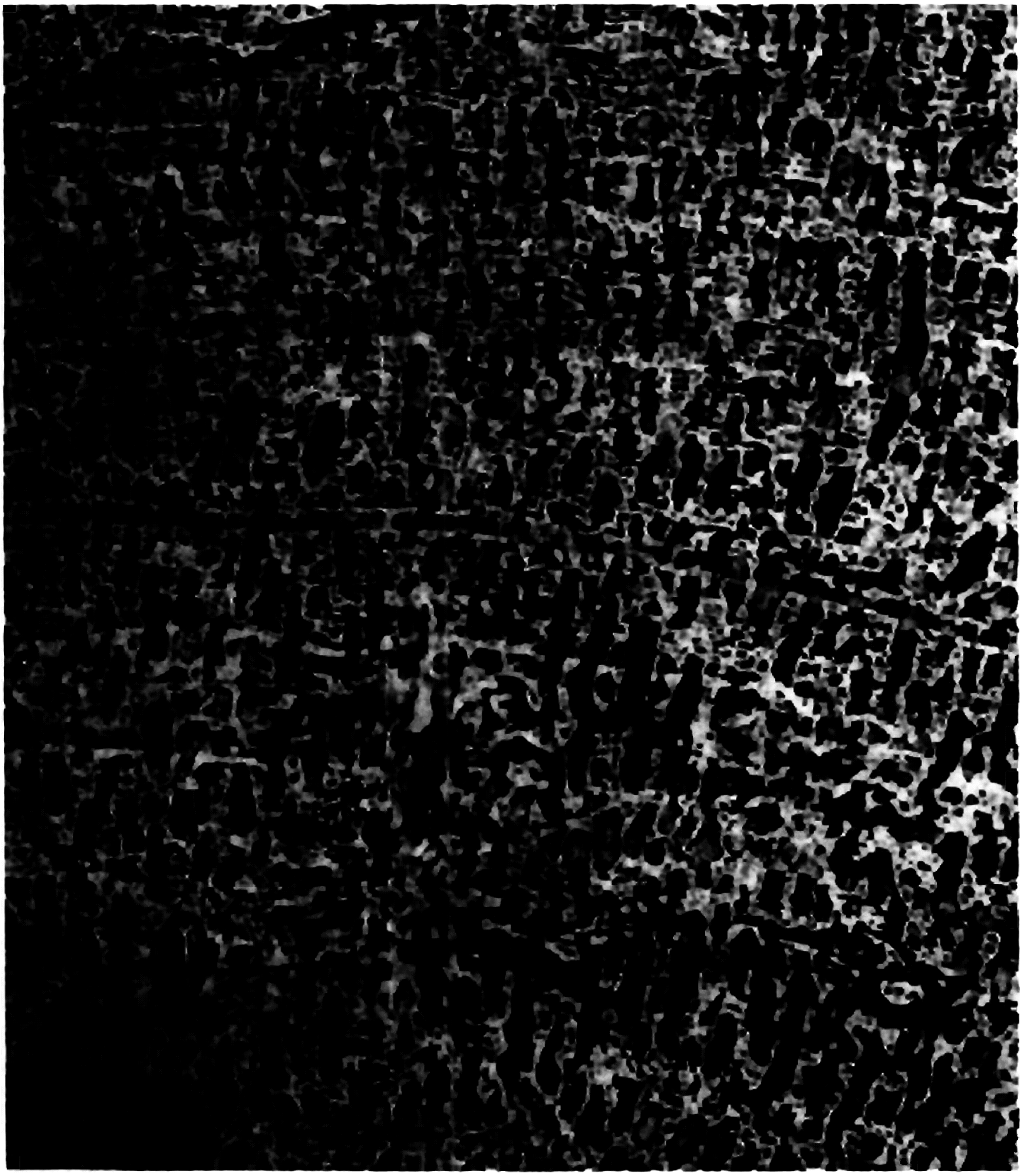
FIG. 3.—Thin-section photomicrographs of some forms of hydrozoans from the central reef actinostromariid zone; all ×4. A. *Actinostromina germovsheki* Turnsek, transverse section showing massive coenosteum within sparry matrix; Mačkevec locality (P-30). B. *Ellipsactinia polypora* Canavari, massive colony with strong lamellar elements; Radovica locality (P-125). C. *Astrostylopsis circoporea* (Gemovšek); longitudinal section of coenosteum; Ojstrovca locality (P-83). D. *Ellipsactinia ellipsoidea* Steinmann, massive coenosteum of hydrozoan overgrown by chaetetid; Slamna vas locality (P-132). E. *Cylicopsis lata* Turnšek, vertical and partly oblique section of coenosteum; Ojstrovca locality (P-203).

FIG. 4.—Thin-section photomicrographs of corals from the actinostromariid zone of the central reef; all ×4. A. *Complexastraeopsis lobata* (Geyer), transverse section of massive colony; Lokovec locality (1902/8B). B. *Complexastraea seriata* Turnšek, transverse section of massive colony; Mrzovec locality (P-245). C. *Microphyllia bachmayeri* Geyer and *Mitrodendron ogilvie* Geyer, transverse sections of both colonies showing both massive and ramose forms; Ivanja vas locality (P-311). D. *Amphiastraea piriformis* Gregory, transverse section of cerioid colony; Ivanja vas locality (P-309). E. *Stylosmilia corallina* Keby, transverse section of a phaceloid-dendroid colony; Lokovec locality (1902/12).

FIG. 5.—Thin-section photomicrographs of some forms of hydrozoans and chaetetids from both the parastromatoporid and *Cladocoropsis* zones of the central reef; all ×4. A.–B. *Cladocoropsis mirabilis* Felix within a micritic matrix; Racna gora locality (Ri/63-1). C.–D. *Parastromatopora compacta* Turnšek, longitudinal and transverse sections of coenosteum; Otlica locality (P-96). E. *Hudsonella otlicensis* Turnšek, transverse section of coenosteum; Otlica locality (P-114b). F. *Bauneia multitabulata* (Deninger), longitudinal and partly oblique section of a chaetetid; Luče locality (P-143). G. *Chaetetopsis krimholzi* Yaworsky, transverse section of colony; Čušperk locality (P-41).



