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DEVELOPMENT AND STRATIGRAPHY OF THE KAPP STAROSTIN FORMATION (PERMIAN) OF SPITSBERGEN

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Deposits of the Permian Kapp Starostin Formation, Spitsbergen, are described. Basing upon a theoretical facies model of the Permian sea, chronostratigraphic correlation of the lithological sets is presented and facies development of the formation is reconstructed.

Key words: Permian, Spitsbergen, litho-chronostratigraphy.

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WYKSZTAŁCENIE LITO-FACJALNE I STRATYGRAFIA OSADÓW FORMACJI KAPP STAROSTIN (FM), PERM ZACHODNIEGO SPITSBERGENU

Streszczenie. — Z terenu zachodniego Spitsbergenu opisano osady permskiej formacji Kapp Starostin (Fm.), odsłonięte w siedmiu miejscach (fig. 1) wzdłuż pasma wychodni równoległych do charakterystycznych dla regionu struktur tektonicznych (NNW—SSE). W profilach poszczególnych odsłonięć (fig. 2, pl. 23-29) wydzielono pakiety warstw, którym podporządkowano teoretyczne strefy facjalne z przyjętego modelu rozkładu facji permskiego morza (fig. 3). Otrzymany zapis zmian facjalnych badanego zbiornika posłużył do przeprowadzenia przybliżonej korelacji chronostratygraficznej profilów (fig. 4) opartej na regule WALTHERA, oraz na przyjętym założeniu o przestrzennym zasięgu permskich, pełnomorskich stref facjalnych. Przeprowadzenie korelacji pozwoliło na przedstawienie rozwoju sedymentacji i elementów paleogeografii badanego regionu w określonym czasie (figs. 5, 6). Wykonany stratygraficzny opis formacji Kapp Starostin umożliwia przystąpienie do badań paleoekologicznych występującej tu bogatej bentonicznej fauny. Praca była finansowana przez Polską Akademię Nauk w ramach problemu międzyresortowego MR. II-16.

INTRODUCTION

Deposits accumulated during the post-Hercynian sedimentary cycle (see ORVIN 1940, BIRKENMAJER 1964) crop out along the eastern boundary of the Spitsbergen orogene (HARLAND 1964, 1974). The sequence starts with continental sediments. Higher in the section, cherts and organodetritic limestones rich in typical marine fossils appear (FREBOLD 1937, 1939; FORBES *et al.* 1958). Their lithological distinctness has permitted them to be recognized as a formal

lithostratigraphical unit, the Kapp Starostin Formation (BUROV *et al.* 1965, CUTBILL and CHALLINOR 1965). The rocks (especially cherts) show a considerable constancy in lithology over large areas of Spitsbergen (SIEDLECKA 1970).

The Kapp Starostin Formation is very variable in total thickness in the area investigated by the present author between Hornsund and Isfjord (fig. 1), over some 150 km in distance.

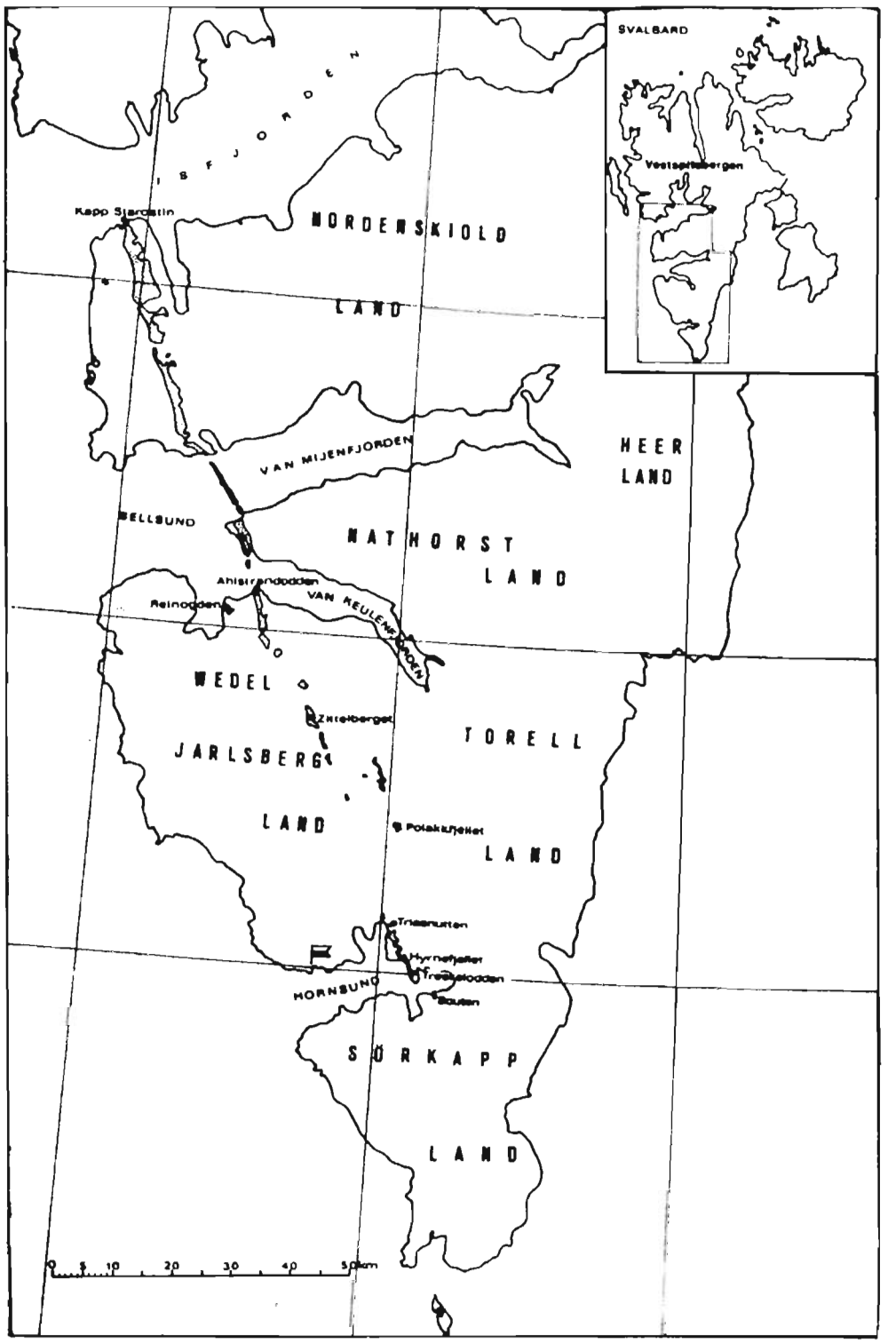

Fig. 1
Outcrop belt of the Kapp Starostin Fm. in the southwestern Spitsbergen; investigated localities are shown.