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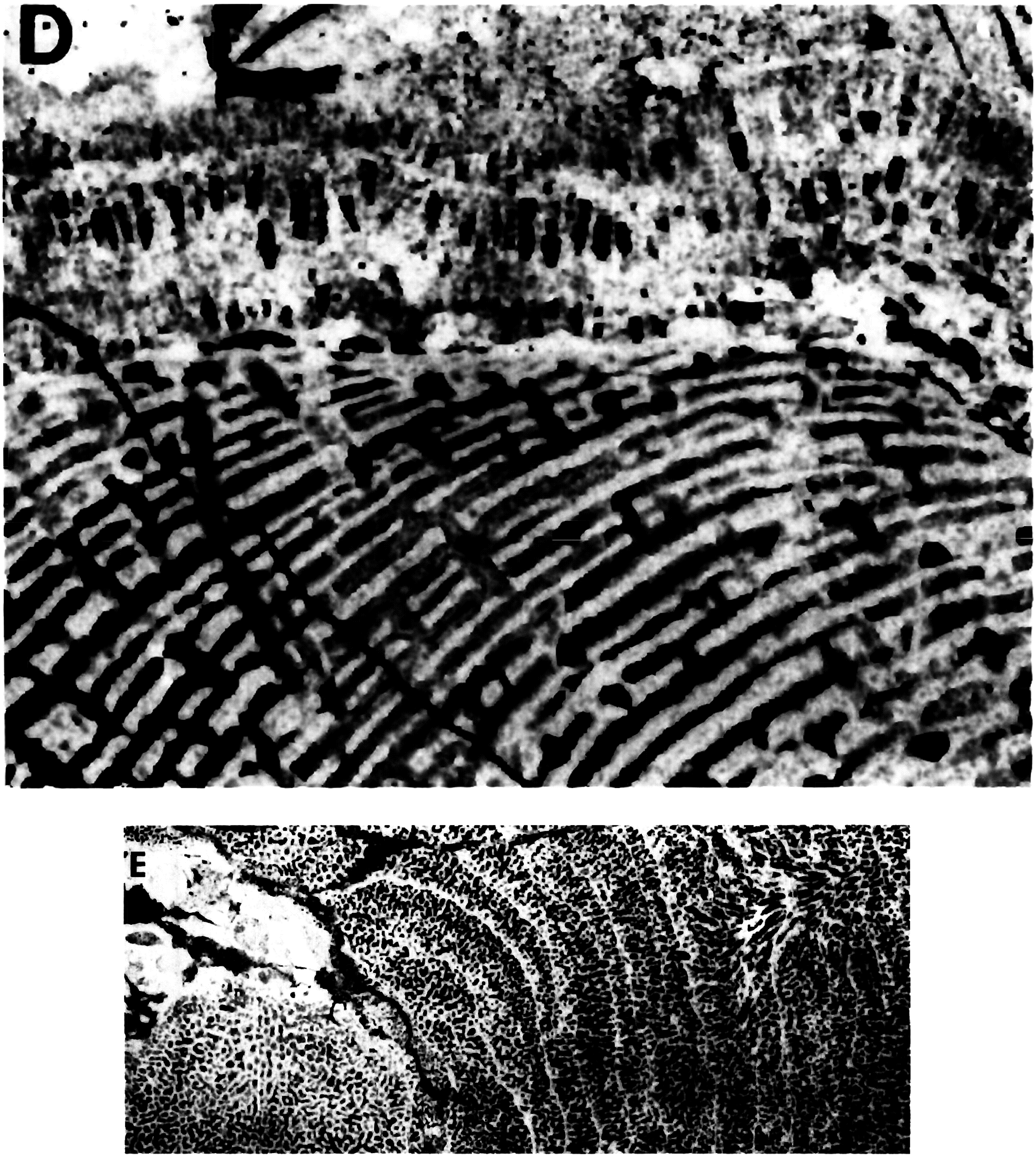
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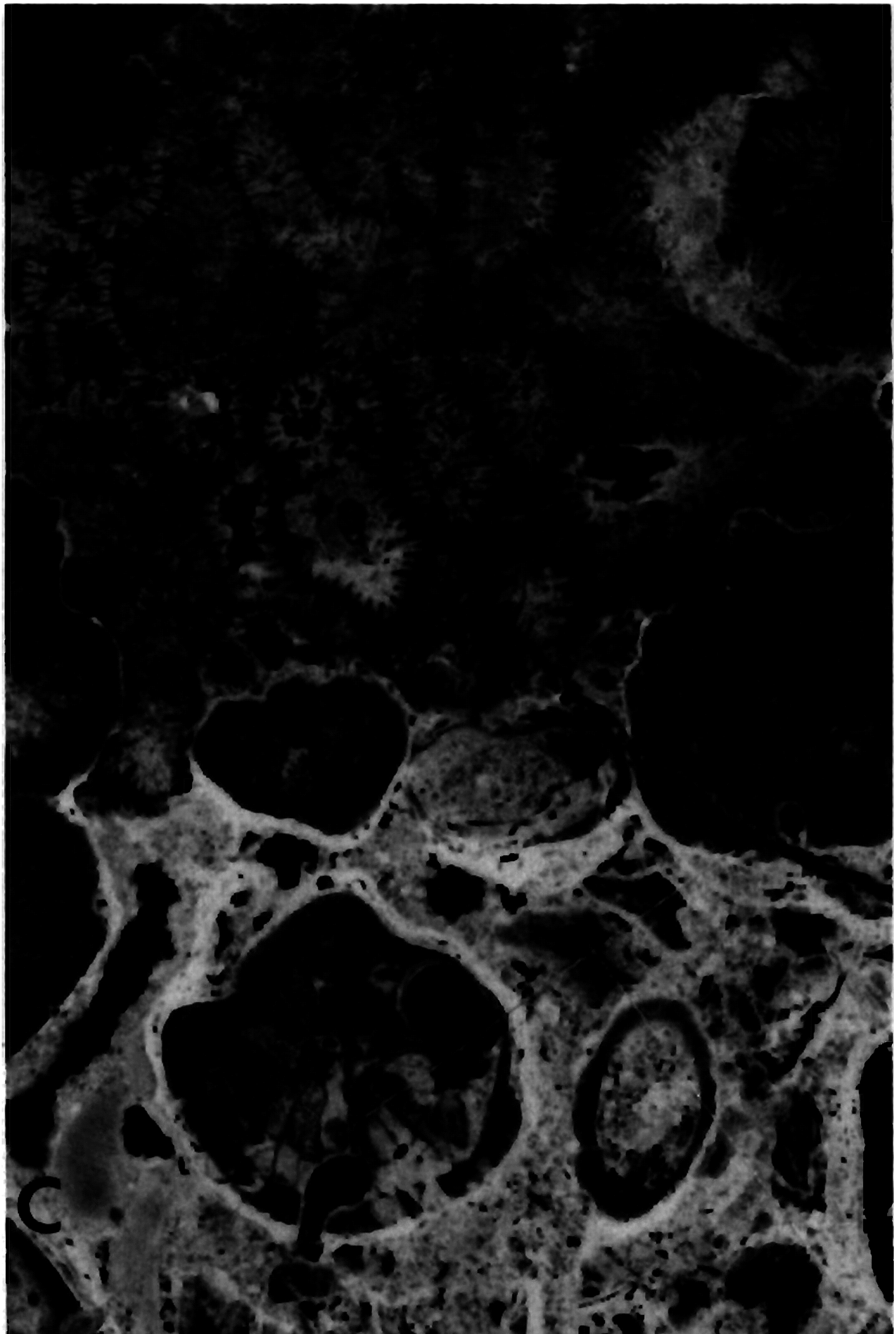
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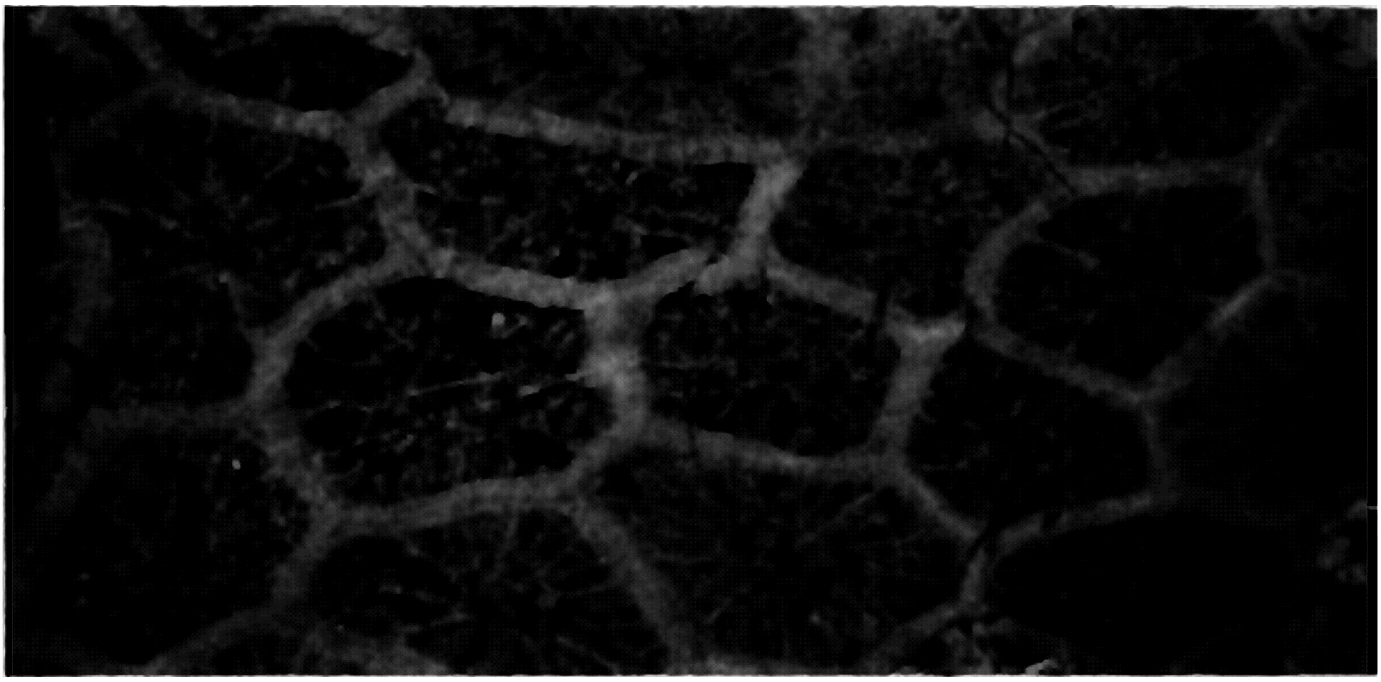

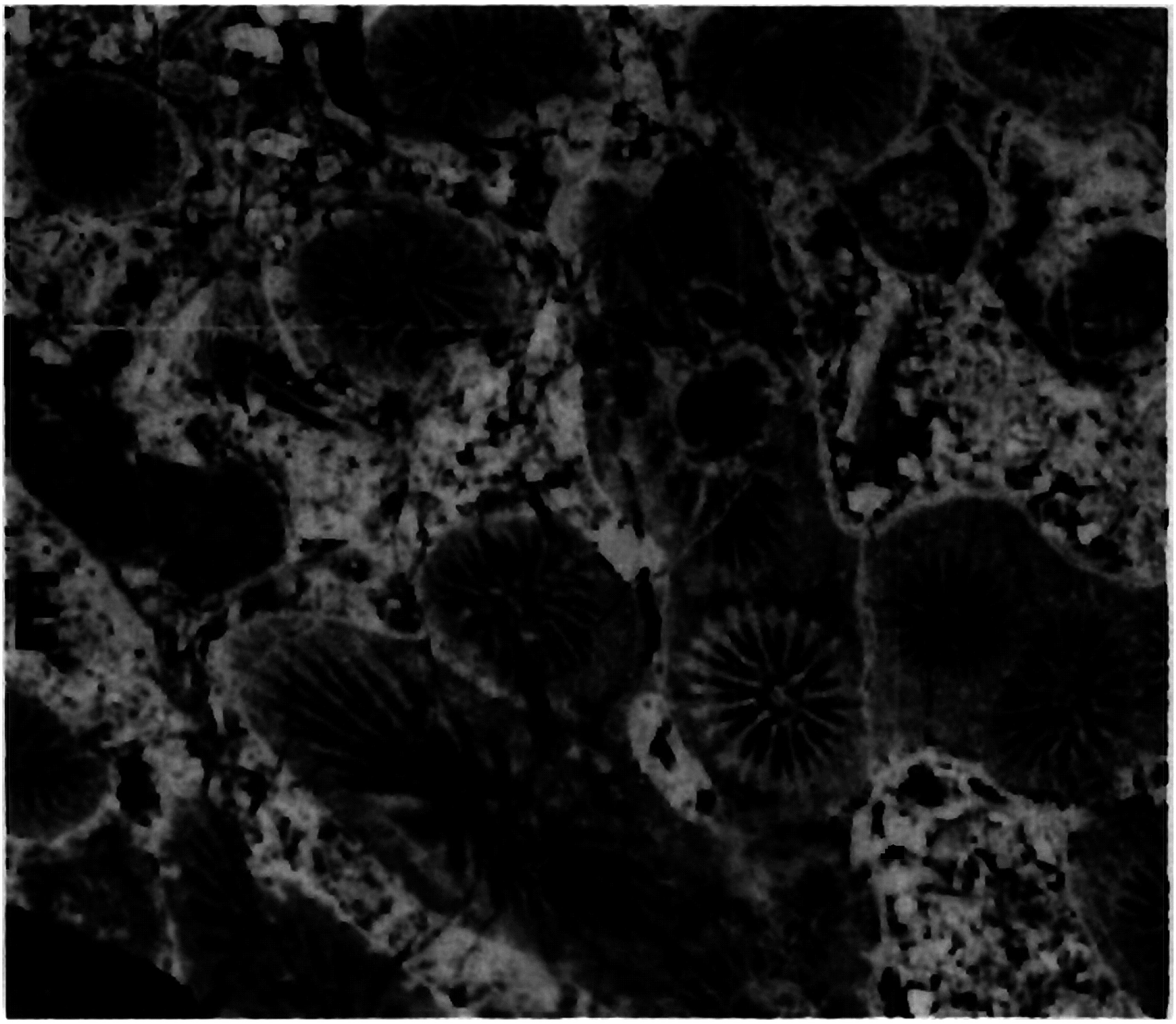

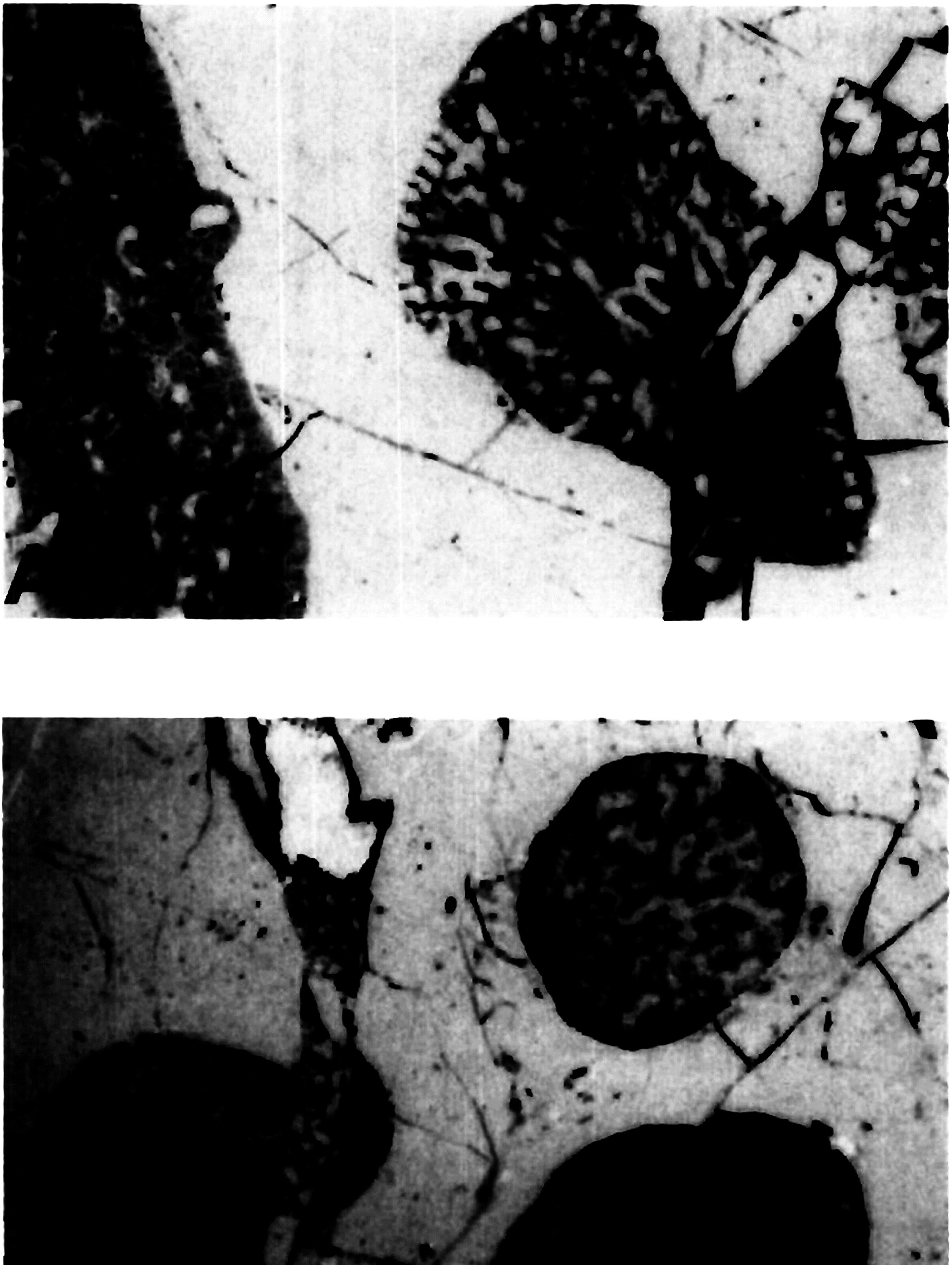
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