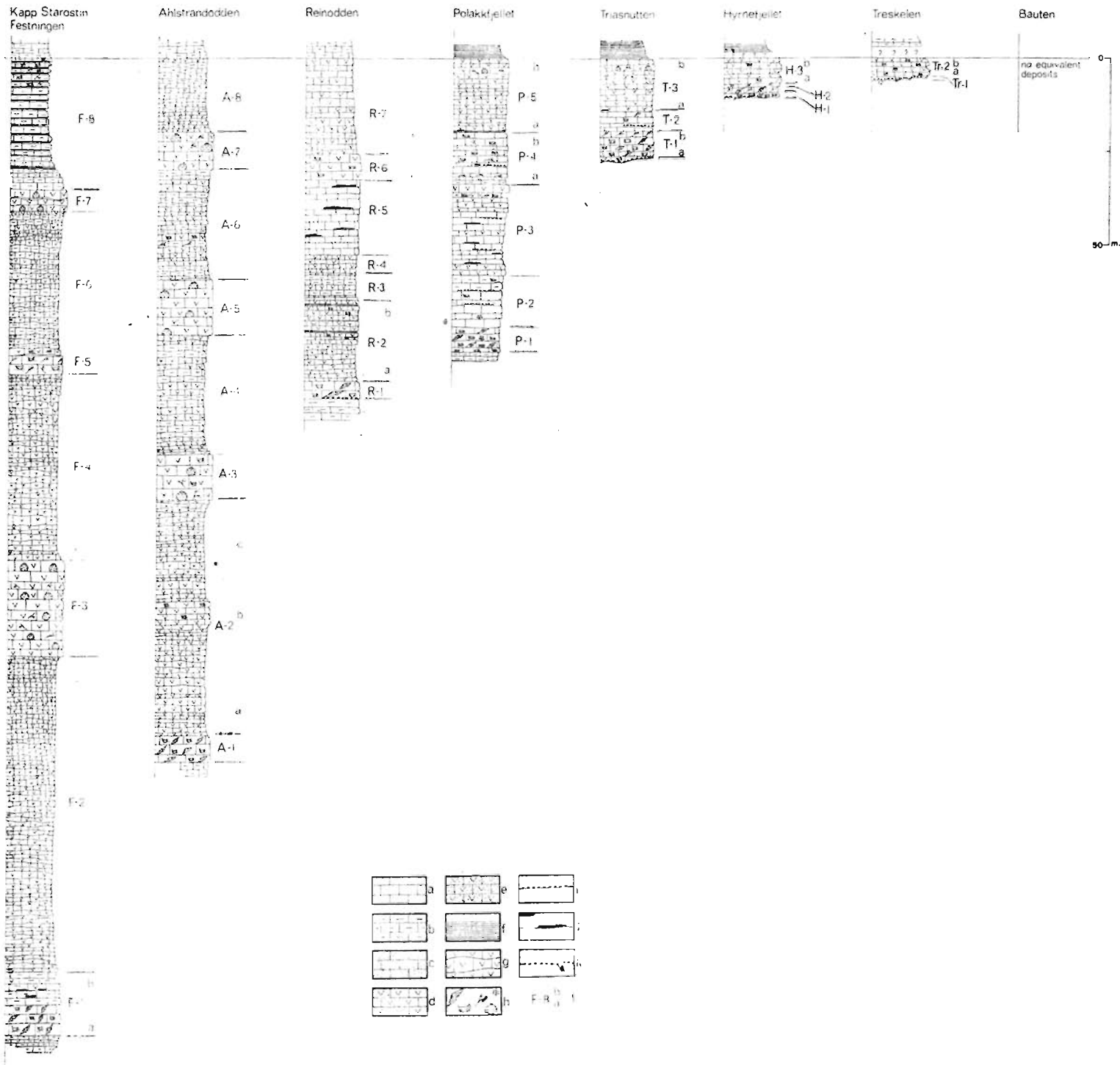

Fig. 2

Investigated sections of the Kapp Starostin Fm. *a* limestones, *b* marly limestones, *c* sandy limestones, *d* platy, silicified limestones, *e* sandy, silicified limestones, *f* marly shales, *g* cherts, *h* fossils, *i* layers enriched in terrigenous matter, *j* siliceous concretions, *k* sedimentary discontinuities (erosional), *l* symbols of the lithological sets.

In the Hornsund region, it attains only a few to a dozen or so meters in thickness (BIRKENMAJER 1964), whereas it ranges up to a several hundred meters in the Bellsund-Isfjord region (FREBOLD 1937, WINSENES 1966). The limestones and cherts alternate without showing any traces of sedimentary discontinuity in FREBOLD's (1937) Festungsprofil designated for the type section of the formation; this is indeed the most complete section of the formation in the investigated area. In contrast, the section is delimited by stratigraphical gaps in the Hornsund region where it comprises merely a single cherty set underlain by conglomerates (BIRKENMAJER 1964).

In spite of the abundant benthic fauna of the Kapp Starostin Formation (FORBES *et al.* 1958, GOBBETT 1963, SOSIPATROVA 1967, MAŁECKI 1968, 1977), no satisfactory biostratigraphical subdivision has insofar been established, nor has the formation been unequivocally correlated with the Cis-Uralian type sections (STIEPANOV 1957, 1973; USTRITSKY 1971). Due to conodont fauna a step has been made towards intercontinental correlation of the Kapp Starostin Formation. Its chronostratigraphical position relative to the Leonardian (Roadian) deposits of the United States is now possible to establish (SZANIAWSKI and MAŁKOWSKI 1979).

Because of a considerable dependence of the benthic species and conodonts (cf. SZANIAWSKI and MAŁKOWSKI 1979) upon the facies pattern any local biostratigraphical correlation is difficult. Therefore, an attempt has been undertaken to restore chronostratigraphical relationships within the formation basing upon a reconstruction of the sedimentary development of the Kapp Starostin Formation. This is achieved by application of the facies model proposed recently by MAŁKOWSKI and HOFFMAN (1979).

ACKNOWLEDGMENTS

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GEOLOGICAL SECTIONS OF THE KAPP STAROSTIN FORMATION

Two basic lithologies are discernible in the Kapp Starostin Formation, namely carbonate rocks and siliceous cherts (SIEDLECKA 1970), consisting mainly of variable proportions of calcium carbonate, amorphous silica, terrigenous matter, and diverse skeletal fragments. The grain size of terrigenous matter and the taxonomic composition of fossils vary throughout the formation and hence, additional lithological units have been distinguished in the investigated geological sections (fig. 2) depending upon the relative proportions of the basic rock constituents.

Distributional patterns of the biotic and abiotic rock constituents recognized in micro-

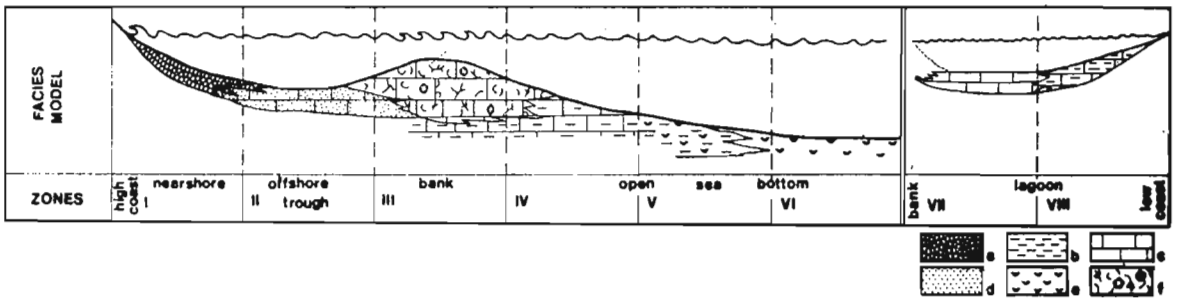

Fig. 3

Facies spatial distribution in the Permian sea in the investigated area (after MAŁKOWSKI and HOFFMAN 1979). *a* coarse-grained terrigenous matter, *b* muds, *c* calcareous muds, *d* sandy deposits, *e* clays to muds with sponge spicules, *f* coquinites.

facies analysis of the Kapp Starostin Formation were studied with application of factor analysis that allowed to recognize a few basic facies types of the formation and to produce a static model of their spatial distribution (fig. 3) in the Permian sea of Spitsbergen (MAŁKOWSKI and HOFFMAN 1979). In the present paper, more or less coherent lithological sets are distinguished in the investigated sections and each assigned to a facies zone making part of that model.

KAPP STAROSTIN SECTION = FREBOLD'S (1937) FESTUNGSPROFIL, SOUTHEASTERN COAST OF ISFJORD BY CAPE STAROSTIN

Lithological sets — Facies zones

F-8 (pl. 23:1): black marls and marly shales with abundant fauna (especially at the top of the set); abundant, mostly thin-shelled brachiopods: Productacea: Buxtoniinae (*Kochiproductus*), Echinoconchinae, Marginiferinae, Costispiniferinae, Linoproductinae (*Cancrinella*); Spiriferacea (*Spiriferella*, *Paeckelmanella*), Chonetacea, Rhynchonellacea (*Camarophoria*);
abundant bryozoans (pl. 25:1): Fenestellidae and Stenoporidae (*Tabulipora*); rare bivalves and solitary corals, sporadical foraminifers, occasionally abundant sponge spicules in marly bands; basal part of the set more calcareous and with conodonts *Neogondolella*. Zone V

F-7 (pl. 23:2): yellow-grey, marly, platy, considerably silicified limestones with grey-greenish, a little wavy limestones in the middle of the set; sponges, brachiopods, and fragile bryozoan colonies (*Fenestella*) abundant and well preserved in platy limestones. Zone IV-V

F-6 (pl. 23:3): grey, wavy, marly cherts (pl. 27:1) to spiculites with sponge spicules in masses throughout the set and brachiopods (pl. 27:2) common at the base; ostracodes and uniserial foraminifers (*Nodosaria*, *Frondicularia*) common. Zone V-VI

F-5 (pl. 23:4): yellow, marly platy limestones with abundant and well preserved fauna (a little redeposited in places); very abundant, mostly large-sized and thick-shelled brachiopods: Productacea (pl. 25:2, 4): Horridoniinae, Rotaridae (*Thuleproductus*), Waagenoconchinae (*Waagenoconcha wimani*), Anidantidae (*Megousia*); Orthotetacea (*Streptorhynchus kempei*), Spiriferacea (*Spiriferella*, *Spiriferina*); very common large-sized bryozoan colonies (pl. 28:1-2): Stenoporidae and Fenestellidae; common crinoid ossicles, rare bivalves, foraminifers and ostracodes. Zone III

F-4 (pl. 23:5): dark-grey to black, wavy cherts interbedded occasionally with black, marly shales; mass occurrence of sponge spicules, sporadical sponges (*Scheiia*); rare brachiopods, foraminifers and ostracodes. Zone VI

F-3 (pl. 23:6): yellow-grey, thick-bedded, platy, considerably silicified, fossiliferous limestones; abundant brachiopods, sponges, and bryozoans, common ostracodes and foraminifers, sporadical solitary corals (pl. 25:3); crinoid ossicles at the base of the set. Zone IV-V

F-2 (pl. 23:7): steel-grey to black, wavy cherts to spiculites with a few sponges (*Scheiia*), common bryozoans (Fenestellidae) and some small-sized, thin-shelled brachiopods. Zone V-VI