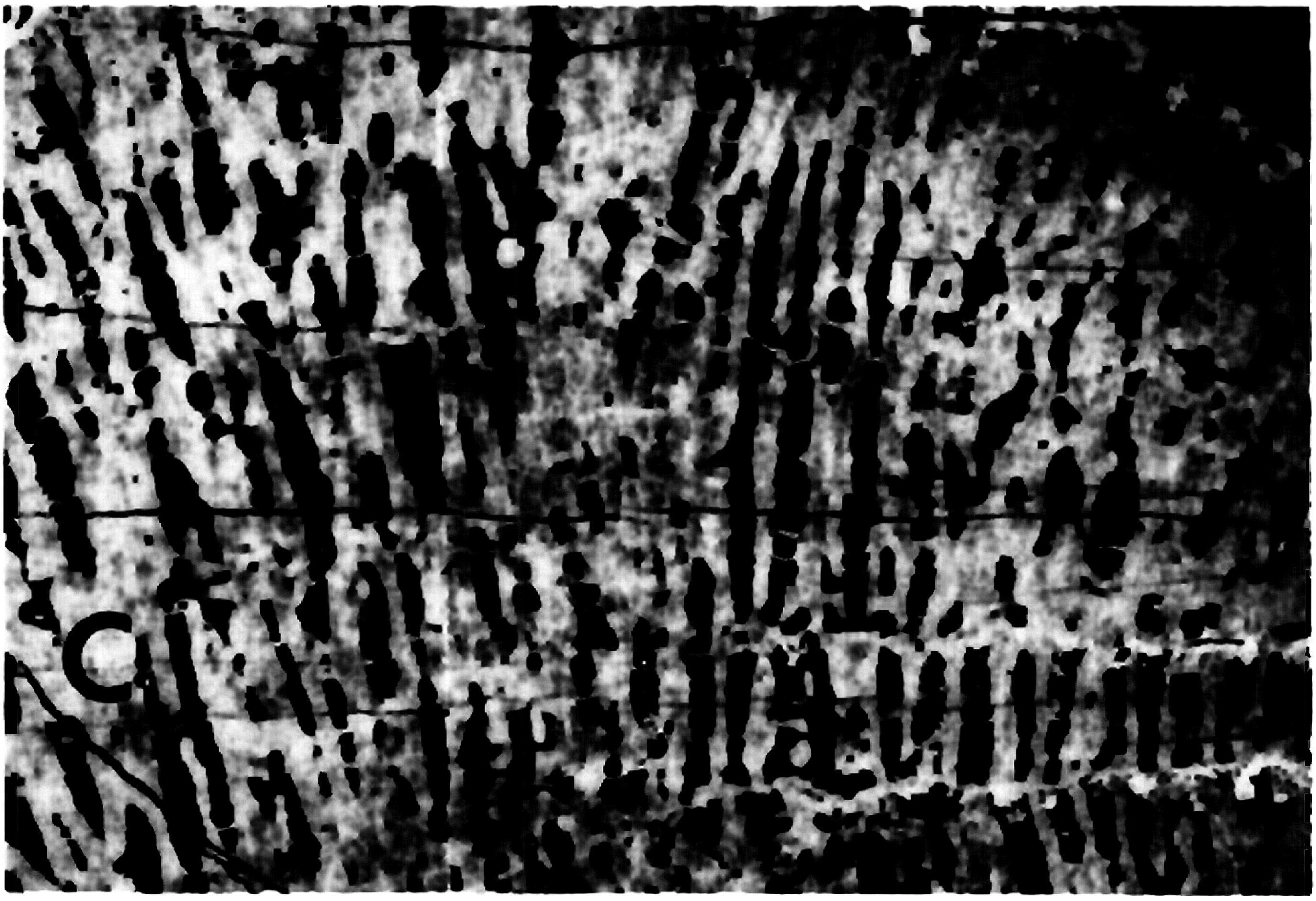
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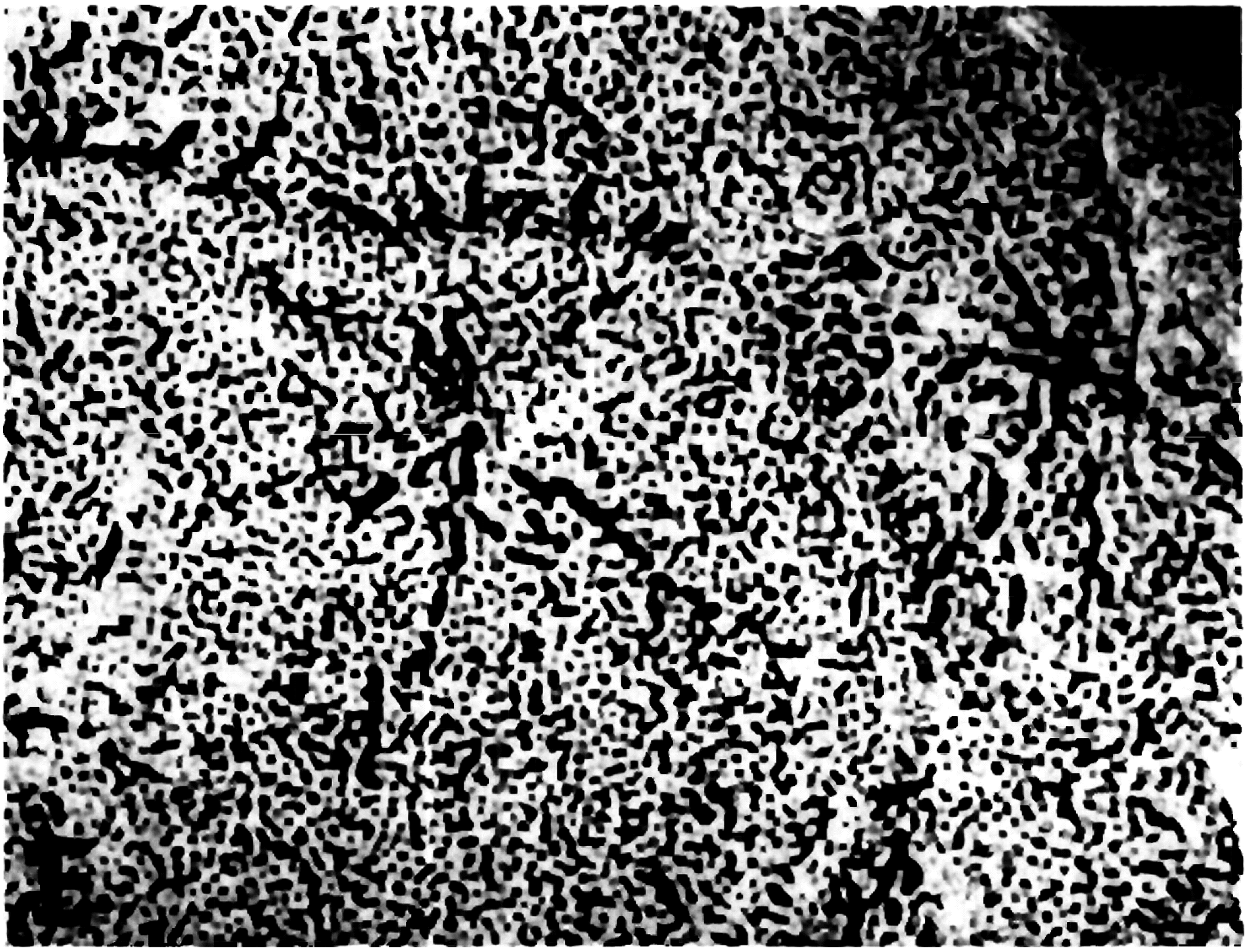

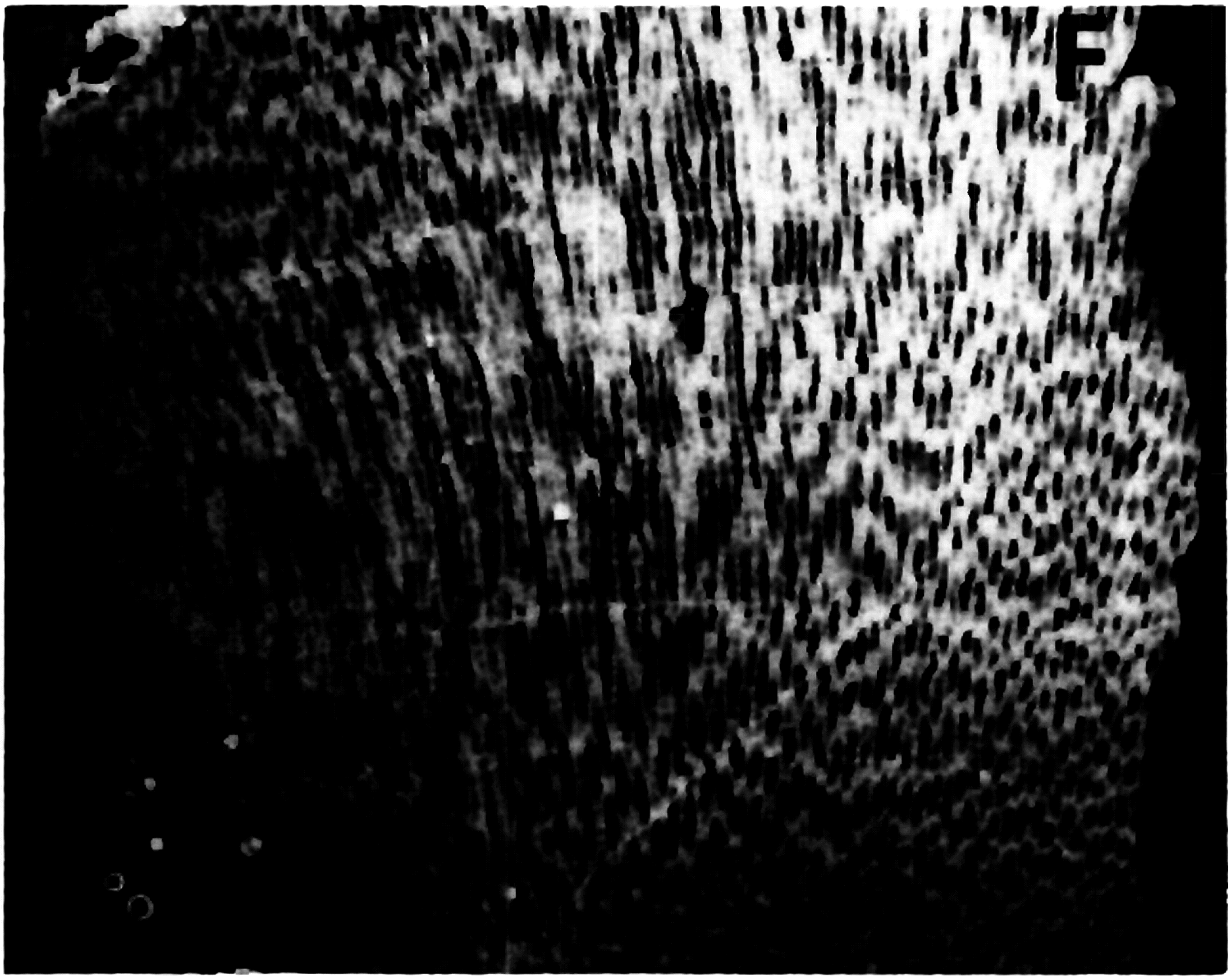
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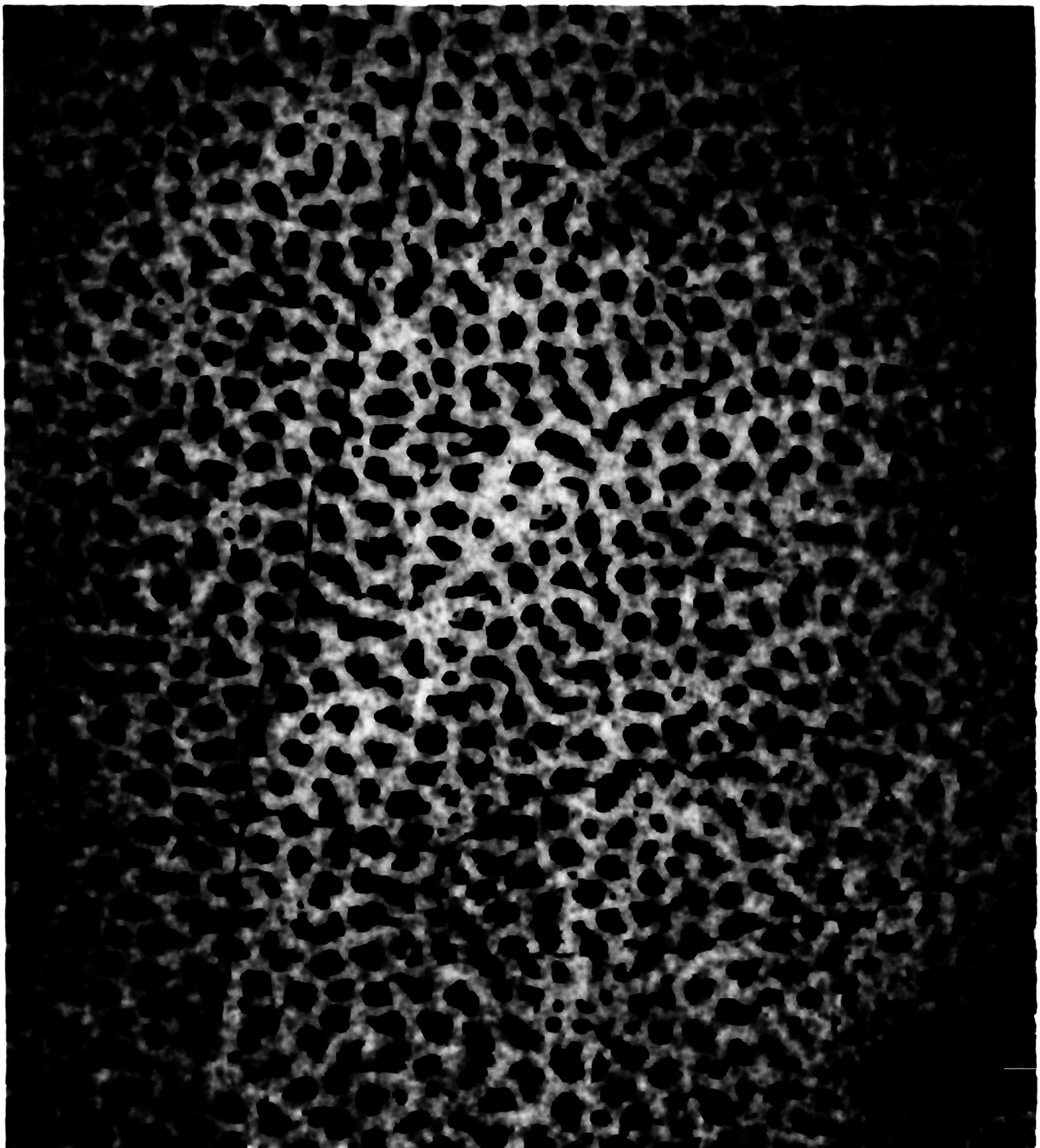