F-1 (b) (pl. 23:8): grey, platy, marly, micritic limestones interbedded with marly shales; sporadical brachiopods (pl. 29:1) and fragile bryozoan colonies; considerably silicified concretions with abundant sponge spicules at the base of the set. Zone IV
(a) (pl. 23:9): grey, detritic limestones to coquinites (pl. 29:2) with skeletal remains a little fragmented as a rule; very abundant brachiopods: Productacea and Spiriferidae; common crinoid ossicles and bryozoans (Stenoporidae, Timanodictyoidae, and Fenestellidae). Zone III

Lower in the section, light-grey, non-fossiliferous marls. Zone VII-VIII

AHLSTRANDODDEN SECTION, SOUTHERN COAST OF VAN KEULEN FJORD BY AHLSTRANDODDEN PENINSULA (cf. HOEL AND ORVIN 1937, WINSENES 1966)

Lithological sets — Facies zones

A-8: black, marly, silicified cherts with rare thin-shelled brachiopods, fragile bryozoans (Fenestellidae), ostracodes and uniserial foraminifers (*Nodosaria*). Zone V

A-7: yellow-grey, platy, marly, considerably silicified limestones with abundant sponges, small-sized brachiopods and fragile bryozoan colonies. Zone IV-V

A-6: dark-grey to black marls to marly cherts and spiculites with mass occurrence of sponge spicules, abundant foraminifers and ostracodes and a few thin-shelled brachiopods (mostly small-sized Productacea). Zone VI

A-5: yellow-grey, platy, sandy, considerably silicified limestones with abundant sponges and infrequent brachiopods, bryozoans, ostracodes and foraminifers. Zone IV-V

A-4: grey to black, a little wavy, marly cherts with sponge spicules in masses here and there. Zone V-VI

A-3: yellow-grey, platy, considerably silicified limestones rich in well preserved sponges (*Scheiia*), thin-shelled brachiopods and fragile bryozoans (Fenestellidae); common ostracodes and uniserial foraminifers. Zone IV-V

A-2: (c): black, a little wavy, marly cherts to spiculites. Zone V-VI

(b): grey-yellowish, marly to calcareous cherts with abundant sponge spicules, small-sized and thin-shelled brachiopods and fragile bryozoans (Fenestellidae); a few trepostome bryozoan colonies. Zone IV-V

(a): black, wavy, marly cherts with sponge spicules in masses and sporadical brachiopods. Zone V-VI

A-1: grey, detritic limestones to coquinites with well preserved, locally fragmented, diverse fauna; abundant brachiopods: Productacea: Waagenoconchinae (*Wirginae*), Horridoniinae, Paucispiniferinae (*Yakovlevia*), abundant Linoproductinae (*Cancrinella*), Anidantidae (*Megousia*); a few Rhynchonellidea, Terebratulacea (*Dielasma*), and Orthotetacea (*Streptorhynchus*); very common Spiriferacea; mass occurrence of bryozoans: Stenoporidae and Timanodictyoidae; Fenestellidae less common; abundant crinoid ossicles; foraminifers (*Globivalvulina, Nodosaria*) and conodonts (*Neostreptognathodus*). Zone III

REINODDEN SECTION, SOUTHERN COAST OF BELLSUND, WESTERN CLIFF AT REINODDEN PENINSULA

Lithological sets Facies zones

R-7: grey to black, marly cherts overcrowded with sponge spicules. Zone VI

R-6: grey, platy, marly limestones with large amounts of amorphous silica in bands or concretions; a few small-sized, thin-shelled brachiopods (Productacea). Zone IV-V

R-5: yellow-greenish, sandy limestones with flat, siliceous concretions; abundant, large-sized brachiopods: mostly Dictyoclostidae and Spiriferacae: bryozoan colonies in places: Stenoporidae, Timanodictyoidae, and Fenestellidae. Zone III

R-4: grey, wavy, marly, considerably silicified limestones with occasional brachiopods. Zone IV-V

R-3: grey to black, marly, locally silicified limestones with rare brachiopods (Productacea), fragile bryozoan colonies (Fenestellidae), smooth ostracodes and uniserial foraminifers (*Nodosaria*). Zone IV

R-2: (b): grey-creamy, marly, considerably silicified limestones rich in small- to medium-sized brachiopods (Productacea, Spiriferacea) and sponge spicules. Zone V

(a): black, a little wavy to platy, marly cherts. Zone IV-V

R-1: grey, detritic limestones with sandy to gravelly layers; very abundant brachiopods, bryozoans, and crinoids (the fauna resemble in composition and preservation state that of A-1 set). Zone III

Lower in the section, light-grey, non-fossiliferous marls.

POLAKKFJELLET SECTION, SOUTHWESTERN SLOPE OF POLAKKFJELLET MASSIF (PL. 24:1), TORELL LAND (cf. BIRKENMAJER 1977:24)

Lithological sets Facies zones

P-5: (b): dark-grey to black, marly cherts to spiculites; at the top of the set — 1 m thick patch of yellow-grey, marly, cherty limestones with abundant mummified (phosphoritized) sponges (*Haplistion*), small-sized brachiopods and bryozoans (Fenestellidae). Zone IV

(a): black, marly, platy cherts with abundant sponge spicules and sporadical brachiopods, interbedded with black, marly, brachiopod-bearing shales. Zone IV-V

P-4 (b): creamy to yellowish-grey, marly to sandy limestones; abundant, large-sized brachiopods (pl. 26:3): Productacea: Rotaridae (*Thuleproductus*), Dictyoclostidae, Paucispiniferidae (*Yakovlevia*), Horridoniinae, Waagenonochinae (*Wwimani*); Spiriferacea (*Spiriferina, Spiriferella, Spirifer*) and Orthotetacea (*Streptorhynchus kempei*); common, massive bryozoan colonies: Stenoporidae and Fenestellidae (*Polypora*); crinoid-ossicle accumulations and rare bivalves. Zone III

(a): grey, micritic to detritic, cross-bedded, locally sandy limestones with micritic intraclasts and fragmented fossils; common crinoid ossicles and bryozoan fragments. Zone II-III

P-3: grey to creamy, marly, considerably silicified limestones with siliceous concretions and gravelly layers at the base of the set; mass accumulations of fragile bryozoan colonies (Fenestellidae), gastropods and brachiopods in marly intercalations at the top of the set. Zone IV-V

P-2: black to gray, platy, detritic limestones with layers enriched in terrigenous matter of variable grain-size-distributions; abundant brachiopods (large-sized *Linoproductus*) in places (pl. 26: 1); accumulations of *Rhynchopora* (pl. 26: 6); considerable amounts of crinoid ossicles. Zone III

P-1: grey, detritic limestones; abundant brachiopods: Productacea: Linoproductinae (*Linoproductus, Cancrinella* — pl. 26:2, 4, 5), Waagenoconchinae (*Wirginae*); common Rhynchonellacea (Rhynchoporidae) and Spiriferacea (*Spiriferina, Licharewia, Spiriferella, Martinia*); sporadical Terebratulacea (*Dielasma*), Athyracea (*Cleiothyridina*) and Orbiculoidinae; mass accumulations of Lingulacea in places; mass occurrence of crinoid ossicles and algal structures; very common encrusting foraminifers; a few gastropods and bivalves; conodonts (*Neostreptognathodus*). Zone II-III

Lower in the section, marly, dolomitic, non-fossiliferous limestones. Zone VIII

TRIASNUTTEN SECTION, WESTERN SLOPE OF TRIASNUTTEN MASSIF, SOUTHERN COAST OF HORNSUND CLOSE TO BURGERBUKTA (cf. BIRKENMAJER 1977:18)

Lithological sets Facies zones

T-3: (b): grey-green, glauconitic sandstones underlain by yellow-grey, marly, considerably silicified limestones with frequent sponges (phosphoritized *Haplistion*), bryozoans (Fenestellidae), small-sized brachiopods and solitary corals. Zone IV

(a): grey to black, platy, marly, silicfied limestones with mass accumulations of sponge spicules and locally abundant brachiopods (small- to medium-sized Productacea). Zone V

T-2: creamy to grey, sandy, occasionally silicified limestones with abundant cryptostome bryozoans, brachiopods and sponges. Zone IV

T-1 (b): grey to black, marly, occasionally sandy limestones with abundant encrusting bryozoans (*Cryptostomata*) and brachiopods (Productacea and Spiriferacea). Zone II-III

(a): black, silicified, conglomeratic limestones rich in redeposited large-sized brachiopods, mummified sponges and uniserial foraminifers at the base of the set. Zone I-II

Lower in the section, rough, erosional surface.

HYRNEFJELLET SECTION, SOUTHERN SLOPE OF HYRNEFJELLET MASSIF (PL. 24:2), NORTHERN COAST OF HORNSUND, CLOSE TO ADRIABUKTA (cf. BIRKENMAJER 1964:81)

Lithological sets Facies zones

H-3: (b): brownish-grey, nodular to wavy, considerably marly cherts intercalated with marly shales rich in sponges (*Haplistion*), bryozoans (Fenestellidae and a few Stenoporidae) and brachiopods; Productacea: Marginiferinae, Horridoniinae, Waagenoconchinae (*Wirginae*), Costispiniferinae, Buxtoniinae (*Kochiproductus*); Spiriferinae, Rhynchonellidae. Zone V

(a): grey to black, wavy, dolomitic cherts with common but poorly preserved sponges, rare brachiopods and bryozoans. Zone IV

H-2: brownish-grey, marly, locally silicified limestones with abundant encrusting bryozoans (Fenestellidae) and small-sized brachiopods, large accumulations of sponge spicules, common foraminifers (*Frondicularia, Geinitzina, Nodosaria*) and ostracodes; infrequent crinoid ossicles. Zone III

H-1: black, silicified limestones conglomeratic at the base of the set; abundant, redeposited brachiopods: Productacea: Echinoconchinae, Dictyoclostinae, Paucispiniferinae, and Costispiniferinae; Spiriferacea (*Spiriferella, Spiriferina*). Zone I-II.

Lower in the section, rough, erosional surface.

TRESKELEN SECTION, NORTHERN COAST OF HORNSUND, CENTRAL PART OF TRESKELODDEN PENINSULA (CREEK IV *IN* BIRKENMAJER 1964)

Lithological sets Facies zones

Tr-2 (b) (pl. 24, 4-5): brown to black, considerably marly cherts to spiculites with abundant, well preserved sponges (*Haplistion*); mass occurrence of brachiopods: Productacea: Marginiferinae, small-sized Linoproductinae, Buxtoniinae (*Kochiproductus*), Waagenoconchinae (*Wirginae*), Horridoniinae; Spiriferacea (*Spiriferella, Spiriferina, Pterospirifer*), Rhynchonellidae, and a few Terebratulacea (*Dielasma*); abundant bryozoans: Fenestellidae and a few Stenoporidae; common foraminifers (*Geinitzina, Nodosaria*) and ostracodes; conodonts (*Neogondolella*). Zone V

(a): grey, detritic, dolomitic, considerably silicified limestones with poorly preserved sponges and brachiopods. Zone III—IV

Tr-1: black, considerably silicified limestones conglomeratic at the base of the set; abundant, fragmented brachiopods and phosphoritized sponges. Zone I-II

Lower in the section, rough, erosional surface of the Treskelodden Formation (BIRKENMAJER 1964).

MT. BAUTEN REGION, SOUTHERN COAST OF HORNSUND

No deposits

The Carboniferous conglomerates are overlain by the Triassic deposits (BIRKENMAJER 1964, 1977), while strata equivalent to the Kapp Starostin Formation are lacking.

STRATIGRAPHICAL CORRELATION OF THE SECTIONS AND SEDIMENTARY DEVELOPMENT OF THE KAPP STAROSTIN FORMATION

All the investigated sections of the Kapp Starostin Formation start with deposits of nearshore to shallow-water marine facies replaced upwards with open-sea facies. Both the sedimentary sequence of the formation itself and the nature of underlying deposits (BIRKENMAJER 1964, CUTBILL and CHALLINOR 1965) point to a transgressive origin of the Kapp Starostin Formation. Most lithological boundaries are therefore expected to be heterochronous within the formation; this undermines any direct chronostratigraphical correlation based solely upon lithological affinities of the strata.

Nearshore facies usually cover much smaller areas than do open-sea facies in modern marine sedimentary basins (DAVIS 1972). Therefore, widely distributed, isochronous strata deposited in open-sea facies zones can be expected to occur within a transgressive sequence. Such a time surface can be marked by a considerable change in lithology caused by some factors of macro-regional scale.

There are open-sea, cherty deposits at the top of the Kapp Starostin Formation, overlain by black, marly shales of the Triassic Vardebukta Formation (BIRKENMAJER 1977). The boundary between the two formations thus coincides with a boundary between two facies widely extending in space; it reflects a change in overall sedimentary regime and biota (BUCHAN *et al.* 1965, BIRKENMAJER 1977) which may indicate its approximate isochronism. Such a change in sedimentary regime shown by an open marine environment must have indeed resulted from some large-scale causes, e. g. a change in paleogeography exerting a preponderant influence upon the climate (BIRKENMAJER 1977).

Basing upon the above consideration, the top surface of the cherty deposits overlain by the Triassic strata has been accepted as a starting point for time correlation of the investigated sections of the Kapp Starostin Formation, and the correlation extended subsequently downwards.

In the sections of Hornsund region (figs. 1-2), lithological sets representative of open-sea and intermediate, shallow-water facies are underlain by conglomerates (T — 1, H — 1, Tr —1) deposited directly at the eroded substrate (BIRKENMAJER 1964, CZARNIECKI 1969). Taking for granted the starting point of the correlation, the basal conglomerates of the Hornsund region are time equivalent to the lithological sets (P—4, R—5, F—5) representative of more and more offshore facies zones according to the assumed model of facies spatial distribution (cf. fig. 3). Chronostratigraphical correlation of the base of all of these lithological sets permits estimation of the stratigraphical gap below the Kapp Starostin Formation in the Hornsund region. It comprises time equivalents of the Voringen and Svenskegga Members of the litho-stratigraphical subdivision established in the Isfjord region (CUTBILL and CHALLINOR 1965).

In the Polakkfjellet to Kapp Starostin sections, the above discussed litho-chronostratigraphical horizon is underlain by rocks indicative of open marine facies zones (P—3, R—4, F—4). The cyclic change in facies in the Bellsund to Isfjord region may be most plausibly explained by an emersion of the Hornsund region, displaying an orogenic activity since the Middle Paleozoic (HARLAND 1961, 1974). The accumulations of terrigenous matter in nearshore deposits (P—4, R—5) reflect a degradation of that land area. The emersion may be related to a regressive episode caused by a glaciation in the southern hemisphere (HARLAND and HEROD 1975, CROWELL 1978) but thus far, there is no data pointing to any global lowering of the sea level at that time.

The carbonate rocks (F—1, A—1, R—1, P—1) typical of shallow-water to nearshore facies zones are probably heterochronous. One may suppose that the corresponding sedimentary environments shifted with time southwestwards, towards the hypothetical land (ORVIN 1940, BIRKENMAJER 1964, CUTBILL and CHALLINOR 1965).

Southwards, the Kapp Starostin Formation disappears somewhere between the Treskelen

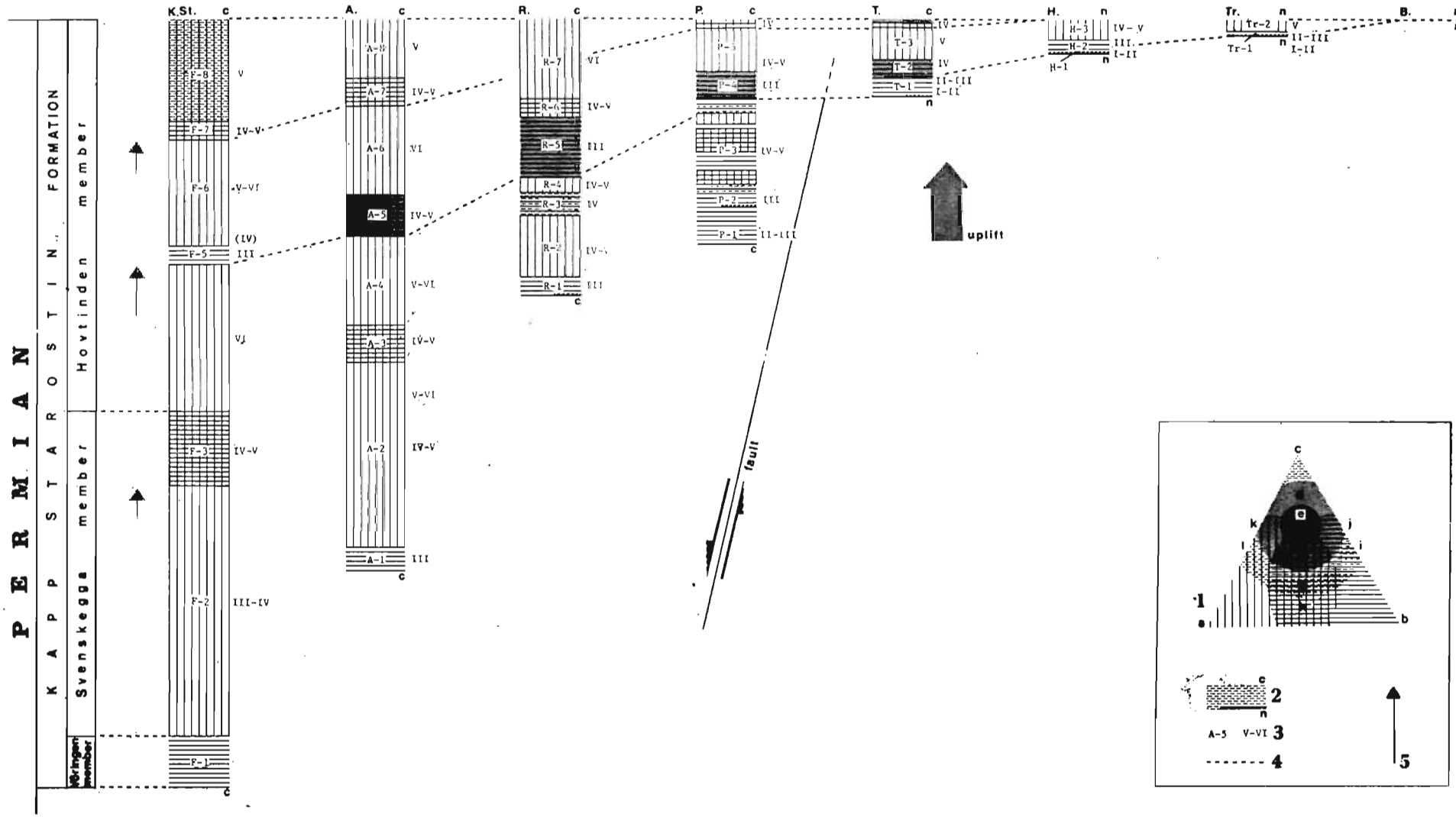

Fig. 4

Litho-chronostratigraphic correlation of the investigated sections of the Kapp Starostin Formation. 1. Lithology: *a* cherts, *b* limestones, *c* marls, *d* sands, *e* pebbles, *f* sandy, cherty limestones, *g* marly, cherty limestones, *h* cherty limestones, *i* marly limestones, *j* sandy limestones, *k* sandy cherts, *l* marly cherts. 2. Contacts of the Kapp Starostin Fm. with the adjacent formations: *c* conformity, *n* nonconformity. 3. Symbols for lithological sets and corresponding facies zones. 4. Isochrones 5. Supposed uplifts.