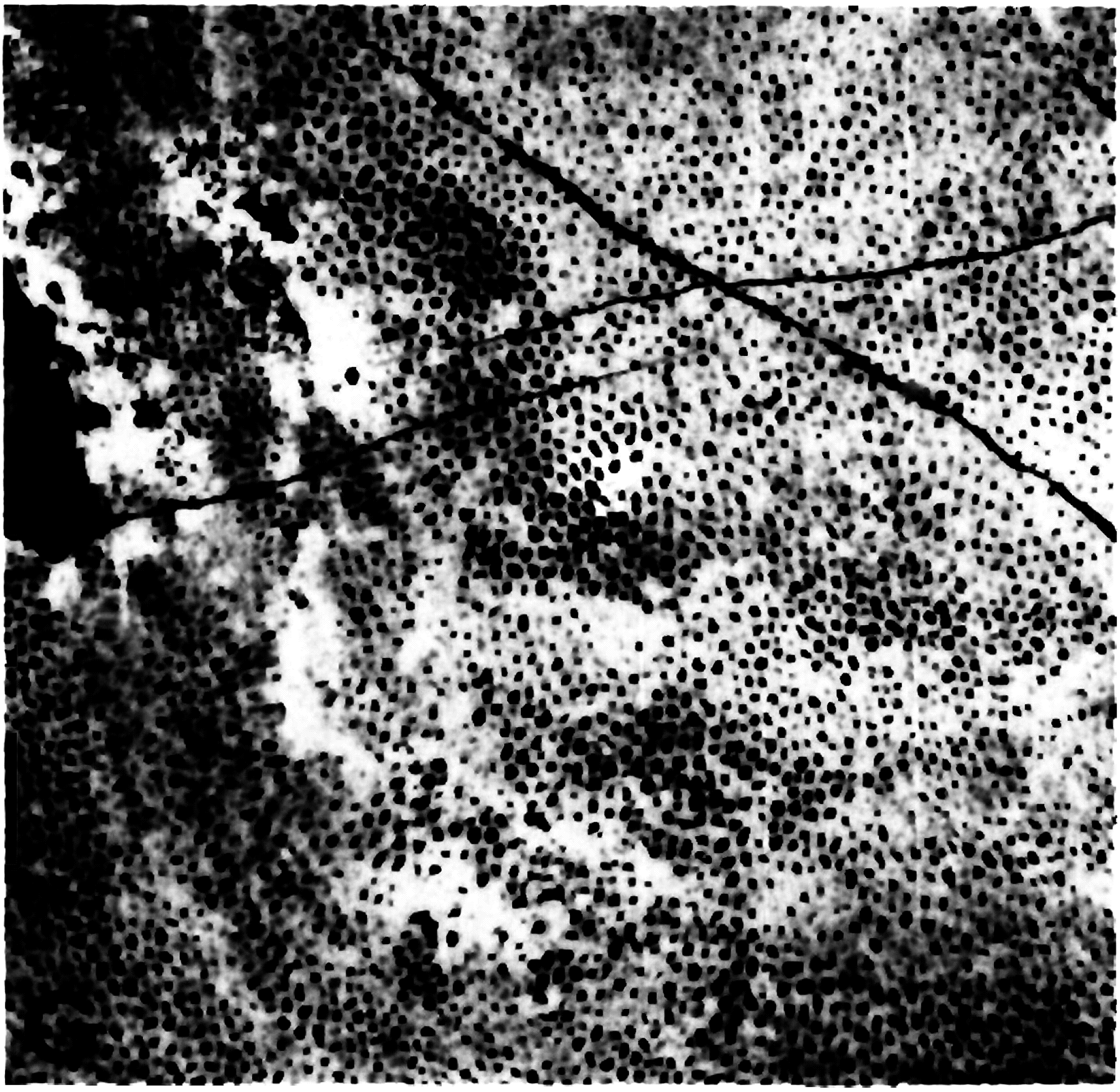

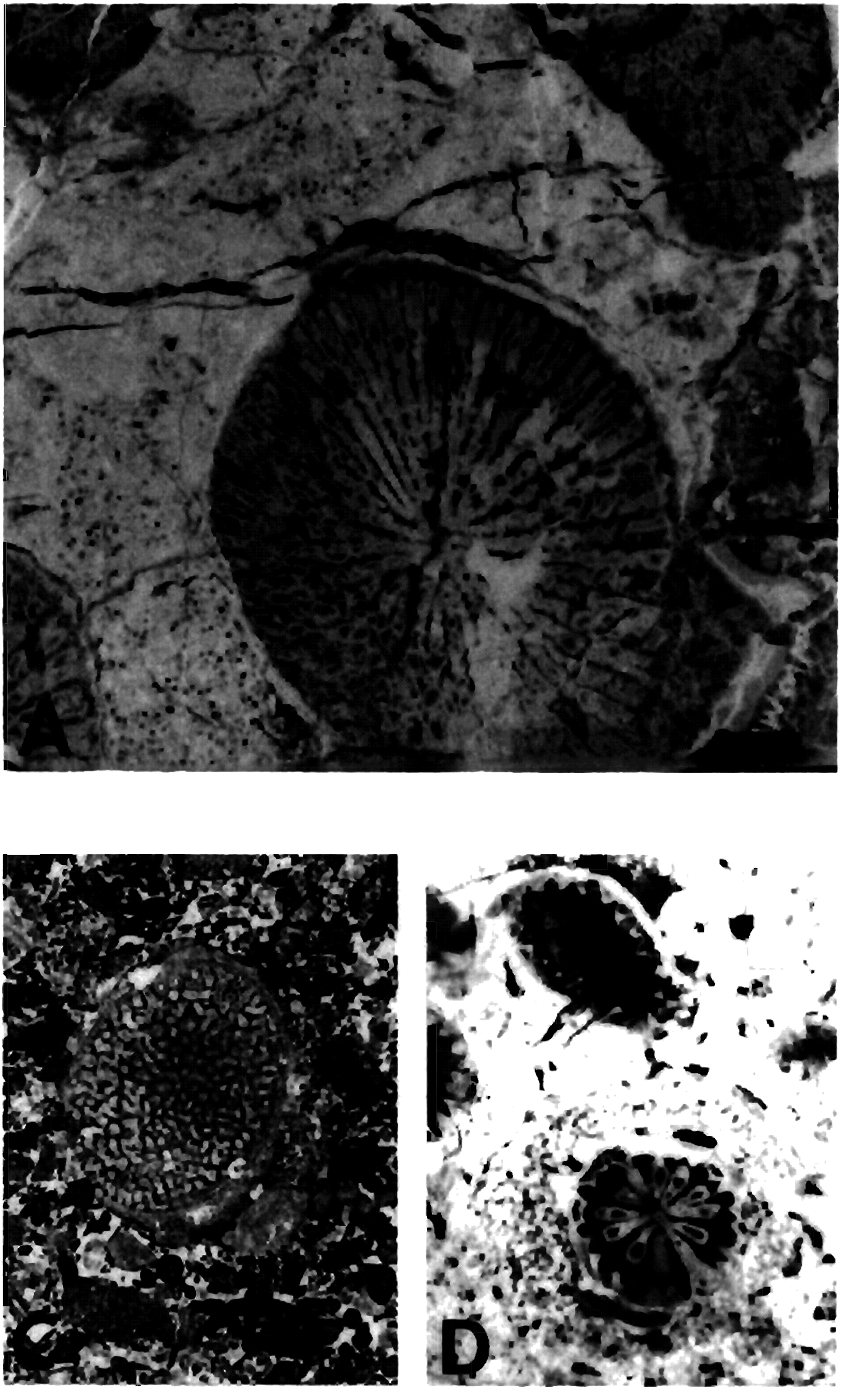
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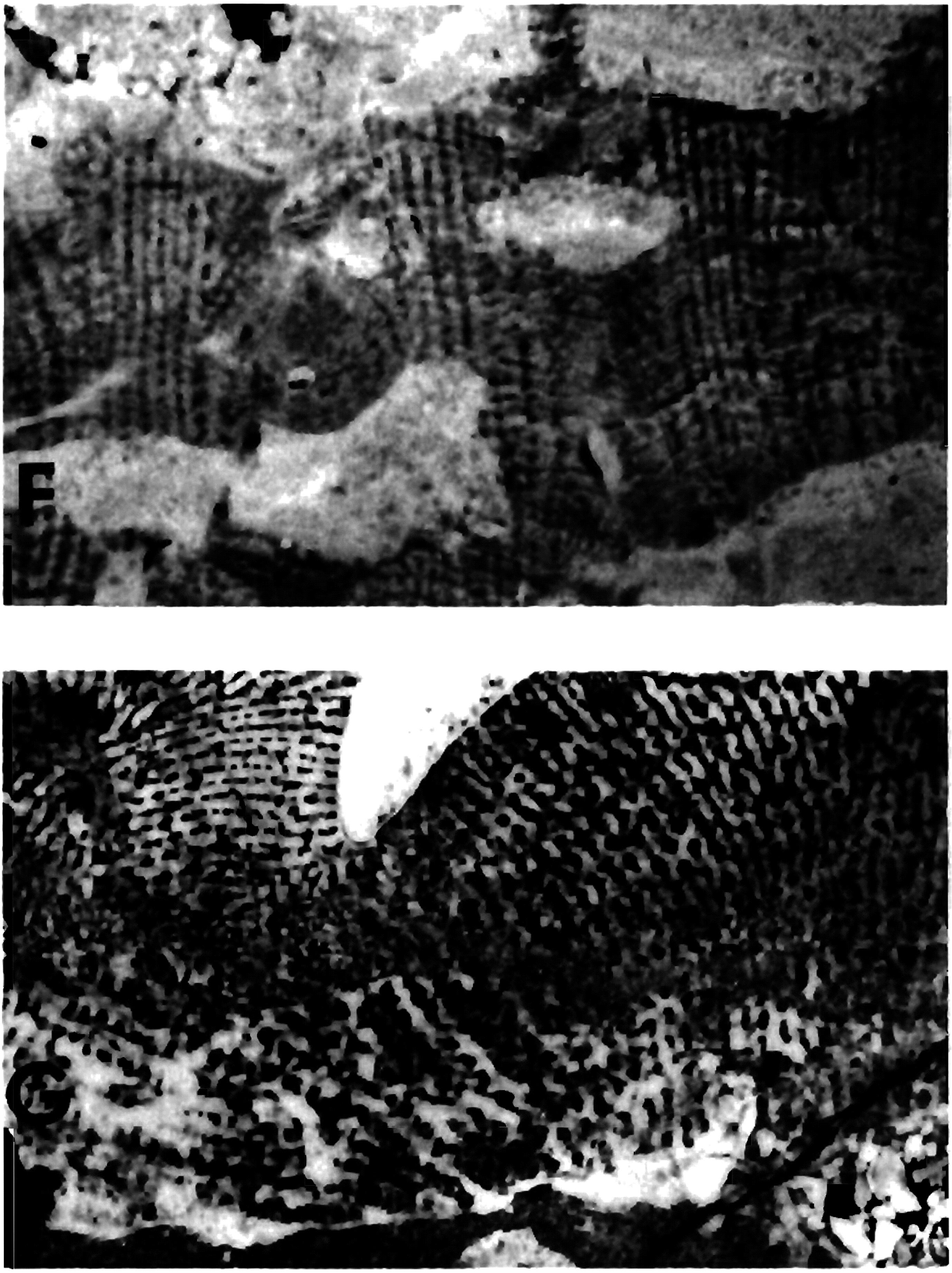