section and Mt. Bauten (figs 1-2). Nevertheless, one may claim that the facies zone, represented by the deposits of the Tr—3 lithological set, extended southwards; the Permian sea presumably reached the southernmost extremity of Hornsund region or even further but its sediments have become eroded during a subsequent emersion. This hypothesis is indeed supported by the occurrence of the Kapp Starostin Formation at the center of Sörkappland (Dr. D. WORSLEY, oral comm.) and at its southern margin (SIEDLECKI 1964). Furthermore, the lithological characteristics of the strata deposited nearby (T—3, P—5 (b)) point to a shallowing of the sea and appearance of a new source of terrigenous matter. This emersion exerted also an influence more offshore (F—7, A—7).

Following from the above presented observations and premises, an approximate chronostratigraphical correlation of most lithological sets distinguished in the investigated sections has been achieved (fig. 4) and the sedimentary development of the area has been reconstructed (fig. 5). Consistency of the reconstruction with Walther's Law of vertical and

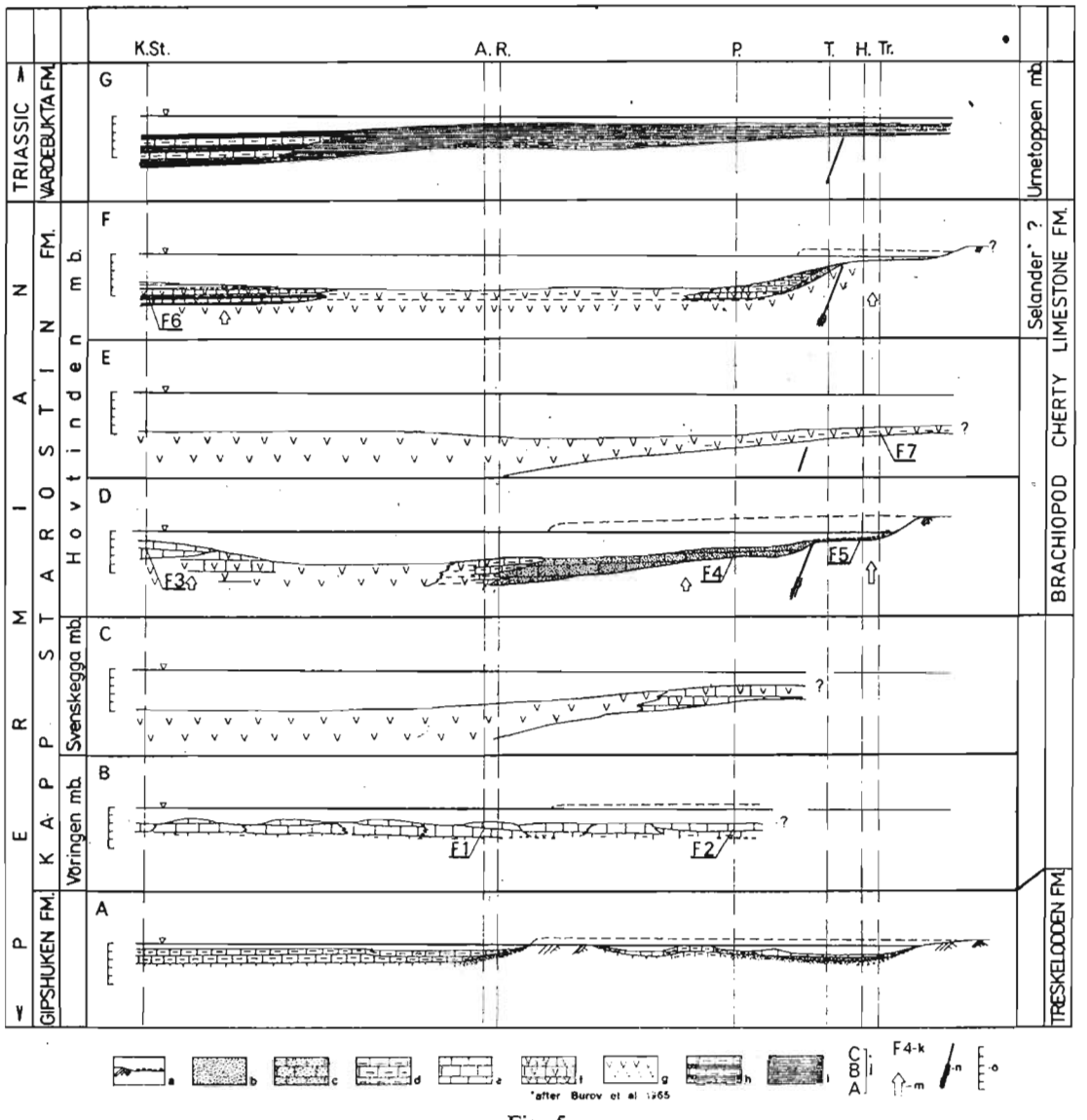

Fig. 5

Sedimentary development of the Kapp Starostin Fm. along with the adjacent, underlying and overlying strata. *a* land areas and nearshore, coarse-clastic deposits, *b* sands, *c* sandy-calcareous deposits, *d* calcareous-marly deposits, *e* limestones, *f* calcareous-siliceous deposits, *g* siliceous muds, *h* marly-clayey shales, *i* marly shales, *j* successive stages of the sedimentary development, *k* macrofaunal collections, *m* uplift, *n* fault, *o* relative depth

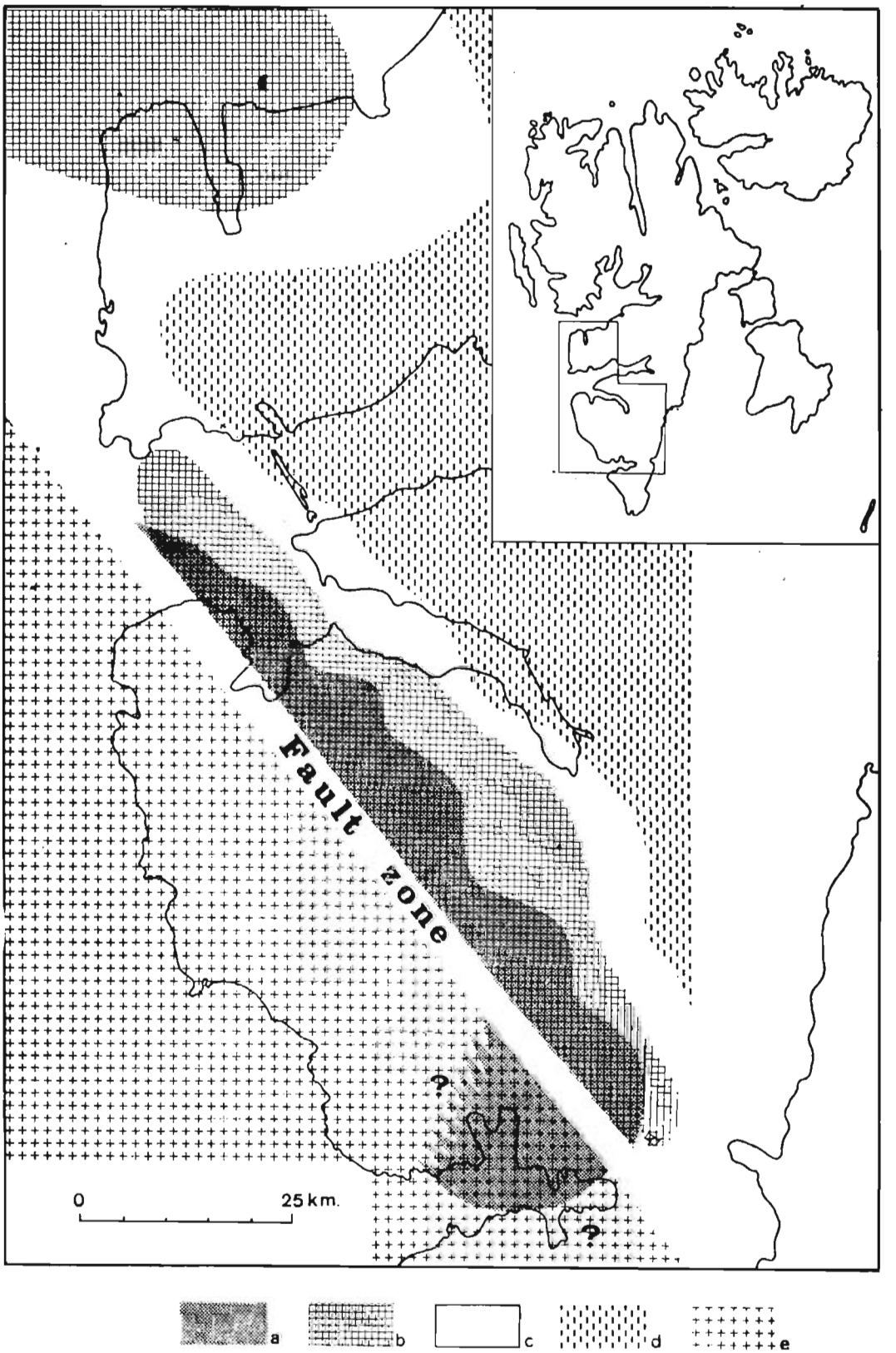

Fig. 6

Reconstruction of supposed facies distribution in the Permian sea in the investigated area at the time of deposition of the basal sediments of the Hovtinden Member. *a* nearshore facies (zones I-II), *b* carbonate facies (zones III-IV), *c* intermediate, carbonate-marly-siliceous facies (zones IV-V), *d* open-sea facies: muds and cherts (zones V-VI), *e* land areas covered successively with transgressive deposits of the Hovtinden Mb.,; question marks indicate areas supposedly covered by the transgression but lacking now any deposits of the Kapp Starostin Fm.

lateral facies succession (WALTHER 1893-1894, see MIDDLETON 1973) suggests the appropriateness of the facies model and the correlation method.

The recognition of an isochronous but facies-diverse, fossiliferous horizon (fig. 2: H—1, P—4, F—5; fig. 6: C) allows to undertake large-scale paleoecological investigations in the future.

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EXPLANATIONS OF THE PLATES 23-29

PLATE 23

Lithological sets of Kapp Starostin section = FREBOLD's (1937) Festungsprofil

1. F-8 set: black, marly limestones and marly shales.
2. F-7 set: yellow-grey, marly, platy, considerably silicified limestones.
3. F-6 set: grey, wavy, marly cherts.
4. F-5 set: yellow, marly, platy limestones.
5. F-4 set: dark-grey to black, wavy cherts interbedded with black, marly shales.
6. F-3 set: yellow-grey, thick-bedded, platy, considerably silicified limestones.
7. F-2 set: steel-grey to black, wavy cherts.
8. F-1 (b) set: grey, platy (a little wavy in places), marly, micritic limestones interbedded with marly shales; flat siliceous concretions occasionally.
9. F-1 (a) set: grey, detritic limestones.

PLATE 24

1. Polakkfjellet section of the Kapp Starostin Fm., southwestern slope of Polakkfjellet massif.
2. Hyrnefjellet section of the Kapp Starostin Fm., southern slope of Hyrnefjellet massif; boundary between the Treskelodden and Kapp Starostin Formations is indicated.
3. Basal part of H-1 lithological set; note cross sections of large-sized Productacea.
4. Cherts typical of Hornsund-Treskelen area.
5. Top surface of a cherty bed with accumulation of sponge and brachiopod remains.

PLATE 25

Preservation state of the fauna derived from Kapp Starostin section = FREBOLD's (1937) Festungsprofil

1. Bryozoans at the top surface of a bed, F-8 set.
2. Large specimen of *Thuleproductus* at the top surface of a bed, F-5 set.
3. Large-sized solitary coral silicified in part, basal part of a bed, F-3 set.
4. *Horridonia timanica* (STUCKENBERG) at the top surface of a bed, F-5 set.

PLATE 26

Preservation state of the brachiopods derived from Polakkfjellet section

1. Large-sized specimens of *Linoproductus* at the top surface of a detritic-limestone bed, P-2 set.
2. Shell accumulation of *Cancrinella*, P-1 set.
3. *Thuleproductus*? with its dorsal valve forced inwards by compaction, P-4 set.
4. Dorsal valve of *Linoproductus* imprinted in a detritic limestone, P-1, set.
5. Cross sections of Linoproductinae in a detritic limestone bed, P-1 set.
6. *In situ* accumulation of *Rhynchopora* shells filled up with calcite, limestone of P-2 set.

PLATE 27

Microfacies of the Kapp Starostin Fm.

1. Spiculite, sample K-29, Kapp Starostin section, F-4 set; × 10.
2. Thick-shelled brachiopod fragments, productacean spines and accumulations of sponge spicules, sample K-29 (base), basal part of F-4 set set; × 10.

PLATE 28

Microfacies of the Kapp Starostin Fm.

1. Fragmented bryozoan colonies, crinoid ossicles and cross section of a gastropod shell, F-5 set × 10.
2. Abundant fragments of bryozoan colonies and brachiopod shells, crinoid ossicles (carbonate bioclasts bored commonly by fungi or algae), top part of F-5 set × 10.

PLATE 29

Microfacies of the Kapp Starostin Fm.

1. Accumulation of thin-shelled brachiopods, basal part of F-1 (b) × 10.
2. Coquinite, mostly brachiopod shells accompanied by productacean spines, fragmented bryozoan colonies and a few crinoid ossicles, F-1 (a) set × 10.


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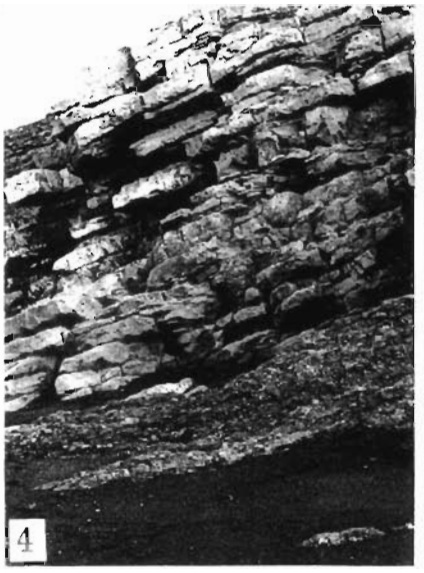
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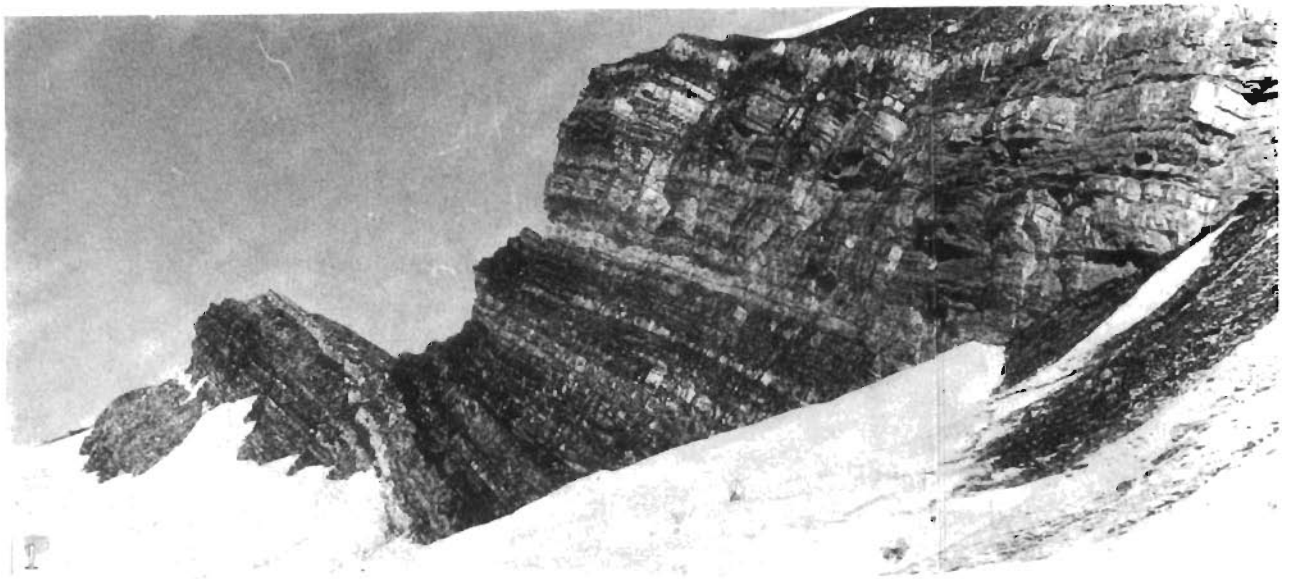