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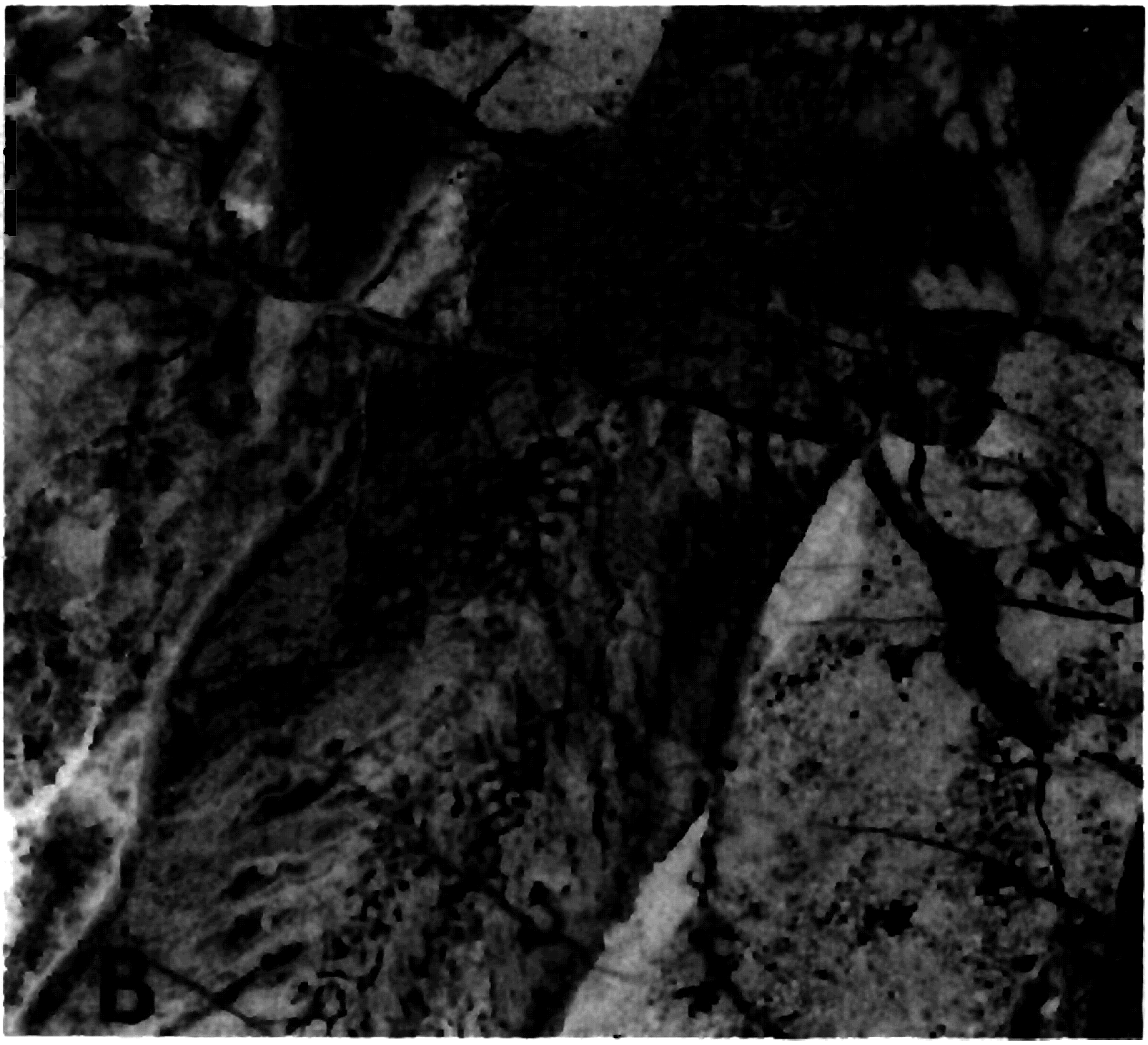
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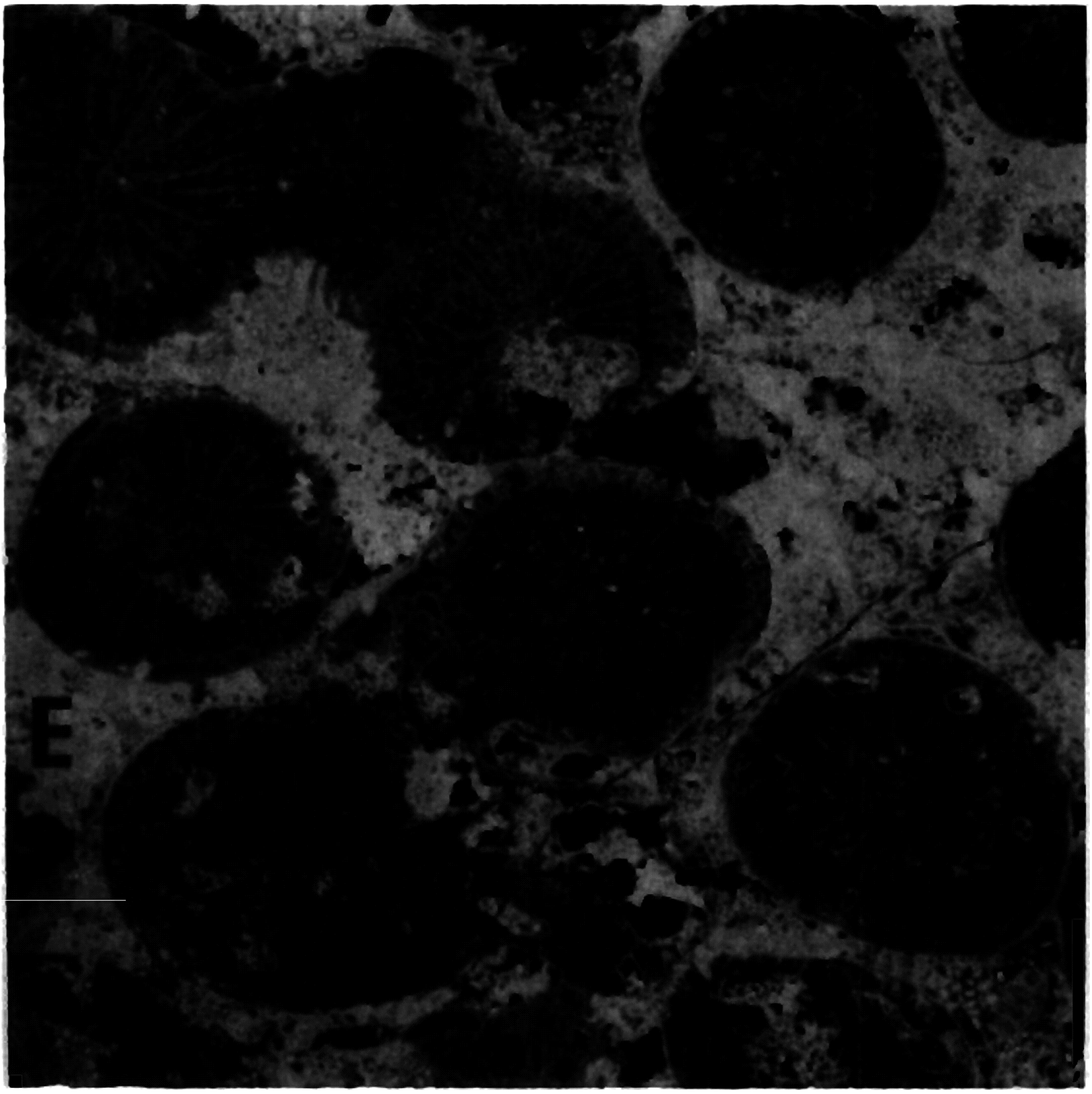
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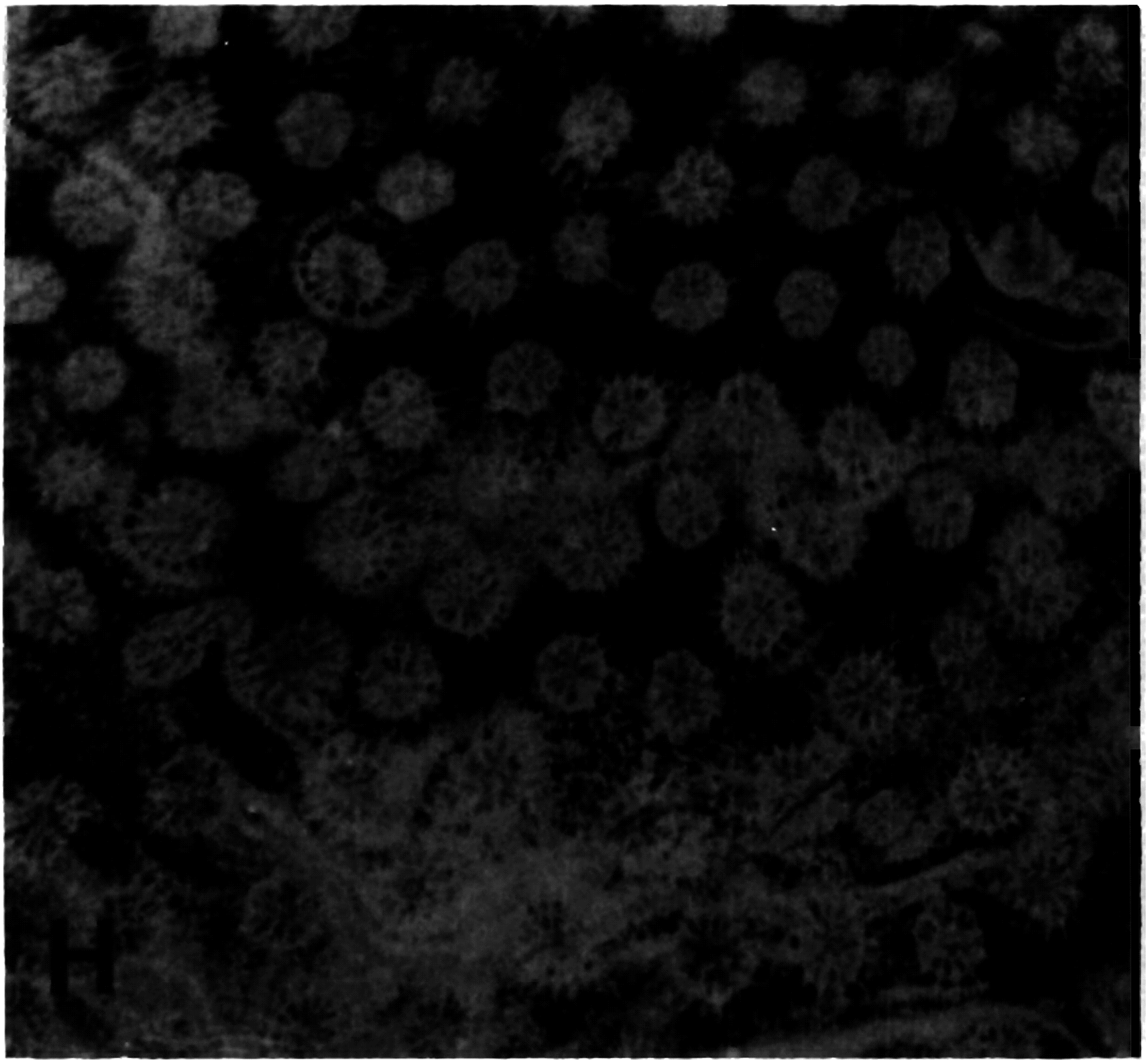