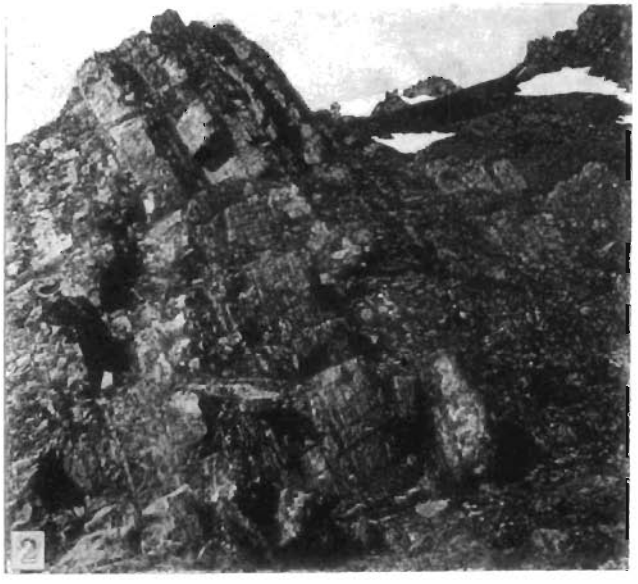

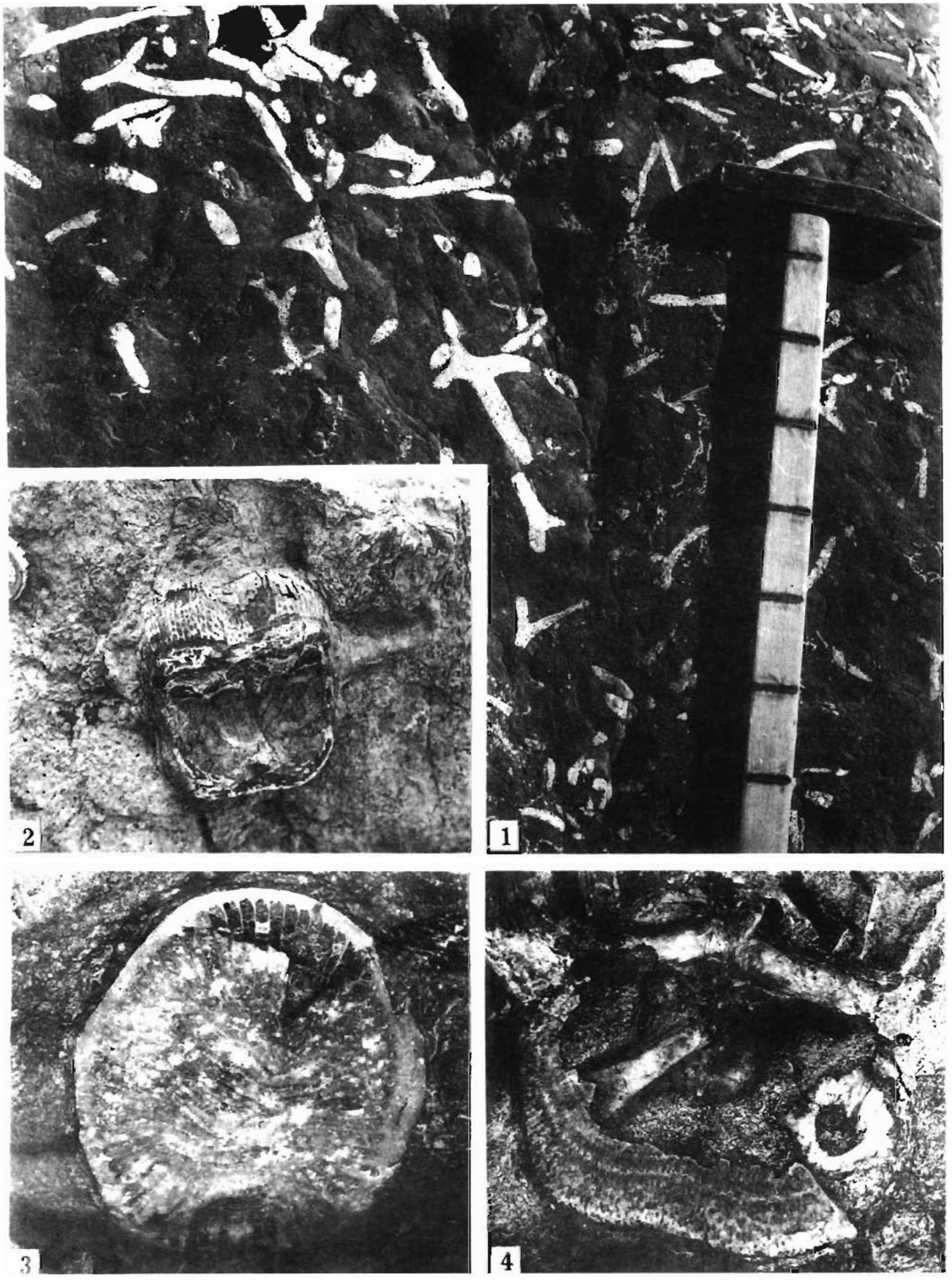
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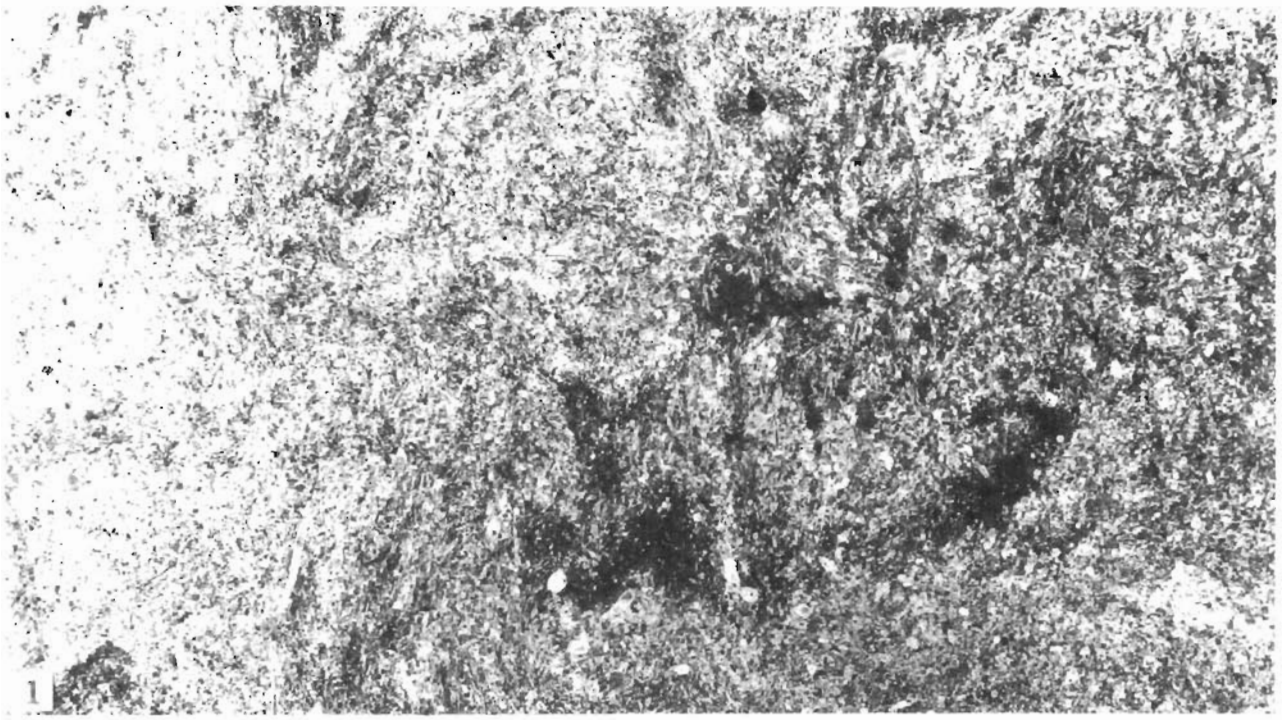
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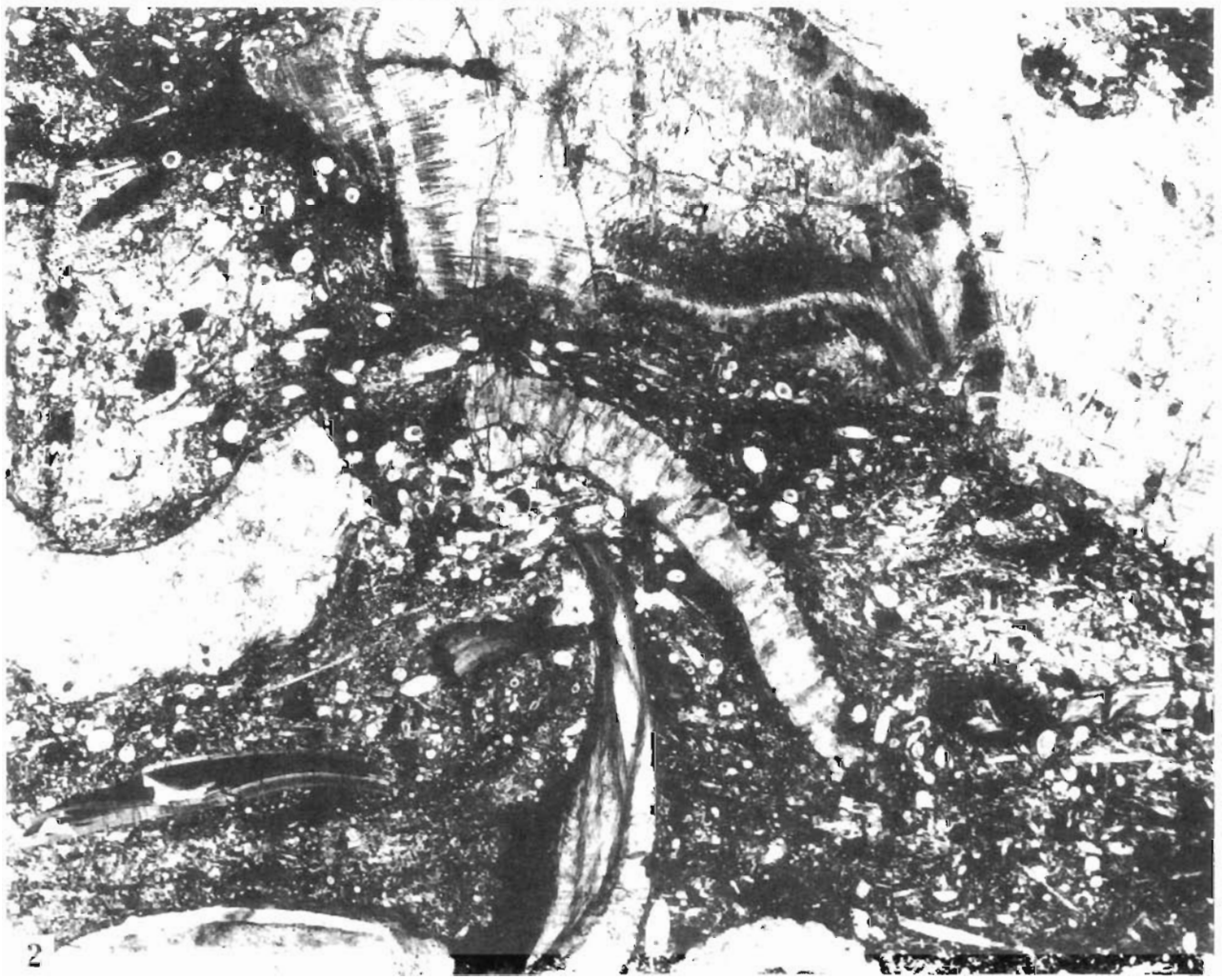
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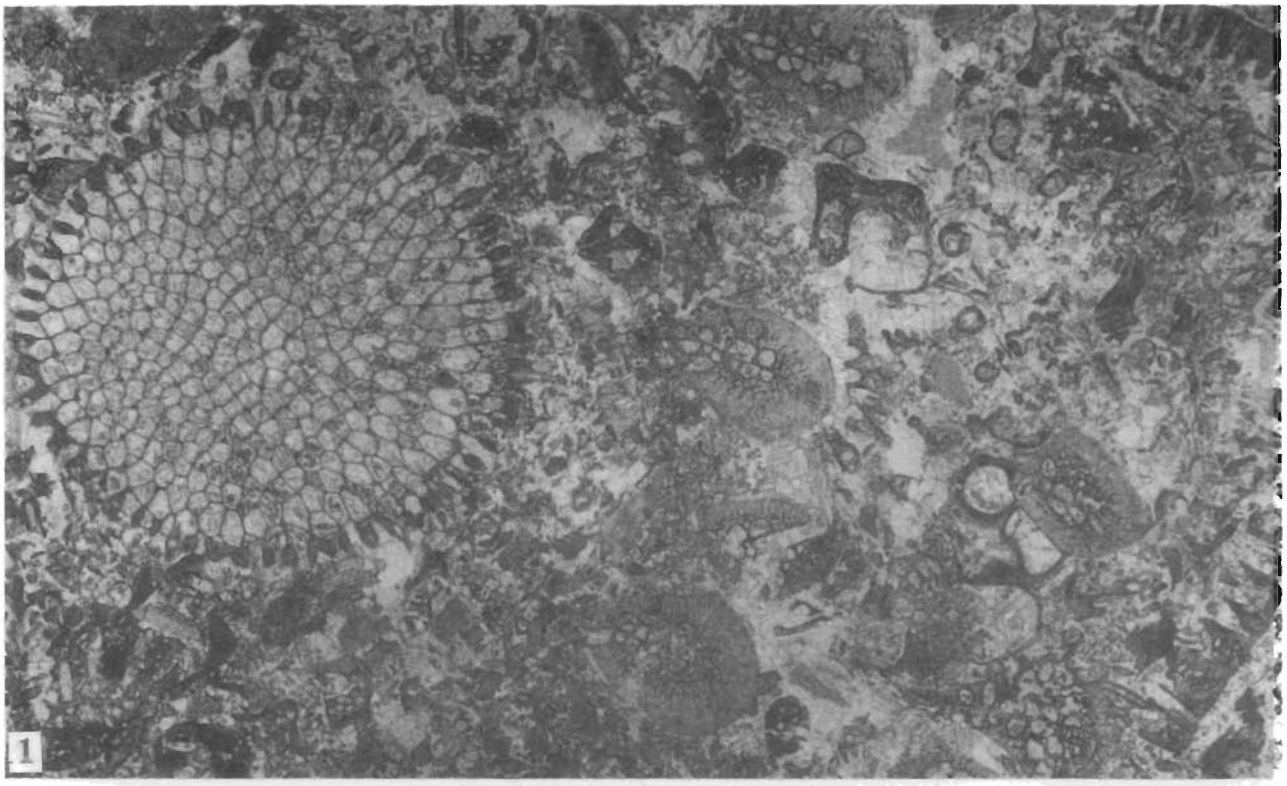

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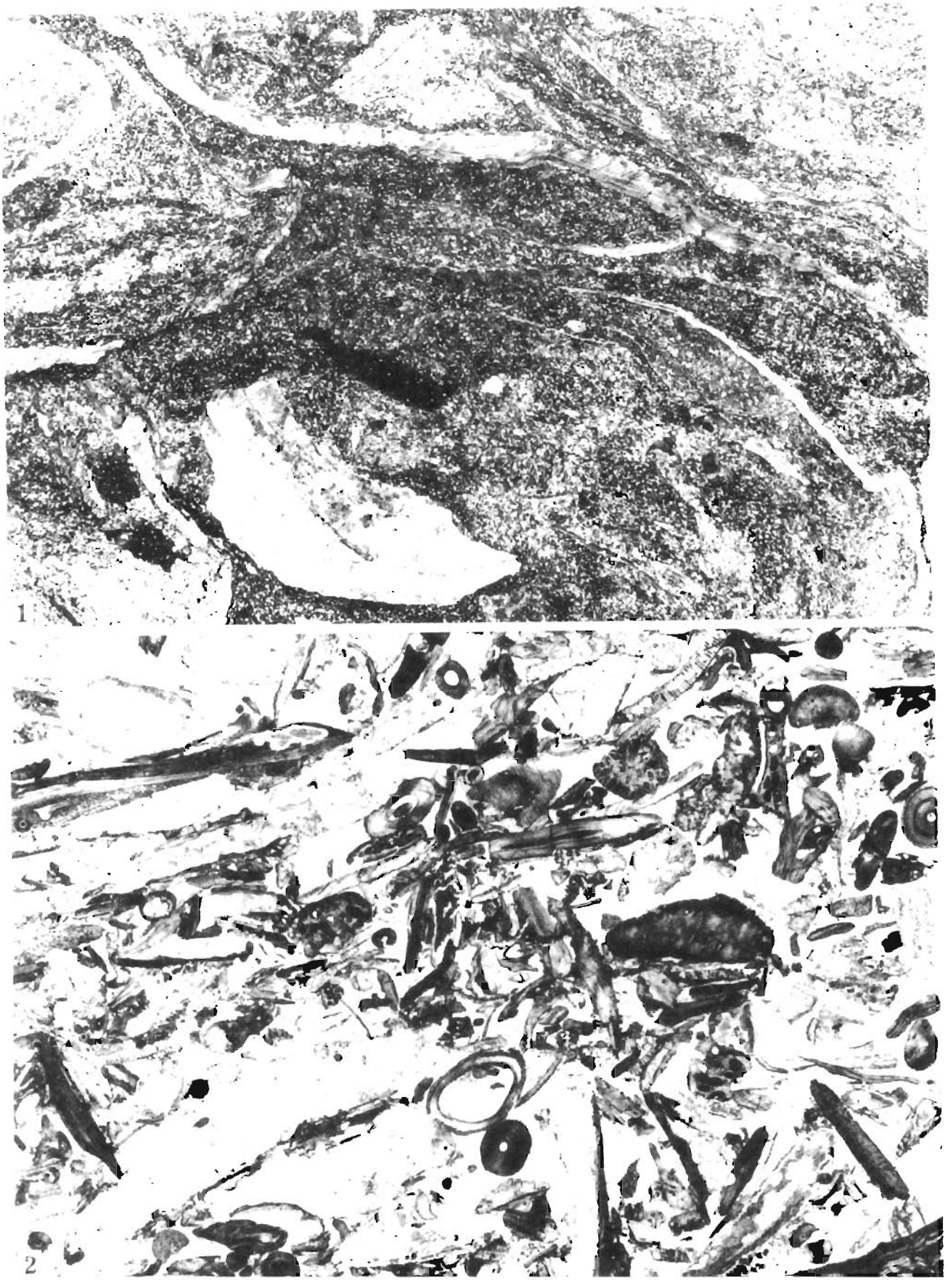

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