2). This area is characterized by quiet, low energy sedimentary environments. In this zone dark-grey massive, micritic limestones formed. Locally these may be bituminous or marly, and may even be peloidal. The dominant organism is the hydrozoan *Cladocoropsis mirabilis* Felix (Fig. 5A–B). Associated with this form are various foraminifers and algae. The foraminifers include: *Kurnubia palastiniensis* Henson, *K. wellingsi* Henson, *Pfenderina trochoidea* Smouth and Sugden, and *P. salernitana* Sartoni and Crescenti. Identified algae include the dasyclads *Macroporella sellii* Crescenti, *Thaumatoporella parvovesiculifera* (Raineri), and others. During short time intervals both the lagoons and shallow shelf areas were covered by oolitic deposits. In addition, some small patch-reefs, composed of a biota similar to that seen in the parastromatoporid zone, developed in this zone. These small patch-reefs are often only several meters thick, and are overlain by typical lagoonal deposits.

The authors anticipate that several more years of detailed paleontological and sedimentological study will be needed to finally analyze all of the parameters of the Upper Jurassic barrier-reef complex of Slovenia.

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REFERENCES

Buser, S., 1965, Neue Forschungsergebnise über die Juraschichten in Südslowenien: Wien, Anzeiger Mat. Nath. Cl. Österr. Akad. Wiss., Jg. 1965, p. 161–165.

———, 1978, Razvoj jurskih plasti Trnovskega gozda, Hrušice in Logaške planote (The Jurassic strata of Trnovski gozd, Hrušica and Logaška planota): Ljubljana, Rudarsko-metalurški zbornik, 1978, 4, p. 385–406.

Nikler, L., 1978, Stratigrafski položaj grebenskog facijesa malma u sjeverozapadnim djelovima Dinarida (Stratigraphic position of the Malmian reef facies in northwestern Dinarids): Zagreb, Geološki vjesnik, 30, 1, p. 137–150.

Turnšek, D., 1966, Zgornjejurska hidrozojska favna iz južne Slovenije (Upper Jurassic Hydrozoan Fauna from Southern Slovenia): Ljubljana, Razprave IV. Razr. SAZU, 9, p. 335–428.

———, 1969, Prispevek k paleoekologiji jurskih hidrozojev v Sloveniji (A Contribution to the Palaeoecology of Jurassic Hydrozoa from Slovenia): Ljubljana, Razprave IV. Razr. SAZU, 12, p. 209–237. Tab. 1.

———, 1972, Zgornjejurske korale iz južne Slovenije (Upper Jŭrassic Corals of Southern Slovenia): Ljubljana, Razprave IV. Razr. SAZU, 15, p. 145–261.

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Fig. 6.—Thin-section photomicrographs of some forms of corals from the parastromatoporid zone of the central reef area; all ×4 except C. which is ×3. A.–B. *Dermosmilia laxata* (Étallon), phaceloid-dendroid colony showing transverse and longitudinal sections of a single corallite; Col locality (P-299). C. Biocalcarenite with hydrozoan fragment derived from breccia within parastromatoporid zone; Otlica locality (6a/630). D. *Goniocora pumila* (Quenstedt), dendroid colony showing transverse sections of two corallites; Frata locality (P-406). E. *Calamophylliopsis flabellum* (Michelin), phaceloid colony showing transverse sections of corallites; Hrušica locality (F-297). F.–G. *Microsolena thurmanni* Koby, encrusting colony showing longitudinal and transverse sections of septa; Frata locality (P-399 and P-354). H. *Heliocoenia variabilis* Étallon, massive small colony showing transverse section of corallites and peritheca; Predole locality (P-381).